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AN EXPLORATORY MODEL AND ECONOMIC EVALUATION OF THE USE OF BIO-REENGINEERED TREES IN PLANTATION FORESTRY

A thesis
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ABSTRACT

The research embodied in the thesis represents a broad conceptual framework regarding the recent developments in the science of biotechnology and their applications to the commercial goals of plantation forestry. The specific developments of tree biotechnology are outlined, with a particular interest in *Eucalyptus grandis* and its hybrids. A brief overview of the international regulatory schemes for protecting intellectual property rights, as well as for safeguarding the biosafety of commercial deployment of genetically engineered plants is developed in order to outline the advantages and disadvantages in investment decisions regarding plantation forestry of bio-reengineered *eucalyptus* trees. A more detailed examination of investment potential in this area is undertaken for New Zealand and Argentina, considering their favourable site-specific characteristics for maximizing the growth potential and the quality of eucalypts. To make the picture of investment in the production and growing of bio-reengineered trees even more focused, the goals of a company are matched to the engineered properties of the natural resource and their effects on the marginal changes of the overall chain of production in the forestry industry.

Given the above broad framework of developments in tree biotechnology, an economic analysis is conducted in order to evaluate the gains associated with producing, growing and utilizing bio-reengineered trees for the production of specific wood products (e.g. mouldings). A detailed model is developed in which each stage of the production process (selection and re-engineering; plantation forest management; processing and reprocessing; market) is examined in its own merit, and stage-specific assumptions about input/output relationships, as well as cost-benefit factors are established.

The qualitative assumptions made in the exploratory model are the base for conducting an economic evaluation of the gains associated with the use of bio-reengineered trees. It is found that the gains in net present value terms from growing the bio-reengineered trees in a shorter rotation length are significant. Such gains, however, are due to both the intertemporal changes involved in shortening the rotation period, as well as to changes of in the product worth due to the higher quality of the grown trees. Thus, an evaluation of the specific gains associated with quality change is also undertaken, where the contribution of each genetic trait of interest (herbicide resistance, insect resistance, lignin enhancement) to changes in the product worth is examined separately. A simple sensitivity analysis is developed to help examine the effects of each trait on the profitability of growing bio-reengineered trees. The internal rate of return of growing the 'superior' trees seems to be more sensitive to changes in the factors associated with lignin enhancement. This, however, is not a general rule and it is susceptible to alterations dependent on the magnitude of the cost factors associated with the other two traits. Given that the gains captured from growing the bio-reengineered trees are attributed to both the technologist and the grower, royalty schemes are developed to suggest the alternative ways of distributing the gains from technological innovation. Finally, it is found that the gains from utilization of bio-reengineered trees are not only captured at harvest, but also a significant increase in the internal rate of return is associated with processing better and more uniform logs for specific high-quality wood products.

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CHAPTER 1

A GENERAL APPROACH TO THE THESIS

1.1. The nature of the thesis

Recent developments in tree biotechnology have driven industry attention towards the future potential of tree breeding and genetic engineering for production purposes. Scientists find it an exciting field of research, which will expand further the knowledge of the genes responsible for the enhancement of specific genetic traits of interest. Private companies have already invested large amounts of money in biotechnology, and are predicting significant returns from the improvement of targeted wood characteristics of trees, their adaptability to adverse environments, and the commercialization of final products from improved raw material. Governments are more skeptical about the potentials of biotechnology, and tend to be more concerned with the effects of biotechnology on the environment, health and safety. Thus, the role of governments in the field of biotechnology has mainly consisted of designing and enforcing a framework of biosafety and biodiversity regulations to control the release of genetically modified organisms into the environment, and to assess the effects of these "new" organisms on the conservation of genetic resources, and the integrity of the surrounding ecosystems.

The greater interest in biotechnology implies that a greater understanding of the process of biotechnology *per se*, and its practical applications is necessary. The understanding of this process, however, can be interpreted in several ways. Scientists are concerned with the importance of the genes for trait specific modifications and the predictability of future changes. Scientific knowledge, however, has been developing at a faster pace than the design of regulatory measures for the use of re-engineered products. This has kept governments very aware of the need to better understand the process of biotechnology, in order to be able to implement correct regulatory measures concerned with the biosafety of the final products. Environmental groups are concerned with the moral, ethical and environmental impacts of biotechnology and their irreversible nature. In business circles, the understanding of biotechnology has offered a great deal of speculation about the future benefits of its products. The returns on biotechnological investment are expected to be great, based on the cost-effectiveness of the process in the long-run, the quality premium of the final products, and the monopoly-like nature of protected biotechnological research.

The process of biotechnology has therefore been adapted in order to suit specific purposes, be they environmental, regulatory, political or economic. Little analysis exists about the specific relationships between the different purposes, such as the link between the scientific goals of biotechnological research and the market goals for biotechnological development. However, if the two purposes are considered in a more complex framework, where they actually interrelate, a better scientific knowledge of biotechnology is more likely to stimulate the practical application of the research and thus lead to greater returns to the company engaged with developing and selling the product. Therefore, a more complex analysis is necessary in order to understand the process of biotechnology as a means of production, where the inputs are renewable resources (e.g. plantation trees) and the outputs are superior quality wood products (e.g. mouldings).

The present thesis has its base on both academic and private grounds. The academic interest is based on the economic evaluation of biotechnology, and its application and effects on trees as renewable resources. The private directions have linked such evaluation to the purposes of plantation forestry, processing, and marketing of final wood products. Private interests have also led to a further expansion of the analysis to include the benefits from investing in a Third World country. The two approaches complement each other and make an extremely interesting and challenging research project, where the economic principles are not only applied to a new field of research (i.e. biotechnology), but are also adapted to the purposes of plantation forestry management.

1.2. Current trends in plantation forestry

The sustainable management of forest resources and their importance for wood and non-wood products are greatly discussed issues in both national and international political circles. Chapter 11 of *Agenda 21* best represents the issues related to the trade and services of forest industries: "The improved management of forests can increase the production of goods and services and, in particular, the yield of wood and non-wood products, thus helping to generate additional employment and income, additional value through processing and trade of forest products, increased contribution to foreign exchange earnings, and increased return on investment. Forest resources, being renewable, can be sustainably managed in a manner that is compatible with environmental conservation. It is also possible to increase the value of forests through non-damaging uses such as the managed supply of genetic materials".

A number of management-related activities, outlined in Agenda 21, are relevant to plantation forestry matters, such as:

- Carry out detailed investment studies, supply-demand harmonization and environmental impact analysis to rationalize and improve trees and forest utilization and to develop and establish appropriate incentive schemes and regulatory measures to provide a favourable investment climate and promote better management,

- Formulate scientifically sound criteria and guidelines for the management, conservation and sustainable development of all types of forests,
- Improve the methods and practices of forest harvesting, which are ecologically sound and economically viable, including planning and management, improved use of equipment, storage and transportation to reduce and, if possible, maximize the use of waste and improve the value of wood products,
- Promote the better use and development of planted forests through appropriate and environmentally sound and economically viable activities, including silvicultural practices,
- Improve and promote methodologies for a comprehensive assessment that will capture the full value of forests, with a view to including that value in the market-based pricing structure of wood products,
- Promote and support the downstream processing of forest products to increase retained value of wood and other benefits; promote value-adding secondary processing for improved employment, income and retained value,
- Develop, expand, and/or improve the effectiveness and efficiency of forest-based processing industries, involving efficient conversion technology and improved sustainable utilization of harvesting and process residues; promote underutilized species in natural forests through research, demonstration and commercialization,
- Promote/improve markets for, and trade in, forest products through relevant institutions, policies and facilities.

The total area of world plantations (100 million hectares) is only about 2.6% of the global forest area. They provide 7-10% of the world's commercial wood production. Among the exotic species grown in forest plantations, *Eucalypts* represent the most commonly used species in the tropics and sub-tropics, planted for both industrial roundwood and non-industrial purposes. The annual increment from plantations of *Eucalyptus* species may be 30 m^3/ha or even more, compared with 2-8 m^3/ha from managed natural tropical forest. Plantations derived from clones of hybrids of *Eucalyptus* species can exhibit even greater productivity and annual yields of up to 70 m^3/ha (attained in Brazil) (FAO, 1994). Thus, the productivity of plantation forests is crucial for the consistent supply of raw material for further processing and production of final products.

Consumption of forest products varies among countries. Developed countries have an average annual consumption of sawnwood and wood-based panels of 300 m^3 per 1000 people and of 150 tonnes of paper per 1000 people. In contrast, in developing countries, average consumption of sawnwood wood-based panels is 30 m^3 per 1000 people and that for paper is 12 tonnes per 1000 people, considering that 80% of the wood used is for fuel.

Between 1990 and 2010, demand for all wood products is projected to grow, with rates being significantly higher for developing than developed countries. The projected world annual average growth rates are 1.2% for fuelwood and charcoal, 2.2% for industrial roundwood, 1.9% for sawnwood, 4.3% for panels and 3% for paper (FAO, 1994). These rates imply both the need for greater supply of wood and the changing nature of preferences among countries for specific wood products.

The forestry sector confronts increased demand not only for its industrial products and services, but also for the conservation of ecosystems and biodiversity, as well as increasing pressure for competing land utilization. Hence, a feasible solution is to supply more from less forest, i.e. make forests more productive per hectare of land. This is one of the main objectives of plantation forests.

Another objective is related to maximizing harvested and processed volume of wood by minimizing waste in both harvesting and processing. Waste management is related to the allocation of residues for alternative purposes in the wood processing industry, but it could also be addressed from the very beginning of the value-adding processes, where trees are grown with the purposes of maximizing quality of wood, until the end point of the production chain, where logs are processed in purpose-built mills.

Moreover, forest products are directed to the most appropriate and remunerative uses by appropriate trade and marketing strategies, further increasing the value of the resource. Developed countries account for more than 80% of the total forest products trade. Many developing countries, on the other hand, are heavily dependent on imports for their supply of manufactured forest products.

This suggests that increased future wood supply will depend not only on increasing the amount of plantation estates, but mainly on better utilization and management of trees through the chain of production. Growing less trees per hectare and capturing a greater outturn per log implies a qualitative, as well as quantitative, management of forest resources for future wood production.

1.3. Fletcher Challenge Forests - a general overview

Fletcher Challenge Limited is a New Zealand based, publicly listed, multinational company. The main areas of operation of the company are related to the management of natural resources - forests and energy - and their utilization for specific production purposes - pulp and paper, sawn wood products, building, and energy consumption.

In December 1993, Fletcher Challenge Group split its equity into two separate classes of shares - the Ordinary Division and the Forests Division. The former manages the areas of energy, pulp and paper, and building industries, while the latter specializes in the management of plantation forestry. The Forests Division represents the Group's solid wood plantation forestry activities in New Zealand, Chile and Argentina. After the acquisition of Forestry Corporation of New Zealand (1996), Fletcher Challenge Forests (FCF) has acquired the greatest proportion of plantation forestry areas in New Zealand and is now New Zealand's largest plantation based solid wood enterprise (with 117,000 hectares of plantation forests), with the capacity to produce around 7 million m^3 of wood per year (around 6 million m^3 in New Zealand and 1 million in Argentina) (FCF, 1997).

The present thesis focuses on the objectives of Fletcher Challenge Forests (FCF). FCF owns and manages 285,000 hectares of plantation forests in the Central North Island[1] in New Zealand, 49,000 planted hectares in the fertile region of Bio Bio in Chile (Forbio subsidiary) and 2,000 hectares in the region of Corrientes in Argentina (Forestadora Tapebicua subsidiary). In 1996 a consortium of FCF, Citifor (the Chinese Government's forestry investment division) and Brierley Investments Limited of New Zealand purchased the remaining New Zealand government plantation forests in the Central North Island (FCF, 1996). The consortium owns the cutting rights for 168,000 hectares of plantations in New Zealand (FCF, 1997).

The planted species are mainly *Pinus radiata*, but also *Eucalypts* and *Douglas Fir*. The present thesis focuses on *Eucalyptus grandis* as a species of economic interest, considering that it is a faster-growing commercial hardwood, currently used for the purposes of pulp and paper, but also suitable for a number of other high-value uses, such as appearance grade products (e.g. mouldings). Eucalyptus grandis hybrids are bred, cloned and grown in Argentina, where they exhibit outstanding growth rates in terms of m^3/ha obtained in a year[2]. Further improvement of the trees' performance, through genetic engineering, provides the opportunity to develop fast growing, superior quality 'supertrees' for the purposes of producing re-manufactured, high-value final products for appearance purposes.

The operations of FCF include tree breeding, re-engineering, seedling nurseries management, forest planting and management, harvesting, processing and re-manufacturing, marketing and distribution. Purpose-grown trees are more likely to maximize returns through minimizing costs of production and maximizing outturn - economies of scale for specific wood products. This is further enhanced by placing the

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[1] The Central North Island is the largest wood-producing region in New Zealand with a total area of planted production forest of around 518 000 hectares, containing a standing volume of 113 247 000 m^3 and annual growth of about 9 082 000 m^3 per year (as in 1992) (MF, 1994).

[2] The growth rates are greater than the ones shown by superior solid wood species in New Zealand and Chile.

purpose-grown tree material into purpose-built processing and re-processing plants. Thus, the company is a vertically integrated economy of scale where the customer needs are the main concern for the management of forest resources and the production of final products. By understanding the needs and preferences of the customer, the company would be able to capture a greater return for a higher quality final product.

The scale of operation of the company is further enhanced by expanding wood processing infrastructure. FCF operates eleven processing plants - four sawmills (Kawerau, Rainbow Mountain, Taupo, Waipa); one plywood mill (Mount Maunganui); one mouldings plant (Taupo), one remanufacturing plant (Waipa); one laminating plant (Kawerau); and one wood processing plant (Mount Maunganui) in New Zealand (Central North Island), as well as one sawmill and one plywood plant in Argentina (Corrientes Province) (*See Appendix 1*). The company's sawmills produce around 500,000 m^3/yr of solid wood products (FCF, 1997).

Major markets for forestry products are Japan, Republic of Korea, China, Taiwan and Australia, with expanding markets in North America (*See Appendix 2*). Even though the export of logs represents a significant proportion of total exports, the demand for re-manufactured high quality products has been increasing, which gives a value-adding advantage to the company. Among the wood products supplied by the company are high quality plywood and veneer for appearance-grade products (e.g. furniture), and mouldings and millwork for construction (*See Appendix 3*).

Mouldings are the wood products of interest in the present thesis, considering that demand for mouldings is linked to specific customer preferences for better wood properties and appearance quality of the product. Moreover, the distribution of mouldings is aimed at the North American market, where the company has already established a direct distribution link (joint-venture) through the American Wood Moulding Corporation. Mouldings are manufactured in New Zealand and sent directly to customers in the mid-West and Eastern USA through the retail chain "Home Depot". Selling directly to consumers implies both a more cost-effective distribution of final products, and a greater responsiveness to the changing preferences of customers. The early success of this distribution link has been represented by a 20% growth in sales (in 1997) of the American Wood Moulding Corporation and a continuing increase in market share. This has been possible due to the strong economy and housing market in the USA, the constrained North American supply of wood and the marketing efforts of FCF (FCF, 1997).

Improvement of production capacity as well as the vertical integration of the company and already established distribution networks and markets suggest that cost reduction as well as higher value creation are the two strategies that combined give the company a leading edge in the field of plantation forestry.

1.4. The company's short, medium and long term objectives

The main focus of the company's objectives is to capture greater returns on investment, while reducing the costs of production by managing the chain of production for maximum value. The goals are designed and implemented throughout different time frames, considering the different nature and time lags of plantation forestry and processing, due to the impacts of biotechnological re-engineering of trees, and the short harvest profile.

The nature of plantation forestry and the time lag between initial investment and return on investment imply the need for a more precise formulation of strategies in the short term, with the capacity to foresee future trends in biotechnological innovations, plantation management, regulatory constraints, market uncertainties and changing consumer preferences.

In the short term (1-5 years), goals are more likely to concentrate on the evaluation of a cost-effective, quality enhancing process of value adding to final products, suited for specific customer preferences. The evaluation of the chain of value-adding should encompass the selection and re-engineering of trees for better performance; their management while planted; the early harvesting of tree stock; the processing of homogeneous logs; further re-processing for higher quality final products; distribution and marketing. If all the criteria for a cost-effective production process are captured correctly today, a better understanding of the interactions of each step of the process will be crucial for predicting the nature and acceptability of the final products tomorrow.

The specific short term aim of the company is to use genetic techniques developed in New Zealand and applied to Eucalyptus grandis in Argentina, in order to improve the stability and structural strength of the species, so that it gains wider market acceptance as a source of timber for solid wood products in USA (FCF, 1997). Thus, important issues to be considered are: the evaluation of the use of genetic engineering and clonal propagation in the development of superior tree stock of *Eucalyptus grandis* for clearwood purposes; the assessment of the investment opportunities in plantation forestry of short rotation species in low-cost regions; and, the identification of the possible regulatory constraints of fast returns on investment.

In the middle term (5-10 years), considering that re-engineered trees have already been planted and have shown initial performance, efforts should focus on better understanding of correlations between biological traits and quality grades, in order to predict with greater certainty how the trees will grow and what volume is to be expected before seedlings are planted. The main objective is to grow trees that are easier to harvest and process, with wood characteristics specifically suited for various end-use purposes. Customers are the final source for quality assessment and whether products will achieve a high premium in value depends not only on the company but also on the customer. Thus, the overall aim of the company is not only to improve trees for better quality, but also to deliver high quality solid wood products to the customers "on a reliable, long-term basis, and move away from commodity-driven log markets where no additional value is created" (FCF, 1996).

Interest would also be extended to capturing new markets for the company's high quality wood products. FCF will keep targeting the plywood and lumber Asian markets, and the large millwork and mouldings market in the United States, keeping up with the resources-to-customer chain for optimum value recovery.

In the long run (10-15 years) attention should be given to further improvements so as to suit the changing needs of the customer and the changing trends of market competition. Predicting what the customer needs and demands 15 years ahead is a very complex task. However, a stable supply of high quality wood products will give a competitive advantage to the company in the long run, when the full realization of value will become apparent. On the other hand, increasing competition in biotechnological improvement of trees, as well as the existence of product substitutes could put pressures on capturing a high quality premium of improvement.

The company's main objective is to deliver high quality solid wood products to its customers on a sustainable, long-term basis, adding value for customers, shareholders and employees, through the management of margins along the chain from customer back to resource. To be successful, the company's strategies must anticipate and capture trends in customer preference, recognize that value continues to be created along the entire chain until a finished solid wood product is sold to a customer, provide for a consistent delivery of high-quality products, and improve the company's cost structures through a vertical integration in both, the production and supply chains (FCF, 1996).

In general, FCF must constantly reassess the goals of biotechnological improvement of trees, plantation management, processing operations, mill configurations, marketing, technology and work practices to maximize output while minimizing costs (FCF, 1996).

1.5. Thesis layout

"When placed in the context of [the company's] pioneering genetic developments, increasingly sophisticated plantation management, and distribution and marketing strategies for niche customer markets, evaluations of worth on the basis of anticipated harvest over 25 years are simplistic and increasingly inadequate" (FCF, 1996). A more complex economic analysis of the stages of value-adding is needed, in order to evaluate the changing genetic characteristics of the tree, and link them to the profitability of growing the tree and utilizing the wood for processing high-quality finished wood products.

The present thesis emphasizes the marginal relationships associated with value-adding to wood products, which capture the changes in genetic composition, growth potential and processing capacity of bio-reengineered trees. A more detailed understanding of the components of each stage of the production process helps establish realistic assumptions and provides the opportunity for more precise evaluation of the discussed marginal relationships.

In **Chapter 2**, an overview of the specific trends in biotechnological developments is made. Attention is given to specific issues concerning tree biotechnology, outlining the case of plantation-grown *eucalypts* and their hybrids. The trade-off between conventional breeding practices and genetic engineering is also discussed in terms of their commercial potential.

Chapter 3 makes a brief recollection of important regulatory issues regarding the intellectual property rights of biotechnological developments, biosafety guidelines to safeguard the deployment of genetically modified organisms, and also the specific regulatory frameworks in New Zealand regarding biotechnological developments and their commercial applications.

Chapter 4 emphasizes plantation forestry investment opportunities in a Third World country. The country of interest is Argentina, where climate, land, economy, politics, and regulations are interrelated to offer a beneficial environment for investment in plantation forestry. Biotechnological developments in Argentina are discussed, as well as strategies for engaging in genetic engineering and commercial deployment of bio-reengineered trees.

Chapter 5 represents the economic and commercial aspects of technological change. The Chapter focuses on the relationship between biotechnology, as a means of production, and economics, as a tool to analyze changes in input-output scenarios, where the characteristics of the inputs, the efficiencies of the production process and the properties of the final products are considered. The issues related to the commercial development of biotechnological products are briefly outlined.

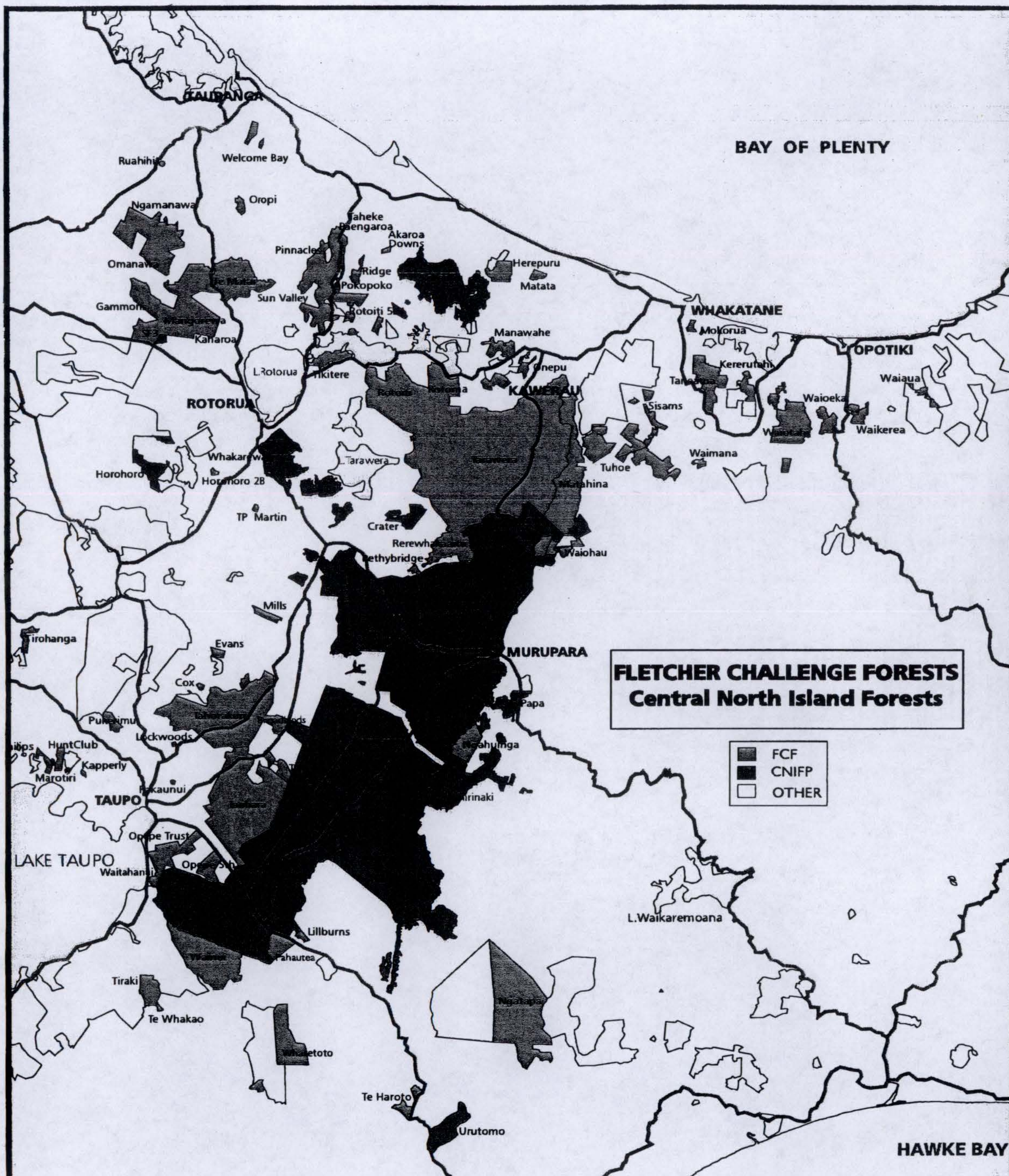
Chapter 6 establishes the essential criteria for analysis and the specific assumptions of the economic model, concerning the value-adding process to commercially grown trees. In this model, each stage of the production process is given separate attention in order to identify the variables which capture more correctly the marginal relationships between intrinsic wood properties, growth potential of trees, and quality grades of final products.

Value-adding occurs in each stage of the process - selection and re-engineering of tree stock; plantation management; processing of logs and further re-processing; distribution and marketing of final products. The model is represented in a schematic form in order to provide a greater understanding of the interactions between the stage-specific inputs and the characteristics of the outputs.

Chapter 7 represents the economic model in a more dynamic form, as an economic evaluation is undertaken to represent the effects of marginal changes in the intrinsic characteristics of the bio-reengineered trees to the profitability of growing the trees and processing the logs. The gains from the utilization of bio-reengineered trees are captured in each stage of the value-adding production process.

In the final concluding section, i.e. **Chapter 8**, a summary of the main findings of the present thesis is made, as well as some recommendations for future research and analysis are given.

Map of Fletcher Challenge Forests' Estate in the Central North Island Region (New Zealand)



Source: Fletcher Challenge Forests

Map of Fletcher Challenge Forests' Estate in the Corrientes Province (Argentina)

Source: *Made by the author. Extracted from The National Geographic Atlas of the World*

CHAPTER 2

DEVELOPMENTS IN TREE BIOTECHNOLOGY AND COMMERCIAL APPLICATIONS

"We need to view biotechnology both as a source of immense promise for the future, and as a source of potential difficulty, as we try to adapt it to the world that still thinks in the way that we approached traditional agricultural research in the past" (Hopper, 1990).

2.1. The promise of the "new" biotechnology

2.1.1. General overview of trends in "new" biotechnology

There are many definitions of biotechnology, each adapted to a specific research purpose. Two of the most frequently used definitions are considered in the present thesis, as they capture explicitly both the scientific and commercial significance of biotechnology. The Office of Technology Assessment of the United States Congress (OTA) describes biotechnology as "any technique that uses living organisms, or substances from those organisms, to make or modify a product, to improve plants or animals, or to develop microorganisms for specific uses" (Persley, 1990). In the definition given by the OECD, biotechnology is regarded as "the application of scientific and engineering principles to the processing of materials by biological agents to provide goods and services" (Kennedy and Davies, 1994).

Technically speaking, biotechnology includes both traditional and modern techniques. The former represent widely used and commercially useful operations, such as breeding, selection and micropropagation, while the latter deal with more complex techniques, such as genetic engineering[3]. The so called "new" biotechnologies have evolved through the development of genetic engineering practices and their increasing scope of application, providing for great scientific potential and commercial promise.

[3] "The basic principle of genetic engineering is that genetic material (DNA) can be transferred from a cell of one species to another, unrelated species, and made to express itself in the recipient cell" (Persley, 1990a).

Genetic engineering is based on a combination of three processes, around which modern biotechnology has evolved:

(1) *recombinant DNA technology* - a series of enabling techniques that allows the manipulation of DNA,

(2) *production of monoclonal antibodies* - specific diagnostic tools that allow the rapid detection of individual proteins,

(3) *cell and tissue culture* - allow for the rapid propagation of genetically engineered plant cells (Persley, 1990a).

The purpose of genetic engineering is to introduce, delete or enhance a particular trait in an organism, by either inserting foreign genes, or by altering the existing genetic makeup of the organism (Kennedy and Davies, 1994). By using genetic engineering, genetic material is transferred from the cell of one species to another, and the recipient cell (and organism) are transformed by the arrival of the new genetic information (traits).

The transfer of genes from one organism to another is a complex process. Successful genetic engineering of a plant generally involves five steps:

1. Identification and characterization of the gene to be inserted;
2. Insertion of the new gene into the plant cell[4]
3. Selection process, i.e. separation of the cells that have successfully incorporated the new gene from those that have not;
4. Expression[5] of the intended trait by the new gene[6], i.e. transformation;
5. Regeneration of the cell into a whole plant that carries and expresses the new genetic trait (Dines, 1991), (Persley, 1990a).

Techniques used in genetic engineering are *Agrobacterium tumephasiens*[7], which is a more direct way of stimulating resistance in the treated embryo, and *Biolistic transformation*, which is based on the use of a "gene gun" to insert (or fire) a foreign DNA into the host cells. Genetic engineering is currently used to confer resistance to herbicides, insects,

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[4] Only a small percentage of the cells subjected to the insertion of the DNA actually take up the DNA in a functional manner.

[5] Expression of transformed genes in plants is controlled by their associated promoters and other DNA-based factors such as enhancers and silencers (Persley, 1990a). When the cell is regenerated to a somatic embryo and subsequently a whole plant, the reporter gene is expressed, and produces the stain showing that the material is actually transformed. Thus, the reporter gene adds a new characteristic to the cell and also indicates that the technology has been applied successfully and that the new genes have been integrated into the plant cell's chromosome and disseminated to the daughter cells during cell division and propagation (NZFRI,1996).

[6] Expression must occur in such a way that the new DNA is integrated into the chromosome of the cell and is stably passed on to future generations.

[7] Agrobacterium tumefaciens is a soil bacterium, which causes a disease in some plants. The bacterium infects a wound, and injects a short stretch of DNA into some of the cells around the wound. The DNA is contained in a tumor induction plasmid, which when transferred to the plant cell causes the cell to grow into a tumor-like structure. Thus, a foreign gene is transferred into the host plant cell, and it becomes integrated into the chromosomes of the plant.

viruses, and fungal and bacterial diseases in crops and woody plants, as well as to improve the control of plant functions, and thus increase quality.

A number of *tissue culture techniques*[8] are used in the process of genetic engineering and offer an alternative approach to delivering genetic variation without the complexities associated with the recombinant methods to introduce foreign genes. Among these techniques are: *clonal propagation*, for clonal multiplication of varieties and the production of uniform and disease-free plants[9]; *somatic embryogenesis*[10], for production of clones that outperform or outyield standard clones of the same variety[11]; *organogenesis*, for generating a plant from a single cell; and *somatic hybridization*, for producing improved varieties by the fusion of protoplasts (cells with no sell walls).

Major limitations in the process of genetic engineering could be the ability to identify the transferred genes which confer new traits to the recipient plant (Persley, 1990). Such limitations, however, have been increasingly overcome by the use of molecular techniques for genetic mapping and specific traits identification.

Some of the more widely used *molecular techniques* for the examination of targeted traits in genotypes are the *restriction fragment length polymorphism (RFLP)* method (for conventional plant breeding purposes) and the *marker assisted selection (MAS)* method (for the purposes of genetic engineering for pathogen resistance). The former technique allows for the tagging of single and multiple gene traits for insertion into economically important plants, and it provides an entirely new approach for an efficient selection of the desired gene combinations from a breeding population. The latter method is utilized for identifying, at the molecular level, the presence of certain genes with desired characteristics. It allows for trait recognition at an early stage and with a high degree of accuracy. The importance of MAS is also related to significantly accelerating the speed with which modified trees can be developed[12]. Another marker system for identification of genes is the *randomly amplified polymorphic DNA (RAPD)*. This technique allows for the identification of genes with specific traits, and it also allows paternity analysis to be carried out (Macalister, 1995).

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[8] Tissue culture techniques stimulate the ability of individual plant cells to generate complete plants.

[9] Members of a clone show less variability than collections of the same organisms bred by sexual methods. Cloning may also provide for rapid multiplication of some desirable individual without having to wait for breeding cycles.

[10] It refers to the making of embryos from cells outside the usual reproductive apparatus. It is used to describe the regeneration of plants from single cells, and it is critical for plant cloning and micropropagation technologies.

[11] Speaking of clones, the existence of somaclonal variation should be accounted for, in order to account for variations between the individuals in a clone. In theory, each of the new plants produced by cloning should be genetically identical to their parent. In practice, however, the cell callus can be quite genetically unstable, causing the genetic information of the regenerated plant to vary from the parent.

[12] Without MAS the process would take about 11 years. With MAS the process halves the time it takes to identify the relevant offspring through genetic fingerprinting (Macalister, 1995).

2.1.2. Public and private involvement in biotechnology

The development of biotechnology within the past generation has raised an entirely new and promising area of research which is attracting both public and private research support. However, the high cost of research and associated risks are two factors that have a strong impact on reducing the financial support offered by the public sector. Moreover, the extension of patent and patent-like protection to an even broader array of products is a further component in the shifting of sources and levels of research funding towards the private sector (Lesser and Lee, 1993).

As James and Krattiger (1996) note, in the past, developing countries had the privilege of accessing non-proprietary conventional technologies from the public sectors of developed countries. In the case of the new biotechnologies, however, development is undertaken primarily by the private sector in developed countries, not the public sector, and these are proprietary technologies. Thus, private firms perceive that they are able to realize financial returns on their research investments in biotechnology (Persley, 1990).

The increasingly 'private' nature of biotechnological developments has also impacted on the perceptions of the potential of biotechnology in both the developing and developed countries. In industrialized countries, private investment leading to private gain has been associated with placing a monetary value on germplasm, which poses constraints on the free exchange of genetic material (Lesser and Lee, 1993).

"The lack of patent protection in most developing countries is a major disincentive for private-sector investments in biotechnology, both by local private-sector companies, and by transnational companies" (Persley, 1990). Thus, in developing countries the research and applications of biotechnology continues to be heavily dependent on investment by their public sectors, even though private sector foreign investment in biotechnology has been slowly, but gradually increasing. However, research funds for biotechnology do not represent a significant proportion of the total public funding for research in most developing countries. Moreover, the existence of financially weak private sectors, and governments allocating limited financial resources to general welfare areas and debt financing and servicing purposes, rather than long-term research, are two factors that have stimulated a significant gap between the abundant endowment of natural resources, on one hand, and the potential for further improving them by greater research and development, on the other. Thus, the economic impact of biotechnology in a given country is associated with the financial, as well as scientific capacity to undertake research in biotechnology and related levels of investment of that country.

In general, one of the major features associated with the development of modern biotechnology, which is meant to have an accelerating effect on research, is private participation. It stimulates research efforts and enhances the effectiveness of biotechnology, considering that the use and applications of biotechnology will be adapted to both biological needs and market expectations for faster returns (Persley, 1990).

2.1.3. Qualitative benefit factors of biotechnology

The benefits of biotechnology as a science are more difficult to appreciate, than those related to the business of biotechnology. This is mainly because, the scientific developments of biotechnology stimulate and enhance commercial applications which are assessed on the basis of greater cost-effectiveness and time-reduction of the new technology. Among some of the qualitative benefit factors are:

- Biotechnology allows for the improvement of genetic material by enhancing old traits or inserting new ones. The improvement is carried out in a shorter period of time, and it is more closely controlled (by the use of molecular markers);
- The application of tissue culture techniques provides for the production of a large number of genetically re-engineered plantlets annually. Moreover, tissue-culture derived plantlets ensure uniformity in genetic composition, leading to a greater uniformity in yields and quality of wood. Even though plantlets are significantly more expensive than conventional seedlings, the scaling up of the multiplication technique and the earnings from improved yields would offset the initial higher production costs[13]. Biotechnology would increase productivity by decreasing costs per unit of output and by increasing wood quality per unit of input. Thus, the value of the resource (tree) is maximized;
- An indirect gain is the provision of a steady supply of superior quality wood material. Biotechnology provides for the reduction, if not the elimination of shortages of wood supply, because of shorter rotations, greater wood quality, as well as the reduction of risks related to the detrimental effects of pathogens on the growing stock.

2.1.4. Qualitative cost factors of biotechnology

As any new technology, biotechnology brings the promise for 'new' products and greater returns, but it also leaves some questions unanswered. The shortcomings or concerns related to biotechnological research are represented by a number of widely discussed qualitative cost factors:

[13] Estimated cost of plantlets is $0.14 (including capital cost and for the production of 1 million plantlets), where labour contributes about 40% to 60% of the total cost of production. In general, an automated plant

- Difficulties associated with the marketing of genetically-modified organisms on a large scale, due to the possible delays of safety requirements, public concerns and the need to carry out more research. The economic viability and dissemination of biotechnological products are constrained by a higher uncertainty regarding consumer acceptance, the biosafety debate and intellectual property protection, as well as the long time lags for implementing production;
- The possible reductions of employment levels. It has been argued, however, that this could be offset by increased employment in downstream sectors;
- Specific technological constraints to the development and use of biotechnology, i.e. the need for consistent progress in the field of plant physiology, biochemistry, molecular biology and genetics and in the isolation and replacement of selected genes;
- Biotechnological developments, and specifically their nature of genotype modifications, could reduce the biodiversity of tree species;
- The magnitude of biological control of newly inserted traits is based on molecular grounds rather than on field deployment experience, which raises concerns related to possible undesirable effects of genetically-modified organisms, as well as to the period in which a newly inserted gene is actually functional.
- Biotechnology is a very expensive and risky way to enhance the quality of genetic material.

Considering that biotechnology is a widely researched, but less widely applied technology, the greatest danger for its future development could be the overreaction to its perceived failures, which could slow down present progress (Hacking, 1986). Thus, the increase in productivity (in terms of quality) needs to be the goal of the overall context of production, where productivity is related to the success of the development and application of biotechnology.

2.1.5. Concluding note

In general, the objectives of biotechnological development vary depending on the needs and capacity of a particular industry to innovate, and the availability and allocation of monetary resources for research. This raises the following questions: *What is biotechnology expected to do? How much would it cost ? What are the alternatives for achieving the set objective?*

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tissue culture technique could be developed as a means of achieving a 60% reduction in production costs (Sasson, 1993).

Biotechnology is constantly developing so as to accommodate for the changing expectations for resource utilization, or in general, for the purposes that it is expected to fulfill. Firstly, it is expected that it will solve the problems that conventional methods have not been able to solve, by improving specific traits of varieties in a shorter period of time. Secondly, it is expected to increase productivity in a cost-effective way. Thirdly, it is expected to generate products with superior quality, and thus to capture a larger market premium.

2.2. Characteristics of tree biotechnology

"Imagine trees that are resistant to herbicide damage, are tolerant to pests and diseases; whose lower branches fall off and so require no pruning, which do not flower but put all of their energy into growing wood, and whose wood has been engineered to be hard, straight-grained and long-lasting" (NZFRI, 1996).

2.2.1. A general overview

Biotechnology has been used in the improvement of different organisms - plants, animals, microorganisms - for a variety of specific purposes. The present thesis is concerned with characteristics of tree biotechnology, and more specifically with the biotechnology of hardwoods. Greater knowledge about the functions of specific genes opens up big opportunities to design new trees for specific environments and industrial purposes. Thus, the specificity of objectives, as well as the adaptability of the research to the purposes of improvement are the two most important issues when considering tree biotechnology.

Biotechnological developments for commercial forestry are not news for commercial growers. Genetic engineering of tree species is taking place in different laboratories around the world. Better scientific knowledge about gene constructs and hereditary functions of specific gene parts has increased interest in biotechnological research. Recent developments in biotechnology and their application to forest-tree species are contributing to both the rapid and reliable multiplication of selected genotypes and the provision of tools for genetic modification of forest tree genomes (Ahuja and Libby, 1993). For example, transformation and regeneration systems for trees have already been developed for Poplar and Walnut species (Persley, 1990), and recent efforts have focused on the transformation and regeneration of Pinus radiata and *Eucalyptus* species. Moreover, "new" biotechnology not only provides the methods for solving specific pathogen problems affecting trees, it also improves the quality of the wood and aims to increase the use of a greater proportion of the tree parts, by reducing the percentage of "waste" wood.

Some of the specific traits selected to bring economic and other benefits through improvement are sterility, volume growth, wood density[14], fiber characteristics, branching habits, resistance to fungal pathogens, as well as to insects and herbicides. Genes which improve the timber's structural strength and stability could result in higher quality logs, and wood products with greater value. A gene which makes the tree resistant to herbicides, for example, would reduce yield loss from the application of herbicides, and reduce or remove the need for herbicide control, a development which would have environmental benefits and reduce forest management costs (NZFRI,1996). Krimsky and Wrubel (1996) argue that it is unlikely that herbicide resistant crops will increase the overall use of herbicides. The likely impact of herbicide resistant crops is to shift the types of herbicides that are used, by increasing the use of a few broad-spectrum herbicides. Thus, herbicide resistant plants are considered more effective[15], less costly and a more environmentally attractive form of weed control.

For trees, the new biotechnology offers the first realistic method for the identification and isolation of useful forest tree genes. In the case of short-term rotation species, benefits of genetic engineering may be expressed so as to provide a degree of natural protection against insects, weeds and certain diseases by the appropriate gene insertion (Persley, 1990).

However, genetic engineering of trees is not an easy task, and three components must be developed consistently:

- the ability to transfer genes, or DNA, to selected tree species;
- the existence of a good, selectable marker system that works for the species of interest, and allows scientists to identify the desired genes;
- the development of a regeneration system to obtain plants from transgenic cells (Macalister, 1995).

Apart form the lengthy consultation process, there is much research yet to be done in terms of identifying specific genes, introducing them, testing the resulting plants (many of the properties under investigation, such as wood density, can be tested only in mature trees), and propagating the successes. And then there may be a 20-to-30-year wait before logs containing the modifications become available to the processing industry (NZFRI,1996).

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[14] For example, a benefit form a density-enhancing gene is the increase in the yield of fibre from a given area of trees by 10% or more.

[15] Some of the advantages of herbicide tolerant plants are related to the ability to remove weeds from plants, rather than kill both with herbicide application, as well as to maintain the genetic purity during seed multiplication of new cultivars. A single safe herbicide can be used instead of a mixture of herbicides,

In general, the success of biotechnology as a problem solving process depends on:

- the existence of new diagnostics for pests or diseases based on the use of monoclonal antibodies;
- the use of rapid propagation systems to allow the multiplication of new varieties; effectiveness of transformation systems to enable new genetic information to be inserted into single plant cells;
- applicability of regeneration systems to enable single cells to be regenerated into whole plants; and,
- progressively shorter time-frame for the commercial applications of new technology (Persley, 1990).

2.2.2. Transfer technologies

In the case of gene transfer technologies, both *Agrobacterium tumefaciens* and *Biolistic transformation* have been used to insert DNA into trees. Progress has been made, especially with hardwoods, where Agrobacterium can be used as a vector. Herbicide resistance in Populus species provides an example. Biolistic approach has also shown promise with coniferous species, and successful transformation has been demonstrated using marker genes (Macer et al., 1991). Besides inserting a desired characteristic into the plant, scientists are also trying to modify naturally occurring genes which have undesirable effects on trees such as poor form, low growth rates of excessive lignin content[16]" (Macalister, 1995).

A frequently asked question is: *What genes should be introduced?* Genes for herbicide resistance are already being incorporated, and there is possibility of introducing genes for resistance to disease, or for the biosynthesis of anti-fungal agents that might extend the natural life of the timber and reduce the need for preservatives; direct manipulation of genes that affect the size, shape, and constituents of the wood fibre cells may even prove a means of influencing wood properties (NZFRI,1996).

2.2.3. Marker systems

Two immediate applications for the new DNA marker technology are genotype matching (tree identification for clone) and confirmation of pedigree (parent identification for seed).

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reducing the chance of weeds becoming resistant to several herbicides. The amount of herbicide used could also be reduced.

[16] This is done by inserting a foreign DNA into the tree tissue to counter the effect of undesirable genes.

Tree genotypes can be verified in long-term field trials and molecular biology experiments, which reduces the possibility of losing an experiment due to 'mix-ups', or simply loosing track of specific clones after large-scale vegetative multiplication. However, the precise genetic control of 'desirable' wood properties is not always clear, but DNA markers which are associated with the genes controlling specific traits can be identified (NZFRI,1996).

Marker-assisted selection can be used to identify trees with superior performance through examination of bands produced by their DNA[17]. Molecular markers hold tremendous promise for marker-assisted selection (MAS) in trees. Their use has the potential to augment the genetic gain which can be obtained using traditional methods, especially for traits which have high heritability, but which are expensive to measure on a large number of trees (e.g. wood property traits). If markers which are linked to genes controlling substantial variation can be found, not only would the selection process be less expensive than through conventional methods, but selection could be carried out immediately after propagation, rather than having to wait until trees are at a mature age. This very early selection would make it possible to capture additional gain in production populations by selecting among offspring for vegetative multiplication for operational plantings, as well as for breeding populations. The goal is to develop strategies that will capture all the potential gains available from conventional selection, plus an additional gain from MAS (NZFRI, 1996).

2.2.4. Regeneration and propagation systems

The recent successes in genetically-engineered trees have been due mainly to advances in both the tissue culture and gene transfer technologies. The advances of tissue culture over conventional breeding methods include speed in duplication, the production of a large number of genetically identical plants and minimizing the breeding problems in plants from which sexual reproductive strategies are both time-consuming and difficult[18]. Bains (1993) notes that considering that trees are difficult to breed, due to their size and long life cycles, genetic engineering techniques offer unusual advantages of speed and the ability to engineer millions of clones.

When genetically engineering trees for greater resistance and uniformity, effort must also be focused on the basic understanding and technology of regeneration of plantlets from callus, micropropagation and rooting, as these areas must be well defined if genetically

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[17] Trees with specific bands may perform better than trees with a different banding pattern.

[18] However, no technique is perfect. One of the shortcomings of tissue culture, besides difficulties for regeneration for some species, is the development of efficient techniques for selecting cells and tissues that are expressing the inserted foreign gene.

manipulated plants are to become clonally propagated on a commercial scale (Dodds, 1983).

A number of propagation options are available or are being developed for the deployment of genetically-modified material. Macropropagation (involving conventional methods) and micropropagation[19] (carried out though tissue-culture technology) are the methods for massive clonal propagation. Tissue culture by both organogenesis and embryogenesis offers systems with high multiplication potential:

- ***Embryogenesis*** - Embryogenic cell lines are established from immature seed, and millions of immature embryos of individual genotypes can potentially be multiplied from each seed. These embryos develop and mature under appropriate conditions and then they are germinated like natural embryos. The technology has the potential to produce unlimited quantities of embryos of desirable genotypes at costs cheaper that current control-pollinated seed prices (NZFRI, 1996).
- ***Organogenesis*** - Starting material for this technology are embryos from control-pollinated seed. Several stages are involved, including shoot initiation, shoot elongation, shoot multiplication and rooting. Sterile tissue is grown in containers on a special medium containing all the necessary nutrients, hormones, and other substances to control growth. When shoots are large enough, they are given a hormone treatment to stimulate rooting, and set as small cuttings in containers in a greenhouse to form roots. After rooting, they can be lined out in a nursery bed and grown on like seedlings or cuttings. Tissue-cultured plantlets are currently expensive to produce because of all the manual stages of transfers and the need for growing in sterile controlled conditions (Te Teko) (NZFRI, 1996). There are a number of costs and risks related to the new technology. Organogenesis systems, for example, are carried out by using many transfer steps, costly facilities and materials, and high rates of mortality to the field, and thus, have proven to be very costly on a per-plant basis (Talbert et al., 1993).

Micropropagation by somatic embryogenesis is a promising way for clonal propagation of plants. Organogenesis is an alternative way of propagating plants from buds. By using organogenesis, plantlets have been produced from over 30 conifer species, while large-scale production and field establishment has been achieved for only four species, including Pinus radiata in New Zealand (Talbert et al, 1993).

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[19] Juvenile material is used for micropropagation, such as embryos, cotyledons, seedlings or young plants. The reason for this is mainly because the rootability of woody cuttings declines with tree maturation.

The most important advantages of *in-vitro* propagation are the following:

1. Production of large numbers of plants or clones in a short period of time,
2. Propagation of materials in an environment free of viruses and other pathogens, under optimum conditions and with better quality control and reliability,
3. Ability to propagate plant species which are difficult to propagate vegetatively once they flower, or to propagate species where *in-vitro* culture techniques are commercially superior to other conventional methods of propagation,
4. Ability to supply plants on a year-round rather than on a seasonal basis, and from locations close to consumers and markets instead of being tied to cultivation sites,
5. Maintenance of heterozygocity and the cloning of superior individuals from both qualitative and quantitative viewpoints (OECD, 1989).

The major goal of the propagation research is to develop reliable high multiplication systems for clonal forestry. One such advantage is the ability to capitalize on genetic engineering. Herbicide resistance has been successfully incorporated into embryogenic seedlings, and in the longer term, traits of interest could include wood properties, wood durability, disease and pathogen resistance among others (NZFRI, 1997).

Clonal deployment of the genetically engineered trees not only maintains and multiplies the genotypes that were favorably modified by genetic engineering, but it is also likely to achieve substantial economies of scale by making many relatively inexpensive copies of plants that were initially very expensive (Ahuja and Libby, 1993).

In the future, it is probable that no single propagation system will be used alone. Instead, there is likely to be a combination of several methods, using a tissue-culture system to produce desired transgenic plants or for clonal storage or rejuvenation, followed by a nursery fascicle cuttings or conventional cuttings system. The tissue culture and fascicle cuttings systems offer high initial multiplication rates, while the nursery cuttings systems can be used to produce high quality plants very cost-effectively. The chosen combination of methods will be tailored to suit the requirements of the individual forest company (NZFRI, 1997).

2.2.5. Concerns regarding genetic engineering

The implications of genetic engineering for tree improvement are generally promising. However, the excitement related to the potential of tree engineering should not ignore the possible shortcomings, or undesired effects that the new technology or product could bring. For example, the genetic variation within a plantation is usually minimal, considering that achieving a uniform crop, harvestable at a specific time, in a technically simple way, is an economic objective. The cost of achieving this uniformity could result in a small loss in productivity (Ahuja and Libby, 1993).

Moreover, objections have been made to the establishment of large blocks of single species, even-aged plantations on environmental and aesthetic grounds. "Greater use of uneven-aged plantations and of mixtures of species is advocated, although not all the environmental benefits of such stands are proven nor are all their management problems worked out" (FAO, 1994).

Another concern about genetic improvements in forestry is related to the nature of the biotechnological research. The lengthy time lags related to research and further growth of the tree can be a significant constraint to an effective use of the transgenic trees. The process of selection and re-engineering takes a considerable amount of time (which is offset by the faster production after successful selection and re-engineering). "First the gene has to be found and cloned; it then takes 15 years to obtain young trees that contain the new gene before tests can determine whether the timber does have the good lasting qualities. Next sufficient numbers of the new tree have to be propagated and planted out, and it's still another 25 years until the tree is harvested and ready for processing" (Macalister, 1995).

Moreover, regulatory restrictions are the bottleneck of the process of producing and testing genetically-modified trees, as field trials and commercialization of products are not yet commonly permitted. Thus, even though a transgenic tree has all the beneficial characteristics from a biological point of view, it might not be legally accepted and thus, it could become economically too expensive to produce. There are many details to be considered along the entire path of biotechnological development, in order to establish a credible estimation of the economic returns of such activity.

2.2.6. Concluding note

In general, like any technology tree biotechnology is subject to constant change and evolution. It will be mainly through new, improved species, with greater volume and quality potential that a contribution can be made to secure a stable global wood supply. The needed increase of productivity per hectare can be achieved through either planting less trees with uniform and improved phenotypic characteristics, that carry both volume and quality advantage, or through planting more trees, which will require a greater proportion of available land.

Thus, the main goal of tree biotechnological research is to engineer highly uniform, superior, higher-yielding, pathogen-free, stress-tolerant clones in a very short time, by using a cost-effective and quality-enhancing production process. It is expected to provide not only a steady supply of logs and wood products, but also to improve log quality for specific wood processing purposes and to diversify the type and quality of wood products. Thus, biotechnology will be used to implement the required change in input resources in order to meet specific consumer preferences for output quality, through the management of bio-reengineering and production processes.

2.3. Conventional tree breeding practices versus genetic engineering techniques

The focus of conventional research has been on the level of the organism, or the entire plant. "The 'new' biotechnology refers to research on parts of organisms, particularly the cellular and molecular levels. Typically, the new biotechnology relies on the old for the development of commercial products; the altered gene must be introduced into a viable plant to release its benefit. What has changed is the ability to act at a more basic level within an organism to achieve the previously impossible or to accelerate what was formerly slow" (Lesser and Lee, 1993).

2.3.1. A general comparison

Traditionally, forests have been regenerated from seedlings derived from seed collected in nature, or more recently from seeds collected from randomly pollinated trees. In most of these forests there is a large variation in growth, form and vigour. Moreover, by employing conventional methods of vegetative propagation, the numbers of plants (stecklings) that can be propagated from a tree species in a growing season often are relatively small. The limiting factors for mass scale utilization of selected materials are restricted availability of improved genotype as a planting material and the available space.

To overcome the problems of conventional techniques, biotechnological approaches offer opportunities not only for mass cloning of selected genotypes throughout the year, but also for the genetic modification of tree species. Thus, biotechnology can serve as an adjunct to conventional genetic and breeding programs for tree improvement (Ahuja and Libby, 1993).

Genetic manipulation in a laboratory environment could fail without the breeders knowledge of true field performance of the variety. Better performing varieties are initially identified by conventional breeding practices. These varieties are consequently used for genetic engineering, converting the already known varieties into "new" varieties with novel characteristics (such as herbicide tolerance, resistance to specific pathogens and diseases). Persley (1990) argues that the widespread use of these novel characteristics will be dependent on their further incorporation through conventional plant breeding into varieties with suitable agronomic characteristics and stable yields. Thus, support from modern biotechnology should not be at the expense of well-established technologies, but it is only when there are weaknesses in these areas that the more sophisticated technologies of modern biology can be grafted onto existing systems.

Genetic engineering is the extension of traditional crop breeding goals. The most obvious improvement accomplished by traditional breeding is increased yield. This increase has been achieved by small increments, leaving a greater potential for genetic techniques to rapidly increase yield and the quality of yield, as they complement the traditional technology (Macer, 1990). Thus, maximization of yield in different environments seems no longer to be the main goal of selection. Quality improvement and marketing appeal are two other important goals.

This suggests that the new technology contributes to further advances, any of which would never be possible using conventional technologies. These advances can generally be characterized as improved products for existing markets. They are not new products for new markets. They offer better solutions to problems solved with conventional technology. Yet substantial improvements in control may be possible with genetically engineered plants that carry their own resistance internally. This would eliminate the adverse environmental effects of chemical pesticides while arguably allowing for better control of application (Dines, 1991).

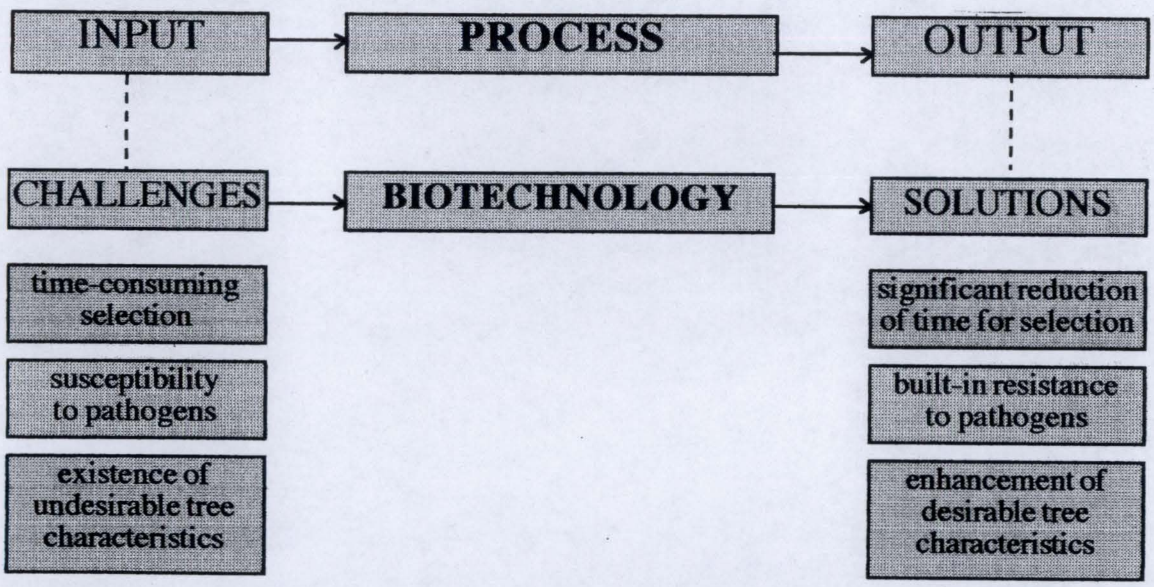
Conventional plant breeding is based on attempting crosses between desirable parents followed by the selection of promising recombinants in subsequent segregating generations. Fixations of the genotype to produce lines breeding true to type requires repeated selection cycles. Such a procedure take a long period of time (6-8 years) according to Sasson (1993), or 10 years according to Persley (1990). Thus, even though traditional breeding practices are the essence of selection, biotechnology offers more rapid methods of testing, reproducing and disseminating new varieties, i.e. new types of inputs would lead to their widespread use and adaptation more quickly than before.

Even though it is frequently argued that genetic engineering will dramatically reduce the time of selection and production of superior varieties, it is not a general rule, and it depends on the gene to be inserted and the host species, as well as on the regeneration capacity of the host species. Thus, transformation and regeneration of plants is highly variety-specific. The gene of choice has to be introduced into a variety that can be manipulated easily in culture, and easily propagated, and then used in a conventional breeding programme (Persley, 1990).

2.3.2. The advantages of "new" biotechnology

The first step in assessing the usefulness of new biotechnologies to forestry is to identify the problems which have not been solved by conventional approaches and which may benefit from the application of new technologies. Thus, in terms of achieving specific goals for commercial utilization, the focus of biotechnology should be on providing purpose-specific solutions to a number of challenges, and the products and processes needed to solve them, rather than on the technology itself (Persley, 1990). The following scheme best describes the idea in terms of the goals of the present thesis:

Figure 1. A scheme of challenges and their solutions, achieved due to biotechnological developments of trees



The challenges are represented by the existence of poorly performing trees in terms of their susceptibility to pathogens (insects, weeds and diseases). The trees are originally selected by using conventional techniques, according to their hereditary characteristics for specific traits of interest. Using conventional methods for further improving the resistance to specific pathogens would be very time consuming and the degree of improvement might not be as significant as expected, thus, leaving some undesirable wood characteristics in trees. For example, in terms of disease resistance, conventional plant breeding methods (selection of resistant varieties and hybridization of crops with wild varieties) have been effective, but very time consuming. Molecular techniques (insertion of anti-viral or antibacterial genes from other species into plants) and cellular methods to allow rapid screening for the desired phenotype, have led to more rapid progress.

The role of genetic engineering in forestry will be concerned with improving traits that are difficult or impossible to accomplish by conventional tree breeding[20] practices, such as disease, insect and herbicide resistance, male sterility, and wood properties such as lignin and natural preservatives. For example, the insertion of Glyphosate tolerance genes into the plant causes herbicide resistance in plants with minimal or no reduction in yield[21]. Work has concentrated on herbicides that are more environmentally friendly than those commonly used, i.e. those herbicides with properties such as low toxicity, low soil mobility, and rapid biodegradation and with broad-spectrum application against various weeds (e.g. Roundup). Thus, the purpose-specific application of biotechnology is expected to overcome the specific limitations of conventional selection and to give solutions to challenges in a more effective way, e.g. by engineering trees for improved performance (greater resistance and improved wood composition characteristics), as well as by speeding up the process of selection.

According to Persley (1990), the attractive features of modern technology for improvement purposes are the genetic specificity, the genetic novelty and the breeding speed of the process. Moreover, Dines (1991) argues that the new technologies are likely to be superior to conventional technologies because they are faster, more precise and they will allow greater flexibility in the selection of genetic traits, as well the new products will deliver the extra desirable trait that was the basis for development of the product in the first place.

The problem or the challenge, in general, can be represented by any commercially important commodity, the demand for which is increasing, while price is volatile and supply is unstable. Thus, the nature of the problems of a specific commodity could be evaluated against the potential of biotechnological solutions. In order to capture the value of any biotechnological improvement, the problems being solved have to be correctly identified.

The solution of the specific problem, on the other hand, depends on the availability and development of the new technology. Conventional breeding practices are already available

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[20] Some gains (better form, faster growth rate, greater number of plantlets) achieved through conventional tree breeding techniques (control pollination, mass vegetative propagation from seedling stool beds, and micropropagation) have come from the selection and accumulation of a wide spectrum of genes already present in the breeding population (NZFRI,1996).

[21] Even though genetically engineered herbicide resistant crops are not necessarily agronomically inferior to classically bred varieties, the development of some herbicide resistance products may be slowed or arrested because of yield and quality deficiencies. "The major developmental problem has been creating crop lines with commercial levels of resistance while maintaining yield and vigour qualities equivalent to non-engineered lines" (Krimsky and Wrubel, 1996).

and widely used for the purposes of forestry or agriculture in general. They have given solutions to many problems, but the questions is, *how effective would they be to solve "new" problems?* It can be argued that "new" problems should be solved by using the means of both conventional knowledge as a base, and biotechnology as a "new" approach to a "new" problem. However, because of the "new" nature of biotechnological research, there is still a lot to be done for greater improvement.

However, even though biotechnology induces incremental improvements in already existing products, the challenge/solutions approach is not the only way to describe the importance of biotechnology. Biotechnology also leads to whole new approaches for attaining useful products from different commodities. Dines (1991) suggests that the applications of biotechnology could be classified as new opportunities rather than new solutions to old problems, considering that these opportunities may not even address what we think of as today's current problems.

2.3.3. Concluding note

The forests of the future will benefit from both conventional breeding technologies and from what genetic engineering has to offer. They will be more resistant to a variety of pathogens and pests, and they will produce wood which is more easily used for specific purposes, and timber with improved durability and structural characteristics. But most of the differences will be 'internal' - forests will look much the same as they do today (NZFRI,1996).

Even though the quality of tree resources has been improved by using conventional techniques for enhancing growth and form characteristics, there are limits to what can be achieved by breeding selected parent trees, leading to the need of further refinements at a more fundamental level, i.e. within the tree's genetic code (NZFRI,1996).

Genetic engineering gives tree breeders something extra - the ability to produce specific alterations in a single trait of interest, as well as to introduce new traits which are not readily available in breeding populations. Biotechnology offers the potential to transfer any given trait from any given organism into a tree of interest, and express it in the new host. Consequently, a specific trait only is added or altered, rather than a non-defined mixture of traits, thereby reducing the chances of breeding an undesirable characteristic into a tree simply because it is associated with a desirable one (NZFRI,1996). Other potential benefits that biotechnology offers are faster growth, greater multiplication, faster and more effective selection process, quality improvement, and increased tree volumes. Thus, tree biotechnology seems to be an exciting task for scientists, but it also represents a great challenge to decision makers.

Biotechnology is just another tool to improve the returns on forestry, but it won't supersede older technologies. Plant breeding seeks new combinations of genes that are well adapted, by rearranging the hundreds of thousands of genes that are present in the two parents. It is limited to genes that are present in the species and will cross with the crop of interest. In contrast, genetic engineering introduces only single new genes into a species, but the genes can come from any source" (Macalister, 1995). Economic returns from introduction of specific genes could be significant[22].

Both conventional and modern methods for tree improvement are interrelated. Biotechnological developments would fail without a correct identification of the performance of a specific line of interest, while conventional breeding would fail to establish lines highly resistant to specific pathogens in a short period of time. Even though conventional knowledge complements the findings of biotechnological developments, both approaches have their specific advantages and shortcomings.

In general, when analyzing solutions to specific challenges by using biotechnology, the combination of conventional breeding, modern genetic and molecular knowledge and economic theory would be the best way to proceed.

2.4. Genetic engineering for commercial purposes - the case of Eucalyptus grandis

The focus of the present thesis is on a single tree species and its hybrids - *Eucalyptus grandis*[23]. Eucalypts are widely planted in tropical, subtropical and temperate regions of the world, and are grown as sources of pulpwood, fuelwood and charcoal, mining timber, fibreboard and essential oils. Recent developments with eucalypts focus on quality enhancement for structural purposes. Wood from eucalypts has been considered applicable for construction purposes and for the production of high-quality re-processed wood products. This has stimulated a greater interest in the selection and genetic engineering of *Eucalyptus* trees for plantation and processing purposes.

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[22] For example, a gene which improves the density in trees could increase the yield of fiber per hectare by 10%, or would cause an overall increase in the volume of ovendried fiber per hectare by between 8,000 kg and 10,000 kg (Macalister, 1995).

[23] About 500-600 eucalypt species are currently recognized. Some are widely, though discontinuously distributed, others are narrowly restricted to localized niches. Many species contain a high level of genetic variation, and variability within local populations. Superimposed on this, hybridization and introgression between interbreeding species may occur where their distributions overlap, as well as hybridization between

2.4.1. The ecology of Eucalypts

In general, eucalypts develop through a number of 'growth' stages - juvenile, sapling, mature, and overmature senescent, and each stage is characterized by different degree of growth in height and in diameter. Both factors vary with the quality of the site where the tree is grown and the specific silvicultural regime undertaken (Florence, 1996).

In general, a well-grown eucalypt on a good quality site can produce a long, clear (branch-free) bole as it develops through the sapling stage to maturity, and this is of considerable advantage in harvesting and processing the wood. However, because growth stresses develop within the wood, there may be difficulties in sawing tree boles, particularly where they have been grown quickly or are small. This suggests that despite the clear and straight bole, many eucalypt species would not make good sawlogs until a large diameter has been reached[24] (Florence, 1996).

2.4.2. Characteristics of Eucalyptus grandis as an exotic

Eucalypt species are generally known as well-adapting to adverse environmental conditions. The magnitude of resistance or survival under different conditions, however, varies among different subgenera of the species. *Eucalyptus grandis* is classified as a coastal zone species with high rates of growth and water use, but with somewhat wider environmental tolerance (Florence, 1996). It also has a surprising level of frost tolerance, despite its tropical-subtropical distribution.

a) Site specification

As exotic species, *Eucalyptus grandis* is mainly grown in the tropics and subtropics, with summer-dominant, but well distributed rainfall. It is also characterized by particularly rapid early growth rates and high rates of water use. It is not resistant to drought, but a mean annual rainfall of 900 mm is generally adequate provided that it is well distributed and the soil is deep. Growth is most rapid in areas receiving 1000-1250 mm per annum. In general, site factors strongly affect species composition, stocking densities, stand structure, and potential sawlog production (Florence, 1996).

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eucalypts planted as exotics, and the potential for creating artificial hybrids for specific environments (Florence, 1996).

[24] The outer wood, or the sapwood, represents the last 7-10 years of growth of the tree, and it also maintains the biomass nutrients important for the growth of the tree. Up to a half of the wood may be present as sapwood in a fast-growing, short rotation (10-15 years) eucalypt plantation.

When planted under suitable conditions, all provenances of the *E. grandis* share on average very rapid height growth with a tall, columnar, naturally self-pruning stem. For example, where grown under hot, wet conditions in Brazil, tropical provenances of *E. grandis* tend to be more resistant to fungal attack than are other provenances (Florence, 1996).

Given the importance of site specific characteristics to the growth of *Eucalyptus grandis*, a modern silvicultural program should take account of a number of factors:

1. The adaptation of species to the general climate of the target region,
2. The range of genetic material which is available in that species,
3. The availability of planting sites which can give adequate expression to a species' inherent capacity to produce wood volume rapidly,
4. The wood properties which will satisfy prospective end users of the timber (Florence, 1996).

b) Breeding, selection and developments in biotechnology

Major research involving the improvement of *Eucalypts* is currently carried out in South Africa, Australia, New Zealand, Brazil, Argentina, India, Zimbabwe and the United States (Florida) among other countries.

The application of 'old' biotechnology (as opposite to 'new' biotechnology, i.e. genetic engineering) on *Eucalyptus* species is not a new phenomenon. The first step consisted in the transition from the use of seedlings to cuttings (clonal *Eucalyptus* forestry). After a number of methodological problems were overcome, the methodology became operational and there was a fast switch from the use of seedlings to the use of stecklings (Ahuja and Libby, 1993). Recently, greater attention has been given to the gains from using alternative techniques (embryogenesis, organogenesis) for speeding up the process of selection and multiplication.

Advantages from vegetative propagation[25] *(use of rooted cuttings)*

An alternative to the collection of seed is a propagation system based on regeneration and rooting of cuttings[26]. Cuttings have mainly been used in preference to micropropagation in

[25] "Vegetative propagation is not a breeding method to develop better genotypes. It is only a method to mass-produce desired trees and to get the increased benefits by using outstanding and known good genotypes. It does not create anything new or directly produce improvements in advanced generations. It does enable taking advantage of differing genes through maturation and using knowledge gained from clonal testing, which indicates the value of the genotype when it is used as a clone" (Zobel, 1993).

vegetatively propagating eucalypts. Nevertheless, the clonal culture of meristems and leaf discs in sterile media is opening new opportunities for the conservation of genotypes, rejuvenation of physiologically old shoots, rapid multiplication of desirable individuals, and mass propagation on a commercial scale (Florence, 1996).

"A cautious approach is necessary in respect of planting stock of various tree species multiplied through micropropagation techniques because of possibilities of somaclonal variation (genetic change through mutation). It may be difficult to obtain exactly true-to-type planting stock. It is necessary to standardize micropropagation techniques for different species which ensure genetic uniformity of planting stock multiplied from a particular clone and test the material before taking up large scale commercial plantations" (Lal, 1994).

Micropropagation is not yet widely used to produce growing stock for industrial plantation, the technology has a great 'research and development' value. Stock plants for the mass production of cuttings can be produced rapidly in this way. It can also be used to clone promising plants where there is only a limited quantity of shoot material, particularly where the material is difficult to root as cuttings and needs to be 'rejuvenated' (Florence, 1996).

Planting of eucalypt clonal stock costs more than a seed tree system or a direct seeding regime, but there are some important advantages, including greater control of stocking density, and more efficient use of machines in subsequent thinning and harvesting operations. Control of stocking density may facilitate the allocation of biomass production by the site to potential crop trees, ensuring a shorter rotation. Early control of stocking density may be particularly important in some of the more intolerant (in terms of competition) eucalypts, particularly *E. grandis* (Florence, 1996).

Zobel (1993) argues that, in addition to greater uniformity, the use of clonal propagation of *Eucalyptus* has shown major advantages resulting from a full capture of the genetic potential of desired genotypes. One of the greatest benefits from clonal propagation is in volume gain since growth rate has a relatively large amount of non-additive variance, which can best be captured through vegetative propagation. The volume measured by m^3/ha/yr and the respective volume of processed wood increase significantly by using cuttings from selected trees than by using improved seedlings. The second and third most important advantages are in the uniformity and desirability of the wood produced. Lal (1994) suggests that the projected theoretical possibilities of gains in yield in clonal

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[26] Through vegetative propagation, average volume production increases from 33 m^3/ha/yr (when improved seedlings are used) to 70 m^3/ha/yr (with cuttings from selected trees are used). This equates from 7.9 tonnes of pulp/ha/yr to 18.5 tonnes from the rooted cuttings. The greater percentage increase in tonnes of pulp relative to volume is due to use of the desired specific gravity and the capturing of greater cellulose yields possible in clonal forestry (Zobel, 1993).

plantation trees range between 17-40% through traditional breeding and 82% through selected superior clone of same species[27].

"Gains in improvement of productivity, yield and upgrading of desirable qualities of the produce will depend on the intensity of selection of clones[28]. Generally, higher the intensity of selection and lesser the number of best performing clones used in the plantation programme, better will be gains in terms of productivity and economic returns. However, too narrow genetic base of clonal plantations will mean taking serious future risks in respect of possible insect pests/disease attacks" (Lal, 1994).

Wood characteristics also vary among the different *Eucalyptus* species. Wood properties differ according to the tree's genotype, as well as the environment in which the tree is grown. However, between-tree variation could be reduced by using different propagation techniques. The benefit will consist in the greater uniformity of the produced wood and the effective clonal selection for desired wood[29] (Zobel, 1993). Economic returns would also be greater due to the uniformity of raw material and the enhanced wood quality of logs.

The uniformity[30] and quality of the wood are important for both the final use of the wood product, as well as the intermediate processing of uniform logs. Uniformity means the reduced variation in both growth patterns and wood density of individual trees, which will make it easier to further process and market the wood for specific purposes. Uniformity and the specific set of characteristics that it implies also mean both cost reduction throughout processing, and quality enhancement of final products.

In general, even though significant gains associated with the use of vegetatively propagated rather than seedling stock have been identified, the large amount of genetic variation in rooting ability and the costs of clonal planting programs, have so far limited the extent to which clonal stock has been used in industrial scale programs (Florence, 1996).

Some tree species can be readily propagated by vegetative means and the production of outstanding genotypes is relatively simple on a large scale (e.g. poplars). Eucalypts,

[27] The author gives examples of specific gains in productivity of eucalypts, achieved by the Brazilian company Aracruz Forestal. "Because of extremely high productivity of clonal plantations, pulpwood cost [for example] has been contained at US$ 17/m^3 delivered at the mill compared to US$ 30/m^3 cost of purchased wood" (Lal, 1994).

[28] Depending on what quality characteristics are sought, clones are selected and multiplied. Clones are nearly always chosen to have desired wood along with superior growth, form, adaptability, and disease resistance. Different final products are best produced from specific wood properties (Zobel, 1993).

[29] "Good looking" trees do not necessarily produce good clonal copies in a plantation. Finding a good *eucalypt* phenotype and then using it as a donor for clonal planting purposes will be successful only if the clonal rooted cutting is field-tested before used in operational plantings.

[30] Excellent uniformity may be obtained from rooted cuttings, with all the trees within one clone, at a given age on the same site, having about the same diameter, height and form.

however, have proved difficult to propagate vegetatively (Hillis and Brown, 1988). However, more recently, vegetative propagation (rooting) has been used for plantation management of eucalypts, as a standard method of operational propagation in species like *Eucalyptus grandis* (Zobel, 1993). As eucalypts of subtropical-tropical origin (e.g. *E. grandis*) are easier to propagate than those of temperate origin, successful, large-scale clonal plantings are more likely to be found in South America and Africa. There has been successful mass propagation of selected trees in Brazil, including hybrids of *E. grandis*[31]. The greater availability and lower cost of labour in some subtropical-tropical countries could also be a factor (Florence, 1996).

"Economic gains from clonal plantations of forest trees will vary from species to species and region to region. Gains will also vary depending on the comparative costs of seedlings and rooted cuttings, interest rates, rotation, yields and market price of the plantation wood on harvest. Comparative gains from clonal plantations will be very high over seed route plantations based on unimproved, genetically poor quality seed. High value of the wood from clonal plantations, because of uniformity and most desirable properties, will result in better economic gains. Apart from genetic superiority of clonal planting stock, economic gains will also depend on the intensity of management, quality of the planting site, soundness of silvicultural practices, protection, including weed/ pest and fire control measures" (Lal, 1994).

So far, only initial approaches to biotechnological improvement of *Eucalypts* have been discussed, mainly the benefits of using rooted cuttings rather than seedlings for the purposes of plantation forestry and further processing. Rooted cuttings, while no better genetically than the trees that they come from, have increased the volume and quality of production, because of the nature of the initial selection and consequent multiplication. Thus, the gain with rooted cuttings is represented by selecting superior trees and propagating them faster. However, when genetic engineering is added to this formula, clones will be engineered to have a different genetic structure than the selected superior trees. The difference will be represented by enhanced built-in resistance to external pathogens (such as insects, weeds, fungus, diseases). This will further increase the gain from faster propagation, as a greater number of re-engineered genetic material of higher quality will be produced. Thus, genetic engineering adds an extra-advantage into the gains from clonal forestry.

[31] In 1975, improvement of eucalypts through a combination of breeding and rooting of cuttings of plus trees was started in the State of Espirito Santo in Brazil by Aracruz Forestal. By 1990, nearly 126 million rooted cuttings of selected clones of *E.urophylla* x *E. grandis* hybrids have been planted. Another company in Brazil, Chamflora Agricola Ltda, Mogi Guacu in Sao Paulo State has also made substantial advances in developing fast growing, disease resistant eucalypt clones (including *E. grandis*) (Lal, 1994).

Disadvantages of clonal forestry of eucalypts

There are a number of disadvantages related to the clonal forestry of *eucalypts*. The disadvantages have to be accounted for in order to adopt appropriate strategies to overcome them. The major biological problem is the 'fallout' of genotypes. A large number of selected trees must be initially available if one is to end with the desired number of clones suitable for operational planting (Zobel, 1993). Therefore, thousands of initial selections might be required to narrow down the selection for the best clones.

Any tree has to satisfy several selection criteria in order to be classified as a well-performing one for a specific objective: good sprouting, rooting and growing (when clonally tested), and it has to have a good tree form, as well as desirable wood, and finally it has to be adaptable to particular planting sites. This order of selection narrows down the number of choices. Many genotypes could fail in one of the required criteria, and even though they might be otherwise superior, they are not being considered. However, it is important to keep the 'rejected' superior genotypes for the purposes of long-term improvement. If this is not done, erosion of the available usable genotypes may occur, which implies the existence of an option value of preserving genetic diversity for future improvement. Besides, by using breeding techniques (sexual recombination), these genotypes might be used to produce additional trees, some of which might become suitable clones (Zobel, 1993).

According to Zobel (1993), it is economically explicable to use a lower, but safer number of trees, because gain is dependent on the intensity of the selection differential. However, the criteria for determining "the safe number" and the nature of the clones depends on the goals of the developer, and on the legal and political factors which influence them. The decision on the 'safe' number of clones, which yet achieve significant gains, can best be made when based upon the knowledge of the species and of what the likely risks of dangerous monoculture will be. The use of 15 unrelated, tested and well-adapted clones for *Eucalyptus* grandis is recommended. The author also notes that if political considerations dictate the use of a very high number of clones with no previous assessment, the potential gains from outstanding performance will be greatly reduced.

Moreover, *Eucalypts* are very sensitive to different environments and a selection and re-engineering program could be genetically successful, but it could fail depending on the adaptability of genotypes to the environmental variations of the sites where field tests are held. Thus, genotype/environment interaction is a major determinant as to where and how that clone will be used (Zobel, 1993). Therefore, field-testing is crucial for identifying the adaptability of selected and regenerated clones to specific environmental settings.

In general, a continuous research is needed for controlling the already established improvements and for future developmental programmes concerned with the production of better genotypes for additional gains. "Currently available best clones will often lead to a dead-end in productivity unless new and better clones are added to the plantation programme through a continuous on-going process of selection of future clones. Best clones of today should be replaced in due course with still better ones in the future. With due precautions in respect of various apprehensions and risks expressed about clonal plantations, productivity levels can be substantially improved on a sustainable basis and desirable qualities of produce can be enhanced through clonal technology combined with sound breeding strategies and appropriate management practices" (Lal, 1994).

c) Silviculture

Plantations based on improved clonal planting stock must be backed-up by sound silvicultural and management practices to take full advantage of the favourable genotype-environment interaction for sustainable gains in productivity (Lal, 1994).

A silvicultural decision is subject to a number of biological, environmental and other factors, such as: the size of the resource, the markets for forest products, the economic viability of forest operations, etc. (Florence, 1996). The main factors to be taken into consideration when making a specific silvicultural decision are the following:

- *ecological factor* - appreciation of the ways in which the composition and structure of the forest are responding to environmental factors, in order to establish the limits to which it is biologically safe to alter the forest composition; and the effects of silvicultural practices on the productivity and ecological sustainability of all vegetational units making up the forest,
- *availability of sawlog and other species* - the role of the forest in supplying wood to one or more markets; and making the most effective use of existing growing stock taking into consideration past growth characteristics and future objectives concerning harvesting and more sustainable wood production,
- *market factors* - strong demand for particular forest products, which the market values highly through the price it is prepared to pay for them; possible changes in the market preference for different species suggests that options should be kept open for diversifying practices,
- *condition of existing growing stock* - sequence of events that produce given attributes of the growing stock,

- *economic and financial factors* - costs reductions due to changing circumstances; financial maturity concept and pricing structure favour the harvesting of trees in relatively early stages of growth[32],
- *technical efficiency* - production of greater volumes of wood under more efficient harvesting systems[33],
- *environmental factor* - nature conservation (e.g. wildlife) (Florence, 1996)

The above factors contribute to the adaptation of silvicultural regimes to specific time constraints and final uses of the resource. Florence (1996) suggests that silvicultural practice in the future may not be 'sawlog driven' to the extent it has been in the past, and the sawlog industry may accept generally smaller logs. This is to say that smaller sawlogs and veneer logs could become the prime products of the forest, with the demand for construction timber, paneling, other high-quality appearance grade products, and so on, being serviced more through modern lamination technologies and reconstitution processes.

The initial spacing of the planted stand, the optimum stand densities[34] and thinning regimes[35] are closely interdependent practices and they are of particular significance in commercial plantations which must be managed as economically as possible in order to achieve one or more prescribed objectives. The number of seedlings which are planted per hectare can influence the rate at which the trees of the stand will grow in diameter, and hence value; and through the process of thinning, the yield of merchantable wood may be increased, and the time taken to achieve a commercial product reduced. Many, and often competing factors must be considered when an optimum thinning regime is to be formulated, including the biological attributes of the species, market requirements and the economics of wood production (Florence, 1996).

The density of the stand influences total productivity between the time of planting and the time when the site is fully occupied. After this the increment is the same in stands of different densities, but it is distributed among more stems at higher plant densities. Tree size is therefore depressed in stands where the density exceeds the minimum necessary to fully utilize the site. Harvesting costs per unit volume are less for the smaller trees which

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[32] If the price per cubic meter for poles and veneer quality logs is greater than conventional sawlogs, there can be financial pressure to harvest pole and veneer log trees as thinnings, despite their excellent sawlog potential, and to harvest other trees as soon as they reach a reasonable sawlog size.

[33] For example, when the primary objectives of a plantation forestry are to ensure high levels of wood production at future harvests, a clearfelling regime which creates a series of even-aged stands would be the most effective way of doing this. Complete clearfelling will normally be considered where there is a market for most of the growing stock.

[34] A reduction in spacing (i.e. an increase in initial density) usually reduces mean height, mean diameter, branch size, and taper, but increases basal area and total stemwood volume (but not necessarily merchantable volume).

[35] Thinning is the reduction of stand density by man for the purpose of management. One of the main objectives is to concentrate the growth potential of the site onto fewer trees, which usually results in larger trees of better quality and the opportunity for shorter rotations.

result from the denser spacing. Mortality can also occur in dense stands, resulting in a loss of net production (Hillis and Brown, 1988).

A wide spacing (500 stems/ha) might be considered for intolerant species[36] such as *E. grandis* that cannot be thinned until 15-25 years of age. *E. grandis* grows more rapidly on high quality sites and reaches a peak in current annual volume production much earlier than other species. The fact that 400 stems/ha could provide as much standing volume as 1400 stems/ha at 22 years of age must reflect a rapid decline in average efficiency of the trees where a thinning program is not maintained. Where the primary objective of management is to produce veneer and sawlogs in the shortest possible time, a thinning for pulpwood or small sawlog might be carried out as soon as is commercially feasible and the stand reduced to 100-200 stems/ha (Florence, 1996).

The minimum acceptable stocking on a logged plot will depend on management objectives. However, where the first commercial use of a forest is for sawlog production, as few as 250-500 stems/ha might be acceptable, particularly where the stems are uniformly distributed and mortality is not likely to be high. Alternatively, where thinning is undertaken for pulpwood, poles and small logs, a minimum stocking of 750-1000 stems/ha might be sought (Florence, 1996).

Intensive site preparation, weed control and fertilizer regimes contribute to rapid initial growth, and the mean annual increment often reaches a maximum before 10 years of age. Given that eucalypt seedlings are more sensitive to competition from weed species than any other tree seedlings, including pine, competition from weeds may cause negative effects on the eucalypt seedling, i.e. stem diameter and crown volume will be affected more than its height.

Herbicides are applied (before and after planting) in order to control weed competition. Pre-plant weed control may involve the application of a broad-spectrum (non-selective) 'knockdown' herbicides such as glyphosate. This herbicide normally provides for good initial weed control without damaging the eucalypt seedlings subsequently planted on the site. However, it cannot be sprayed safely over eucalypt seedlings to eliminate woody weeds. Alternatively, a selective herbicide might be used (grass-specific), or a pre-emergent herbicide applied when the planted seedling is sufficiently tolerant to it. While herbicides are now widely used to control weeds in eucalypt plantations, and results are generally very good, there have been reports of unacceptable phytotoxicity under some conditions. The tolerance of eucalypts to herbicidal sprays is variable, reflecting differences between species, the concentration at which the herbicide is applied, the timing of the application, and the type and condition of the seedling (Florence, 1996).

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[36] Species intolerant to competition (from other trees) have the ability to thin themselves. The most intolerant of the eucalypts are almost certainly best managed as even-aged stands.

d) Wood characteristics

Wood is a variable commodity. The properties of individual trees may differ markedly and even material taken from different parts of a single tree can have different density, strength, and fibre characteristics. An understanding of these differences in properties is essential if the raw material is to be directed to appropriate end uses, and processed in an appropriate way, to make products with an acceptable level of performance (NZFRI, 1997).

Species selected for the purposes of wood production should have the capacity of producing wood with technical properties that are suitable for the intended end product. For sawlogs the tree must have a large diameter and provide long, straight logs that meet strict quality criteria (uniformity, strength, stability, working properties) (Hillis and Brown, 1988). Some species develop very high levels of growth stress within the bole which may cause severe end splitting in logs, distortion during sawing, and severe shrinkage during drying.

Large areas of different eucalypt species are being planted because of the rapid growth rate in the genus and the increasing demand for wood. The trees are marketable after a few years, although a large proportion of juvenile wood is present. The presence of a greater proportion of juvenile wood means that wood properties are different from those of slow-grown, over-mature forests. "The resource of plantation eucalypts will be used most effectively when it is realized that fast-grown eucalypt woods are, in many ways, 'new' woods. They have properties requiring improved conversion processes and different methods of utilization. Furthermore, knowledge of the structure and formation of wood in young trees will facilitate the modification of wood properties through silviculture. The short rotation cycle involved will assist the introduction of trees with wood quality improved by genetic manipulation and selection. The shorter rotation periods of intensively grown plantations also enable decisions concerning their likely end-use to be made with greater certainty" (Hillis and Brown, 1988).

The timber of *E. grandis* is lighter and softer than that of most eucalypts. It is extensively used for house construction and young material is suitable for case timber and for paper pulp. It also has potential for plywood. Young wood is very pale but becomes reddish brown as heartwood forms. It is moderately hard and it has an average basic density[37] of 600 m^{-3}. The wood also has moderate strength and durability (Hillis and Brown, 1988). Significant variations in density and heartwood formation are associated with both site and tree age.

[37] Basic density reflects the thickness of the fibre wall and the number of fibers per unit mass, and it has an important influence on the structural and mechanical properties of a wood product.

Wood density[38] has an appreciable influence on many properties and conversion processes, including cutting, gluing, finishing, and rate of paper making. It provides a good but not always direct indication of the strength and stiffness of the timber (Hillis and Brown, 1988). It appears that the mean wood density for a tree is not influenced by, or is insignificantly correlated with, growth rate, although some exceptions have been reported. The wood density in a particular tree is controlled more by a combination of environmental factors than it is by the radial growth rate (Hillis and Brown, 1988). Because of the significant variations in density in unselected trees, and because of the high heritability of density in some eucalypts, changes could be made in wood quality by selection and tree breeding.

On average, the wood of eucalypts contain 40-62% of cellulose, 12-22% hemicelluloses (hemicellulose and cellulose make holocellulose), 15-22% lignins. The lignins of eucalypts are with minor variations in composition within the tree and between species. The amount of lignins can vary between trees and as such can affect the development of collapse and other properties (Hillis and Brown, 1988).

The main characteristics of eucalypts that make them difficult to handle are their relatively high density and high undried moisture content, which cause gluing and peeling problems (in veneer production), and the free splitting of log ends on cross cutting and the susceptibility to collapse during drying, which adversely affect veneer quality and yield (Hillis and Brown, 1988). When wood densities are below 650 kg/m^{-3} (air-dry basis), satisfactory face veneers can be peeled. Above this density the peeling quality deteriorates and typical veneer from the denser eucalypts is loose, contains many surface cracks and is difficult to handle without breakage (Hillis and Brown, 1988) (*See Appendix 4*).

Eucalypt wood generally dries slowly. Typical features are collapse, surface checking of back-sawn faces, high shrinkage, steep moisture gradients, and pronounced drying stresses and sets. Densities are generally lower in wood from younger than from older trees of the same species. As low-density species generally collapse more than those of higher density, collapse may be more prevalent in wood from younger trees. However, the lower density and greater permeability of younger material indicates that it should be easier to dry than mature wood. (Hillis and Brown, 1988).

The inherent disadvantages of the eucalypts in plywood manufacture have been alleviated by the correct selection of the product for a particular end use. The structural grade of plywood produced is more than adequate for its end use and it has advantages over softwood plywood, having greater strength for the same thickness. Moreover, a greater proportion of clear, knot-free veneer can be obtained from eucalypts than from pines

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[38] Density is usually reported as basic wood density (the mass of oven-dry wood per unit volume measured in the green or water-soaked condition).

(Hillis and Brown, 1988). Grading rules for eucalypt logs attempt to relate the visible characteristics of the log to its value for various end uses.

The decrease in log size (in terms of diameter) is causing concern because in contrast to conifers, eucalypts are not easy to mill successfully, particularly when the logs are small. The main problem is that the logs can contain a range of defects irregularly dispersed through the log which are not readily detected from its external appearance. The sawmilling system must be able to cope with these defects as they are revealed during sawing, and in consequence the high-speed production techniques developed for softwoods cannot be readily applied. These problems will continue to be compounded while markets demand sawn timber of a quality that is in some cases unnecessarily high for some end uses, such as framing, flooring, etc. (Hillis and Brown, 1988).

2.4.3. Concluding note

Eucalypts grow fast provided adequate attention is given to the special requirements for land preparation, site, nutrients and silvicultural treatment. Some of the advantages regarding the use of Eucalypts for commercial forestry are the existence of natural pruning and the fine furniture/veneer properties of the timber, apart from the desirable pulping properties. The possible disadvantages of eucalypts are the site sensitivity, the tendency to develop "growth stresses", causing timber distortion during sawing, and also difficulties in drying the timber (MF, 1994b).

An improved understanding of wood properties allows the matching of raw material to intended product, and forests, stands, logs and parts of logs are now routinely allocated to appropriate end uses. The improving interrelationships between wood properties and forest management opens up possibilities of breeding and managing forests for specific end uses.

Variability in basic properties and volume is a factor affecting quality in the fast growing planted *Eucalypts*. Genetic engineering provides the means for controlling such variability in basic properties. The existence of greater uniformity will make it easier to attribute a specific value to quality improvement.

An important question to be answered is: *how do changes in wood quality and processing factors affect the quality of a specific wood product?* Variation in the quality of wood depends on variations in wood composition. A better understanding of the relationship between the chemical, morphological and physical characteristics, and the conversion and utilization properties of eucalypt wood will assist in the planning of programmes to improve the wood properties of future generations of particular eucalypt species (Hillis and Brown, 1988).

2.5. Sources of risk and uncertainty

Although genetic engineering of trees represents an exciting area of research, it also poses a number of questions which are still unanswered - *Will newly introduced genes be expressed consistently and in the right tissue and organs of the genetically engineered tree? Can we predict the behaviour of those genes over the life span of the tree? Will a genetically engineered tree grow 'normally', or will a change in its environment trigger unexpected processes that might make it perform poorly?* (NZFRI, 1996). All of these questions relate to the long-term and spatial expression of introduced genes in forest trees, for which only partial knowledge exists.

Genetic improvement is based on a wide range of expectations, with little predictability of undesired, "spill-over" effects. There are a number of concerns about the nature and magnitude of the risks of releasing genetically modified organisms (GMOs), and their effects on health and safety, ecosystem integrity and the environment.

2.5.1. Risk assessment

Risk can be classified as "acceptable", as long as it is considered in the context of specific safety margins[39]. Hazardousness[40] is another important concept related to risk. In general, because different organisms behave differently, and through genetic engineering pose different potential problems, it is considered preferable to use a case-by-case assessment criteria (Macer et al., 1991).

Risks associated with the deployment of GMOs can be characterized as low probability/high consequence type. As experience with GMOs grows, a standard of acceptable risk will be established through appropriate regulations. The average risk to the environment from products of genetic engineering may be similar for quite different types of products. However, the variability in risk among successive individual cases may be higher from GMOs than other products. This produces a broader risk profile, as there are

[39] A useful technique applied to risk assessment is the comparison of risks (costs) and benefits, which is particularly appropriate for the determination of safety factors in genetic engineering.

[40] A hazard is the potential harm that may result from a risky decision. The public tends to view the potential harm of genetic engineering much more seriously that the probability of that harm occurring.

not only different products, but also different types of risks originating from these - to health, food safety, ecosystem disruption, pollution and technology failure (Macer, 1990).

In general, risk assessment is the use of scientific data to estimate the effects of exposure to hazardous materials or conditions. Risk management, on the other hand, is the process of weighing alternatives to select the most appropriate regulatory strategy or action. It integrates the results of the risk assessment of different criteria (e.g. potential for negative effects, survival of the organism, reproductive organism, transfer of genetic information, and transport and dissemination of the organism). Risk assessment is needed when examining proposals for the release of GMOs at an experimental level. The first part of risk assessment is risk identification, after which comes risk estimation. Only after the results are known, risk management can take place. Benefits are part of risk management, rather than risk assessment (Macer et al., 1991).

Major areas of risk are related to the genetic composition of the genetically modified plants, and their interaction with other species in the surrounding ecosystem. The insertion of a foreign gene in the plant genome raises doubts as to the genetic stability of the plant and the magnitude of the performance of the "new" gene, i.e. even though the traits of interest have been targeted, a question still to be answered is whether such targeting has side effects on other non-targeted wood composition elements. There are speculations that GMOs will be less fit than the parent organism, due to the extra load of the foreign DNA, which will slow the reproductive rate. An additional issue also arise: How long does the genetically induced resistance last?

Serious consequences could result if a genetic engineer, by accident or on purpose, cut and spliced "bad" genes and so created undesirable plants, animals or microorganisms. It is impossible to predict with certainty whether introduced genes would function as predicted or, for example, whether what was thought to be a transgenic non-pathogen might turn out to be capable of causing disease (Tribe, 1994). Thus, the deployment of transgenic plants raises concerns related to the spreading of new genes to crop relatives, and thus affecting genetic diversity.

2.5.2. Biodiversity and biosafety concerns

Environmental concerns focus on both the effects of biotechnology on the environment as well as on the monoculture nature of plantation forestry[41]. While the former is increasingly

[41] It should be noted here that the monoclonal nature of plantation forestry is perceived from the public on the grounds of planting the same species on a specific area. However, genetically, the planted material could be different, as different superior clones have been selected and regenerated, and thus, there is some genetic diversity in plantation forestry.

regulated through biosafety guidelines, the latter still faces significant public objections based on possible environmental threats, such as erosion, soil and water pollution. The possible effects of transgenic trees on natural trees (through the spread of pollen), and the use of only a limited number of genotypes have stimulated growing concerns about the preservation of biodiversity. Another concern related to the uniformity of genetic material and monoculture plantation is related to the vulnerability of planted varieties to unexpected spread of disease. Thus, maintaining diversity is not only biologically important, but also economically desirable.

On the other hand, herbicide resistant plants could be considered as a threat to the environment, by giving the plants the ability to evade man's most effective herbicides. What will be changed is the nature of weed control - instead of spraying with different herbicides in order to kill different weed types, the idea is to make the plant resistant to one particular herbicide, and by spraying, the plant would not be affected, while the weed will be killed. Thus, the tolerance mechanism is designed to counteract the negative effects of the herbicide on the plant. There are concerns, however, that the use of herbicides will be increased and it might be possible for herbicide resistant plants to become weeds, or to transfer their resistant genes onto other weed species. "At the present, the potential for enhanced weediness is the major environmental risk perceived for introductions of genetically modified plants" (Persley, 1990).

"The challenge for genetic resources conservation is not to select, set aside and guard protected areas containing genetic resources, nor to preserve seed, pollen or tissue in a seed bank. It is to maintain the genetic variability of target species within a mosaic of economically and socially acceptable land-use options, including protected areas and managed forest reserves. Such *in situ* conservation should, where feasible, be complemented by *ex situ* conservation of genetic resources of priority species" (Kemp and Palmberg-Lerche, 1994).

Thus, the option value of genetic diversity is important for both the integrity of the ecosystems and the utilization of renewable resources in the future. "The scale of forests and the life span of trees to harvestable size, relative to the unit value of their marketed produce, preclude large-scale, human changes to their environment, except at the nursery stage or in controlled propagation. Increased forest productivity therefore depends on selection, breeding and propagation aimed at matching the crop as closely as possible to its environment and end-use objectives, as well as on the maintenance of a broad genetic base to buffer tree populations against changes in the environment" (Kemp and Palmberg-Lerche, 1994).

A strong argument, based on moral and ethical grounds, is that by using genetic engineering, trees are modified in order to suit the purposes of a limited number of customers as well as to capture a greater market value. *But would you rather cut a 100 years old tree in order to supply a small number of customers willing to pay a high price for it and loose the tree forever, or cut a managed, plantation-grown, 15 year old tree, which will have similar characteristics and is also renewable?* There have always been trade-offs between nature and human needs and preferences, and genetic engineering offers an approximation to a balance. Trees are grown in a sustainable way, where controlled pollination reduces the possibility of crossing between wild and engineered trees. Natural forests will be preserved and their aesthetical value further increased, while plantation forests will respond to world demands for logs and wood products.

2.5.3. Concluding note

Even though the nature of transformed organisms poses some ethical questions related to the integrity of species and their biological diversity, as Macer (1990) notes, to challenge the integrity of a species requires more than a single gene change. Experience with recombinant DNA, involving mixing genes from different species, has not indicated inherent danger in the source of DNA, which implies that possible danger comes from the type of gene, rather than its source. Moreover, transgenic strains made with controlled gene integration may be considered within naturally occurring range of variation. Thus, controlling the expression of the inserted genes in transgenic plants is crucial, not only for scientific purposes, but also for minimizing environmental and biodiversity risks. Gene banks are also important in order to preserve (*ex-situ*) the stock of original species, and thus minimizing the danger of limiting the biological diversity of species.

Environmental concerns will always exist. However, they should not only consider the possible adverse effects on the environment, but also the alternative benefits that new technologies could bring to both the environment and to the increased knowledge of biological interactions. Environmental groups, for example, opposed the development of hybrids when these were developed and introduced, even though the existence of hybrids was both beneficial to the rising world population and to agriculture in general (as yield per hectare was significantly increased, and this reduced the pressure on use of marginal land, deforestation, and soil degradation). Thus, it is essential that concerns, related to the large-scale planting of cloned genetic resources (selected and re-engineered), be based on facts, and be as realistic as possible.

Environmental lobbies are campaigning for the reduced use of chemicals (such as herbicides and insecticides). There is also a growing public discontent with the use of these chemicals and their effects on the environment and on human health in general. Minimizing the application of agrochemicals is thus desirable. Bio-reengineered trees, which are designed to resist pathogen attacks and to be tolerant to herbicides, represent a viable solution for the future. "It is strategy of most agrochemical companies that the sale of novel varieties will compensate them for the loss of revenue due to reduced use of agricultural chemicals. In the case of herbicide-tolerant varieties, a proprietary package of seeds and herbicides may be marketed" (Persley, 1990).

In general, the advent of GMOs could be beneficial in firstly preserving the environment from agrochemicals, secondly from the changing climatic conditions, which affect ecosystems and make plants more vulnerable to their environment, and thirdly providing good quality and steadier supply of wood for different purposes.

CHAPTER 3

INTERNATIONAL REGULATORY ISSUES RELATED TO BIOTECHNOLOGY

3.1. Intellectual property rights

Science today seems to be more dominated by intellectual property questions than by the old research traditions of science. This is due to the fact that the products of scientific research need to have not only a scientific justification, but also some intellectual property protection. Intellectual property rights (IPRs) have long been an issue of discussion among interested groups (industrialized countries), opposing groups (developing countries) and international organizations (General Agreements on Tariffs and Trade (GATT) and the World Intellectual Property Organization (WIPO)).

The complexity of IPRs begins with the lack of a precise and standardized international definition, and ends with the on-going debate about who controls such rights and who benefits from them. Different countries have different perceptions of the value of intellectual property. Industrialized countries argue that without IPRs the transfer of technology to less developed countries will be virtually impossible. The expenditure in terms of money, time, labour and knowledge on R&D investments has to be internalized by capturing the greater possible returns. If such returns are not captured, this will have a negative effect on incentives for innovation and further investment. Developing countries, on the other hand, argue that IPRs would simply deprive them from the right to explore their own resources, or they could simply mean a greater dependence of these countries on the technological advances of industrialized countries.

"The perspective of countries on the desirability or otherwise of international protection of intellectual property rights depends on whether a country is: (1) a technology seller (e.g. USA, Japan); (2) a technology buyer and an adapter of imported technology, with large internal markets (e.g. Brazil); or (3) a technology buyer, with no local adaptive capacity and small internal markets (e.g. Ghana). The technology sellers favour international protection, while the technology adapters and the importers do not see international protection as a 'right', but a point of negotiation, on which they would allow the technology sellers access to their internal markets" (Persley, 1990).

The protection of research activity is also present in an intra-country basis, i.e. the trends of research and investment of public and private enterprises within each country. The value of the research in a public enterprise is measured by the marginal costs and benefits to society. In a private company, the value of research is usually calculated against the future returns that it will bring. The products of the research of the public sector belong to the public, and therefore protection is not needed, as everyone has the equal right to benefit from the research. The products from a private research, however, are considered commercial secrets and belong to the company. Thus, intellectual property is needed to ensure that both the products, as well as the process of developing of such products, are monopolistically controlled by the company for a certain period of time.

Broadly speaking, intellectual property comprises a design of rights protecting aesthetic creations, trade marks, copyright, confidential information, patents, and other special rights including Plant Breeders' Rights.

3.1.1. Trade secrets

Confidential information is a general title covering trade secrets, other know-how and proprietary information, and it could cover technical as well as commercial information, including pricing and marketing policies, names and attitudes of customers. This precaution is necessary in order to prevent the secrets from leaking out and becoming public knowledge. This is achieved by confidentiality agreements between the parties involved. "Keeping something as a trade secret can, in some instances be a good policy and it tends to be cheaper than obtaining patents, at least in the short run. Nevertheless, trade secrets often leak out over time and it would be rare to be able to keep one for more than 10 years. Additionally, keeping a trade secret does not prevent third parties from doing their own research work and from discovering the secret for themselves and from publishing it too" (Gaythwaite, 1991). In biotechnology there are a number of areas where there is considerable potential for keeping trade secrets, for example, in techniques of manipulation which are often developed in-house, and which involve a long sequence of steps, difficult to repeat unless the whole technology is known.

3.1.2. Patents

"The central issue in the debate on 'patenting life' is that patents have been obtainable traditionally only for manufactured inventions, not for naturally occurring subject matter, which belongs in the public domain. The argument in favour of extending patent protection in biotechnology is that the processes, substances, and organisms that fall under the rubrics of biotechnology do not occur naturally, or, if the substance also occurs naturally, the process used to produce it in commercial quantities is made by people. The arguments against are based on the concept of the naturally occurring germplasm being part of the common heritage of mankind" (Persley, 1990).

Patents are a way of encouraging inventors not to keep their discoveries secret. The basic idea is that in a detailed specification, which is published, the inventor discloses his invention and how it can be carried out. For a limited period of time (17-20 years) the inventor has a monopoly, but after this period the invention may be freely used by the public. However, when an inventor has made an invention there is an obligation on him to patent it in order to be able to exploit it, and partly because of this it sometimes may be better to keep the invention as a trade secret. The patent does not give the inventor the right to do something which he would otherwise not be able to do, but simply excludes third parties from the right to use the invention (Gaythwaite, 1991).

Patents involve a lot of time and expense in negotiation with the issuing Patent Office and even after a patent has been obtained there is no guarantee that it is valid. "Furthermore, the existence of the patent does not immediately protect the inventor either from regulatory or other constraints or from the possibility that the operation of his invention may infringe another patent belonging to a third party. Nevertheless, the existence of a patent may have the effect of deterring rivals from infringement, it may cause the rival to find an alternative non-infringing process or product ("engineering round the patent") or it may prompt the rival to approach the patentee to ask for a license" (Gaythwaite, 1991). Considering that the policing of the patent is responsibility of the patentee, in the case of patent infringement litigation processes tend to be lengthy and expensive.

Patents can be granted for most industrially applicable processes and devices. A cardinal rule of patents is that whatever is claimed must be new and must also not be obvious. Novelty includes both anticipation and obviousness. "Anticipation is something concrete which can be tested objectively, assuming the necessary background information. Obviousness is a subjective matter and it must be tested by skilled 'man in the art'" (Gaythwaite, 1991).

"For a new industry, such as biotechnology, the acquisition of patents can serve many purposes. The existence of pending applications can provide tangible evidence for potential investors of the research progress and intellectual assets of a company. A granted patent may affect the early course of a company's development planning and future market strategies. Biotechnology companies are especially eager to obtain patents of broad scope to help carve out areas of exclusivity for their future developments" (Greenlee, 1991).

The patent law is designed to stimulate innovation, by providing a reward to inventors for making and fully disclosing their inventions. A major function of a patent is to define the scope of protection. It should be noted however, that a good market position does not begin and end with a patent, but includes other forms of entry barriers to keep competitors out of the market. These include federal regulations, trademarks, marketing and the acquisition of customer confidence and trade secrets for unpatented aspects of the product, all of which are used to reinforce an exclusive position.

Persley (1990) summarizes the regulatory framework for protecting inventions:

1. *Seed and breed certification systems* - a sufficient labeling of marketed products is required in order to identify the origin of the seed and give its genetic heritage. Other are not prevented from using or selling the same plant and animal varieties as long as they do not misrepresent it.
2. *Plant patent and variety protection* - the plant breeder is granted limited rights to exclude others from commercializing new plant varieties that he has developed.
3. *Invention patents* - the inventor is given the right to exclude others from practicing the invention for a certain period of time (15-20 years).
4. *Petty patents* - the inventor is given the right to exclude others from practicing the invention for some period of time, but apart from that, they require novelty and utility, without requiring any inventive step above the prior art. Thus, these patents preserve the rights to minor variations of known devices rather than to major technical innovations having broad adaptability.

In general, the problem is not only whether to patent or not, but focuses on what should be patented - the products or the processes. It is more difficult to police the infringement of a patented process. However, it is possible to patent a product made by a specific method, where both the process and the final product are protected. Macer (1990) argues that it is easier to obtain a process patent, but in practice it has been harder to prove that a competitor is using the protected process, as access to the competitors' production facilities may be restricted.

Another major shortcoming with patents is related to the lack of consistent international regulations concerning intellectual property. Each country has a different framework for patenting. "For example, in Japan intellectual property is not given meaningful protection, as a narrow refinement to a patented product can qualify for a new patent" (Burrill and Lee, 1990). The conditions for obtaining patents also vary depending on what is protected. For example, according to the European Convention Article, microorganisms are patentable, but "plant or animal varieties or essentially biological processes for the production of plants and animals" are expressly prohibited (Macer, 1990). This is also the case in Japan and Canada. The time span of patents is also different across countries. Such inconsistencies is more likely to either reduce technology transfer or to increase incentives for international industrial "espionage", rather than stimulate investment in innovative enterprises.

3.1.3. Concluding note

In choosing whether or not to patent, a company would evaluate such factors as whether there is a likelihood of others discovering the invention independently, how easily the patent could be policed, the rate of technological change in the area, and whether or not the invention is likely to meet legal requirements for patenting. A company may choose to keep any or all of a particular process or product secret. In this case, the diffusion of knowledge will depend on personnel mobility within the industry (Daly, 1985).

It should be noted that with a trade secret, even if some of the company's secret leaks, this does not mean that the whole company's strategy would be disclosed - partial spill of information is detrimental up to a certain level. Patenting, on the other hand, discloses the required information in its totality, which permits others to modify the invention and possibly improve it. If someone is to be able to repeat the invention, due to instructions required for patenting, then someone would also be able to slightly modify the result and reap profit of the originally developed and patented process. Thus, patents might not be very useful for a dynamic company, whose processes and products are constantly modified so as to suit changing demands in a competitive environment.

Even though there are benefits from intellectual property protection via patents, they have proven to be rather time-consuming and costly regulatory tools. The lag in issuing patents, inconsistencies in patent approvals and lengthy regulatory processes are perceived to be burdens that handicap companies' ability to devote resources to international competitiveness. Yet another constraint is represented by the fact that patents are not consistent between countries in terms of the monopoly period granted, the nature of protection, and other patent rights, which makes it more expensive and virtually impossible for an international company to sell its patented products or use its patented techniques in different countries. Patent litigation would also be made difficult.

3.2. Applications to biotechnology

"The research needed to produce improved, transgenic crops is expensive, but the rewards, potentially, are extremely high and, therefore, private companies and corporations have become increasingly active in biotechnological research. Having invested large sums for many years in experimental investigations, companies naturally seek to recoup these outlays, and to earn profits for their shareholders, if and when they eventually produce an improved transgenic crop. They hope to secure this income by covering their innovations with appropriate intellectual property protection, primarily through patents or plant variety protection. The all important question is what makes a patent or other protection 'appropriate' or 'inappropriate'" (Tribe, 1994).

Confidential information and patents are the two widely used tools to accommodate for biotechnological developments. However, a number of other alternatives exist to capture the changing nature of biotechnological processes and applications in plant biology.

3.2.1. Plant Breeders' Rights

Plant Breeders' Rights allow for a limited monopoly in capturing the gains form newly developed plant varieties. The nature of the variety is not publicly disclosed, though it is evaluated and it is required to be stable. Thus, there is no legal requirement for the description of how the new variety was produced. The protection under the Rights allows the holder to prevent the sale of propagated material without a license. It doesn't, however, prevent the buyer from developing and/or modifying the variety and producing a new variety.

"In the USA the position over plant breeders' rights is rather complicated as there are a number of separate systems in operation. The first, that of Plant Patents was introduced in the 1930s by relaxing the disclosure requirements, normally needed for ordinary patents ('utility patents') and extends only to asexually reproduced plants. The second system which deals with sexually reproduced plants was introduced in 1970 by the Plant Variety Protection Act (PVPA), but both systems specifically exclude tubers, hybrids, bacteria and fungi. These botanical entities, if they are to be protected at all have to be covered by utility patent, and that, of course, is possible if an adequate description of the invention can be given" (Gaythwaite, 1991).

A problem exists when there is a potential overlap with other intellectual property rights, and where the general public disagrees with granting specific rights for products of nature or for living organisms. There are other problems concerned with the definition of precisely what is patentable and what is not.

3.2.2. Licensing of new technology

The most obvious method of exploiting a new technology is to put it into practice and to sell articles and to carry out a process which makes use of the technology. However that is not always the most practical method, particularly for a new venture, and especially if it involves heavy capital expenditure; nor is it necessarily the most remunerative. There are two major types of agreements which the inventor could make with another interested party. One involves outright sale of the invented technology, the other implies licensing the interested party to make use of the technology. If the technology is sold outright then the inventor loses his security in the property, but equally sheds the responsibilities of paying for it. Licensing is much more complicated but allows the inventor to retain the security of the underlying rights (Gaythwaite, 1991).

A license merely permits the licensee to do certain things which the licenser would otherwise be able to prevent. Typically the license permits the licensee to operate within the scope of the licensed patent without thereby being subject to an action for infringement of the patent. In the case of an outright sale the inventor will normally transfer all his rights to the buyer by means of an assignment, and after receiving the price payable, will no longer be involved with the exploitation of the technology except possibly as a consultant (Gaythwaite, 1991).

However, a problem arises when someone is to license a new technology, considering that it is virtually impossible to identify the correct market value for the new technology (putting a cash value on the assignment is a gamble!). The price of the assignment could be paid in annual installments. Moreover, there is no reason why part or all of the price cannot be taken in the form of payments geared to the actual use of the technology which is made by the buyer (such geared payments are known as 'royalties'). Taking royalties as a price for the assignment means that some of the guesswork in how valuable the technology proves can be removed (Gaythwaite, 1991).

A license is a much more complex business as it must deal not only with the rights to be licensed, but also with the exact nature of the license (how are royalties payable) and the conditions under which it can come to an end. There are three types of licenses. The exclusive license means that the inventor not only cannot grant any more licenses, but also cannot operate the technology himself. A sole license means that the inventor agrees not to grant any more licenses, but both the licensee and the inventor can operate the technology. A non-exclusive license implies that the inventor can grant as many more licenses as he wishes and he can operate the technology himself. The value of the license depends critically on the nature of the license. In the context of a new technology, where substantial capital investment is going to be made by the licensee, an exclusive license would be preferred. A down payment is made when the license is signed and then royalties are payable on products which use the technology (Gaythwaite, 1991).

Royalty rates and other conditions are determined in a legal agreement. The royalty could be in a form of a percentage of the licensee's sale price or a fixed sum, where there may be minimum royalties payable. The royalty rates would depend upon the exclusivity of the product in terms of the product's characteristics and its comparative advantage (e.g. a tree resistant to insects). The royalty rate would also reflect the weight of technological improvement, incorporated in the product. Moreover, standards of performance of the new technology might be required, as well as an agreement reached on the efforts that the licensee should make to manufacture and sell the product (Hacking, 1986). In general, the licensing of inventions is a way of selling the products of technological development, without the need to disclose information about the process of development, and it can be a quick way for recovering research and development expenses[42].

"The decision as to what type of license to offer is primarily a commercial one and may vary from country to country. For example, a company might well decide to grant non-exclusive licenses in their home country territory where they are very familiar with the market and what acceptable royalty rates should be. But for a distant and unfamiliar market they may prefer a single exclusive license" (Gaythwaite, 1991). Moreover, licenses can treat manufacturing and sales in different ways.

3.2.3. Concluding note

The products of new technology, and the processes of this technology are constantly evolving. This requires the adaptability of regulatory frameworks to the protection of inventions and to the definition of the specific scope of inventiveness and protection. Thus, if patents are to grant protection for a certain invention, they should be designed so as to embody the changing nature of the process which led to the invention. Hopes for greater consistency within specific biotechnological developments, as well as among countries, would provide better grounds for legal protection of costly, and time-consuming innovations. "The process of bringing the paradigms of the law in line with modern scientific thought requires creative thought, debate and a keen sense of policy values. While the standard of ordinary skill is too useful to abandon, its misuse to favour empiricism over logical scientific progress must be avoided" (Greenlee, 1991).

[42] According to Hacking (1986), the cost of a license is US$10,000 per annum plus a royalty on sales of any product made by the technique of 1% of the first US$5 million in sales ranging down to 0.5% of sales over US$10 million.

Even though monopolies on patents are discouraged, competition policy still lacks the ability to encompass the rapidly changing nature of the processes and products of biotechnological development. However, issues concerning the conditions of patents and their nature to exclude others from the benefits of the invention have practical solutions, e.g. plant variety licensing.

Even though the cost of patenting processes can be justified by the potential value of the invention, the ultimate value of the product is not known, and patents are not always used, which adds an element of risk, considering the cost of patenting and the disclosure of commercially sensitive information to the public. Also infringement of process patents could be difficult to legally challenge, considering that obviousness is a subjective concept, and simply the infringement would cost a lot of money (in legal fees) to the process developer who holds the patent.

"Because of the elusiveness of property in ideas, there is uncertainty and unreliability in the legal protection of patents and copyrights, and even less protection for trade secrets not covered by patent or copyright. The result is that unlicensed uses often escape control. Short of ideal conditions there will be losses from both underproduction and underutilization, and in practice something of a trade-off: provision of greater legal protection to investors tends to ameliorate the underproduction problem, but to worsen the underutilization problem" (Hirshleifer, 1989).

Moreover, Hirshleifer (1989) argues that, in general, under a patent system there will be some shortfall in the return to the inventor, due to costs and risks in acquiring and enforcing his rights, their limited duration in time, and the unfeasibility of a perfectly discriminatory fee policy. This is added to the already recognized disadvantages of patents: the social costs of the administrative judicial-process, the possible anticompetitive impact, and restriction of output due to the marginal burden of patent fees. However, "as a second-best kind of judgment, some degree of patent protection has seemed a reasonable compromise" (Hirshleifer, 1989).

3.3. Biosafety regulations

The rapid development of genetic engineering and the increasing need for testing the genetically modified organisms (GMOs) have increased the importance of accounting for the possible risks of deployment and have led to the designing of biosafety regulatory frameworks. As Persley (1990) observes, a safe and efficient regulatory environment is in itself a comparative advantage in biotechnology, as the regulatory requirements come from the legitimate need to assure environmental safety and public health. The new requirements of the guidelines should cover the handling of genetically engineered organisms at the experimental stage, and the methods for risk assessment prior to widespread commercial use.

James and Krattiger (1996) present the two main views regarding regulations of genetically engineered crops. On one side, transgenic crops are considered a progression of conventional crop improvement, which leads to the assumption that past guidelines are adequate for transgenic crops. On the other side, the 'new' nature of transgenic crops is seen as a requirement to develop new and more detailed regulations for a new unfamiliar technology.

There are no internationally accepted guidelines for the field-testing of transgenic organisms. Countries have different approaches for judging the nature and the potential of risks associated with transgenic organisms. All countries have adopted some degree of regulation, but the process of regulation varies among countries. For example, vertical regulation, adopted by the USA and Canada, is a selective product-based system which aims to define the characteristics of crops without requiring that all the products from the transgenic process be regulated. This approach seems to be more transparent and case-specific, without compromising all the products of genetic engineering. On the other hand, horizontal regulation, adopted by the European Union, is also a process-based system, but it is non-exclusive, in terms of regulating all the plants produced by the transgenic process (Dale, 1995), (James and Krattiger, 1996).

In countries where regulations are already in place, the tests necessary to satisfy biosafety requirements vary according to the particular organism. They are based on the competitive advantages of the organism, its pathogenicity and toxicity, including possible adverse effects on human health and non-target organisms, the control of genetic transfer, the possible spill-over effects and required containment, and the possible risk to endangered species (Mannon, 1992). The potential risks come from the fact that there are countries with no specific regulatory schemes concerning the testing of transgenic organisms, i.e. regulatory attention seems to be more concerned with the intrinsic nature of the transgenic organism, rather than the risks of utilization of such organisms.

There are no doubts that an international harmonization of regulations is of fundamental importance. However, "despite the continuing international efforts to harmonize regulations governing the release of transgenic plants, there is little evidence of equity of fees being charged by regulatory authorities to anyone wishing to carry out a transgenic plant field trial[43]. The cost will be a significant expense in the commercial development of

[43] The fee charged by regulatory authorities covers assessment and approval to carry out a field experiment. Thus, the fee will depend on the amount of assessment needed, excluding the cost of preparation of a release proposal for submission to the regulatory authority.

a transgenic plant variety for only a few countries and companies, but a charge of a few thousand US dollars can be a significant cost in academic research budgets. Such restrictions may inhibit innovative research in some countries and encourage academic and industrial scientists to move their field trials to countries with the lowest costs" (Dale, 1995).

In general, the diversity of organisms to be modified, the functions that will be engineered and the environments which will receive altered organisms makes ecological risk evaluation a complex process.

3.3.1. Field testing of transgenic plants

According to James and Krattiger (1996), in the years between 1986 and 1995, more than 3,500 field trials of transgenic crops have been conducted on more than 15,000 individual sites, in 34 countries with at least 56 crops, mostly in North America and the European Union. The proportions of the pie are represented as follows: 91% of the trials have been conducted in industrialized countries, 1% in Eastern Europe and Russia, and the rest 8% have been distributed between developing countries, mainly in Latin America and the Caribbean, but also China[44] and South Africa. The countries with the greatest proportion of conducted field trials are the USA, Canada, France, United Kingdom, the Netherlands, Belgium, Argentina, Italy, China, Germany, Australia, Chile and Mexico. In this scenario, Argentina holds the highest number of transgenic crop field trials among the developing countries (78), while New Zealand represents the fifth lowest number of such trials among developed countries (15).

Among the most intensively field tested transgenic crops, and the ones that are already commercialized or are close to being commercialized, are canola, rapeseed, cotton, maize corn, melon, potato, soybean, tobacco, tomato, while tree species like eucalypts are still in their experimental phase of field testing. The most frequent trait for the interests transformation is herbicide resistance (35%), followed by product quality (20%) and insect resistance (18%).

Field trials of eucalyptus appear to be at an experimental stage (James and Krattiger, 1996). Dale (1995) establishes that there has been only one field release of transgenic eucalypt up to 1993. The number is more likely to have slightly increased between 1993 and 1996. However, no specification of location of the experiments has been provided.

[44] China is reported as the first country to commercialize transgenic virus resistant tobacco and virus resistant tomato in the early 1990s.

3.3.2. Some important regulatory issues

The 1987 US National Academy of Science summarized the possible impacts of the use of recombinant DNA techniques, within the scope of environmental safety and public health of biotechnology application. Some of the conclusions made are the following:

1. No evidence was found that unique hazards exist either in the use of recombinant DNA techniques or in the movement of genes between unrelated organisms;
2. The risks associated with the introduction of GMOs are the same in kind as those associated with the introduction of unmodified organisms and organisms modified by other methods;
3. Assessment of the risks of introducing genetically engineered organisms into the environment should be based on the nature of the organism and the environment into which it is introduced, not on the method by which it was produced. The ecological society of America also supports the point that genetically modified organisms should be evaluated and regulated according to their biological properties (phenotypes), rather than according to the genetic techniques used to produce them;
4. Recombinant DNA techniques provide a powerful and safe new means for the modification of organisms;
5. Genetically modified organisms will contribute substantially to improved health care, production efficiency and the solution to many pressing environmental problems that have resulted from the extensive reliance on chemicals;
6. The timely development and the rational introduction of recombinant DNA-modified organisms into the environment depend on the formulation of sound regulatory policy that stimulates innovation without compromising good environmental management. The Ecological Society of America supports the development of methods for scaling the level of oversight needed for individual cases according to objective, scientific criteria, with an aim of minimizing unnecessary regulatory burdens. With this in mind, the scientific community should provide guidance to both investigators and regulators in evaluating planned introductions of modified organisms from an ecological, biological and molecular perspective (Persley, 1990).

Moreover, in a study presented in 1988, the Office of Technology Assessment of the United States Congress (OTA) made a number of important conclusions related to the problems of risk assessment and the impact of public perception. It establishes that the applications of genetically engineered organisms should be carefully assessed, but there are no causes for alarm. Even though scientific uncertainties exist, adequate pre-release safety reviews, as well as realistic small scale field tests are likely to be the only way potential risks from commercial-scale uses of genetically engineered organisms can be evaluated. The criteria for safety and risk minimization has to be case specific, depending on the nature of the modified organism, the critical scientific evaluation, the country where the modified organism will be introduced. Sources of low, medium, and high risk have to be differentiated in order to receive correct risk assessment and permitted magnitude of release. "Although there are enough uncertainties that introductions should be approached with caution, a large body of reassuring data supports the conclusion that with the appropriate regulatory oversight, the field tests and introductions planned or probable in the near future are not likely to result in serious ecological problems" (Persley, 1990).

"The need for statutory regulations on the conditions governing release are not embraced enthusiastically when they are excessively rigid, expensive and time-consuming. Such regulations may be self-defeating in that they encourage unauthorized experimentation (Persley, 1990). A solution to this problem is the establishment of guidelines by a technical committee rather than by legislative regulators, as the former has the advantage over statutory regulations of greater flexibility and rapid change in a field where the expansion of knowledge is constantly altered.

The commercial use of genetically engineered organisms has increased the need for some degree of harmonization of biosafety policies in the OECD countries. Having this in mind, the OECD, made a number of recommendations, two of which are of specific importance:

1. With respect to large-scale industrial applications of recombinant DNA techniques, it was recommended to ensure that modified organisms are handled correctly with the use of appropriate containment measures, and to also further develop research to improve techniques for monitoring and controlling non-intentional release of recombinant DNA organisms;
2. With respect to environmental applications, it was recommended that recombinant DNA organisms are evaluated for potential risks on a case-by-case basis prior to application, and also in a stepwise fashion, from laboratory, to growth chamber, to greenhouse, to limited field testing and after enough information is collected to large-scale field testing (Persley, 1990).

The need for more appropriate regulation measures is being currently addressed. The challenge to the effectiveness of such measures, however, consists in the diversity of biotechnological developments. Science seems to be going at a faster pace than legislation, and therefore, in order to safeguard the interest of both society and industry a comprehensive and non-bureaucratic regulatory framework has to be generated and adapted to the case and country specific developments of biotechnology. Permits for field trials are just recently being granted in some countries and are related to specific crops, released in a specific area, under strict control.

In 1992 field trials' rights of genetically modified plant species were granted on limited grounds for only experimental work, not for commercial purposes. Field trials were conducted mainly in developed countries, and in some developing countries. The first commercially grown transgenic crops (two tomato varieties) were tested in late 1992. The principle transgenic crops in present are potato, cotton, rapeseed, tomato, tobacco, soybean, and maize (Sasson, 1993). There have also been field trials of plants containing Bacillus turingensis insecticidal protein, and also herbicide resistant genes, and plants have shown excellent insect and/or weed control, suffering no damage next to parent plants that have been totally affected by pathogens (Macer, 1990).

3.3.3. Concluding note

Risk assessment is crucial for the establishment of biosafety guidelines, but it is unclear what the correct definition of risk is. Field testing is essential to increase the knowledge about the relative safety of large-scale use of genetically modified organisms, and to determine the potential utility of the modified organisms. The US National Academy of Science points out that "although modification by molecular methods may be more powerful and capable of producing a wider range of phenotypes, no conceptual distinction exists between genetic modification of plants and microorganisms by classical methods or by molecular methods that modify DNA and transfer genes" (Persley, 1990). "Among scientists, there is wide consensus that risk is primarily a function of the characteristics of a product (whether it is inert or a living organism), rather than the use of a particular technique of genetic modification" (Miller, 1994).

Organisms modified by molecular and cellular methods should not pose risks that are different from those modified by classical genetic methods for similar traits. As the molecular methods are more specific, users of these methods will be more certain about the traits they introduce into the plants. Traits that are unfamiliar in the specific plant will require careful evaluation in small-scale field tests where plants exhibiting undesirable phenotypes can be destroyed. Moreover, confinement is the primary condition for ensuring safety of field introductions, where depending on the species, proven confinement options include biological, chemical, physical, spatial, environmental and temporal isolation, as well as size of field plot (Persley, 1990).

Legislation for the introduction of new genetically engineered varieties has to be introduced up to the level which will provide for the safeguarding of the rules to be followed in order to control the possible adverse effects. Regulations should not be restrictive, but rather prohibitive on the basis of non-compliance with safeguarding the environment and the well-being of present and future generations. This is to say that as long as plantations with transgenic trees are well managed, biologically and in the field, they could operate in a sustainable way. The possible adverse effects have to be minimized, which greatly depends on the knowledge of the first steps of re-engineering in the laboratory.

In general, a crucial point in the further development and marketing of transgenic crops or trees is the need to harmonize international safety principles and intellectual property rights. Some degree of standardization of regulations will eventually reduce the cost of market research and related constraints, and will enhance the production and commercialization of transgenic organisms and their products.

3.4. Biosafety regulatory framework in New Zealand

Many OECD countries, including New Zealand, have existing regulations concerning the release of genetically modified organisms. "These usually provide sufficient protection for the approval of the commercial sale of the products of biotechnology, since existing legislation governing the release of products such as agrochemical, biological control agents, animal vaccines and new plant varieties is as relevant to the products produced with the aid of modern biotechnology as it is to more conventionally produced products" (Persley, 1990).

3.4.1. Early developments

In 1986, a working party - *Field Release Working Party* - was established by the Minister of Science and Technology to make recommendations on the regulation of field-testing[45] and release of GMOs[46]. The first regulatory recommendations were outlined. With the lack of new legislation, however, it was agreed that an interim system for assessing GMOs would be necessary to ensure that field tested GMOs received proper prior assessment. Thus, in 1988, the Ministry of the Environment established a group - *GMO Interim Assessment Group (IAG)* - responsible for the control of new organisms, including new imported species and new transformed varieties[47]. The operating procedures of the IAG were based on a discussion document - "New Organisms in New Zealand", which outlines the principles and processes proposed to govern the assessment of new organisms (MFE, 1994).

[45] Field-testing is defined as the practice of carrying out trials on the use and safety of the organism under conditions similar to those of the natural environment into which release is planned, but from which the organism or any heritable material arising from it could be retrieved or removed by destruction at the end of the period of field testing (MFE, 1988).

[46] A genetically modified organism is defined as any organism which has undergone genetic modification, manipulation or engineering involving formation of new combinations of heritable material, by insertion, deletion or recombination of nucleic acid molecules, produced with whatever means outside the cell so as to allow incorporation into the host organism in which they do not naturally occur, but in which they are capable of replication. It doesn't include plant hybrids formed by normal sexual means (MFE, 1988).

[47] "The release of GMOs into the environment shares common features with the importation of new species - it implies the release into the New Zealand Environment of an organism which has not previously occurred in the country, and whose impacts cannot be fully predicted" (MFE, 1994).

Both private and public sector researchers are advised to submit their proposals[48] for conducting a field trial of a specific GMO to the IAG for assessment. Assessment is based on the national guidelines for the use of GMOs in agriculture, industry and environment. The guidelines[49] represent a framework for consistent risk assessment of proposals in a case-by-case basis. The possible sources of risk and containment approaches are indicated to researchers when undertaking a field trial or release. When applications for work with GMOs are assessed, conditions related to the containment methods are responsibility of the *Advisory Committee on Novel Genetic Techniques (ACNGT)*[50].

The nature of the proposal implies that both public and private knowledge are in stake. This is to say, while the general public has the right to be informed of and comment on proposals for GMOs assessment, as well as to know the possible environmental impacts, private researchers also have the right to keep confidential any commercially sensitive information regarding their proposal[51]. Thus, while all proposals have to be publicly notified, the applicant has the right to retain in confidence part of the information submitted. The division of information is examined by the responsible agency, and if agreed upon, only the non-confidential information will be supplied.

Withholding information is weighted against considerations which render it otherwise desirable for the general public to make the information available, i.e. the information will be withheld if it did not deprive the public of any significant knowledge concerning environmental or other risks of the proposal. Thus, it is more likely that the specific details of a particular technique used to perform genetic manipulation would be withheld, while information regarding particular behavioural or growth characteristics of the organisms would not be kept secret.

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[48] When submitting a proposal, its aim and expected outcomes have to be outlined. These include the overall benefits of the approach, as compared with other available methods, the experimental feasibility of the approach and the precise justification for performing a field trial.

[49] The guidelines are in practice a checklist which covers the questions that researchers should address when planning a field test or release. The checklist forms the basis for an application to the IAG, and is constantly updated.

[50] "The ACNGT is responsible for the laboratory and glasshouse genetic manipulation work which is defined as any process involving novel genetic techniques that are properly contained and that can be terminated at any point without loss of containment" (MFE, 1994).

[51] The Official Information Act provides for official information to be withheld where making it available would disclose a trade secret or would be likely to prejudice unreasonably the commercial position of the person who supplied the information.

3.4.2. Recent developments

The Biosecurity Act (1993) represents the regulatory framework for the control and management of risk goods[52], such as pests, pest agents, and unwanted organisms. For the purposes of the act, an "organism" does not include a human being or a genetic structure derived from a human being, but it does include micro-organisms, genetic structures capable of replicating themselves, as well, it includes reproductive cells or developmental stages of organisms. On the other hand, restricted organisms are those organisms for which a containment approval has been granted, and strict containment measures need to be undertaken to reduce the risks of escape by the organism from a containment facility, as opposed to unwanted organisms, which are considered to be potentially capable of causing unwanted harm to any natural resource, and to which approval has been declined.

The Act establishes the framework for surveillance and prevention of biosecurity emergencies regarding pests and unwanted organisms. The specific criteria for pest management strategies is also discussed. Such strategy is applicable when the organism under consideration is capable of causing a serious adverse and unintended effect in relation to New Zealand, thus compromising the following:

- the economic well-being;
- the viability of rare or endangered species of organisms;
- the survival and distribution of indigenous plants and animals;
- the sustainability of natural and developed ecosystems, ecological processes, and biological diversity;
- the soil resources and water quality;
- the human health and enjoyment of the recreational value of the natural environment;
- the relationship of Maori and their culture and traditions with ancestral land and natural resources; the country's international obligations, assurances, and reputation.

Each strategy is case specific and depends on the risk potential of each organism, as well as on the potential effects on environmental integrity of the place of deployment. Moreover, each strategy can have a range of side-effects, which could be both beneficial and detrimental on the environment. Thus, strategies are evaluated on the basis of their respective costs and benefits (including social costs and benefits), in order to identify a feasible strategy in financial or economic terms.

Small-scale management of unwanted organisms may, however, be undertaken without a specified pest management strategy, in order to differentiate between: (1) unwanted organisms that could become serious pests unless early action to control them is taken, and

[52] According to the *Biosecurity Act (1993)*, a risk good means any organism, organic material, or other thing or substance , that (by reason of its nature or origin) it is reasonable to suspect to constitute, contain or otherwise pose a risk that its presence in New Zealand will result in either the exposure of organisms in New Zealand to damage, disease, loss or harm, or the interference with the diagnosis, management, or treatment, in New Zealand of pests or unwanted organisms.

(2) organisms that can be effectively controlled by small-scale measures within 3 years after the beginning of the measures, due to their limited distribution and the availability of technical means to control the organisms.

The early policy developments led to the establishment of a new independent agency - The Hazards Control Commission - responsible for assessing and licensing the use of hazardous substances and new organisms. Besides, in 1996 the *Environmental Risk Management Authority (ERMA)* was appointed to evaluate applications for the manufacture, import, or release of hazardous substances and new organisms in New Zealand.

The functions of the ERMA are determined within the framework of the *Hazardous Substances and New Organisms Act (1996)*, which establishes the necessary procedures and benchmarks for managing the health and environmental risks of introducing hazardous substances and new organisms[53]. In this Act, provisions concerning genetically modified organisms[54] are made. Containment measures established in the Act refer to restricting organisms or substances to a secure location or facility to prevent escape, including genetically modified organisms, field testing[55] and large scale fermentation.

Any action involving new organisms has to be evaluated and approved by the ERMA. Applications for the release of new organisms, for example, need to provide full information concerning the identification of the organism and the possible adverse effects on the environment, as well as the affinities of the organism with other organisms in the country and its potential use. The amount and nature of the acquired information are crucial for a more correct approach to reducing uncertainty and evaluating risks, considering that different potential risks will require different levels of detail of information. The decision for granting a permission for release would depend on several risk assessment criteria, such as minimum standards regarding ecosystem integrity and future reproductive effects on resource sustainability. An approval for the release of organisms is 5 years in duration after the date of the approval.

Considering that environmental risk assessment is always subject to uncertainty, the management of uncertainty is of great importance to environmental decision making. "Two

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[53] A new organism can be interpreted as an organism in containment, a genetically modified organism which has not been previously approved for release or a risk species. Sometimes there may be some uncertainty whether an organism is a new organism or a different breed of an existing organism.

[54] In the *Hazardous Substances and New Organisms Act (1996)*, genetically modified organisms is defined as any organism in which any of the genes or other genetic material have been modified by *in vitro* techniques, or are inherited or otherwise derived, through any number of replications, from any genes or other genetic material which has been modified by *in vitro* techniques.

[55] Field test is defined in the *Hazardous Substances and New Organisms Act (1996)* as the carrying on of trials on the effects of the organism under conditions similar to those of the environment into which the organism is likely to be released, but from which the organism, or any heritable material arising from it, could be retrieved or destroyed at the end of the trials.

types of uncertainty can be identified: measurement or statistical uncertainty (variability), and ignorance or lack of knowledge of physical and biological processes (which means outcomes may not be known and risks may not be able to be identified)" (ERMA, 1997). Outcomes may not be properly identified until years later, by which time they may be irreversible. Thus, in order to reduce the impact of uncertainty on environmental decision-making, the assessment and evaluation of applications will require a scientific review (which will identify modeling assumptions and consider statistical variability), and a risk assessment review (which will assess unknown effects and provide known uncertainty (ERMA, 1997).

Applications for field testing a genetically modified organism have to be publicly notified. However, provisions are made in the Act to allow for protecting confidential information, such as trade secrets or information that has commercial value that would be likely to be diminished by disclosure. Thus, ERMA is granted with the power to withhold sensitive information on request.

When applying for containment approval for new organisms, the following information about the containment system of the organism is required:

- the identification of the organism;
- the description of the project and the experimental procedures to be used;
- the details of the biological material to be used;
- the expression of foreign DNA;
- all the possible adverse effects of the organism on the environment.

In the case of field testing, the same criteria applies, and the purpose for field testing needs to be established. In general, adverse effects are assessed on the basis of their probability of occurrence due to genetic modification. Thus, risk assessment criteria would vary on a case-by-case basis, given that genetic modification leads to different changes in the organisms' genotypes, and therefore depends on the organism that it is applied to and on the nature of the process of genetic modification. This implies the need to evaluate the risks associated with the entire life-cycle of an organism.

An application would be approved if all the effects of the organism and any inseparable organism are accounted for, and the beneficial effects of having the organism outweigh the adverse effects of the organism, should the organism escape, given that adequate containment systems are in place.

Generally speaking, the *Biosecurity Act (1993)* and the *Hazardous Substances and New Organisms Act (1996)* complement each other in establishing a detailed regulatory framework for controlling the development and deployment (in contained conditions or in the form of field tests) of GMOs, and their effects on the environment.

3.4.3. Assessment criteria

When assessing the organism to be released, both the genetic characteristics of the organisms and its ecological and environmental characteristics are considered. As a general rule, applications to field test an organism must be preceded by trials carried out under contained conditions.

In case of required genetic information, details should be given regarding:

- the parent organism (identification, taxonomy, source, strain, reproductive cycle and capacity for genetic transfer);
- the source and function of the DNA used to modify the organism (identification of the donor organism);
- the place and institution where the modification was carried out;
- the recommended level of containment and special precautions for laboratory experiments with the modified organism;
- the expected changes to the original phenotype of the organism after modification - the possibility of easy distinction between the modified organism and the wild organism;
- technical information of the vector - its construction, introduction into the organism and the amount remaining in the modified organism;
- the selection of the organism prior to modification and genetic structure after modification
- tests carried out to measure genetic stability and expression of the introduced DNA in the modified organism.

When environmental protection is considered, two particular difficulties arise - the identification and quantification of any particular environmental problem, and the determination of a level of risk that is considered acceptable to society (ERMA, 1997). Environmental considerations are based on the unmodified parent organism and the prediction of any changes that might result from modification:

- the organism's habitat, geographical distribution, factors affecting its survival, reproduction and dispersal, host range;
- the involvement of the organism in biochemical or biological cycling processes (e.g. cellulose and lignin degradation, pesticide degradation);
- the effects of the modified organism on the characteristics of other species, including the transfer of the inserted genetic trait to other organisms at the release site and in the surrounding environment;

- the possible consequences of the release of the modified organism on human health, agricultural production, other organisms, environmental quality, Maori traditional resources;
- the consequences of the organism remaining in the environment beyond the planned period;
- the methods used to monitor environmental impacts and the population of the modified and other organisms.

Another important consideration is the nature and the magnitude of the field trials, in order to assess the potential risk:

- the place of the release;
- the target ecosystem - the magnitude of vulnerability of the ecosystem to disturbances;
- the method of release and control - separation of the experiment from the surrounding environment and contingency plans to cope with extreme conditions;
- the quantity and transportation of the modified organism;
- the survival and reproduction rates of the modified organism; the potential hazards or deleterious effects;
- the future intentions for a general release if the trials are successful.

Laboratory containment[56] of *in-vitro* recombinant DNA experiments is achieved through a combination of both biological and physical containment. There are five levels of physical containment, ranging from 0 (sound microbiological practice) to 4 (a purpose built laboratory is required to reduce the risk of deployment). Experiments are categorized on the basis of perceived risk and the required level of containment. In terms of glasshouse releases, containment levels range from 1 (low risk) to 3 (high risk). Risk is concerned with the potential of an organism to have a detrimental impact on economic activity, human health or the environment generally. The level of risk is assessed not only as the probability that a certain event will occur, but also in terms of the potential severity of the consequences.

3.4.4. Applications

In New Zealand, the sectors with the greatest impact from biotechnological developments are agriculture, beverage, dairy, food, forestry, fruit and vegetables, meat processing and

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[56] Containment is defined as the restriction of an organism to a defined area or location where it is confined under security appropriate to the species and to the perceived type of risk, and is also designed to prevent escape (MFE, 1988).

waste treatment. "Since its first meeting in August 1988, the IAG has received 27 applications involving the use of GMOs outside strictly contained facilities. Of these 23 were for field trials, glasshouse trials and taste tests, 3 were for large scale fermentation of genetically modified *Escherichia coli* bacteria, and one was to transport a GMO within New Zealand. An inquiry relating the export of GMOs was also received" (MFE, 1994).

There are a number of approved field trials of genetically modified plants in New Zealand: potato, kiwifruit, rape, kale, asparagus, broccoli, corn, ornamental plants. A more specific example is the case of transferring a gene from bacteria that confers resistance to the herbicide glyphosate (Roundup) to asparagus. The new genetically engineered crops are characterized by greater resistance to pathogens, by making them resistant to the agrochemicals[57] used to control the pathogens. According to James and Krattiger, efforts in New Zealand have been devoted to testing virus and herbicide resistance in potatoes.

In the area of forestry, in the past 10 years, the impact of biotechnology has mainly been associated with clonal afforestation, where a tree with superior characteristics[58] is selected and by using micropropagation technology clones of the same tree are produced in large quantities for afforestation. Recently, genetic engineering has begun to have an impact on forestry by selecting trees with desirable characteristics and modifying their genotypes by introducing new genes for enhancing specific function. The future of forestry biotechnology is promising, considering that the resistance by the consumer to genetically altered wood products will be minimal (Kennedy and Davies, 1994).

3.4.5. Concluding note

The regulatory developments have been designed to control the possible spill-over effects of genetically modified organisms. The existence of advanced risk assessment guidelines implies that scientific developments have to fulfill the requirements of public and environmental acceptance in a sustainable way. A regulatory approach also establishes the margins of applied modification to living organisms. The only shortcoming of a specific regulatory framework is the fact that the changes that take place in the scientific field happen faster than they can be appropriated by regulations. Besides, in theory a genetically modified organism could be well-performing and fit the requirements of the specific regulatory framework, but in practice outcomes could be slightly or greatly different from what was expected due to unidentified factors.

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[57] In the case of pest control, the pesticide market in New Zealand is significant - there are about 3,500 tones of 270 different active ingredients applied per year, from which 2,200 tones are herbicides, 900 tones are fungicides and 500 tones are insecticides (Macer, 1990).

[58] Some of the desirable characteristics could be tolerance to extreme climates (e.g. drought), disease resistance, reduced branching (i.e. amount of knots), fast growth, and enhancement of wood properties for wood production.

3.5. Intellectual Property Rights in New Zealand

There are three main types of intellectual property protection relevant to living matter in New Zealand - patents for invention governed by the *Patents Act (1953)*, plant variety rights[59] governed by *Plant Variety Rights Act (1987)*, and trade secrets[60] which are governed by common law. These can partially or completely overlap or be mutually exclusive[61].

3.5.1. Patents

Patent protection is a way to appropriate the gain of an invention regarding a GMO and its further field testing. The timing of patent application is important. If there is already a public notification of a proposal, any subsequent patenting of the results would be invalid. This could be avoided by filing a provisional application, where a proof of the invention by experiments carried out in containment should be submitted in order to seek permission regarding field release. However, patenting is a rather expensive and time consuming alternative. Probably a more cost-effective and time and resources-saving option is to maintain secrecy, by properly managing security systems and contractual agreements with employees.

Another problem is that the New Zealand patent law concerning genes and genetically engineered micro-organisms is considered to be inadequate, because the law has not kept pace with the rapid advancement in biotechnology (*Patents Act (1953)*). Moreover, the enforcement of patent or plant variety rights in living material has not been considered by the courts in New Zealand, which makes uncertain how far the patent will extend. This could be due to the conflicting between the interests of the public and those of the investors, and also to the little commercial development of biotechnology. Moreover, the

[59] A plant variety right is the right to exclude others from producing for sale or selling reproductive material of the protected variety and in New Zealand. It extends to the propagating of protected varieties for the purpose of commercial production of a product. To be eligible for a plant variety grant, the new variety must be distinct from all other varieties of common knowledge. Reproductive material of the variety must not have been sold for more than one year in New Zealand (four or six years outside New Zealand, depending on the type of plant) before making an application. Populations of the variety must be homogeneous within the limits common to that species. Varieties must be stable from generation to generation (Macer et al., 1991).

[60] A trade secret is information or living genetic material itself that is of commercial value. There is no absolute property right in a trade secret to prevent anyone else from making commercial use of the information. The owner of a trade secret only has the right to prevent someone, who has improperly taken that trade secret (misused confidential information), from taking commercial advantage of the information. The owner of a trade secret cannot stop somebody who has independently developed the information themselves (Macer et al., 1991).

[61] Trade secrets and plant variety rights are mutually exclusive.

current patent term of 16 years[62] is considered inadequate to justify the considerable costs of investment in R&D. In general, the patenting of plants is possible in New Zealand under the current law (Macer et al., 1991).

3.5.2. Plant Variety Rights

Another area of protection available for biotechnological inventions is the *Plant Variety Rights Act (1987)*. The Act enables the discoverer of a new plant variety[63] to obtain protection (through a grant[64]) for the discovery, for a period of between 20 and 23 years (for woody plants) depending on the type of plant, as long as the applicant shows that the plant is "new"[65], distinct[66], homogeneous[67], and stable[68]. The breeder has the exclusive right to produce for sale, and to sell, reproductive material of the variety concerned, to propagate that variety for the purposes of commercial production, or to authorize any other party, subject to specific terms and conditions, and to engage in selling the protected variety. This implies that the rights of the breeder, under a grant, are proprietary rights, and any action which reduces the benefits to the breeder from the protected variety is considered an infringement.

The only exceptions to the above rights are related to the propagation, and use of a protected variety for non-commercial purposes, as well as the utilization of reproductive material from a protected variety for human consumption or other non-reproductive purposes. Another exception is when the production of the hybrid or new variety concerned does not require repeated use of that variety, and a new variety (hybrid) has been produced and sold from a protected variety. The sale of the new variety (hybrid) is not an infringement of the plant variety right for the variety from which the new variety was derived.

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[62] This is the period of time that the patent grants the patentee to exercise the right to exclude others from making, using, selling the patented invention. In return for the power to exclude others from using the patented invention, the patentee must make information about the invention available to the public. Patent validity requires that the invention shows novelty, non-obviousness and utility.

[63] According to the *Plant Variety Act (1987)* a variety means a cultivar, or cultivated variety, of a plant, and includes any clone, hybrid, stock, or line, of a plant; but does not include a botanical variety of plant.

[64] A grant means a grant of plant variety rights, which represents a form of protecting the right to use a new plant variety by its inventor or developer.

[65] A variety is new if there has been no sale of that variety for more than 12 months before the date on which the application for a grant has been made, in the case of New Zealand, and for more than 6 years before that date in the case of woody plants, or for more than 4 years before that date in every other case overseas.

[66] A variety is distinct if it is distinguishable by one or more characteristics from any other variety known when the application for a grant is made.

[67] Homogeneity refers to the particular features of the sexual reproduction or vegetative propagation of the variety.

[68] A variety is stable if no changes have occurred to its particular cycles of reproduction or multiplication, at end of each such cycle, or after repeated propagation or reproduction.

In three years period, since the granting of the right, reproductive material of the protected variety of reasonable quality must be reasonably available at a reasonable price or third parties may apply for compulsory licenses to sell plant material of that variety (Macer et al., 1991). When a license has been issued, a royalty or payment or a means of calculating a royalty or payment, need to be specified and be payable by the licensee or purchaser concerned to the breeder concerned. The Commissioner, being the mediator in the licensing agreement, should give his opinion regarding the equitable distribution of the royalty between the breeder and licensee.

In the case of plant genetic engineering, a patent could be granted for different aspects of the invention: the DNA sequence comprising the gene, the transforming vehicle (e.g. vector or plasmid), the process of transformation, the transformed plant. However, the transformed plant would represent a new variety and if it satisfies the other eligibility criteria, it could be granted protection under the Plant Variety Act. The issue becomes more complex when infringement occurs to both the patent and the plant variety right. "If a transformation had been done by a person other than the patentee, then there would be conflicting rights. The owner of the plant variety grant would not be able to produce and sell the protected variety without infringing the patent. The patentee [on the other hand] would not be able to sell reproductive material of the protected variety without infringing the plant variety rights of the grant owner. That conflict [of rights] would have to be resolved by a commercial settlement involving a cross licensing arrangement[69]" (Macer et al., 1991).

3.6. Other regulatory frameworks in New Zealand

Other legislative frameworks which affect any natural resource, including forestry, in New Zealand are represented by the *Resource Management Act (1991)*, which promotes the sustainable management of natural and physical resources. Decisions focus on results or 'intended outcomes' rather than only on the regulation of the resource use. Resource use is subject to specific resource consents granted by regional entities.

In the case of forestry, the *Resource Management Act (1991)* places increased legal obligations on both woodlot owner and logger in maintaining soil, water and other environmental values during and after the harvesting process. Regional authorities may require consent procedures to be undertaken as part of the harvest planning stage, for example (Hammond, 1995).

[69] There are compulsory licensing provisions under both the Patents Act and the Plant Variety Rights Act.

CHAPTER 4

INVESTMENT OPPORTUNITIES FOR PLANTATION FORESTRY IN ARGENTINA

4.1. Political/economic environment and investment opportunities

4.1.1. Political and economic environment

Since the beginning of President Menem's administration (1989 -), market-oriented reforms have been implemented in Argentina in order to increase the country's competitiveness in foreign markets, to stimulate the development of private sector enterprises, and to attract foreign investment. The State Reform Act (1989) commenced a massive privatization of the energy, communication and distribution industries. The Economic Emergency Act (1989) initiated a big deregulation program in the areas of foreign investment, capital markets, domestic markets for goods and services and state regulatory agencies. It eliminated interest rate, currency exchange, price and salary controls, as well as local content requirements, subsidies and preferential tax treatments. Under the Convertibility Act (1991) one peso is equal to one American dollar. There are no foreign exchange controls of any kind, which enables a single foreign exchange market to operate. Moreover, individuals and corporations have the right to freely hold, conduct business, collect revenues and maintain bank accounts in foreign currency.

4.1.2. Foreign investment opportunities

Foreign investment has been regarded as essential for Argentinean development, and it is supported by one of the most pro-business foreign investment legislation in the world. Foreign companies have been allowed to operate in Argentina with virtually no restrictions. The Foreign Investment Law of 1993 is designed to encourage both domestic and foreign investment. No prior government approval or registration are required for foreign investments. Foreign investors are also entitled to repatriate capital, remit profits or make transfers abroad at any time. No approvals are needed for making transfers abroad, which virtually opens up the opportunities for access to foreign exchange markets.

There is no discrimination of any sort against foreign investors, as foreign and domestic companies are treated equally under the law, and therefore are eligible for both domestic and foreign currency financing in the local market. Foreign investors are not required to achieve a certain degree of performance. The equal treatment also means that domestic and foreign investors face the same tax liabilities (whether branches or entire corporations are taxed at a 30% flat rate on their taxable income). The burden of taxes in Argentina is further reduced by the lack of: provincial income tax, capital gains tax, income tax paid on dividends paid by corporations, income tax on interest on fixed-term deposits, tax on income derived from public or private securities and export tax on manufactured products.

The equal treatment of foreign investors entitles them to enter any area of economic activity on their own, as no law or regulation forces them to associate with local partners. Moreover, foreign investors are entitled to utilize any of the corporate structures recognized by Argentine law in order to enter freely the market through the most suitable partnership (merger, takeover, joint venture). Foreign investment is also strengthened by a number of bilateral treaties for the promotion and protection under international law of foreign investment. New Zealand has not negotiated such a treaty with Argentina. Considering that FCF has already entered in a partnership (joint venture) agreement with an Argentinean company and a large investment is at stake, it could be beneficial that New Zealand negotiated the grounds for such a bilateral treaty with Argentina. Such a treaty could further reduce the legal risks of investment to the New Zealand company and could stimulate future investment in Argentina.

Another factor that provides foreign investors with some degree of security of their investment is the fact that Argentina is a member of the Multilateral Investment Guarantee Agency and the Overseas Private Corporation. These institutions insure foreign investors against political and other risks, given that the investment project has the written approval of the Argentinean government. Moreover, another option available to protect the interests of foreign investors is through international arbitration. This is possible considering that Argentina is also a member of the International Center for the Settlement of Investment Disputes. Thus, the membership of Argentina in these and other international organizations makes international law enforceable for the purposes of investment, and provides foreign companies with greater flexibility in terms of sources and regulations for investment protection.

4.1.3. Labour environment

Argentina's human resources represent the country's competitive advantage, and the vehicle for implementation of the market-oriented reforms. The level of training of the average Argentine is relatively high and it is improving. The capacity of the human resources, as well as the low rate of population growth are the two factors that determine the high Argentine wages. The wages are higher than the average wage in other Latin American countries, but they are lower than the average wage in industrialized countries.

This gives a double opportunity for foreign investment to employ skilled labour, and pay the required competitive wage for the standards of Argentina, while saving on wage premiums offered to skilled labour in industrialized countries. However, the wage differential could be less significant than expected, considering that employment costs in Argentina are boosted by the complex employment compensation legislation, the social security taxes and the traditionally powerful labour unions.

4.2. Institutional biotechnology developments

Argentina's interest in biotechnology has been increasing. The formulation of public programs for biotechnology development have failed due to the lack of financial resources. The private sector has taken the initiative to apply biotechnology and has established joint-ventures with foreign companies in order to overcome the financial constraint of biotechnological investment. Early developments of biotechnology have been in the area of pharmaceuticals, and some of the developed products have already been allowed to be commercialized. Recent developments have been achieved in the areas of plant and animal biotechnologies.

4.2.1. Public sector framework of biotechnology

Argentina is one of the four major Latin American countries (Brazil, Mexico, Chile) that undertakes biotechnological research, which is backed-up by national policies and it is also safeguarded by the existence of biosafety committees. According to Sasson (1993) biotechnological research in Argentina is mainly oriented towards *in-vitro* tissue culture, micropropagation and clonal multiplication of crop species. Recent developments have been directed towards the adoption of molecular genetics (e.g. marker assisted selection) for the identification of specific traits in plants' genome, related to diseases, and genetic transformation.

Argentina has a National Biotechnology Program, established by the State Secretariat for Science and Technology (SECYT). The Program's objective is to promote and finance research and training projects, as well as to serve as a link between national private and public centers, and promote international cooperation. Program's priority areas of interest for the project are plant tissue culture and plant molecular biology. The Program, however, did not create great interest among public authorities and industry.

Some of the institutes carrying out biotechnological research, as well as supporting the National Council of Science and Technological Research (CONICET) and the Scientific Research Commission of the Province of Buenos Aires (CIC) are:

1. Institute of Genetic Engineering and Molecular Biology Research (INGEBI), Buenos Aires - plant molecular biology and resistance to viruses of crop species
2. Institute of Botany of the North-East (IBONE), Corrientes - tissue culture of several plant species
3. Institute of Biochemistry of the Foundation Campomar, Buenos Aires - somatic embryogenesis of carrots, nitrogen fixation and molecular biology of photosynthesis
4. Plant Ecophysiology Centre (CEVEG), Buenos Aires - micropropagation of several species
5. National Institute for Agricultural and Livestock Husbandry Research (INTA)
6. Institute of Molecular Biology (CICV)
7. Agricultural Research Centre (CICA)
8. National Institute for Industrial Technology (INTI).

The role of the public sector in the development of biotechnological research in Argentina is important to the future technological competitiveness of the country. There is a very limited number of private companies with enough financial and technological capacity to carry out an expensive research. Thus, research relationships between Universities or other public institutions and private companies make biotechnological developments a more realistic objective. The shared research implies a greater capacity for the actual application of biotechnological research.

4.2.2. Private sector biotechnology involvement

A common feature among the developing countries is the lack of significant involvement of the private sector in biotechnological research. The main reason for this seems to be the fact that "biotechnology is considered to be a long-term, high-risk venture which does not lend itself to the operations of the smaller, private-sector companies in the developing world which are more geared to short-term, production-oriented objectives and cannot support long-term R&D objectives" (Persley, 1990). The costs for access to scientific information, technological developments and market information are very high. Venture capital is scarce for providing a financial base for private biotechnological companies.

In Argentina, there are a number of relatively big private biotechnological companies that have operated for a number of years, and even though their international competitiveness is relatively limited, their focus on supplying niche domestic and some international markets has been increasing and with success. Initial involvement in private biotechnological research was represented by pharmaceutical companies. Companies investing in plant breeding and biotechnological improvement are recent actors in Argentina's development in private biotechnological research. Industrial interests in biotechnological research are represented by the professional association called Argentinean Forum of Biotechnology, which promotes and monitors national and international biotechnology developments.

Some of the major[70] private companies involved in biotechnology (and their respective area of application of biotechnology) are:

1. Bio Sidus S.A. (created in 1983) - second biggest pharmaceutical company in Argentina and a leading national laboratory; it has produced and already marketed some products.
2. Dr. Gador Laboratories y Compañía SACI (created in 1940) - leading pharmaceutical company.
3. The Pilot Plant for Microbial Industrial Processes (PRIOMI) - uses microorganisms in industrial processes.
4. Laboratorios Bago - pharmaceuticals.
5. Industrias Químicas Almidar S.A. (IQA) and Bio-Almidar - agrochemical and veterinary products; it offers a service to Argentinean potato farmers on the diagnosis of potato viral infections.
6. Polychaco SACI - plant biotechnologies.
7. Technoplant S.A.[71] (created in 1985) - leading in-vitro micropropagation company in Argentina, and second in Latin America; it is involved with selection and massive propagation of vegetable and fruit species[72]. In 1992, Tecnoplant S.A. became the Division of Plant Biotechnology of Bio Sidus, S.A. The importance of the company has been in finding a niche market for an already known technology (Sasson, 1993).

According to Sasson (1993), Argentina has adopted an industry-led strategy for entering biotechnological research. Such strategy tries to turn scientific output into industrial outcome. In general, private research in biotechnology seems to be driven by the demands

[70] The companies are classified in terms of their size and research capacity.

[71] Tecnoplant S.A. had not only introduced new species of commercial importance and carried out their massive propagation, but also provided advisory services for micropropagation, multiplication, management, harvest, and post-harvest technologies, marketing, etc. (Sasson, 1993). The strategy of the company is focused on close client-producer relationships, where the client gives the material for micropropagation, and the company uses this exclusive genetic material for production purposes. Technical secrets, rather than patents are the only protection mechanism that the company relies on (Correa, 1994).

[72] The techniques used are meristem culture for micropropagation and clonal multiplication, with future interests in somatic embryogenesis.

in niche markets, national and international, where there is someone willing to pay a higher price for the improved product, while the producer finds it profit maximizing to receive returns for his value-added new biotechnological product[73].Thus, private sector biotechnological research and product development evolve around niche markets, where each company acquires a natural monopoly in markets for specific products. Competition is mainly based on the adoption of a new biotechnology technique which leads to a specific product improvement. Product differentiation increases the possibility of capturing a higher premium on the developed improvement. Because of the costs involved in biotechnological research, the improvement of the product has to be economically significant.

The involvement of private companies in biotechnological research has important implications to the future of the developed products. "Industry usually has a comparative advantage in finishing, commercializing and distributing products. Lack of industry involvement represents a missing link in the production chain in relation to product commercialization and distribution" (Persley, 1990).

4.3. Opportunities for investment in plantation forestry

Some of the major facilities required to support investment in plantation forestry and wood processing are the specific costs of resources (human and capital), transport, supply of energy and water, and regulatory framework.

4.3.1. Investment opportunities in the forestry sector

Forestry is one of Argentina's primary sector industries that has the highest economic return. The provinces have control over natural resources (including forests). The National Forestry Institute, however, is responsible for the promotion of all aspects of the forestry industry. When planning to invest in forestry, it might be important to consider the fact that, in general, forestry operations require a license and are carefully supervised, in terms of the area in which trees may be felled, and the obligation to reforest. Thus, the cost of the license and the specific regulations should be identified among other criteria before selecting a specific area for planting.

[73] The company improved varieties delivered by customers, carrying out under contract the propagation of banana varieties, asparagus, strawberry, raspberry, kiwi, apple, cherry, pear, vine, blackcurrant. As a result of requests of large-scale producers and planters, the company has developed new lines for massive propagation (e.g. asparagus, garlic, eucalyptus and mate), by using appropriate techniques (e.g. cloning of parental lines for future production of hybrids) that unable the company to deliver the amount required by the agro-industry.

Land prices are low in Argentina, compared to the prices in Brazil and Chile. The price of land (US$/acre) in Argentina varies between provinces, with the highest land prices charged in Entre Ríos, followed by Corrientes province, with the cheapest prices charged in Patagonia. Planting costs (US$/acre) also vary between provinces. They are determined by the scale of production, the utilization of mechanized methods, the demand and conditions of land. Planting costs are average in Entre Ríos, and a little above average in Corrientes. The highest planting costs are in Misiones, and the lowest in Patagonia. Moreover, in the most productive regions forest planting is carried out without land leveling, clearing, or any other operation that might increase planting costs.

Moreover, the Federal Government has established a reimbursement scheme, after 18 months of plantation, as an incentive for planted forests. The amount varies with regions (US$160-US$240 per acre^{-1}). This incentive can be obtained by national and foreign enterprises. The limit is 1700 acres/yr of planting per enterprise. There are also complementary provincial incentive schemes.

Wood values are determined by the price that the producer receives (US$/ton) for selling a specific product. The value of sawn wood from *Eucalypts* is slightly higher in Entre Ríos than in Corrientes. The greatest value of sawn wood is from pines grown in Patagonia. Therefore, wood values, are not only differentiated on the basis of the region where trees are grown, but also they are species specific.

A number of forestry projects have been carried out in Argentina by domestic and foreign companies. There is a number of companies able to compete (in terms of sector of interest, and not nature of product) with Fletcher Challenge Forests' project in Argentina.

Table 1. Private investment in forestry projects in Argentina

Investor	Country of origin	Sector	Location	Project	Total US$ million	Period
Protisa	Chile	Forestry	Corrientes	Industrial plant	50	1993
Albano SA Fletcher Challenge F	Argentina New Zealand	Timber	Corrientes	Processing-lumber, mouldings	2,5	1993/94
MAM SA	Spain	Timber	Neuquén	Boxes	5	1993/95
Danzer Forestal	Germany	Forestry	Misiones	Laminated timber	5	1993
Masisa	Chile	Forestry	Entre Rios	Particle board plant	100	1994
Masisa	Chile	Forestry	Entre Rios	Formalin plant	7,5	1995
Fiplasto	Argentina	Forestry	Entre Rios	Wood boards	15	1995
Fletcher Challenge Forests	New Zealand	Forestry	Corrientes	Sawn wood of high value	22,5	1995

Another private domestic forestry company is Jopeco S.A. It manages 5,000 hectares of forest plantations, and it offers number of forestry services (e.g. land values and feasibility, forestry inventories, densities according to the uses one wants to obtain, tonnage, species, fire control).

In general, Argentina has the infrastructure and the capacity for primary and secondary wood processing. The former comprises timber saw mill, impregnated solid wood, veneer, laminated wood, plywood, particleboard, fiberboard, pulp, paper. The latter focuses on the production of furniture, edge-glued panels, blanks and mouldings. Wood processing is supported by both domestic and foreign investment.

Argentina has an important domestic market for wood products, with increasing levels of plywood consumption. Wood products are one of the most important components of the total exports of the country. So far, cellulose and paper have been the products contributing the most to total exports. In the future, exports are predicted to significantly increase due to the use of new technologies for reducing the growth cycle and productivity of trees.

Argentine workers are highly qualified for carrying out industrial activities. There is a large supply of labour for planting and harvesting trees. There is also an adequate capacity for equipment maintenance. A number of qualified professionals is also needed with specific forestry knowledge.

The free market economy has reduced the cost and increased the efficiency of the transport and communications sectors. This provides an adequate freight structure for moving forestry products nationally and internationally.

The importance of investment in plantation forestry has led to the formulation of an Argentinean Forestry Development Plan. The plan sets measures and incentives for better management strategies, which will enable the companies to support themselves operationally and commercially. Some of the most important objectives of the Plan are related to:

1. free market and standardization policies for freight permits, record keeping, regulations in frontier lines and administrative procedures on imports,
2. investment and promotion of forestry activities, in order to include new forestry activities, and assisting potential foreign investors,
3. strengthening the support services such as the incorporation of forestry products' quality specification into the National System of Rules, Quality and Certification, the implementation of support activities (e.g. planted forests inventory, applied research, extension, technology transfer and forestry certification of seeds and seedlings), and,

the creation of a private consortium network for the joint adoption of technologies and commercialization of wood.

In general, the Argentine forestry sector seem to offer favourable conditions and opportunities for foreign investment, due to the country's natural potential and good vertical coordination of the forestry production process.

4.3.2. The case of Eucalyptus grandis in Argentina

The growth rate of Argentine forests, in general, is ranked among the highest in the world. Climate and soil conditions in Argentina allow for high tree growth rates and short harvesting profiles in planted *Eucalypt* forests.

In Argentina, *Eucalypts* species are grown among other natural as well as introduced varieties[74]. Average rainfall is abundant with good growing temperatures throughout the year, which allows faster growing species such as *Eucalypts* to perform better, thus reducing the length of the harvest profile. The growth rates and the rotation period vary among provinces and also depend on the end use of the logs. The biggest planted areas with *Eucalyptus grandis* are located in the province of Mesopotamia, with rotation periods of 10-12 years (Dalla-Tea, 1995). However, *Eucalyptus grandis* adapts best to the Argentinean provinces of Corrientes and Entre Rios. The harvest profile of *Eucalypts* in these provinces is between 8 to 10 years, which is a great opportunity for investment plans. In general, logs are used for the purposes of sawmill, laminations, pulp and particleboard production.

Another important characteristic for the growth of *Eucalypts* is the density of the plantation[75]. The initial density of the plantation influences the planting costs, the plantation management, and the processing of logs. Generally, lower density is found to correspond to greater growth of *Eucalypts*. Greater density increases the cost of harvesting and transport, thus, increasing the overall costs of production. The combination between

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[74] Eucalypts are also essential species of plantation forestry in Brazil. Aracruz forestal, a private company, has carried out research in the area of genetic improvement of Eucalypt species, introduced from Australia and Indonesia. The selection of better trees resistant to pests and diseases and also adapted to the region's environmental conditions were reported to yield higher volumes ($45m^3$/ha/yr). Species such as Eucalyptus grandis were reported to perform particularly well - reaching high increments in volume ($70m^3$/ha/yr), when the clone and the soil interacted well. Results achieved in this clonal experimentation phase showed high productivity and a wood of homogeneous characteristics clones (seeds by clonal plantations were used since). In 1986, harvesting of the first clonal plantations proved the research expectations - wood consumption at plant level decreased from 4.87 m^3 to 4.26 m^3 per ton of pulp. Significant advantages in product quality, production, and plant equipment usage optimization were achieved. Clonal plantations also present advantages of about 22% in harvesting and logging operations as well as reductions in costs, due to tree uniformity, high survival and branch-free stems (Campinhos, 1994).

greater density and short rotation period also puts pressure on the nutritive quality of soil. Moreover, such combination could increase the volume of production, but the productivity of sawmill will be lower (Dalla-Tea, 1995).

On the other hand, greater density could bring problems with knots, as branches tend to be thicker, and it could also generate a greater proportion of trees with juvenile wood. Thus, the density of the plantation is important for the volume of production and productivity of logs, and depends on the nature of the regions where the plantation is situated and on the purposes of the wood products demanded. The optimal density is a function of the productivity of the region, the length of the rotation, and the properties of the final product[76] (Dalla-Tea, 1995).

The region of Corrientes has a slightly higher production capacity (m^3/acre/yr) that Entre Ríos. There is no important competition for land use between forestry and other agricultural activities in these regions. The price of land and the planting costs are discussed in the previous section, but in general, these two regions are extremely favourable for plantation forestry. The planted areas which bring the highest internal rate of return[77] are in the province of Entre Ríos (13-14%), followed by Corrientes (12-13%), where *Eucalypts* are grown. Another factor that boosts the quality of the plantation and thus the future returns is the fact that there are no pests of economic importance in any of the production regions in Argentina.

4.4. Regulatory framework for biotechnological research and products

The advances of biotechnological research have put increasing pressure on governments around the world to establish national policies related to the testing and commercialization of genetically modified organisms. As biotechnological research is mainly carried out in developed countries, biosafety committees and other legislative approaches have been established there in order to control the possible environmental and health related effects of the genetically engineered varieties. Governments in developing countries are starting to realize that if biosafety regulations are not speeded-up, a wide margin for field trials will

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[75] For more detailed information and a regression analysis of the effects of density on growth of eucalypts in Argentina consult Dalla-Tea (1995).

[76] In Brazil, species, origins and progenies of eucalypts adapted to local conditions have been selected through tests evaluating the interaction of the genetic material with the prevailing environment at the plantation site, in order to increase productivity and at the same time minimize environmental impacts by introducing exotic species. Moreover, biodiversity preservation has also been a concern for plantation managers. Remaining natural vegetation integrated in forestry plantations is maintained and enriched, where there is 1 ha of natural vegetation for every 2.4 ha of eucalyptus plantation (Campinhos, 1994).

[77] The investment return is based on plantation costs and current prices for wood. Returns will be higher for vertically coordinated, bigger scale plantations.

be left and the biological diversity in these countries could be threatened if these tests are not carried out in a suitable way.

4.4.1. Intellectual property regulations

There are two legislative frameworks that consider the importance of technological innovation. The Law on the Promotion of Technological Innovation, enacted in 1990, finds its main objectives in stimulating private investment into technology improvement and in enhancing relations between research and industry, both through tax incentives and the creation of a fund to promote innovation. On the other hand, the Law on Technology Transfer, enacted in 1981, governs all contracts[78] for transfer, assignment or licensing of technology or trademarks by non-residents (individuals or judicial entities) to residents. The concept of technology, according to the regulations, comprises patents, models and industrial designs, and all other forms of technical knowledge for the making of a product or for offering a service. Thus, the contracts covering the transfer of technology must be registered with the Institute of Industrial Technology.

In the case of trademarks, protection is granted upon registration with the National Industrial Property Board. The registration is also covered by the payment of a fee. Protection is granted for a maximum of ten years each time a trademark is registered. Another guarantee of protection is the standardization of Argentinean regulation in the field of technological innovation, based on the international classification of goods and services of the International Intellectual Property Organization.

The details and regulations concerning the protection of intellectual property rights are the responsibility of the Patent office and the National Industrial Property Board. The office grants patents for 5, 10 or 15 years, depending on its own judgment as to what the appropriate period is. Foreign patents may be renewed for a maximum of 10 years, but the term for which their Argentine registration is granted may not exceed the period of time of the original foreign patent. The duration of patents for plant varieties depends on the nature of the variety - for annual varieties it is 12 years; for biennial varieties it is 15 years; for perennials it is 20 years.

The legislation exists, but what is the essence of the regulations? The concept of patent is very broad as to what is specifically protected. It could refer to the intrinsic nature of the invention or the particular application of the invention (independent of its quality or

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[78] Such contracts should be submitted in Spanish and they must be registered with the Institute of Technology (for statistical purposes only!), whose main object is the transfer, assignment or licensing of technology (According to the regulations, technology comprises patents, models and industrial designs, and all other forms of technical know how for making a product or rendering a service.)

process of production). In the case of pharmaceuticals, the application of the product is protected rather than its intrinsic nature (IICA, 1991). Patents in Argentina are granted for the process of creation of a variety, rather than the product itself (Gutiérrez, 1991).

In Argentina, the only group of inventions in the area of biotechnology that count with patent protection are the pharmaceutical and diagnostic products, as well as medicines. The process of the production of these products is also protected under the rights of the patent (IICA, 1991). The protection of the invention in the area of pharmaceuticals has provided the incentives for industrial research and application, mainly in the private sector. This could explain the strong focus of biotechnological developments in the field of pharmaceuticals, with weak participation in the area of plant and animal biotechnology.

In Argentina, the early regulations concerning the protection of the industrial property did not contemplate the patenting of living organisms, especially asexually reproduced plants or animal varieties. Such stringent regulations have been slightly modified since 1985 and to date there have been a number of patents granted for asexually reproduced plants (by using their seeds) (Gutiérrez, 1991). Persley (1990) argues that Argentina is the only developing country (apart from South Korea) to make provision for plants of any kind to be patented, and to permit sexually reproduced plants to be patented.

The only protection granted in the area of plant varieties, in Argentina, refers to the varieties of plants found in nature, rather than modified varieties obtained from plant breeding and engineering practices. The legal regulations in this field do not include a list of varieties, for which a specific protection could be demanded. It is established that protection could be granted if the following is fulfilled in the case of plant varieties: novelty; differentiation; homogeneity or uniformity and stability. The variety has to be new (not previously sold), be different or distinguishable, count with a limited variation (which is predictable and commercially acceptable) of the genotype characteristics and finally, keep heredity characteristics unchanged after reproduction or multiplication, i.e. pure variety (IICA, 1991).

Moreover, Argentina is the only Latin American country with legislation which requires the deposit of biological material in order for a patent application to be considered. When biotechnological invention is evaluated, the detailed description of the nature of the invention is not sufficient. The biological material needs to be deposited for conservation and for obtaining samples of the material. These samples are made public, at the same time the invention is granted with protection (IICA, 1991).

In general, in Argentina the patent protects the rights of the holder for the import or introduction of the protected product and its commercialization. This is true in the case of production, reproduction and multiplication of the protected plant variety. The regulations further narrow the protection of the variety by allowing its free utilization by third parties who wish to create new varieties (IICA, 1991).

According to Correa (1994), when considering the interests of a private company, a patent is not very useful for establishing a market position. A patent could possibly help boost the image of the company (even though the cost of doing so could be very high) rather than protect the innovation from being imitated from the competition. The patent legislation lacks specific regulations regarding the patentability in the area of biotechnology. Some consideration is given to the control of microorganisms. Such uncertainty doesn't favour the protection of biotechnological developments and could be one of the major concerns of investors.

The regulations give an emphasis on the duration of the patent, and not on a specific technological margin for application of the intellectual property[79]. There are no clear intellectual property regulations and the existent patent protection seems to be in contrary to the research and application interests of foreign companies. "The lack of adequate patent protection is certainly a factor which dissuades transnational companies from conducting research activities on marketing biotechnology products in certain countries. The local subsidiaries of the transnational companies tend to rely on their parent companies to conduct R&D, on the basis that opportunities for product commercialization for local markets can explored later when markets can be more easily assessed" (Persley, 1990).

"The reluctance to support patent protection relates to concerns that it would suppress in-country development of biotechnology, and lead to dominance by transnational companies; and a fear that local genetic resources would be modified and patented by others, thereby denying the country access to the products or, alternatively, limiting access through purchase at unacceptable price. As a result of this most of the developing countries do not provide patent protection for animal or plant products, or if they do it's in the form of concessions to allow future patent protection for biotechnology processes, but still excluding protection for plant and animal products" (Persley, 1990).

An alternative way for protection of new varieties is through plant breeder's rights, which is a system of protection titles for the property of varieties, different from patents, but which margin of protection is much more restricted than the case of patents. With these rights, the holder has the exclusive right to produce and sell the propagated material (not the derived plants). Such legislation was established in Argentina - Law for Seeds and Fitogenetic Creations. The register of products, in the case of plant varieties seeking commercialization, requires the complete description, the origin and the genetic structure,

[79] Patents protecting industrial property rights are granted by the Patent Office for 5, 10, 15 years depending on the Patent Office's judgment of the appropriate period, upon application by the owner and subject to payment of a fee.

as well as sampling of the reproduced material in order to establish an identity and agronomic value.

The secret of the production process is the main point for concern. Thus, the property is based on a commercial secret, which is not legally protected, but it is only institutionally enforced under a resolution. Argentinean law does not recognize any property right of know-how. There is no trade secret law *per se*, but some laws recognize the concept regarding contracts, labour and property. Penalties exist for the revelation of trade secrets.

4.4.2. Regulatory framework for field trials of genetically modified organisms (GMOs)

Argentina seems to be more relaxed on the topic of field testing on national territory, considering that it is one of the few Latin American countries that actually allows the field testing and commercialization of transformed crops. Since 1991 requests for field tests of genetically modified organisms (developed in industrialized countries[80]) have been forwarded to the assigned authorities. Argentina appears to have the highest total number of transgenic crop field trials among developing countries (78) that have undertaken some field trials as until December 1995[81].. This is a result of either a weakly enforced biosafety legislation (which enables rent-seeking and revenue collection) or simply from an increasing interest in biotechnological research (which stimulates technological developments and keeps up with standards in the developed countries). The number of field trials in Argentina has been increasing significantly, compared to the significant drop in numbers in New Zealand.

The crops tested in field trials in Argentina are canola, corn, cotton, potato, soybean, sugarbeet, sunflower, wheat, raspberry, asparagus, etc. Not only field trials have been permitted in Argentina, but a step further has been taken and the number of applicants for commercial clearance[82] of transgenic crops is currently increasing. In Argentina, Monsanto's herbicide tolerant (glyphosate) soybean (375,000 acres) has been granted a clearance for its commercial growing. Another crop with a pending status for clearance is corn/maize, with different improved traits (herbicide tolerance, insect resistance), developed by AgrEvo, Ciba-Geigy, DeKalb, Monsanto and Northrup King.

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[80] According to James and Krattiger (1996), all the transgenic crop material tested in developing countries has been developed externally and imported by the developers of the technology subsequent to obtaining approval for trial implementation

[81] New Zealand is the fifth lowest among the developed countries involved in field trials, as the country counts with a total of 15 field trials of mainly potato, but also kiwi fruit, asparagus, broccoli, corn.

[82] Commercial clearance can apply to different crops, as well as different uses of the same crop.

It should be noted that among the genetically modified crops field tested in Argentina, and for which a formal approval has been granted, is a herbicide resistant soybean. This suggests that other herbicide resistant crops, or trees, could be given the approval for testing.

There is a general belief that most of the transgenic material tested in developing countries has been developed externally and imported by developers of the technology subsequent to obtaining approval for trial implementation. Argentina does not escape from such speculations. A more case-specific regulatory framework for field tests is needed in order to monitor the introduction, the further utilization and the release of genetically modified organisms in the country. Regulations should be strictly implemented and enforced in order to safeguard the flora and fauna of the country.

Argentina has developed operational field testing regulation, known as "*Guidelines for Testing Genetically Modified Organisms*"[83]. The authority responsible for licensing experimentation on and/or releases into the environment of genetically modified plant organisms is the Department of Agriculture, Stockbreeding and Fisheries (DASF). The release is also a subject to approval by the National Advisory Commission for Agricultural Biotechnology (CONABIA). Applications are initially processed by the National Seed Institute (INASE), followed by approval by CONABIA and DASF. The identified areas for license granting are:

1. Use of recombinant DNA techniques for manipulation of organisms
2. Laboratory testing
3. Small-scale field testing
4. Large-scale field testing
5. Pre-commercial breeding of the material.
6. Licensing, however, does not constitute an exemption from checks that may be carried out during commercial distribution of the seed[84].

The Guidelines are composed by three main sections: the application form, the supplementary information and the rules for compliance. A case-specific and greatly detailed application form needs to be completed by the applicant, in order to assess the suitability for a license for the release of genetically modified plant organisms into the environment[85]. The form comprises areas such as general information about the GMOs

[83] The full version of the Guidelines can be obtained from the Department of Agriculture, Stockbreeding and Fisheries, or the National Advisory Commission for Agricultural Biotechnology, or refer to the appropriate web site. In the present thesis only highlights of the most important parts of the Guidelines are presented in order to provide an insight into the Argentinean regulatory framework for the introduction and field testing of genetically modified organisms.

[84] The term "seed" is defined by the Seed and Plant Breeding Act as any plant organism used for propagation.

[85] There are two special cases to be mentioned. Firstly, a repetition of the same experiment requires just a renewal of the initial application. Secondly, additional applications are needed for: the back-crossing

(the donor and the recipient organisms, the vector or vector agent and the controlled organism or product), the aim and details of the experiment, as well as the proposed schedule of operations to be carried out with the GMO. In the application form, detailed information is also requested about the method of introduction of GMOs into the country, including any accompanying biological material (e.g. culture medium or host material); the quantity and the type of material to be introduced, field or laboratory release in Argentina, as well as the country, place and institution of origin of the material.

There is also a supplementary form to be completed regarding the characteristics of the material, such as:

1. Scientific name and brief phenotypic description,
2. Possibilities of cross-pollination with individuals of the same species and/or indigenous relatives; propagation mechanisms and periods of latent life of inactivity; weed conversion potential of the organism and the taxonomically related weeds that are usually present at the site where GMOs are to be released.
3. Detailed description of the molecular biology of the donor-recipient-vector system that has been already used or it will be used in the future for the production of the controlled GMO.

The rules outline the compliance requirements with the guidelines regulatory framework. The compliance will be evaluated by National Advisory Commission for Agricultural Biotechnology. In order to assess compliance, after license granting periodic checks are made to the place where genetically modified organisms are located. Such inspections have a cost, which is met by the applicant. The Commission has to be notified of any abnormal behaviour by the GMO. After experimentation, it is the applicant's responsibility to safeguard the plot of land where the field trial was conducted.

In the rules, the question of confidentiality of the nature of information submitted for assessment is considered. No intellectual protection is granted to the detailed information given by the applicant. What is offered is the possibility of classifying parts of the application as confidential, where such parts shall be deleted from one of the two application copies submitted. The copy with the confidential information shall be deposited in safe keeping at the National Seed Institute, and may be disclosed, with previous approval from the applicant, to a selected number of experts for decision-making purposes, only if this is necessary. In general, persons having access to classified information shall sign a confidentiality agreement.

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insertion process; a delayed harvesting beyond the permitted time frame; an extension of amendment to a previous application still in force.

4.4.3. Biosafety regulations

Argentina is one of the few Latin American countries that have taken into consideration the implications of field trials and the need for country- and case- specific biosafety regulation. In 1991 Argentina set up an inter-ministerial commission to evaluate requests for testing and releasing genetically engineered organisms. The National Bio-Ethics Committee was established under the surveillance of the Presidency of the Republic.

In the supplementary information of *"Guidelines for Testing Genetically Modified Organisms"* a detailed description is required about the biosafety methods and procedures used in the country of origin of the genetically modified organism, and their suitability to preventing contamination, release or dispersal into the environment of the donor organism, the recipient organism, vector or vector agent or any component of the GMO to be controlled, during the production process.

Biosafety measures are also considered at the laboratory testing stage (isolation and monitoring of recombinant genetic material) as well as at the field testing stage (techniques for detecting gene transfer from the GMO to the biotic environment). In the former stage information needs to be provided on the treatment of residual material after harvesting, while in the latter stage concerns focus on land treatment and future land use. Detailed description is also required about the distribution of the GMO, products and by-products, the method suggested for its final disposal and the method for controlling possible escapes.

4.4.4. Concluding note

The need of a detailed regulatory framework to deal with novel organisms and to safeguard the biosafety of the environment and society in general is indisputable. However, such a regulatory framework has to be backed up with a sound intellectual property protection, in order to fulfill its initial requirements and at the same time provide protected investment opportunities to private research. The nature of the guidelines requires the disclosure of very detailed scientific information, which needs to be assessed in order for a license to be granted. The information disclosed needs to be legally protected in order to provide the grounds for successful investment in field testing of biotechnologically engineered material. Such legal protection has not been identified in the structure of the guidelines. Considering that legal frameworks for biosafety and intellectual property are already in place, the operational aspects of the regulatory approaches need further attention.

4.5. Fletcher Challenge's strategies in Argentina

There is a great potential for forestry in Argentina - 50 million acres of land suitable for plantations of different species, abundant rains, diversity of climates and soils allow for high growth rates in forestry. There is no legislation in the country restricting the productive use of private planted forests. Economic criteria seems to be satisfactory for forestry due to land values, planting costs, trained labour force and the possibilities to be found in terms of sales and processing of wood. It is emphasized in the literature that because of its natural potential and the very good vertical coordination of the productive process the Argentine forestry sector offers highly favorable conditions and excellent opportunities for foreign investment.

In general, political, economic and geographical aspects are beneficial for foreign company investment in forestry. There are considerable opportunities for Fletcher Challenge's future objectives regarding the planting of improved *Eucalyptus grandis* varieties. Fletcher Challenge Forests has already established a joint-venture agreement with an Argentinean company, Forestadora Tapebicua, to develop a clonal breeding programme to use on the region's fast-growing *Eucalyptus grandis* trees. The joint-venture will provide the company with better knowledge about tree growth conditions in the country, relevant legislation, possible competition, social and cultural features, and general market information.

One of the factors favoring increased foreign investment in plantation forestry in Argentina is the significant growth potential of trees. Considering that output has been expanding through timber cutting of new forest land, rather than through improved productivity, highly performing, improved tree stock would be beneficial for the sustainable development of the natural resources in the country.

The overall Argentinean legal framework concerning foreign investment seems to be suitable for the purposes of the company, considering its pro-foreign investment character. In theory, legal and administrative constraints seem to be reduced to a minimum. However, it should be kept in mind that Argentinean government structure in general, allows for a number of uncertainties, such as the centralized power of the President, which limits the responsibility of each government department, and also increases the possibility for rent-seeking. Thus, for a foreign investor, especially dealing with a sensitive area of investment such as biotechnology, filling in all the required documentation is more likely to be only the first step of climbing the bureaucratic ladder.

The nature of intellectual property protection in Argentina is a serious factor to be taken into consideration when transferring technology into the country. Joint-venture agreements between foreign and national companies are one alternative to enter the countries market and to be less susceptible to political, economic and social uncertainties. However, with weak patent protection, the foreign firm's technology may become available to local firms at a relatively low cost. "Many firms prefer direct investment in wholly owned subsidiaries as a channel by which to transfer their technology to other countries, particularly if they believe that licensing will give away valuable know-how to foreign producers who are likely to be competitors in the future. Also, firms prefer direct investment over licensing when the technology is sophisticated and foreigners lack the know-how to assimilate it, or when a firm is concerned about protecting quality standards" (Mansfield, 1993).

Mansfield (1993) surveys a number of large US firms interested in investing in developing countries. The general conclusions are that these firms report that intellectual property protection in Argentina is average to weak (however, much stronger than protection in Brazil), which is a constraint for investment in joint-ventures with local partners, for transfer of their newest or most effective technology to wholly owned subsidiaries, and even for licensing their new technology. However, evaluation criteria for investment should take into consideration the differences in each industry, and an intra-industry evaluation should be made before generalizing the impacts of patenting on overall investment. For example, Argentina's laws deny patent protection to pharmaceutical products, while it provides for protection of new plant varieties.

The vagueness of patent protection in Argentina concerning the invention and commercialization of the products of new tree varieties should be of concern to the company. Thus, if the company obtains a patent in New Zealand, Argentina will grant a patent protection for a maximum of 10 years, which will safe the company a lot of paper work and time. The lack of well defined intellectual property rights, as well as the lack of specific legislation dealing with commercial secrets could be a main hindrance to the company's investment project. Even though climatic, economic and field testing conditions in Argentina suggest that significant gains can be made, without correct intellectual protection, the company would not only find it difficult to generate expected returns, but it could also be a subject to commercial secrets violations.

Considering the nature of the Argentinean regulations regarding the introduction and use of genetically modified organisms, and the patenting of inventions, Fletcher Challenge Forests would be better off re-engineering *Eucalypts* in New Zealand and exporting the transgenic material for field trial purposes in Argentina. Exporting improved material from New Zealand to Argentina has its own benefits in terms of overcoming quarantine restrictions. Clones introduced into Argentina would be pest and disease free, due to their *in vitro* nature.

Moreover, given that intending exporters of forest produce are required to lodge an application of intention to export with the Ministry of Forestry (New Zealand), it is the responsibility of this institution to safeguard the quarantine restrictions concerning any part of any living tree or plant suitable for propagation or any tree seed. Certification requirements vary according to the requirements of the importing country, but they could possibly be significantly speeded up with a quarantine assurance given by the Ministry of Forestry to the importing parties (MF, 1994c).

Argentina has a recent history of granting the right for field tests and commercialization of transgenic material, which could guarantee a successful field testing and commercialization license to the company. The only constraint could be the nature of the transformed material, considering that no field tests of transgenic trees have been yet allowed[86].

Vertically integrating the production process of the company in Argentina will lead to significant cost-efficiencies. Moreover, an area of interest for the company's investment strategies is related to the production of final wood products and their specific market destination. The fact that production of specific wood products is undertaken in Argentina rather than in New Zealand can have significant trade implications for the purposes of exporting the products to the US market. Even though tree germplasm has been imported from New Zealand, value has been added to the resource in Argentina considering that trees are grown in the latter and the processing of final products is also carried out there. The fact that a significant proportion of the value of the final product has been added in Argentina also means that such product can be sold to the US market under the scheme of Generalized System of Preferences (GSP)[87].

The US GSP rates apply to beneficiary countries, subject that at least 35% of the value of the imported product is added in the beneficiary country (Edgar et al., 1992). Even though the object of the system is to help developing countries to diversity their economic structures away from the production of primary goods, it can prove beneficial for the purposes the company by reducing, if not completely eliminating, the duty rates applying to value-added, high-quality products[88].

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[86] The reason for this could be the lack of applications for field testing of re-engineered trees, rather than a negative response from the government concerning the field testing of trees.

[87] The GSP was negotiated under the UNCAD (UN Conference on Trade and Development) and it guarantees that special treatment could reduce the duties that exporters face by reducing duty rates for developing country exporters. This results in many products from developing countries entering developed countries free or at least at reducedrates of duty (Edgar et al., 1992). This can be beneficial for an eligible developing country, but at the same time it can be detrimental for the competitiveness of exports from a developed country. For example, Chile, an important competitor to New Zealand in the export of Radiata Pine products, is provided with such a preferential trade advantage in Japan, European Union, and the USA.

[88] Most New Zealand wood products (from Radiata Pine) are tariff-free for the US market, except some high-quality, high-value wood products - plywood (20% tariff rate), particleboard (4%), fibreboard (3%), furniture (2.5%-6.6%) (Edgar et al, 1992). This suggests that tariff rates are quite high for value-added wood products, where it seems that products which have been subject to greater processing generally face the highest tariff rates. Tariffs by species are high for plywood from coniferous (20%), while they are only 3% from non-coniferous woods. Thus, it could be concluded that selling products from non-coniferous wood will bring greater returns, due to lower tariff restrictions.

In general, even though in issues regarding the intellectual protection of inventions Argentina might not provide a fully certain regulatory framework for the purposes of risk-free investment, a careful assessment of such risk factor should provide for an optimistic picture of future profitability. In other words, if the specific risk factors are correctly approached, there are significant gains to be made from growing bio-reengineered trees and from processing high-quality logs in Argentina.

CHAPTER 5

ECONOMICS AND COMMERCIAL APPLICATION OF BIOTECHNOLOGY

The importance of biotechnology has been and still is a very debated topic. Scientists agree that the future potential of biotechnology will be significant in terms of improving the biological characteristics and learning more about the nature of plants, animals and microorganisms. Environmental groups argue that the moral, ethical and environmental consequences of biotechnological improvement could cause adverse and irreversible effects to world natural resources and to human beings themselves. Investors exhibit risk-taking behaviour by investing large amounts of money in research and development of biotechnology, expecting huge returns from the products of the biotechnological R&D. However, the excitement about the potential of biotechnology needs to be reassessed in order to provide for more realistic predictions about the future developments and applications of the new technologies and the likely time-frame between invention, release and returns and their magnitude.

5.1. The economics of biotechnology

"In the neoclassical theory of production, productivity is a function of the state of technology, the quantities and types of resources used as inputs into the production process, and the efficiency with which those resources are used" (Carlson et al., 1993). In this conceptual framework, productivity can be interpreted as a function of the achieved biotechnological developments, and their impact on the overall production process, due to changes in the quantity and quality of the natural resource input.

Various economic studies have concentrated on the development of biotechnology as a means of production, but the formulation of models has been a very difficult task for a number of reasons. Hacking (1986) notes that biotechnology is not an industry that produces specific products or services, but it is rather a means of production. Its products and services have a wide range of applications for the purposes of different industries. Similarly genetic engineering is a technique to alter cells to perform functions more beneficially, i.e. to produce more or better products or to do so more efficiently. Therefore, genetic engineering itself cannot be subjected to economic analysis, only the processes or the improvements that it makes possible could be evaluated.

In general, to analyze biotechnology in economic terms it is necessary to examine the size of the industry, the nature of the products, and the relative importance of its markets, considering that the products span a wide range of market conditions, volume, demand and price. "The effect of the different markets on production economics is one of the most significant factors shaping the industry" (Hacking, 1986).

5.1.1. General considerations

Generally speaking, the nature of biotechnological development involves a number of both quantitative as well as qualitative factors. Given the novel characteristics of biotechnological improvement, both quantitative, and mainly qualitative assumptions are made on the basis of a wide range of existent uncertainties, which are difficult to capture in even the simplest assumptions. Correlations of the important variables are difficult to establish scientifically, which makes economic evaluation a difficult task. Thus, in order to overcome some of the limitations, the nature of biotechnological re-engineering is better captured and explained by the theory of economics through a number of well defined assumptions.

Biotechnology brings marginal changes in both the input (the resource) and the output (the product derived from this resource). Such marginal changes are reflected by cost reductions, quality changes, yield or volume increases, or simply by a more efficient utilization of the resource. Economic theory provides the tools for assessing such changes, as well as for evaluating the competitiveness of the technology and its products in the open market. Some of the elements of economic theory relevant in the context of the proposed project are the economics of project evaluation - estimation of the net present value and internal rate of return of investment, as well as some qualitative evaluation of the economics of a chain of production, where value-adding is the main goal of research and production.

Even though biotechnological developments add value to the final product, the problem arises when such value is to be apportioned so as to represent the magnitude of value adding attributable to biotechnology. Biotechnology is the starting point of product development and may only be a minor component of the selling price, especially when the chain of production has a number of phases and it takes 15 to 20 years to develop a final product.

The concern of both economics and biotechnology is how to increase productivity in a cost-effective and input-output efficient way. Increasing productivity depends on the amount and quality of undertaken research, and it can be accomplished in a number of ways:

1. Research increases the returns from productive inputs by increasing output or lowering the costs of production;
2. Research reduces the risk and uncertainties associated with production in an environment where many sources of uncertainties exist;
3. Research results in improved quality of both outputs and inputs (Lesser and Lee, 1993).

Improved input quality reflects the effectiveness of the process of selection and engineering. The improved quality of output, on the other hand, reflects an increased economic value, enhanced consumer utility, and improved product characteristics. Both, input and output quality are determinants to the productivity of the process of production.

Factors that determine the costs of research and their magnitude also have to be identified and fully incorporated when estimating returns on investment - costs of conducting and extending the research results, administrative research costs, costs associated with research failures, extension programme costs, and other costs associated with conveying information regarding the research innovations to producers and the specific quality characteristics to consumers. Costs are also incurred in the process of experimenting with and testing new innovations and also in the process of adaptation of the new technologies to specific objectives.

The costs will mainly depend on the magnitude of biotechnological research, the nature of trait selection and resistance enhancement and the number of lines per generation subject to biotechnological engineering. The costs of specific inputs (labour, capital, R&D, land, management) over time are also needed. The utilization and the gains from the improved trees depend on their advantages over existing tree varieties. Thus, the gain depends on the success of selection and genetic engineering, which in turn depend on the identification the economically significant traits, the nature of the tree and the effort put into research. The total returns from a "new" and improved variety is the sum of the value of the additional production resulting from the variety and the increase in the premium captured for quality improvement (per unit). Defining the final use of genetically engineered trees will help estimate the marginal gains of transformation.

Moreover, the high relative costs of biotechnological processes imply that biotechnological products tend to compete in high value markets where a premium is paid for natural products with better characteristics (e.g. appearance of wood products) (Hacking, 1986).

Even though the potential of biotechnology is important in terms of its capacity to induce changes in the genetic composition of the resource, as well as to influence the economics of the production process, such potential could be overestimated when the overall biotechnological effort is justified against total market potential of developed products or when biotechnology is compared to alternative technologies. Furthermore, economic impact assessment of biotechnology should give attention to such issues as consumer acceptance, environment and safety concerns and intellectual property protection, as well as biotechnology-induced quality improvements (Sasson, 1993).

The evaluation of investment in biotechnological research and its application is a minefield of challenges. The critical factors include the set of analytical assumptions made and the different theoretical approaches used, leading to different results. Lesser and Lee (1993) observe that questions have been raised about both data and estimation procedures, and the appropriateness of extrapolating past results to the future, all of which are elements of the debate about under- versus over-investment in this area. Another area of concern, in terms of possible errors of estimation, is the apportioning of returns to the several factors of production considered, as well as the distribution of benefits and the high returns.

In general, when the process of biotechnological development is in stake, economic analysis is valuable as it can reveal the cost sensitivity of the process, compared to other conventional processes, and it can also provide information regarding product pricing and availability and price of raw materials (Hacking, 1986). However, the diversity of markets and the novelty of many techniques, and the respective uncertainty and risk components, make economic analysis difficult, but more challenging and interesting.

5.1.2. Scarcity and resource allocation

Considering that, biotechnology includes a wide array of products, processes and research areas, a key management problem in the immediate term is deciding which applications should be given priority, in terms of allocating scarce resources (Persley, 1990). The scarcity of resources implies the need for specific choices to be made about their use. In the case of a private enterprise, resources are allocated so as to maximize research and investment objectives. "Private firms typically use financial return analysis with simple decision criterion such as the 'highest returns' or 'all positive returns' for budget setting and project selection purposes. [However], different methods of analysis can yield differing rankings, while competing projects may not be separable/independent" (Lesser and Lee, 1993). Both economic efficiency (the project with the highest return), and market efficiency (competitiveness) are the concern of investment. "In this framework, biotechnological processes must be analyzed both against one another and against competing technologies to determine the most beneficial route to a given commodity" (Hacking, 1986).

On the other hand, the scarcity of resources has dictated the need for sustainable management and use of the renewable resources. However, the sustainable use of resources itself does not mean that supply of resources will increase in order to meet an increasing demand. It only implies that the use of these resources by future generations will not be compromised. Something has to be done in the present which will focus on both the sustainable use and increase in supply of the specific renewable resource. Plantation forestry has so far proved to be able to manage resources sustainably and to improve the quality and the volume of the resource itself. Thus, the scarcity of the resource is more a function of the limits on the volume of production, rather than the loss of the resource. The limit on the volume of production, however, is a manageable variable. Better management before and after planting the trees can improve the supply of wood stock.

How would biotechnology fit into a similar frame of thinking? What is the nature of the gains that biotechnology could possibly offer? In a world of scarcity, plantation forestry management has been effective so as to provide for a greater volume of trees and stabilize the supply of wood stock. However, management practices might not be as effective as they have been so far in responding to the changing nature of consumer preferences. Management can safeguard the factors influencing the growth of trees, but they can't change the nature of the planted stock. Essentially, biotechnology can. By using genetic engineering, trees could be engineered to perform better, to grow faster, to correspond to specific preferences for wood quality, and to be adaptable to adverse environmental conditions.

The genetic control of trees would simply alter the initial intrinsic tree characteristics. The management practices will then be adapted for the purposes of fast growing plantation forests. Thus, forests will be sustainably managed, limits on the volume of production will be minimized, in terms of harvesting trees in shorter rotation periods and establishing a more steady supply of wood stock. Moreover, the quality of the final wood products will be greatly enhanced, considering the selection, genetic engineering and management of the tree stock. Thus, biotechnology is not only about capturing premiums for faster, better, cheaper production, but it is also about adapting past practices to present limitations and demands.

In this context, the scarcity of the resource (trees) would simply be based on a possible depletion of genetic diversity, rather than on limits on the quantity of utilized resource. This suggests that, when considering the scarcity of a resource, the option value of genetic material should be given a significant importance.

5.1.3. Biotechnology and the life cycle of products

According to Hacking (1986), the current interest in biotechnology is founded less on historical success than on technological expectations. Thus, the process of biotechnology can be perceived as highly speculative, research oriented and dependent upon a high rate of innovation. Economists have had much more success in dealing with the consequences of technological change that with its determinants. Technology push rather than market pull has tended to be the goal of new technologies, due to the rapidly changing nature of innovation, and the lack of understanding of the specific problems of invention and innovation, and their transition into new industry, i.e. their life-cycle. The product life-cycle thus depends on the specific application of biotechnology as a mean of production. The success of the product, on the other hand, depends on a careful step-wise exploration, starting with the strengths and weaknesses of the technology at present.

Evenson (1992) gives a comprehensive description of the dynamics of any product's life cycle. Each capital product has a life cycle in which it is produced and enters into economic use. After use it may be superseded by a substitute or a follow-on product that builds on the initial product. If it is superseded by a product that is additive, its lifetime will be permanent even though the original product is rendered obsolete. If it is superseded by an entirely different product, its effect on productivity will decline and it will then depreciate. New technology typically has a longer life because even when inventions are superseded, the new inventions are built upon the old inventions. This is true for the case of genetic engineering of tree species. Old developments (tree breeding and selection) are simply extended by new technology (genetic engineering) to improve the performance of the tree itself and the quality of already existing wood products.

According to Hacking (1986) the life cycle of technologically developed products comprises the following stages: conception, development, application, launch, growth, maturity, and a possible decline. Sales and profits from a product, process or technology are determined mainly by the stage of the cycle reached. Profits are initially realized after the product is launched and is in the stage of further growth, i.e. the product generates returns to cover the costs of the initial stages of development. With increasing sales and technology improvement unit costs are significantly reduced. The unit cost reduction, however, is feasible up to a certain point considering that profits are not made infinitely, and competition can lead to demand satiation. Thus, the maturity phase is reached. How long each phase lasts depends on the production process, the nature of the product and the targeted market. In the case of biotechnological developments, the high levels of innovation are more likely to lead to shorter-product life cycles, as newly developed substitutes emerge.

In the early stages of its life cycle a new industry product innovation predominates. As the industry matures, this slows down and gives place to increases in process innovations. However, process innovations have always been crucial to commercially successful product innovations. In the case of biotechnology, a new product based on genetic engineering cannot be considered separately from the process innovation which allows its commercialization (Daly, 1985).

The division of technological change into three components provides a useful framework for examining disciplinary approaches to the study of innovation:

1. *Scientific research* - invention refers to primary discovery;
2. *Technical development* - innovation is the application of primary discoveries to commercial products or processes. Innovation could be considered as a set of stages, including discovery, patenting, technological feasibility, economic evaluation, regulations, markets, and competition. Thus, an innovation may fail to meet the threshold criteria at any of these stages of development
3. *Commercial application* - diffusion of innovation refers to the adoption of the innovations within or among industrial sectors.

It should be noted that even though most innovations follow the path from science to device to commercial success, this is not a general rule (Krimsky and Wrubel, 1996). Most new ideas do not lead directly to new products. These ideas are firstly analyzed, then the product is further developed and tested and only then it could be marketed. The proportions of each stage are important to consider. After each stage of the product life cycle there is an average of 55% chance of the initial idea to be dismissed or rejected. "Companies must have a critical mass of research and development organization to ensure one or two big successes among many failures.

Considering that technological change refers to the changes in the production process resulting from the application of scientific knowledge, the changes can be captured at different stages. "First, technological change can be embodied in inputs when there are changes in input quality. Second, disembodied technological change takes the form of knowledge about improved methods of production that is not embodied in physical inputs. Third, technological change can occur because of the invention of entirely new processes and new inputs. Many inventions involve a combination of these three phenomena" (Carlson et al., 1993). A good example is tree biotechnology, and the process of genetically engineering trees, i.e. higher quality inputs. Carlson et al. (1993) argue that embodied technological changes represent problems for measuring input and output quality changes. In tree biotechnology such input quality measurement problems arise with changes in the genetic nature of trees.

Each stage of the life cycle is characterized with a set of costs, e.g. cost for developing, producing and diffusing the innovation or improvement. Costs are mainly incurred in the first couple of years of the product life cycle (the time period varies with the product). The early stages of new technology are characterized by great degree of uncertainty, which leads to higher opportunity costs of capital due to increased risk factors.

Considering the high costs of product development, the faster the revenue is captured and the greater it is, the better for the investor. Cash outflow (cost) is apparent during the initial years of investment (could be up to 10 years). However, when a product is really successful, success can last long. As product volume rises, development costs tend to fall but sales price does not necessarily fall in step, so that a successful mature product often becomes more and more profitable with the passing of time. Thus, if a new product is successful, sales are generated right from the beginning - entering a market which is itself developing, or as a novelty trying to get a market share in an existing market, which may be expanded in size. As the product matures its sales volume may grow ever greater, but eventually the market becomes saturated and while growth may cease, the product can nevertheless continue to generate substantial revenues for its owners. This can last for as long as new product development appears, either from a competitor, or through improving the qualities of the existent product. Thus, the goal is to not only design a new successful product, but to try and keep it "alive" and profitable for a longer period of time.

Technological uncertainty exists in both product and process levels. Process uncertainty arises from, the simultaneous emergence of a number of alternative new processes and doubt about their advantages and disadvantages relative to existing processes. For example, recombinant DNA technology uses a variety of traits of interest. The choice of a specific trait will have an impact on the performance of the product and on the economics of the process (cost-benefit considerations of the chosen technique). The choice of product is also uncertain, considering that information on future market performance of the product is incomplete, and resources can't be allocated so as to produce all the possible products. A further level of product uncertainty is introduced by the development of second generation products, which is related to the choice of technological strategy (Daly, 1985).

Conditions of resource scarcity provide economic incentives for firms to develop substitution products. Thus factor scarcity, intense market competition, and efficiency are the key motivators of industrial innovation (Krimsky and Wrubel, 1996). Technology is advanced by order of discovery within the constraints of economic profitability, while technical innovations are said to be developed in response to factor scarcities, i.e. the level of relative prices, which is a surrogate of factor scarcities in market economies.

Another important issue to be considered when discussing the process of generation and development of new products is the difference between improvements and innovations.

According to Krimsky and Wrubel (1996), improvements refer to the modifications of existing technology, whereas innovations represent departures from the latter. Innovations are more likely to be additive and incremental because there is less risk in improving an operating production system in which existing markets are secured. In the case of biotechnology, it could be argued that biotechnological developments lead to improvements of conventional selection and breeding practices, but at the same time these improvements have a degree of innovation and bring new, incremental characteristics to both the process of biotechnology, as well as to the product from biotechnological development.

There are several factors necessary for the adoption of technological innovation. The technology must work, and it must be credible, observable, and documented in terms easily understood and properly valued by the ultimate user, to acknowledge both the benefits that the technology offers to a specific operation, and the incremental costs to such operation (Talbert et al., 1993). The least quantifiable character of innovation is uncertainty or risk (Hacking, 1986).

Hacking (1986) argues that the high rate of innovation implies that the life span of many products is short (even though this is not a general rule for all products of biotechnology). In these cases only limited returns are to be gained from process improvements or economies of scale, while adaptability and flexibility are often obtained at the expense of economic efficiency in the production of a particular product.

Moreover, technological innovation is directly linked to market behaviour. Technological advances can be either induced ("technology push") or autonomous ("demand pull"). In other words, some innovations and research and development programs innovate first and then seek or create the demand, while other programs respond to the current market demands. In the former case, people do not know that they need a product until it is available, and they can be informed about it, while in the latter case, the incentives for innovation come directly from the users, i.e. consumers (Krimsky and Wrubel, 1996).

The rate of adoption of technological innovation depends on the assessment of risk by entrepreneurs and corporate decision makers. According to Hacking (1986) some of the high risk associated with biotechnology has been reduced through government policies, e.g. research grants, tax exemptions, etc. Moreover, the concept and magnitude of risk greatly depend on timing, considering the time involved in product development and regulation.

Biotechnology could be described from both points of view. Consumer demand for better products, is related to the improvement of the resource, and thus the application of genetic engineering for specific traits of interest. At the same time, demand push could be represented by the fact that the new products provide additional options that are not on the whole being sought by consumers, but are consistent with the general needs and interest of a specific sector. The wider capacity of application of biotechnology, leads to consider it more as a technology in search of applications (technology push), rather than technology to satisfy specific demands. Consumers do not demand biotechnology, they only care about the qualities of the final good. How are these qualities to be achieved is a question to which biotechnology provides an answer.

Such a general approach to biotechnology should be altered slightly in the case of tree biotechnology, in order to accommodate for the long-term investment profile and the changing nature of consumer demands, which become important factors when adopting specific supply strategies. It could be argued that "technology push" strategies are adopted by forestry companies in order to improve the exotic resources and to provide for a higher quality timber and more consistent supply of a wide variety of products for which the market already exists. On the other hand, "demand pull" is important for assessing the preferences of customers for specific quality characteristics of the product demanded. Thus, in the case of tree biotechnology and value-adding processes, "demand pull" predetermines "technology push", considering that the latter represents the technological advance, which goal is to produce a better quality substitute for which the market is already existent.

A particular problem for an innovative industry is the estimation of the price that the consumer is prepared to pay for a product which he has no experience with. The price will reflect the magnitude of the premium for improved quality, as well as the cost of producing the product its. Considering that the product will be competing with already existing substitute products of similar nature, the distinctive characteristics have to be emphasized, in order to allow for better recognition from the consumer and for capturing of greater premium.

However, price is not the sole consideration of a customer. Other factors such as quality (which includes an element of innovation) and reliability of supply are important. "Customers will often not switch suppliers for a marginal price cut; longer term questions of supply and future pricing are always considered. In particular, major industrial customers will maintain more than one supplier for reasons of reliability and potential vulnerability, even if this means paying more in the short term" (Hacking, 1986). Thus, considering that biotechnological developments lead to quality improvements and are also accompanied by *ex-situ* control of genetic resources, a more steady production of wood products, for example, is feasible, as both the process and the resource are controlled. Then it could be argued that industrial customers will be willing to pay the higher price of genetic engineered, value-added products in order to keep the reliability of the products on the market.

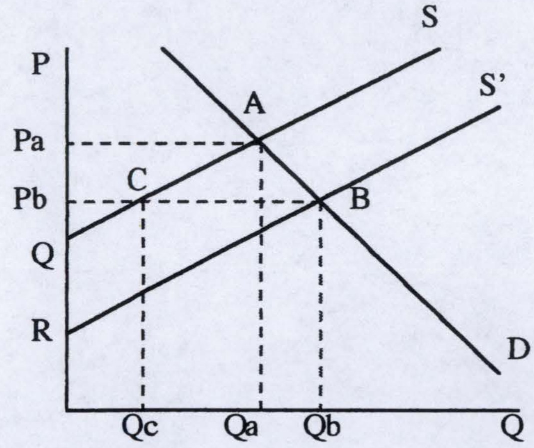
5.1.4. The economic surplus approach

There are two traditional approaches to *ex-post* estimation of returns to research investment (in agriculture): an economic surplus approach and an approach based on econometric production functions.

The economic surplus approach is based on estimation of the underlying consumer and producer surpluses generated by shifts in the supply function, as a result from research-induced unit cost reductions or productivity enhancements (Lesser and Lee, 1993).

Research induced innovation shifts the supply curve from S to S'. This shift reflects the unit cost savings involved in producing any given level of output Qa, or the additional output produced at any given price level Pb. In general, the area RQAB represents the gains from research. Consumer surplus increases by the area PaPbAB, while producer surplus changes from QPaA to RPbB. The changes in both surpluses could be given some qualitative explanation. Due to research, consumers surplus is greater not only because of lower price, but also because of increased product quality, and thus, satisfaction of consumer specific preferences. For the producer, the change of producer surplus reflects the reduced per unit cost of production and increase in the volume of output.

Figure 2. Representation of the economic surplus approach to technological innovation.



The changes in the surpluses are dependent on the respective elasticities of the demand and supply curves. The magnitude of the shift of the supply curve also needs to be accounted for before any conclusions are made. Lesser and Lee (1993) note that studies using the economic surplus approach, which incorporate misspecification of supply function shifts, may generate overestimates, as well as underestimates, of returns to research. Similarly, assuming a demand function characterized by inappropriately high price elasticity of demand will overestimate gains to producers by underestimating the output price reduction resulting from a research-induced supply shift.

Hacking (1986) discusses the relationship between price elasticity of demand and research expenditure. Higher elasticity of demand leads to lower risks, which are deemed acceptable, and thus, the research expenditure will be lower, considering that greater competition will reduce the magnitude of returns. Therefore, products with inelastic demand (e.g. pharmaceuticals) support high levels of research, as returns are greater and this induces further investment in research and development.

The general principles underlying elasticity of demand in biotechnology are the following:

1. The number and closeness of substitutes,
2. The importance of the commodity to the buyer,
3. The number of the possible uses. If there are only a few uses demand is often inelastic, but as the uses expand, the demand becomes more elastic,
4. The legal protection of a new product (e.g. patents) (Hacking, 1986).

In the case of wood products, to which genetic engineering has added value at the initial stages of product development, demand is more likely to be elastic, considering the number of uses of the products and also that the new products will compete with a wide range of natural (wood) and reconstituted products. But, even though the products will be demand elastic, research expenditure is likely to be high, considering that biotechnological improvements of the input bring a greater cost-effectiveness for the entire production process of the final product. Thus, even though the product is demand elastic there are gains from research in terms of production cost minimization and faster process of production.

On the supply side, price elasticity and supply curves are major considerations in long-term capital investment decisions and returns on investment. Biotechnology may suffer from periodic price drops due to overproduction, competition, or economic recession (Hacking, 1986).

Hirshleifer (1989) discusses the differences between technological and pecuniary effects of invention which lead to shifts in the supply curve. "The technological effects are the improvements in production functions - interpreted in the widest sense to include the possible production of new commodities, the discovery of new resources, etc. - consequent upon the new idea. The pecuniary effects are the wealth shifts due to the price revaluations that take place upon release and/or utilization of the information".

5.1.5. The econometric production function approach

The econometric production function approach is used for estimating the economic rates of return to research as an integral part of the production process. As Lesser and Lee (1993) describe it, this approach is based on the estimation of a production function for output in which research expenditures are included as one of several inputs.

$$Y = \beta_0 X_1^{\beta_1} X_2^{\beta_2} \cdots X_k^{\beta_k} R_1^{\alpha_1} R_2^{\alpha_2} \cdots R_n^{\alpha_n} e^{\mu} \qquad (1)$$

In the case of three non-research and three research inputs in a time period of three years, the econometric production function would look like this:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_n X_n + \alpha_1 R_1 + \alpha_2 R_2 + \alpha_n R_n + \mu \qquad (1.1)$$

where:

Y	value of output
Xi	non-research inputs ($i = 1, \ldots, K$)
Rt	research input in year t ($t = 1, \ldots, n$)
βi	coefficients of non-research inputs ($i = 1, \ldots, k$)
α	estimated coefficients of research inputs
μ	disturbance term

The estimation procedure is briefly presented by Lesser and Lee (1993). Based on the estimates of α's, which are the partial (or total) coefficients of research, a two-step procedure is then used to estimate the marginal internal rate of return. Firstly the value (total or partial) marginal product (VMP) of research is determined by multiplying the estimated coefficients by the average product of research. Secondly, the internal rate of return is found by equating discounted costs and benefits of research. It is assumed that research benefits accrue in an "inverted-V" manner, i.e. benefits lag expenditures in such a way as to be symmetrically distributed around an intermediate midpoint year following a research innovation, and then the marginal internal rate of return r can be calculated. The individual weights Wi pertain to each *ith* period through to the last period n, in which research has an effect:

$$VMP\left[\frac{\sum_{i=1}^{n} Wi}{(1+r)^{i}}\right] = 1 \qquad (2)$$

Ehrhardt (1994) also discusses the process of selection of the discount rate. Firstly, the author suggests that the current cost of each source of funds (the marginal cost of any incremental funds, rather than the historical cost of capital) is estimated. Secondly, the weighted average of costs of these separate sources of capital is found, with the weights based on the market values of the sources of financing. The result is the 'weighted average cost of capital'. This weighted average cost of capital r should be used to discount the appropriate after-tax cash flows of the project

The estimated rates or return vary significantly. According to Lesser and Lee (1993) a positive 438% rate of return was estimated for forestry research in the United States. However, the estimation of rates of return could be subject to analytical bias, i.e. under- or over-estimation of returns to research.

5.1.6. Rate of return and economic analysis

When long-term projects are evaluated, there are two important variables to be taken into consideration: the return on capital invested in the project, and the price of the product. If the price can be estimated accurately, the return on capital can be calculated and a decision made on the favourability of the project. However, accurate estimates of future product prices could result difficult due to the changing demands for specific products and also due to the lack of time series data for biotechnologically engineered products. Thus, if the price is not known, the company can dictate a desired return based on other projects or current interest rates and use this to calculate the price. If this price fits with the expectations of the market, the project can be approved (Hacking, 1986).

Moreover, the rate of return on investment is generally determined by risk and it is also industry dependent. Large corporations that produce a relatively high volume of highly value added products, and higher risk bearing have greater expectations of return. The rate also reflects the general level of profitability on turnover of any industry.

Given the scarcity of both natural and financial resources, selecting the 'best' way of spending a budget on projects involves some form of evaluation. The conventional economic approach to project selection is based on benefit-cost evaluation. Discounted cash flow analysis is one example. The essential feature of this method is that it is designed to assess the worth of a project, taking account of the timing as well as the amount of cash flow. The present value (PV) of a series of cash flows is referred to as net present value (NPV) and is the algebraic sum of the PV of individual cash flows. A premium is placed on money today. This premium, or rate of exchange for converting future value to present value is referred to as the discount rate (Hammond, 1995). In other words, the rate of return is a measure of the efficiency of an investment, while the NPV is a measure of the amount of profit that a project will generate.

When selecting a project, two NPV factors have to be taken into consideration:

1. A project should be accepted if the NPV is positive at a predeterimned discount rate, and it should be rejected if the NPV is negative. A positive NPV can be interpreted as an immediate return, while a negative NPV indicates a loss.
2. Where a number of projects are being evaluated, the project with highest NPV, at a given discount rate, should be selected.

In using the NPV, the benchmark estimate of market valuation is obtained using assumptions which are 'economically rational' for the particular situation. In the case of commercial forestry, there needs to be an underlying management and harvesting strategy which is realistic for the forest being valued and the purpose of valuation. In general, this strategy should reflect what an 'economically rational' owner would do taking into account wood supply commitments and logistical, marketing, social, political and environmental considerations (Hammond, 1995).

The success of the discounted cash flow analysis depends on the magnitude of discounting, i.e. the choice of discount rates. The discount rate used in the analysis is the foregone rate of return on the marginal project displaced by the investment in question (i.e. the opportunity cost of the capital being used). The greater the discount rate the faster the resource has to be utilized in order to capture positive returns, as the sooner a return is obtained from an investment, the more valuable it is. In general, if the discount rate is lower than the internal rate of return, the project may be considered favourable. Ehrhardt (1994) suggests, if a rate that is too high is used, projects that add value to the firm can be rejected. On the other hand, if a rate of return is too low, projects that subtract value can be accepted. According to Hacking (1986), rates are generally chosen between 10% and 20%, but projects of an uncertain nature may be discounted at about 25% or higher.

Moreover, the discount rate could be adjusted to the riskiness of the investment. The riskier the project, the lower the probability of achieving a certain outcome, and thus, the greater the premium, i.e. the discount rate, and the faster the harvest (when applied to forestry). Thus, the choice of a project with a specific rate of return also exhibits the risk preferences of the manager. Adjustments may also be made to reflect a pre- or post-tax environment or to convert a nominal into a real discount rate.

Because it is impossible to predict the long-term effects of inflation on costs and prices, financial data is considered in present day values. This is equivalent to assuming that in the long term, inflation will affect costs and prices in the same way, or that costs and prices will inflate at the same rate. As inflation can be expected to affect many comparable forestry projects in approximately the same way, the relative profitability of projects under consideration at any time will often be correctly indicated on the basis of the assumption of constant costs and prices. It is worth noting that if, as expected, wood prices rise faster than costs and the general price level in the economy, then the effect of assuming constant costs and prices will be to underestimate the actual profitability of a project. The reverse is true if costs move more rapidly than prices. (Hammond, 1995).

In general, the discounted cash flow analysis captures the direct impacts of investments, but it can be further extended to include indirect effects, such as option values (a value of future use) and existence value (an aesthetic value). This method, even though applicable for long-term projects, fails to quantitatively measure the need for sustainable development of the resource. The return on an investment measured in terms of net discounted revenue, does not acknowledge the fact that erosion could be increased due to deforestation, or the fairness in distributing the intergenerational costs and benefits. Thus, the main use of the discounted cash flow analysis is in comparing alternative courses of action rather than in providing absolute measures of their outcomes (Hammond, 1995).

"Though discounting is an elegant technique its construction makes great demands on detailed information or estimates of expenditure and income over the project's predicted life. The calculations can be done accurately, but there is always uncertainty with the input data. The procedure as described does not take account of inflation. Constant inflation means the real value of a given sum at a future date will be less than the present value, but income from the project in actual terms will be higher. Also in this and other budgeting techniques, no account of taxation has been considered" (Hacking, 1986).

5.1.7. Sensitivity analysis

The rate of return of a project is usually calculated on what appears to be the most likely set of assumptions regarding investment and income (Haritatos, 1991). Thus, subjective assumptions may lead to under- or over-estimation of the profitability of a project. Moreover, assumptions are based on underlying cost and revenue factors that are more likely to change over time. Such change will affect the magnitude of the rate of return, due to its sensitivity to specific factors.

As Hacking (1986) summarizes it, a sensitivity analysis is a procedure which determines the sensitivity of the profitability of a project to changes in each of a number of factors. Sensitivity may be measured in terms of the variation of pay-back time, return on investment, net present value or internal rate of return against changes in costs which may include raw materials, utilities, yield, capital and so on.

The statement of results as single-valued estimates provides no indication of the characteristics of other possible results. Thus, changes in previously analyzed data, due to greater or lower costs, and their effects on the internal rate of return could be estimated by using a sensitivity analysis. In many studies it will be found that small changes in some data may have an effect equivalent to large variations in others. As a first step in carrying out a sensitivity analysis it is important to identify the physical and financial elements which have the greatest effect on results. The next step is to test the sensitivity of results to changes in these key elements (Hammond, 1995).

The evaluation of the rate of return of a long-term project involves a great amount of uncertainty, in terms of how would the factors considered today will behave 5, 10, 15, 20 years in the future. Thus, the rate of return of any project is sensitive to changes in the factors considered when evaluating the project. Moreover, risk and risky events can be handled within the analysis by appropriate adjustments to either costs or returns associated with these events[89], so that they become certainty equivalents. This is not possible in the case of uncertainty, as this concept relates to events which have not been considered and ones for which there are no agreed or accepted probabilities of occurrence.

Sensitivity analysis may be extended to include risk evaluation, by assigning probabilities to particular values of the various factors being attained in order to calculate an expected value for the factor. Considering the contemporary nature of biotechnological developments and commercialization of products, objective estimates of the values of input figures, based on historical evidence, can't be obtained. Thus, subjective probabilities, based on intuitive judgments, are more likely when allowing for risk.

The most common sources of risk and uncertainty when considering long-term commercial forestry investment are:

- management - changes in forest management personnel and strategies;
- market - unknown market conditions for different log grades, changing consumer preferences for products and specific quality characteristics of each product;
- fire - from natural causes, negligence of arson (fire losses are covered by insurance)
- pests & diseases - the emergence of new pathogens or diseases to which the engineered trees are not resistant
- financial - changes in financial circumstances, discount rates, taxation policy.

"This type of analysis can provide some of the most valuable information on the viability of a process or project proposal. It can show the limits in any one variable which may be tolerated, it can show where the process improvements need to be made, where optimum conditions lie and which expenditures may not in fact be needed. It is particularly valuable

[89] For example, the possibility of loss from a known cause has probabilities of occurrence that are either known or accepted.

in exercises such as determining the potential impact of genetic engineering on a project or process" (Hacking, 1986)

5.1.8. Some limitations associated with economic analysis

The sensitivity of analysis regarding estimated rates of return to research depends on the assumptions made and variables identified. "Different sets of assumptions regarding the most appropriate estimation methodology, the hypothesized shapes and shifts in supply functions, elasticities of demand, the temporal distribution of research impacts, inclusion (or not) of spillover effects, resulting unemployed productive inputs, size and degree of complementarity of private sector research, and many other factors will predetermine, in large part, the nature of estimated rate of return to research" (Lesser and Lee, 1993).

Even though economic analysis is an important tool to estimating returns on investment, there are certain qualitative factors that are not fully accounted for in quantitative estimations. Among the potential determinants of underestimates of returns to research are misspecification of supply function shifts and the difficulties of accounting for 'spillover' effects of research" (Lesser and Lee, 1993).

Spillover effects refer to benefits from research which are excluded from calculated rates of return due to estimation and measurement problems. These effects can be of several types:

1. Intertemporal spillovers of research benefits occur when anything less than the complete stream of research impacts is included in rate of return estimates. The impacts of research can persist for several years, so it may be difficult to measure adequately the full complement of effects over this period;
2. Cross-commodity spillover effects occur when research on one commodity or on a general input such as management processes, generates unit cost decreases or productivity increases in another region or commodity, which are not captured in the estimated benefits from research into the first commodity;
3. Geographic spillover effects occur when research in one region or country generates benefits in other regions or countries. In this case, the magnitude of investment in research for a specific commodity depends on whether the commodity is imported, exported or a non-tradable (Lesser and Lee, 1993).

This implies that the validity and correct definition of assumptions is crucial for estimating returns on investment, in order to reduce the amount of potential sources of error. However, the hypothetical nature of the assumptions, presented by the analyst, allows for misconception of different settings of real events, as well as bias. Thus, analytical bias, as well as upward bias (attempting to explain the high rates of return typically estimated) are not the only concern for the correctness of a specific investment analysis. The analyst himself could make inappropriate decisions regarding methodological choices necessary in estimating rates of return to research. However, as Lesser and Lee (1993) suggest, although the dependence of estimated rates of return to research on analysts' assumptions may render the resulting estimates 'highly subjective', it would be going too far to suggest that these estimates are purely arbitrary. Thus, in order to reduce the subjective nature of analytical assumptions, they should be adjusted according the specific circumstances and details surrounding the research, as an initial stage of a chain of production.

Moreover, one of the primary assumptions of most rate of return studies is that variable factors of production released through cost-reducing, productivity-enhancing research instantaneously find full employment in alternative uses. To the extent that research-induced technological change results in unemployed or underemployed resources, even if only temporarily, the benefits of research must be appropriately discounted (Lesser and Lee, 1993).

Finally, the contemporary nature of biotechnological research and related products, is the reason for the lack of significant quantitative information. Biotechnologically modified organisms are still only beginning to obtain the rights to practical implementation. Estimates are mainly based on biological characteristics of the genetically modified organisms (e.g. quality improvement coefficients, age-to-age correlation alterations, cloning and regeneration capabilities, speed of growth, etc.), rather than on specific market data of prices, supply and demand schedules of such products. Thus, market uncertainties are added to biological uncertainties about the specific performance of the transgenic trees, which makes cost-benefit analysis a bigger challenge and leaves broader margins for speculation.

5.1.9. Biotechnology and joint products

Most production operations in biotechnology produce two or more products, which differ by grade. In other cases, a range of different products is produced from the same raw material. For example, if a genetically engineered tree is grown and harvested, the log is allocated among competing end uses, such as pulping, sawing, production of posts and poles, or chipping. Thus, the value of the tree depends of the product that it is allocated for, and such allocation will depend on the desired grade of the product, i.e. logs for pulping won't be appropriate for sawing if a high quality product is to be produced, their greatest value will be captured when used for pulping.

In general, when a group of individual products is produced, with each product having a significant relative sales value, the outputs are referred to as joint products. If the value of the joint-product is low, it is often called by-product. For example, the by-product in each log is the residue. Joint-products are not identifiable as individual products until split-off point in the production chain is reached, e.g. when logs are harvested and are to be evaluated for quality. Costs incurred before this point apply to the initial product or raw material, while costs after this point can be allocated to the individual joint-product concerned. In general, incremental and opportunity costs are relevant in planning the use of a joint-product.

5.2. Commercial application and developments of biotechnological products

Biotechnology is regarded as a high-technology or knowledge intensive industry. This knowledge intensity involves a close relationship between basic and applied science, and commercial activity.

5.2.1. A general overview of developments

"The early years of industrial R&D in biotechnology (until 1985) could be characterized as a powerful, "science push" period. Scientific enthusiasm and competition have led many companies to spend considerable R&D money on the same few products without sufficient regard for markets. Also, insufficient attention was paid to costs. In the more recent past, companies have become more selective in their research strategies, have begun to take both technical limits and real market needs better into account, and are using more network planning and ex-ante assessments for new products" (OECD, 1989).

This suggests that biotechnology investment performance in the 1980s was not as promising as expected. The major reasons outlined for such slow development were:

1. returns on biotechnology investments did not reach expected levels, which made profit generation hard to aim for and/or impossible to achieve;
2. product developments took longer than expected, mainly because of technical problems and regulatory constraints, including tight regulation on field testing and administrative costs of patent rights (Sasson, 1993).

In the case of genetic engineering of trees, factors that have contributed to the small amount of commercial applications are: the time frame for transformation and tree growth, cost and species-specific limitations for transformation, the need for field trials for the assessment of changes, as well as the stringent government regulation on the testing of transgenic trees and the marketing of products from genetically modified organisms.

At present, there are a number of marketed biotechnological products, mainly in the area of pharmaceuticals, which have been characterized by significant improvements. Returns for the "new" products have been significant, however, initial costs of investment and product development have also been great. Generally speaking, the production costs in tissue culture are high, and it is only economic for high-value products worth more than US$700/kg (Persley, 1990). Thus, reducing the production costs of tissue culture would make it more competitive for a wider range of products, leading to their greater commercial deployment.

New market strategies which link the plant of interest with the trait of interest are already formulated. For example, the introduction of plants resistant to a specific herbicide compound allows for the selling of a herbicide plus resistant plant package which can extend the life of a profitable product. Given the profitability of the herbicide industry, and the wide application of Roundup (the world's largest selling herbicide), the production of glyphosate herbicide resistant plants and their potential sale would aid sales of glyphosate.

Estimates of the future markets for biotechnology products vary widely, but their common trend is their optimism. Billions of dollars are expected as a return to biotechnology investments. Persley (1990) suggests that the emphasis is likely to be on novel products, which are going to take an increasing share of existing markets, leading to some restructuring of those markets, rather than on any major expansion in the markets for common products. In general, the value of the global market of products from genetically modified organisms is projected to increase significantly.

James and Krattiger (1996) further expand the trend of optimism in biotechnology investment by noting that the projected value of the global market in transgenic crops is estimated at between $2 billion and $3 billion dollars for the year 2000 increasing up to $6 billion in 2005.

5.2.2. Biotechnology and trade

At any given period, the pattern of international trade is shaped by the following factors:

1. The characteristics of the goods supplied and demanded in the international market;
2. The location of the main centers of supply, as shaped by productive capacity and levels of competitiveness;

3. The location of markets, the size of which, in terms of effective demand is determined by size of population and the level of per capita income (OECD, 1989).

Today resource endowments and hence comparative advantage, have become less linked to climatic and geographical factors and much more shaped by 'man-made' innovation and investment driven phenomena. Thus, innovative capacity should be viewed as a basic source of difference in comparative advantage, and technological change as a chronic disturber of existing patterns of comparative advantage (OECD, 1989). These "chronic disturbance" effects of technology may occur in two main ways:

1. By modifying trade flows as a result of the marketing either of totally new products or of new, better and differently sourced substitutes, whether they are material inputs to other industries or products from final consumption; and
2. By creating differences or gaps between countries (OECD, 1989).

Thus, biotechnology creates trade, but at the same time it has strong trade displacing effects.

Biotechnology causes trade substitution effects, where industries capture markets away from traditional sources of production. One of the potential benefits from biotechnology to private industry interests is the development of new methods of producing commodities. As Sasson (1993) observes, the need for biotechnological development has arisen to a considerable extent from the fluctuations in commodity prices. Such trends have induced producers to bring down production costs, to diversify and to increase the added value of products, all of which require biotechnology inputs.

Sasson (1993) argues that biotechnology-derived substitutes would make a small proportion of the whole market for a specific commodity. This could be the case in the short-term, considering that it takes time for a product to position itself on the market. In the longer-term, however, what will matter are the quality characteristics of such products and their ability to outperform existent products. Thus, in terms of capturing a greater market share and competing with other products, the products of biotechnology will bring significant shifts in comparative advantage between countries and commodities. And as Hopper (1990) puts it, there may well be a significant contribution from biotechnology to increase the export competitiveness of selected commodities and even to foster diversification into new export markets.

As the OECD (1989) points out, plant tissue culture offers increased possibilities of substituting agricultural products by industrially produced inputs. The impact of successful production of substitutes will be felt by countries (mainly developing countries) dependent upon exports of the natural products concerned, in which they have enjoyed resource endowment comparative advantage because of the specific conditions required for growth.

Another feature of biotechnological developments is the fact that they contribute to the dematerialisation of production within each country (mainly developed countries), i.e. a shift in the composition of demand in industrialized countries away from the products of the more intensely raw material-consuming industries and a diminution in the intensity of raw material use in existing manufacturing industries (OECD, 1989).

Thus, it could be argued that in the case of biotechnology, a number of factors preclude a traditional analysis of international competitiveness. The first factor relates to the impossibility at present of measuring and comparing performances. Competitiveness is as much, and in new industries and technologies generally more, a question of quality and novelty than of price. Secondly, even with many more products on the market, a traditional competitive analysis might not be appropriate because an economic analysis of competitiveness is usually addresses a specific industrial sector. The set of techniques that constitute biotechnology, however, are potentially applicable to many industrial sectors. Thus, biotechnology offers unique opportunities for creating totally new products, opening up totally new markets for which there exists at present no competition and so no issue of competitiveness. A further novel feature of competitiveness in biotechnology is the fact that the framework of competition is shaped by previous processes of technological accumulation, industrial concentration and multinationalisation. Biotechnology has begun to grow exclusively, but to a considerable extent, within the framework of already stringly concentrated and highly globalized industries (OECD, 1989).

A closer analysis of the trade modifying effects of technology shows that these can occur through four main channels or mechanisms:

1. The creation of new trade through the marketing through exports of totally new products. In the area of high technology industries, the worldwide marketing of new products may take place through delocated manufacture and the foreign operations of multinational enterprises and have little effect on trade flows *per se*.
2. Shifts in the structure of trade, marked by the reduction and at some stage possibly the outright disappearance of particular trade flows, resulting from the creation of entirely new substitutes for previous products.
3. Shifts in the structure of trade, marked by the reduction of particular trade flows, resulting from the introduction of new production processes which change major factor proportions (e.g. capital/labour ratios) and reduce trade flows based on an abundant cheap labour type of comparative advantage.
4. Shifts in the structure of trade, also involving a reduction in the level of trade flows, which stem from the reduction of material inputs to production, as a consequence of a number of parallel and/or related processes of economization and substitution (OECD, 1989).

"The commercialization of products through exports is only one of the several ways in which firms can exploit the temporary monopoly-advantages and firm-specific assets stemming form technological lead times and unique experience with new technologies. Such advantages are more and more often exploited through foreign direct investment and the international network of delocated production units based on transnational or multinational enterprises and corporation. A number of factors lie behind this development, in particular: i) the large range of factors which place a premium on delocated production inside foreign economies, *inter alia* non-tariff and reglamentary barriers to trade, but also proximity to scientific and technical skills" (OECD, 1989).

5.2.3. Biotechnology and the market

As Haritatos (1991) observes, developing and commercializing a new or improved process for manufacturing any product can be a very risky enterprise. It can be risky to make and market a new product; and it can be risky to develop a new process for making an already-commercialized product. For every new process that makes it to the marketplace, there are dozens of others that did not meet the economic requirements. The economics of a process must be evaluated at a very early stage in this development. Then, as the process is moved from bench-scale to pilot plant to design and construction, the economics must be re-evaluated at timely intervals.

The results of estimates carried out early in a project could often be too optimistic. Thus, the economic evaluation should take into consideration the following key objectives:

1. Identify areas which have a significant effect on cost,
2. Add a large allowance for contingencies (to allow for problems which have not yet been identified).

As the project matures, and more and more problems are identified and solved, the estimated investment and operating costs for the project will tend to rise. On the other hand, the allowance for contingencies can be reduced. If the project looks good, project management needs to make a key decision. *Should the project be commercialized immediately, even though there is room for improvement? Or, should the research effort be continued with the aim of improving the economics still further?* Potential savings in the process need to be balanced against the cost of delay in entering the market (Haritatos, 1991).

According to Daly (1985), the main entry barriers in the biotechnology industry are proprietary technology (both patented and secret), cost of R&D and regulation, and access to distribution channels. Hacking (1986) expands the cost framework to include the cost of maintenance of a high level of technological expertise and capital outlay on new plants with sufficient economies of scale and process efficiency to compete in the market. The cost of research and development represents a significant proportion of total costs, and thus, poses constraints to entry, based on the financial capacity of companies to undertake biotechnological research. Moreover, some types of research are inherently more expensive than others because of the size of the research teams required, the inherent technical difficulty and the differing requirements for investment in research facilities and pilot plant.

Generally speaking, the factors that affect significantly the market strategies of biotechnological companies are the following. Firstly, regulatory constraints slow down the utilization and commercialization of products and further increase the cost of biotechnological developments. Secondly, competition strategies need to be designed. Biotechnology companies compete for technology, product sales, financing, partners and qualified employees. Success in the product marketplace is not driven by technology alone. Product positioning, success in obtaining regulatory approvals, the effectiveness of their sales and customer support organizations, and product pricing, customer access, distribution channels will determine the market winners (Burrill and Lee, 1990).

Moreover, the nature of distribution channels depends on the application area of biotechnology and on the country in question. For example, in the USA a marketing strategy implies direct selling to big retail companies. To achieve such strategy it would be better to undertake in-house manufacture combined with marketing agreements with companies in the home country and overseas, until a foreign subsidiary is established.

Decision-making strategies for production and commercialization of genetically engineered products should also consider the possible limitations embodied in the scale of production and the marketing environment for the product. There is a significant difference between the strategies of a company and its scale of production. While small and mid-size companies are concerned with financing, the large companies, which have more consistent access to capital, are concerned with issues about their success in the marketplace - competition, regulatory environment, expansion in research and volume of production, as well as the uncertainties surrounding product reimbursement (Burrill and Lee, 1990).

Furthermore, when considering the scale of production of a biotechnological company, it should also be noted that production strategies vary between a biotechnological company *per se*, which specialize in biotechnology for the production of final goods, and a vertically integrated company, for which biotechnology represents one stage of the complex, multi-stages chain of production and value-adding of the final product. In general, a fully integrated manufacturing and marketing company, involves commercialization of R&D, investment in plant, and financing of entry into production markets, including capital investments and cost of regulatory barriers.

Product pricing is another complex issue. Pricing must adequately cover a product's development costs, generate capital for future product development, and create profits to compensate shareholders for their invested capital and risk. The factors that companies consider most important in pricing their products are the competition's prices, effectiveness of existing products, marketing costs, manufacturing costs, ease of usage, future R&D needs and costs[90] (Burrill and Lee, 1990). The overall cost for product development and marketing, as well as the marginal improvement in quality will determine the magnitude of price increase of the product.

Another important issue is the need to focus on a technology in which the company has a realistic chance to be a leader, to target a market in which its technology can make a meaningful difference to the end user, and to define an initial line of products that can be realized in a reasonable time frame (Burrill and Lee, 1990). Concentration on niche markets, for example, can bring a greater value for products sold. Entering in joint venture agreements opens up great opportunities for entering different set of markets.

Competition among biotechnology companies in a given industry is based mainly on product differentiation, which in turn depends on the quality and productivity of R&D. Plant biotechnology business, for example, varies greatly in the costs of R&D and market entry depending on the type of product and the genetic manipulation attempted, e.g. micropropagation of commercial plants will be much less costly and involve a shorter developmental period than complex recombinant DNA work on areas such as herbicide resistance.

Hacking (1986) argues that the refining and development of a biotechnological process, after specific patent expiry, tends to lead to an increase in the size and concentration of firms through economies of scale and ultimately to an oligopolistic industry structure. Ultimately, the rate of diffusion of biotechnology will depend on the speed at which it can confer economic advantages over its competition. As the author suggests, this may be a fairly smooth progression world-wide, or more probably it will be a more piecemeal process dependent on specific products and local conditions.

Moreover, there is a number of issues concerned with the production, regulation and export of biotechnology products and processes. The speed with which a product can be introduced to a market and the conditions governing its export will have important implications for the competitiveness of a firm selling the product. Targeted governmental actions in the area of regulation can improve the competitiveness of companies. This could be achieved by increasing the speed of the process of product approval, by instituting abbreviated data requirements for biotechnology-derived products; by devising more

[90] The costs associated with R&D are particularly important because companies' long-term success depends upon innovating and developing a continuing flow of products.

efficient regulatory process (through rationalization of agency functions and elimination of duplication); by amending export regulations to facilitate the export of biotechnology products by national companies; and by engaging in bilateral negotiations with other governments to improve market access for national companies (Daly, 1985).

5.2.4. The issue of technology transfer

No matter what strategy has been adopted, in-house research is crucial for the development of novel products for which the company can obtain proprietary rights, and either enter or expand its already established international distribution and sales system. Expansion of research and development is crucial for the future of biotechnology companies, considering the rapid changes in technology and product development. Expansion of R&D, however, is not only subject to the availability of funds, but also on the need to diversify the knowledge of the adaptability of a certain technique to different environments. To achieve this, companies tend to engage in a protected technology transfer.

Technology transfer depends on four key elements. Firstly, if private companies are planning to transfer technology to the developing world, it is critical that there is a supportive commercial environment in the recipient country, i.e. that there is reasonable property protection to legally safeguard investment. Secondly, sensible regulatory processes and procedures should be in place. Thirdly, the only way that transfer can really take place is if there are appropriate local skills to develop and build on techniques or traits transferred from the developed world and to produce products appropriate to the recipient country (Sundstrom, 1992).

The transfer of technology is also an issue between public institutions and private enterprises in a particular country. In this case, the meaning of technology transfer implies the need to narrow the gap between universities, where usually inventions are made, and the development and application of these inventions by businesses, in order to capture grater returns form commercialization. Thus, considering that the goals of public and private institutions differ, technology transfer has its limitations. According to Hacking (1986) the three major limitations are poor inter-sector communication, differing priorities and inappropriate administrative systems.

5.2.5. Concluding note

In general, the commercialization of the products of biotechnology is a complex issue, where many factors should be accounted for. The existence of advanced technology and the continuous expansion of R&D will lead to greater product development, and further product differentiation, which will provide the opportunities to widen distribution networks in old markets, as well as to enter new "niche" markets.

There are both costs and benefits associated with different distribution strategies. In the case of old markets, for example, as the company already has national and international distribution networks, consumers identify the specific product of the company and recognize the assurance quality of the product. Thus, considering that it takes a while to position a new product in the market and sell it successfully, it could be argued that it would be easier for the company to introduce a "new" product with a greater quality in the old market because of the greater confidence for the products of a known supplier, and because of already established supplier-consumer relationships, which could reduce hurdles related to selling a "new" product. Some of the limitations regarding the marketing of new products in old markets, on the other hand, are related to greater competition, which would imply greater reduction in profits and also greater substitutability between similar goods. Thus, a premium for enhanced quality in the new product would be difficult to capture, and this would lead to the need to explore "new" markets, and successfully position the "new" product there.

A direct entry into niche markets could also be beneficial, due to a lack of strong competition and the existence of specific demand tastes for particular products. However, the cost of establishing the distribution network, in the first place, and the need for greater knowledge about the specific consumer preferences, could offset the expected returns in the short run.

Where R&D costs are high, and hence cash flows from investment in innovation low in relation to R&D and start-up investment, firms may often focus their multinational production and marketing strategies at the expense of exports. "A subsidiary, generally considerably less advantageous form of recouping R&D costs and reaping benefits from innovation is through foreign licensing and/or the establishment of joint/ventures and other inter-firm technological and industrial co-operation agreements. This course is one which small innovative firms or else larger firms with low levels of multinationalization may be forced to adopt because they do not posses the complete range of assets required to reap the profits stemming from their innovations" (OECD, 1989). Strategic partnerships are another way of spreading costs and risks of new products.

Moreover, competition between established producers is different according to the market sector involved. With many products, for example, competition is not just between biotechnological developments, but between biotechnology and other conventional techniques of production. "Competition in these case is not just a matter of efficient production, distribution and marketing, but it is dependent on the relative costs of the two routes and is frequently determined by costs of raw materials or political [and legal] intervention" (Hacking, 1986).

CHAPTER 6

THE MODEL:

THE STAGES OF THE PROCESS OF PRODUCTION AND VALUE-ADDING IN PLANTATION FORESTRY

The main emphasis of the model is on the impacts of selection and re-engineering of *Eucalyptus grandis* trees on the characteristics and marketing of the final wood product, mouldings. The model comprises of four stages of value-adding to the final output from a re-engineered input. Each stage is treated separately in order to establish the relevant relationships between variables within that stage and to identify their significance in the whole chain of production. The links between selection and re-engineering, growing trees, processing and re-processing and final product characteristics and marketing are important for the value creation efforts of the company, which are influenced by changing customer demands and market needs. Thus, the main concern of the model will be to capture the marginal changes of quality that affect the value of the final product. This will enable the company "to take full advantage of margin management opportunities as they arise - particularly in the area of value-added downstream processing, where the final product meets a customer need precisely and commands a price premium" (FCF, 1996).

Marginal changes are captured by making specific assumptions for each stage, where each assumption embodies a set of changes in the *status quo* of selecting, growing or processing a tree. Thus, in order to emphasize the nature of change considered, comparisons between "unmodified" and "modified" trees are made.

6.1. The stages of the production process

As mentioned above the schematic representation of the model comprises of four stages of the chain of production.

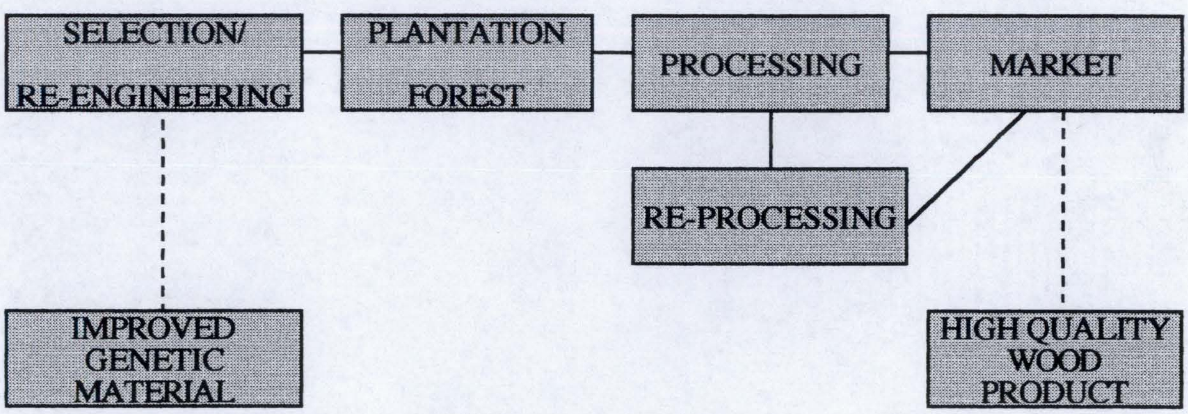
- **Stage one** - *selection and re-engineering* - is probably the most complex stage, considering that it is when a project has to be selected and assessed in terms of future returns, and also it is where the bulk of investment funds in research and development is allocated.

- **Stage two** - *plantation forest* - represents a more conventional approach to tree growth and management of a renewable resource, and evaluation of the worth of a chosen silvicultural practice. The new element in stage two is represented by the nature of the tree stock, on one hand, and the rotation length, on the other. The new element also implies the existence of new, cost-effective and specific purpose-driven management approaches for maximizing growth and final output.

- **Stage three** - *processing and re-processing* - is important in terms of converting the raw material into a high-quality finished good. The nature of the improved tree stock also contributes to cost-efficiencies in this stage.

- **Stage four** - *market and distribution* - links the value adding in the previous stages with the final characteristics and performance of the product at the market place. It is in this stage when a quality premium is to be gained.

Figure 3. A simple scheme of the model - the chain of value-adding to a forest product



6.1.1. Stage one - selection and re-engineering

The first stage of the value-adding process originates in Tasman Forestry's Centre for Advanced Forest Biotechnology, situated at Te Teko (New Zealand) - a world leader in propagation and tree breeding of *Pinus radiata*. Efforts have been widened to include the biotechnological re-engineering of other fast-growing species, such as *Eucalyptus grandis*. "The Te Teko facility is both a high technology research centre and a cost efficient nursery, producing 9 million *radiata pine* plantlets and 2.6 million *eucalyptus* seedlings each year" (FCF, 1994).

In the mid-1980s the Centre adopted cloning techniques to propagate thousands of plantlets from superior parent trees, hence producing a significantly greater number of plantlets in a more cost-effective and time-reducing way. The development of the molecular biology programme has improved the understanding of specific trait characteristics in the selected trees, and has provided for more precise re-engineering results. The better knowledge of the biological characteristics of trees (wood composition, growth rate, form) means that "seedlings can be chosen specifically for their suitability to a particular planting site, for their wood density or the distance between branches" (FCF, 1994) The greater knowledge of the specific wood characteristics and their molecular identification also suggests that trees can be selected and re-engineered to suit specific customer preferences.

The process of selection, re-engineering and trait specification of better performing lines provides the biological and genetic grounds to believe that the "new" tree would not only carry better wood quality characteristics, but it will also be resistant to a number of pathogens[91]. This suggests that the tree itself will be pathogen-free, grow faster, perform better in terms of wood quality and contribute to more cost-effective plantation forest management. The overall biological and growth characteristics of the tree would also contribute to a more cost-effective management approach, as cloned trees will be very similar in terms of volume and wood composition. "Since the introduction of the tree improvement programme, production volumes [of *Pinus radiata*] have risen by as much as 40% over stands of unimproved and unmanaged trees. Volumes continue to increase as better clones are bred" (FCF, 1994). In 1994, the capacity of the Te Teko micropropagation laboratory was 80,000 pine tree seedlings produced, by using tissue culture techniques, from a single seed in one year. The anticipated capacity of plant production was 52,000 plants a week[92]. (Kennedy and Davies, 1994)

From the tissue culture laboratory a large number of plantlets (produced from cloned seeds or buds) are transferred to the greenhouse. The difference, however, is the genetic composition of the plantlets. By using conventional selection and breeding practices and biological re-engineering for resistance, the plantlets are not only genetically identical, but they are also of uniformly superior quality. The uniformity of the input suggests a further reduction in maintenance costs per hectare. The superior quality simply adds initial value to the input. "Better tree stock means fewer seedlings are needed to establish quality stands" (FCF, 1994).

"Genetically improved planting stock has obvious potential to improve site use. Productivity is increased through rate of growth, stand and tree uniformity, and specificity to particular site conditions. Log quality is improved because of less malformation and wood quality because of both improved intrinsic characteristics and more even growth in

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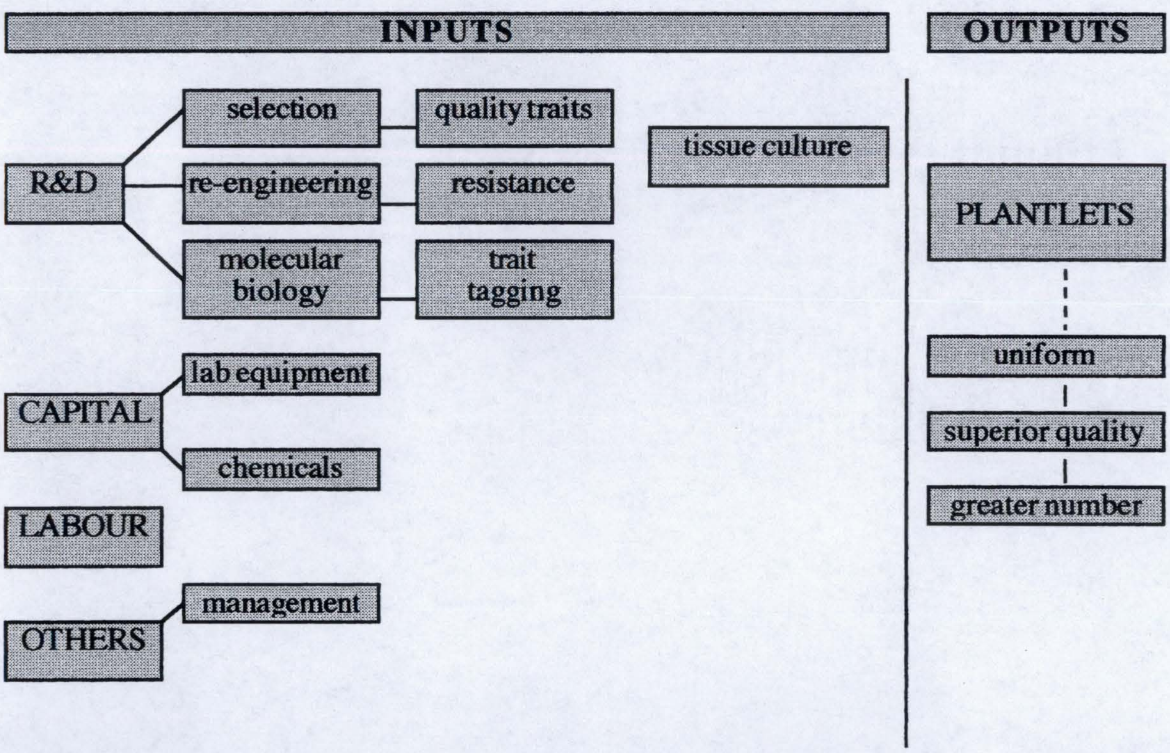
[91] Through genetic engineering old traits could be enhanced or new traits could be introduced into production clones. The engineered traits of interest are insect resistance, herbicide tolerance, and lignin enhancement.

the stand. Pest and disease resistance may also be enhanced" (Lewis and Ferguson, 1993).

In general, the goal of the first stage of the production chain is to produce uniform re-engineered *Eucalyptus* plantlets, which exhibit superior wood quality (in terms of a mix of desirable characteristics - density, number of knots and form of the tree), which are tolerant to herbicides or resistant to insects, and which can be propagated in great numbers (by using tissue culture techniques). This goal is achieved by combining a number of inputs, such as research and development for better selection, genetic engineering and molecular identification of the traits of interest; capital (comprising both the equipment and the chemicals used in the laboratory); labour (both scientists and technicians) and purpose specific management.

Figure 4. Input-output scheme for the first stage of the model



Assumptions

1. The selection of tree genetic material is based on specific high performing traits of interest which contribute to desired structural properties of processed logs. More specifically, the selection criteria is based on the performance of the following structural properties of wood:

[92] The overall mortality rate for plants through the system is 10%. (Kennedy and Davies, 1994)

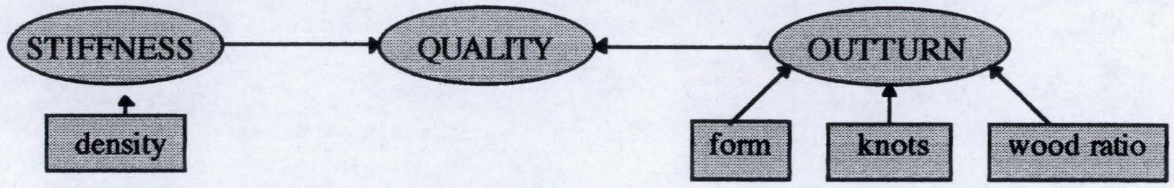
1.1. modulus of elasticity, i.e. stiffness (**S**) - density (**D**)

1.2. specific outturn (**O**) - form of tree (**F**), number of knots (**K**), and proportion of mature / juvenile wood (**MJ**).

Thus, the selection criteria of traits for a specific quality mix is based on their performance:

$$Quality = f(S, O),$$
$$where\ Outturn = f(F, K, MJ)$$
$$and\ Stiffness = f(D)$$

Figure 5. A mix of specific physical characteristics of a tree



There are a number of factors which affect tree size and quality, where each factor depends on a set of characteristics:

- *diameter* (genotype, site fertility, initial stocking and timing of thinning, pruning intensity, final stocking, rotation age)
- *height* (genotype, climate, site fertility, initial stocking, final stocking, rotation age)
- *wood density* (genotype, rotation age, initial stocking, altitude/latitude, timing of thinning, final stocking)
- *tree form* (genotype, physiological age of planting stock, site location, site index, site fertility, fertilizer application, initial stocking, final stocking
- *internode index* (genotype, mean annual rainfall, site index).

Branch size and wood density have been shown to be the most important factors influencing timber stiffness and strength (Hammond, 1995).

The selection of a particular quality mix is also based on the final use or purpose of the tree, i.e. specific wood quality properties are selected in order to fulfill future wood product goals. Thus, if mouldings is the final wood products of interest, then the external appearance will be the most important characteristic when grading the final product for quality. Thus, a preference ordering of specific appearance characteristics is needed, which is then linked to the corresponding quality mix of the physical properties of wood, and then according to the quality mix identified, selection of the best performing genetic material is undertaken.

The fact that properties are preferred implies that properties are not constant, and thus vary depending on specific genetic, environmental, or other characteristics. Thus, it is important to identify changes in the quality of mouldings, due to a specific change in each of the identified properties. Changes that lead to a "best" performing combination of properties are assumed to give greater returns in terms of mouldings quality premiums.

2. It is assumed that the rest of the physical characteristics are not economically significant for the desired changes of quality, and thus, they will not be integrated into the model (they will remain constant). Site specific characteristics would also remain constant in the model for further simplification of the number of variables used. The site specific characteristics are assumed to be beneficial for faster-growing of Eucalyptus grandis and thus, would provide for optimal returns. Successful establishment of a eucalypt resource requires the right species to be matched to the site conditions available. Preferred sites for eucalypts tend to be sheltered, gently sloping, moist and fertile valley. The main site limiting factors are temperature and out of season frosts (mean annual rainfall - 750-2000 mm, mean annual temperature - 12 C°). For eucalypts to provide wood suitable for the desired objectives an appropriate establishment and tending regime are required. Moreover, successful establishment of eucalypts requires a combination of cultivation, weed control, good planting stock and fertilizer (Hammond, 1995).

3. The process of selection for a specific quality mix of wood properties, is further expanded to accommodate for changes due to genetic engineering. Genetic re-engineering involves a number of specific objectives, such as inducing the resistance to pathogens (weeds, insects, and other diseases) in trees, or enhancing wood quality by modifying the lignin/cellulose ratio in trees. Genetic engineering in the present thesis is assumed to be carried out through Agrobacterium techniques, where the trait of interest is inducing herbicide tolerance to selected tree lines. Even though the probability of transformation by using Agrobacterium is 10-40 plants out of 100 selected calli, it is assumed that only transformed plantlets are actually deployed. The new trait in such plantlets is assumed to have already been identified by the use of molecular markers. Thus, assume that the selected material is genetically identical in terms of quality characteristics, as well as resistance performance. Thus, marginal changes in the first stage will be due not only to the selection of genetic material, but also on the built-in tolerance to herbicides.

Figure 6. The 'new' quality mix

The difference between a "modified" and a "unmodified" plantlet will be captured by changes in each of the variables, i.e. the magnitude of re-engineering and the magnitude of changes in quality mix. Thus, the change in quality of the "modified" plantlet will be subject to the selected physical characteristics (**PC**) and the degree of re-engineering (**R**).

The degree of re-engineering can be evaluated by defining the goal of engineering (e.g. herbicide resistance or lignin enhancement) and then identifying the magnitude of changes in the quality mix. The magnitude of change could be identified by comparing the quality mix of a non-engineered material with the quality mix of re-engineered material, i.e. weighting the trait of interest by the probability of an effective change. The degree of transformation is also related to the choice of genetic re-engineering technique (e.g. Agrobacterium). Due to the fact that each technique is likely to perform differently in terms of the percentage of transformed embryos, different weightings can be allocated. Such comparison is more qualitative, but it would allow for the quantitative representation of the "new" quality mix.

$$\text{“New” quality} = a + bPC + cT,$$

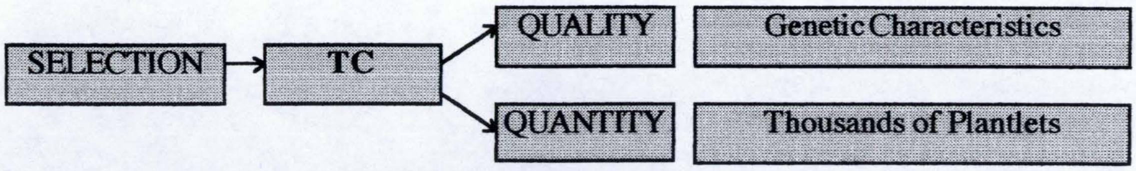
where: ***a***, ***b***, ***c*** - coefficients,
PC, ***T*** - research variables

(**PC** represents the factors that affect the specific quality mix (stiffness, outturn) and **T** stands for a specific trait of interest for bio-reengineering (**R**)).

If it is assumed that **PC** are bound to induce better performance (due to selection), then changes in **R** have to be assessed in terms of their effects on **PC** and on the overall "new" performance. Genetically, changes in the "new" performance due to changes in **R** can be identified by using molecular markers (marker assisted selection - MAS), and physiological changes in the selected genotype, i.e. changes in **PC**, can also be identified through molecular biology (RFLP). Thus, there is a base for qualitative assessment of the two components of "new" performance, what is lacking is a quantitative assessment. In general, quality change is quantifiable when considered as an intrinsic characteristic of the improved product. The difference between the new and old product will constitute the magnitude of change.

4. The next stage is multiplication of the selected material. Tissue culture techniques (embryogenesis, organogenesis) are used for increasing the quantity of the selected material for planting, while keeping its genetic composition unchanged, i.e. the physical properties already selected. Thus, both the quantity and the quality of initial planting material will be enhanced, providing the possibility for greater future returns.

Figure 7. Qualitative and quantitative effects of tissue culture (TC)



Cloning for quantity depends on the lab and greenhouse capacity for allowing clones to regenerate and grow as plantlets. The objectives are the production of species which grow faster and/or are resistant to disease, chemicals, insects, or adverse weather or environmental conditions. Cloning for quality implies the multiplication of the set of the selected best performing lines. Thus, quality would mean a greater specialization and diversification of products in order to respond to specific demands. Thus, assume that the results from cloning will be a greater quantity of genetically identical and superior clones.

5. Considering the previous assumptions, the main object of the first stage of the model is to evaluate the interactions and changes between the identified properties of the genetic material, and the effects of such changes on the quality of the plantlet initially, and later on the tree. Selected and re-engineered plantlets will be cost-effective in terms of quantity, quality and time. A greater quantity of plantlets could be produced, with enhanced quality and uniformity, and in a shorter period of time.

In the present model all "new" plantlets are considered to be "uniform" in terms of sharing the same genetic characteristics. What is important however is the structure of such uniformity and the levels of desirable uniformity, i.e. the properties embodied in this uniformity (PC, R). Thus, the properties that determine the level of uniformity are the same as the properties influencing the "new" quality.

6. Some of the contributions from biotechnology are gains in yield through new plants resistant to environmental stresses; lower costs in labour and agricultural inputs; higher-quality value-added products; environmentally benign methods of managing weeds and insect pests. Thus, genetic re-engineering brings gains to the nature of product, to the producer, consumer, and the environment.

Cost-Revenue Considerations

Costs are incurred in the early years of investment in selection and re-engineering. Benefits are initially obtained once plantlets are produced and sold. For a vertically integrated company, however, the benefits from the first stage would simply contribute to the whole process of value adding.

Even though the actual selection, re-engineering and propagating of the genetic material takes 2-5 years, it is assumed that all research and development has been put together and the output is the production and selling of plantlets in year 1 of the investment period. The total cost of producing them is the sum of the cost of research and development (including selection, re-engineering, molecular markers, deployment), the cost of labour in labs, greenhouse and open nursery, the cost of capital, which includes the cost of the specific machinery, and chemicals for the lab, and the cost of other things, such as cost of contingencies.

Returns are calculated in year 1, when re-engineered plantlets are sold. "Modified" plantlets are differentiated by their higher quality, and cost of production, and this determines a higher market price for them. Another possible source of income is through licensing, i.e. royalties receipts, for the use of the "modified" plantlets.

One of the most difficult areas for biotechnology is market figures. Many of the potential products are completely new and it is not possible to estimate future sales by extrapolation from the price and sales volume of existing products.

6.1.2. Stage two - plantation forest management

Plantation forests are a renewable resource, and as such require sustainable management for both environmental and production purposes, i.e. to produce high-quality timber without depleting the world's remaining natural forests. The existence of well managed plantation forests not only increases the supply of logs, but also provides a close substitute to the wood from natural forests, and thus allows for the reduction of the use of such forests with high cultural and environmental values. "World wood forecasts suggest that demand for plantation-grown clearwood is increasing as traditional supplies from natural forests dwindle" (FCF, 1994).

In general, the forest management strategy of Fletcher Challenge Forests is based on the idea that the increase in the value of the plantation forests is the true measure of performance. This value is found by using net present value (NPV) of future cash flows, which incorporates changes in the costs of growing, managing and harvesting forests in addition to revenue gains, as affected by log grade mix and market prices (FCF, 1994). An improvement in any of these factors results in increased forest value.

Improved management is important for both the maximization of output, and the sustainability and environmental viability of the planted forests. Maximization of output implies both the sustainable use of the resource and the maximum utilization of the resource, thus reducing the proportion of waste in cut and processed logs. "Large and small sawlogs are used for housing, furniture and other solid wood products. Sawdust and offcuts from lumber processing go into wood panel products. Thinnings and small logs make pulp and paper. Waste material from processing is burnt as fuel" (FCF, 1994).

Moreover, the understanding of the genetics and the growth patterns of trees is crucial for the effective and value enhancing management of plantation forestry. Plantation forestry of selected and re-engineered trees follows similar management criteria as any other plantation forest. The difference, however, is in the greater uniformity of the tree stock, the faster growth rate, the shorter rotation periods, and the difference in the variable costs of forest management.

The economic size of logs changes with the change in both the genetic characteristics of the "modified" plantation trees and the changing consumer preferences, which lead to changes in silvicultural regimes and time-frames for rotation. A rotation period of 25 years, for example, is no more economically significant, as better performing trees' economic size could be reduced to a maximum of 15 years. This adapted short-rotation harvesting profile is possible due of the superior genetic quality of the trees. The "faster rotation will increase the value of the estate, both from improving short-term returns, and replanting earlier with genetically improved stock" (FCF, 1994). The harvest is timed so as to capture the highest value. Faster harvest will increase supply, which could have a downturn effect on prices, while slowing down the harvest as a result of lower prices would further increase the value of the trees for a future use.

"The revised harvest profile reflects a number of factors: Firstly, the supply of genetically improved trees with superior characteristics at a given age is now increasing, and will continue to do so. In addition, product research and development is identifying new end uses and markets for the wood produced from these trees. Consequently, it is becoming more appropriate to make harvesting decisions on the basis of the type of lumber that can be processed from the tree, and on the planned end use, rather than simply on the age of the tree. Secondly, improved technology is allowing the forest estate to be measured and monitored more precisely, improving the accuracy of the forest growth models [which allow to plan harvesting] with maximum accuracy, for the best fit with market conditions and product requirements, and therefore, for maximum value creation." (FCF, 1994) Plantation forestry also has the flexibility to respond to short-term changes in prices "increasing harvest rates in times of high prices, or reducing them when greater value is likely to be created if trees are left to grow for later harvest" (FCF, 1994). This implies an 'option value' which is not directly incorporated in conventional valuation.

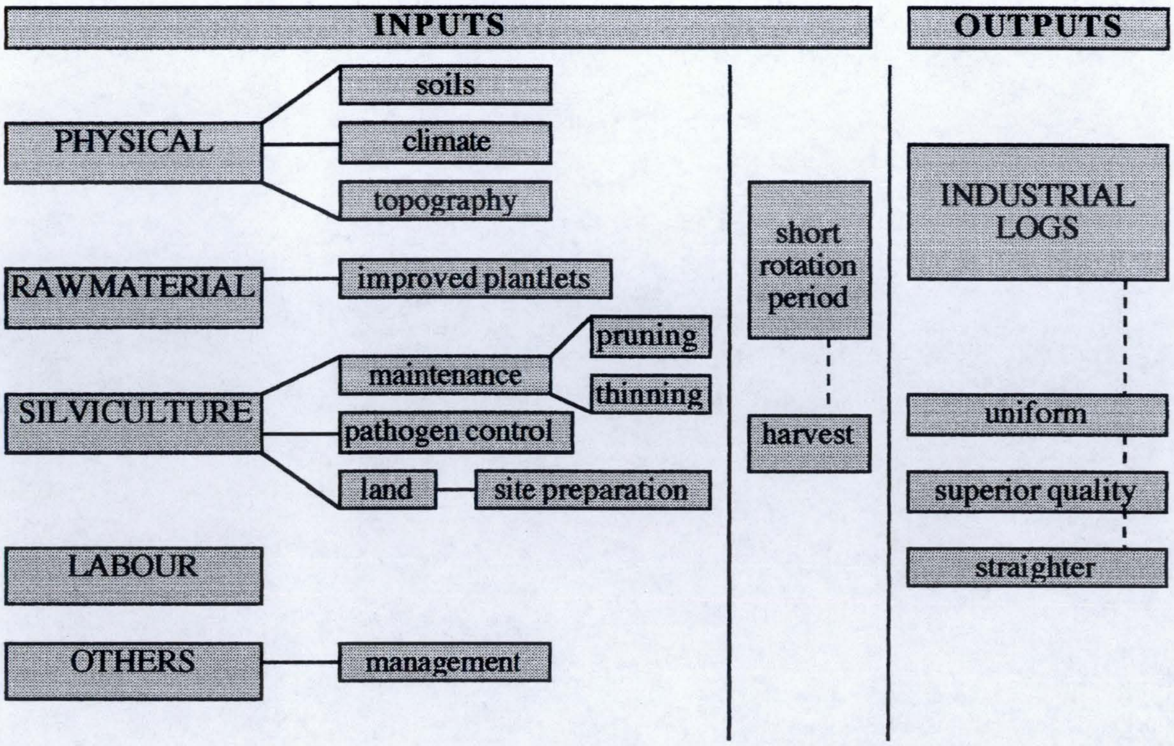
When some hypothesis about end uses has been formulated, the desirable rotation length can be considered for each species suitable for that use. On the other hand, when rotation length is known, thinning and tending regimes can be decided. Variability in basic properties of wood is controllable primarily by correct siting, initial spacing of young trees, retarded thinning to control width of inner growth rings and rotations of sufficient length to provide peeler logs and some narrow ringed wood for specialty purposes.

The demand for straighter and knot-free logs is one of the determinants of the "modified" trees' harvest profile. Decisions on rotation length are made for a given species treated under a given thinning regime, while species choice is made with some idea of rotation period and end use in mind. Pruning and thinning practices are adapted to the management of trees for desired economic size, in order to offer better (straighter, pruned, knot-free) logs, which will attract high prices as clearwood timber or veneer products. Thus, in the second stage of the model, changes in growth and in timber quality are a result of the combination of both genetic improvement and modified silvicultural regimes.

The assessment for quality grades of logs is further eased by the uniformity of the "modified" trees. The characteristics for assessment of each part of the stem (number and size of knots, amount of sweep or bend, stem diameter) are predetermined, due to the link between selected quality mix of physical characteristics and wood properties, discussed in the first stage. However, changes of expected performance in this period could be due to environmental and site factors.

In general, the goal of the second stage of the production process is to generate uniform industrial logs of superior quality (in terms of their wood characteristics - a greater proportion of mature wood and reduced number of knots), and better form, i.e. straighter and easy to process logs. This is achieved by a set of inputs - improved raw material, the physical characteristics of the plantation site, the silvicultural regime applied, labour, and overall management.

Figure 8. Input-output scheme for the second stage of the model



Assumptions

1. Trees are genetically uniform and are expected to perform similarly, i.e. grow faster, have desired wood characteristics and be resistant to herbicides.

2. The enhanced wood quality of the tree stock means that less trees can be grown per hectare (600), thus reducing the need for production thinning (one thinning would be enough), reducing the cost of pruning per hectare, and reaching the same final number of trees per hectare (300) as in the case of 1000 trees of initial stocking. Faster growth suggests shorter rotation periods, which on the other hand mean greater returns in less time, even though recoverable volume (m^3/ha) will not be as great as if the tree was grown for a longer period of time.

Assume that "modified" *Eucalyptus* trees are harvested under 15 year-rotation schedules, with an average recoverable volume of 400 m^3/ha. The case of "unmodified" trees is represented by a longer rotation period (25 years), and an output of 650 m^3/ha. Initial stocking in the former case is 600 trees per hectare, while in the latter case - 1000 trees per hectare. Final stocking is the same for both cases - 300 trees per hectare. "Normal initial stocking is between 600 to 1000 stems/ha, while final crop stocking is between 200 to 350 stems/ha" (Hammond, 1995). An initial stocking of 1000 stems/ha, which allows for adequate tree selection, is indicative of the lack of genetic improvement on current planting stock. For timber production, a large tree minimizes the effect of internal growth stresses thereby reducing problems during sawing and drying (Hammond, 1995).

3. Timber grown in plantations tends to have greater amounts of juvenile wood. The principal concern here is related to the inferior structural properties and lower product yields of juvenile wood compared to mature wood. The presence of juvenile wood leads to lower lumber recovery and quality when processed (lower strength). Lumber yields are more likely to decrease because of smaller diameters, more defects from edges and trim, more damage in the kiln and the planer mill, and more lumber degrade. Genetic engineering has the potential to improve the amount of yield captured per tree, by carrying out selection and gene modification for lignin enhancement. Yield is also increased by changing the silvicultural regimes, where less trees are grown in order to provide greater diameter growth per tree, and thus more mature wood.

In general, yield influences harvesting costs in three ways: the volume removed per hectare will affect the costs of felling and extraction, the mean annual increment will influence the area of the supply zone and therefore haulage costs, and both these aspects will affect the costs of road construction. Thus, it could be argued that the yield in terms of number of trees per hectare is the same for modified and unmodified trees (300 trees/ha) which means that log cutting and handling costs as well as roading costs are not altered.

When trees are to be harvested, the cost of harvesting is more uniform on average as trees will have similar form and volume. The effects on transporting the logs will be minimal, because on average each truck will transport the same amount of trees per cubic meter. However, in order to further reduce the costs of transportation, purpose-grown and managed plantations are assumed to be located near purpose-built processing plants.

4. Harvesting uniform trees also implies that uniform distribution of log types will be supplied for processing, i.e. considering that trees have uniform physical and genetic characteristics, logs will also exhibit a degree of uniformity in terms of similar distribution of the grade mix. The difference in the log grade mix is assumed to be due to the percentage of outturn achieved before the log is processed.

Pruned logs of the same size and similar external appearance can, however, differ in potential clearwood yields by up to 100%. This implies the need to define pruned log quality by measurable variables. The variables that influence the clearwood potential of a pruned sawlog are log size, log shape, and size of the defect core (knottiness). Those measurable log variables are combined in the Pruned Log Index (PLI) which is a single expression of pruned sawlog potential to produce clears grade timber "off the saw", i.e. without grade enhancement by docking or defecting (Hammond, 1995). (*See Appendix 5*)

Thus, the process of conversion of sawlogs has two important steps:

1. The total conversion to sawn timber (all grades);
2. Conversion of clears grades alone (or the ratio of clears to total conversion). Clears grade ratios to sawn outturn can vary markedly depending on the mill, the sizes produced and the overall sawing strategy and end use (Hammond, 1995).

Greater yield per tree would lead to gains in processing, as less timber would be used for to make the same amount of net wood product volume, which also means that less degrade will be generated and greater utilization of wood per log is more likely. The greater uniformity and wood volume of logs would further increase processing capacity.

5. The growing regime adopted has an impact on the timing of harvest and on the log type mix (*See Appendix 6*). The availability of improved stock is assumed to enable wider initial spacing and lower initial stocking. The value of the crop at clearfelling is dependent more on the quality mix than the absolute harvest volume. Despite the influence of the growing regime, a tree yields a composite of joint log products, not a single, homogeneous, quality log.

If profit from the sale of wood is the principal goal of growing trees, then the best silvicultural regime will be attained by a combination of:

- maximizing net harvest revenue (this is a product of both quantity and quality, i.e. both merchantable volume per ha and mean stumpage per m3)
- minimizing costs - including the costs of land preparation, planting, tending, harvesting and supervision
- optimizing the timing of cost and revenue streams, so as to minimize the 'opportunity cost' of investment expenditure (wherever possible, costs should be delayed and revenue brought forward)
- minimizing risks, including lower than expected revenues for certain log assortments; failure to undertake timely and effective silviculture; and physical risks partly under the influence of management, such as disease, windthrow, fire of livestock damage.

Regime choice depends on site factors (such as soil, climate, topography, and presence of weeds), on location (distance to markets, nature of local processing plants), and on the manager's financial profile (discount rates and time preference) and attitude to risk.

The merchantable volume depends not only on the quantity and characteristics of the trees in a stand but also on the desired products required from that stand, and on the cross-cutting strategy employed in log making. Changing the last two factors can not only affect the types of logs cut, but also the amount of waste and hence the volume recovered from the stand. Merchantable volumes as a percentage of the total standing volume, based on past experience of harvesting radiata pine are: good condition, well tended stands - 90%; average stands, on moderately steep land - 85%; untended stands, with malformation - 80%; stands with merchantable percentages as low as 70%, or as high as 95% are not uncommon.

Cost - Revenue Considerations

The costs are the usual plantation forestry costs: site preparation, land purchase, planting, releasing, pruning, thinning and production thinning, harvest roading, log and load, transport, harvest fee/administration, periodic costs, project management, local authority rates, fire insurance, weed control, animal control, cost of labour. Costs are spread through the whole period of rotation, where some costs are fixed and are born in the first year of plantation, while most costs are variable and depend on the quantity of planted stock.

The cost of thinning depends on whether a plantation has been pruned to facilitate inspection and harvesting; but whether any pruning at all is worthwhile depends on whether there is a premium on knot-free timber, which in turn depends on whether thinning is designed for quality market (Price, 1989).

Revenue is generated by selling the different logs to appropriate processing mills. Revenue will be determined by both, the recoverable volume per hectare, and more specifically by the grade mix of each log and its respective price. Revenue is obtained in the last year of the rotation period and it is discounted to the year of initial investment. Revenue depends on the rotation length and the percent of log outturn.

6.1.3. Stage three - processing and re-processing

Value-adding also occurs in this stage in terms of maximizing the value of the raw material by carefully processing it and converting it into specific products. The clearwood logs (P1/P2), originated from "modified" material under intensive management (pruning and thinning), are converted[93] into products, where appearance is the main concern for quality grading (*See Appendix 7*). In general, quality attributes in a log depend primarily upon what it is to be converted into. In the case of sawnwood and veneer, for example, quality grades in the conversion product are most affected by log defects (Lewis and Ferguson, 1993).

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[93] Conversion of standing tree to logs can produce potentially major losses in both fiber and grade recovery if careful and log specific processing is not adopted. Losses can occur through breakage at critical grade points, breakage at key recoverable fiber points and excessive stump height.

Moreover, the specific customer preferences are matched to the raw material through the development of purpose-built processing mills[94] (*See Appendix 8*). Remanufacturing operations use high speed finger-jointers, moulders and lamination equipment providing precisely engineered products to meet the building requirements of international customers. The company's processing operations are certified to the ISO 9002 standard, providing customers with a consistent guarantee of quality. (FCF, 1996)

Lumber used for solid mouldings comes from the outer portion of the log that develops clear lumber. The grade of lumber used to manufacture softwood mouldings is referred to as Mouldings and Better (Btr.) and includes the grades of Moulding, D Select, and C & Better Select. The grade of lumber used to manufacture hardwood mouldings is referred to as FAS (Firsts and Seconds), FAS 1F and Selects and Number 1. Finger-jointed mouldings are most often taken from the shop or cutting types of lumber that requires cross cutting to eliminate undesirable characteristics. The clear pieces that develop from cross-cutting are finger-jointed and joined by adhesives to produce long clear lengths suitable for paint finishes. Moreover, lumber use in moulding is uniformly dried to 8-12% moisture content to ensure size stability and provide surface that will be smooth when milled (WM, 1996).

Considering that timber varies among species, size of logs, grade of logs, amount of defects in the logs, among other factors, a purpose built processing plant, which processes one particular species of wood with uniform logs (in size and grade, and minimal defects), is likely to produce a greater volume and better quality products per cubic meter of processed material. Thus, a higher value outturn, is due to the greater volume recovery per log, as well as a maximized recovery of desired log grades.

"High grades in sawnwood products are the most demanding of log quality. Attributes of strength, stiffness, stability, workability and appearance are variously required. The best source of most wood with these properties is the outerwood parts of lower stem logs. Between the butt log and the green level is the potentially most valuable part of the stem. It has a low proportion of juvenile core, a high proportion of medium and long length fibers, medium to high density and a rising proportion of latewood. The largest log with the highest proportion of high grade and low-defect wood, and the lowest taper and therefore the highest recovery, is the first log above the butt swell; and this is the log upon which, in principle, silviculture should logically concentrate" (Lewis and Ferguson, 1993).

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[94] "In the case of solid wood mouldings we will take the superior quality logs from our genetic and silvicultural enhancement programmes and process them through the new Taupo plant to the precise specifications of North American customers. Similarly, the remanufacturing mill at Kawerau adds value by taking lower quality logs and converting them into high-value laminated posts for the Japanese housing market" (FCF, 1996).

The efficiency of the processing stage of the production process is very important. The length of rotation regimes would imply the supply of raw material with a specific age and thus a particular combination of mature wood, suitable for processing. Thus, if an economic age of cutting is determined, then the processing should also be adapted to suit the specific characteristics of the wood material in this specific growth stage, in order to maximize outturn.

Moreover, investment into wood processing facilities are long term and the intermediate and final products carry a rather large capital cost component. The accumulation of stock, in various stages of processing, at various points of the production chain, is large. This means that it takes a long time to the logging industry to react to a change in market demand, which is initially felt by the retail trade in the importing country. In a similar manner, but not to the same extent, the production chain is slow to react to sudden changes in primary supply. This implies that the system has limited ability to absorb and adjust to sudden fluctuations in raw material supply and market demand without serious adverse economic effects in the industry. The reoccurring over- and under-supply situations also tend to generate wide fluctuations in prices, especially of primary timber products. Therefore, good market projections are needed.

In general, the conversion process of logs into wood products is in itself a complex process. For example, an average New Zealand sawmill operates on a 50% conversion rate, producing half a tonne of timber for each tonne of log input, where 20%-30% is converted to chip, and the remainder lost as residue such as bark and sawdust (MF, 1994c). Moreover, the increasing emphasis on value added remanufacturing has made drying an integral part of the production process and has also put pressure on the industry's kiln drying capacity. The quick drying times associated with high temperature kilns allow high production levels, making the process ideal for drying framing timber with a low rejection rate from distortion (such as mouldings). Drying is important for the production of a high quality, dimensionally stable product. All this suggests that, value-adding to the raw material should also be applied to the transition production process, where the raw material is processed and re-processed in a way to obtain the greatest possible outturn from the desired grade.

In order to maximize conversion of logs into high quality veneers, for example, it is essential that the log is round with central pith, has no sweep, and is free from defects such as scars, machine damage, sapstain. Sliced veneer is produced to specified lengths and widths for different end use markets. The length of the log delivered to the veneer plant will determine the maximum length or width that can be produced. Larger diameter logs in excess of 45 cm (small end diameter) are preferred in order to maximize recovery of clear veneer from each log (Hammond, 1995).

There are a number of key factors which determine log specification:

- end use - it determines the log quality variables[95] acceptable within a log to ensure customer satisfaction (e.g. pruned logs are used in applications where knot-free appearance is essential, such as high quality veneers);
- transportation - the availability and cost of transportation can determine the log length requested by a customer (small logs are generally more expensive to transport on a per cubic meter basis);
- processing equipment limits;
- supply from other sources.

Log specifications will change over time as new end uses are developed, and as improved processing and transport technologies become available. The lack of standardized grades today is testimony to the need for producers to customize log specifications to specific customer requirements within a broad framework of 'standard' log qualities (Hammond, 1995).

In general, the tendency is to relate grades of sawn timber to alternative end uses of the wood product. The problem of the present project is related to the need to evaluate the profitability of an unfamiliar wood for the purposes of a familiar use (moulding). Thus, the quality grading criteria should capture, the physical properties of the wood, the appearance attributes of the wood product and the end use of the product. A careful examination of basic properties of an unfamiliar wood is a prerequisite to the development of grading rules. The basic properties determine the potential groups of wood uses for a given species, but realization of its potential is subject to the availability of suitable grades at prices which will be competitive with those of alternative woods or other materials.

Moreover, the emphasis on preserving natural resources has brought veneer wrapped mouldings into the market place. Finger-jointed mouldings are used as a substrate and then a veneer of any specie is glued to this substrate with profile wrapping machinery. This product uses approximately 1/17th of the material if the moulding were made out of solid wood. This expands out natural resources and provides long, clear mouldings for far less money. Medium Density Fiberboard is a by-product of wood waste from manufacturers of wood products, including sawmills and wood moulding manufacturers (WM, 1996).

"Improved dry recovery in both quantity and quality rests upon better drying practices, recovery and re-manufacture of fall-down material, re-manufacture of lower grades into higher grade products, and recovery and use of residues" (Lewis and Ferguson, 1993).

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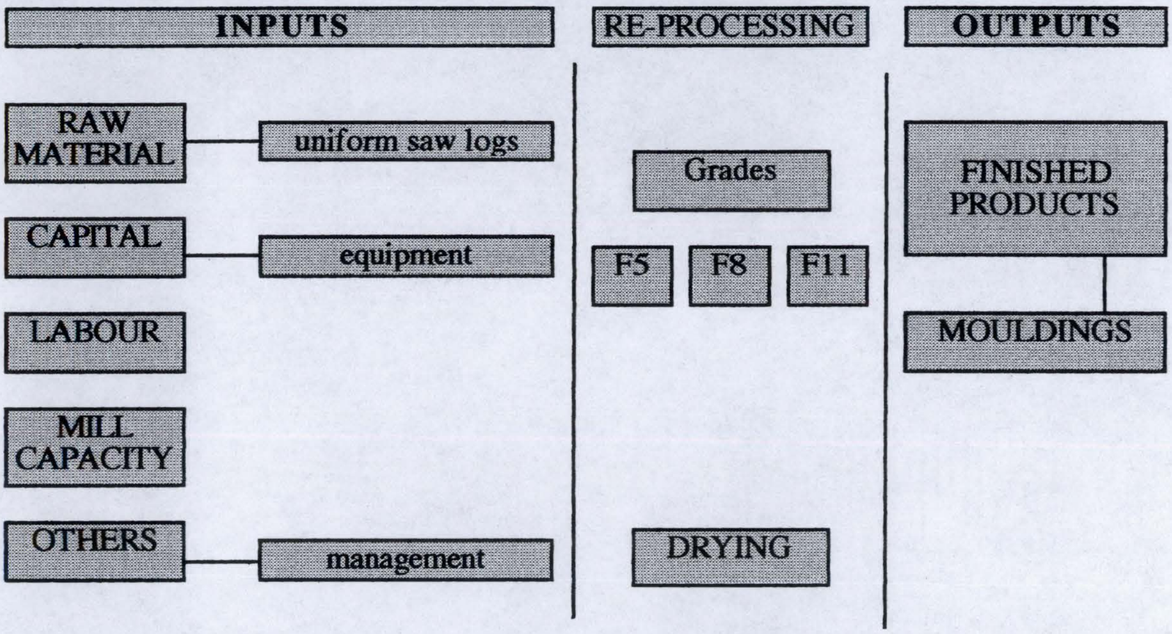
[95] Log quality is generally described in terms of the following variables - the degree of pruning, the number, size, distribution of knots along the length of the log, the existence of spike knots, the degree of sweep or wobble present in the log, the location of pith, the number of defects (scars, rot, splits, machine damage), the presence of sap stain and nodal swelling (Hammond, 1995).

In general, the goal of the third stage of the production process is the efficient use of the raw material for the production of finished wood products, i.e. maximizing the production of mouldings per cubic meter of wood, and reducing the amount of waste from processing. This is achieved partly due to the utilization of uniform logs, but also due to purpose-built and more efficient processing mills. The process of re-processing is also of great importance for finishing the product and enhancing its appearance features.

Figure 9. Input-output scheme for the third stage of the model



Assumptions

1. Saw logs share similar wood characteristics (density, form, number of knots) and volume. Trees are uniform and straight, which makes their processing easier and faster. The enhanced genetic quality of the tree is reflected in the wood quality of the log by reducing the amount of degrade (and maximizing the recoverable amount of wood), and also by obtaining "clean" boards. The performance of the desired wood properties is improved in terms that at harvest time, the originally immature tree will have the characteristics of a mature tree (i.e. well expressed density and desired correlations between immature and mature wood for the purposes of processing and drying).

2. Initial processing of better logs will be more suitable for further re-processing and kiln-drying purposes. Uniformity of logs would also imply reduced within-board and board-to-board deviation, and more uniform drying of the processed boards. This means that a higher value outturn per log would be produced.

3. Grading of the sawn logs is easier due to their uniformity. This would imply savings in terms of time and money related to log sorting and it would also minimize errors related to separation of logs by grade.

In general, the improved wood quality characteristics of the trees, by the enhancement of greater density in shorter rotation stands, is intended to maximize returns, through the use of purpose-specific processing techniques which allow a greater outturn of the young (15-years old) logs. Thus, because the stands are genetically engineered to perform well for a 15 years rotation regime, the impacts to processing are not considered to be negative in terms of the reduction in the physical dimension of the logs, or yielding less attractive financial returns. The opposite would be more likely, as trees are selected for clearfelling and their uniformity would allow for cost-effective, quality enhancing processing and re-processing.

"The potential to process the expanding harvest volume by greater utilization of the currently installed capacity is the most significant non-capital-intensive expansion opportunity open to the industry. The contribution from the sawmilling sector has the greatest impact. Not only is this sector operating at the lowest effective shift rate, but also the residues from sawmilling (typically 30-35% of log input volumes) are then available to relieve the pulplog shortages facing the pulp, paper and panel sectors" (Edgar et al., 1992).

Cost - Revenue Considerations

Costs are incurred in the final year of the model, when trees are harvested and logs are sorted and processed (cutting and conditioning logs for further purposes) and re-processed (drying and cutting boards into final products, i.e. mouldings, joinery, etc.).

The cost considered involves the cost of raw material (according to log type, and volume), the cost of milling, and the cost of re-processing and drying.

Revenue is generated by selling the final products. However, final products are graded differently, considering both their specific quality characteristics and the level of processing that they have been subject to. Thus, prices are allocated on the basis of the specific quality mix of the product and its final use destination.

It should be noted that in the case of vertically integrated economy of scale, returns are more likely to be increasing. This is due to the minimized costs of production, as more uniform inputs are used and greater specialization is generated, thus improving the productivity of the production line. Another source of revenue maximization is related to the fact that not only the quantity, but also the quality of the final product will be greater.

6.1.4. Stage four - market

Logs are sold in commodity markets, where prices are volatile. This reduces the options for capturing premiums from tree improvement. An increasing focus on managing margins throughout the customer-to-resource chain is meant to reduce exposure price volatility in commodity log markets, by generating a different, value-added wood product. The product is sold as a finished good with a greater quality, rather than a commodity. Thus, the price of such product is determined not only by the quantity supplied, but also by its enhanced quality characteristics. The quality of the finished good is the main determinant of the premium from improvement and re-processing captured by the price paid.

In general, the goal of the forth stage of the production process is focused on specific distribution and marketing strategies of the finished products in order to capture higher price. The attention is on one product, mouldings, and the distribution channels are directed to supplying the United States' market for the product. Thus, a strategic entry in a foreign market exists, and the potential for steady supply of high quality mouldings is also there. Moreover, marketing strategies should concentrate on positioning the products in a way that the consumer learnt that the "new" product is different from the existing ones and valued the enhanced quality characteristics of the product, and to. Failure to do so would imply the impossibility to capture high quality premiums in a market with close substitutes, and thus, strong competition.

"The high cost of new construction plays a role in the revival of wood mouldings. Many people are upgrading their homes by remodeling or face-lifting. This has been a huge market for wood mouldings which are uniquely adapted for glamorizing plain rooms on a minimal budget. Considered by many to exceed the new home construction market in dollar volume, remodeling is 82.8% professionally done, with 16.5% done by do-it-yourself ... the opportunities for retail decorative moulding sales are unlimited. Accustomed to utilitarian moulding installations prevalent in years past, potential customers must be exposed to new ideas for mouldings usage. This is an opportunity for salespeople who want to expand the market. While this means extra dollars for the retailer, it is also an invaluable service to the customer" (WM, 1996).

There are other great markets for wood mouldings apart from housing. These include the numerous small projects such as do-it-yourself picture frames and plain unfinished furniture among others. If the customer is made aware of these applications, repeat sales may follow. "Applications from picture frames and unfinished furniture decor to new construction, remodeling, face-lifting and pre-finished paneling installations have created uses for mouldings today never dreamed of 100 years ago" (WM, 1996). In both, new construction and remodeling, wood mouldings have a dual purpose - decorative or architectural detailing and functionality (cover seams, protect walls, etc.) (WM, 1996).

In the case of Fletcher Challenge Forests a targeted market is the clearwood mouldings market in the United States and distribution to retail customers will be achieved through the American Moulding Corporation retail outlet 'Home Depot'. "To date, most mouldings from New Zealand have been shipped to the West Coast for remanufacturing before sale on the East Coast, where demand - especially for repair and remodeling work - is strongest. A direct link to customers will enable the Division to derive more value from its products, and create the opportunity to develop products specifically to meet their needs" (FCF, 1995).

In the United States, "softwood lumber comes primarily from the Western forests and hardwood lumber from the Great Lakes and mid-Atlantic forests. The primary softwood species used in moulding production are: Ponderosa Pine, Sugar Pine, Southern Yellow Pine, Douglas Fir, White Fir, Cedar and Hemlock. Hardwood species used in moulding production are: Oak (Red and White), Cherry, Poplar and Maple. Some imported hardwoods and softwoods are also used to manufacture wood mouldings. For softwood mouldings, the Western woods have long been favored for their even grain and consistent texture. In finished form, mouldings produced from Western species are known for their easy workability and smooth, versatile finishing surface. Most hardwoods are grown in the Great Lakes and Mid-Atlantic regions where hardwoods offer a consistent color and texture and develop a smooth finishing surface" (WM, 1996) *(See Appendix 9 and Appendix 10)*.

According to the Western Wood Products Association (1991) grading of appearance timber is by visual inspection and is a judgment of appearance and suitability to end-use rather than strength. Natural characteristics (form, size and occurrence of knots) and manufacturing imperfections (defects) are taken into account. "Uniform grading assures the buyer of comparable properties regardless of manufacturer or log quality. Grading provides the buyer with a yardstick for determining relative timber values, and facilitates specifying and identifying" (WWPA, 1991).

If mouldings are to be sold in the USA their characteristics have to be in accordance with the Wood Mouldings and Millwork Producers Associations' general requirements for wood moulding patterns. "All hardwood interior trim and moulding sold as conforming to this standard (HWM 2-91) shall be clear-face trim, except where characteristics of the wood and seasoning defects, may be present in not to exceed 5% of any pattern. It shall be well manufactured in accordance with the following requirements:

1. Seasoning - material shall be properly kiln dried according to accepted for the species in question to a moisture content of 5% to 9% when shipped from the mill,
2. Grading - all hardwood interior trim and moulding shall be graded from the face side. Wood mouldings are available in two grades. "N Grade" is intended for natural or clear finishes and the exposed face must be of one single piece. "P Grade" is intended for opaque paint finishes or overlays and can be finger jointed and/or edge glued" (WM, 1991; WM, 1993).

Considering the goals of the present thesis, N-grade would be of specific importance. The amount of specific defects permitted has to be minimal, i.e. the maximum quantity of material containing a specific imperfection shall not exceed 5% of the quantity of any one item. Imperfections are listed as amount of sapwood, stain, streaks, worm holes, knots, machine imperfections and torn grain.

A company must design its marketing strategy around its strengths and weaknesses, size and relative industry position. Hammond (1995) makes a list of the most important areas which will help develop a company's competitive advantage:

1. Long term objectives - company's goals in selling products to markets
2. Competitor activity - who are the competitor, what are they doing, their strategies
3. Product range and product development - detail a company's product range as well as suitable product development initiatives designed to increase competitive advantage
4. Customers - both current and future; this relates to market segmentation and to product and brand positioning. A customer centered company is in a position to identify new opportunities and to establish long term customer-supplier relationships
5. Quality assurance - quality of products and associated services is the key to successful positioning. Quality assurance and standards provide customers with confidence and guarantees as to the performance of not only the products they have been sold, but also for the company they are dealing with. Quality should extend beyond the actual product by transcending commodity limitations through attributes such as service and delivery
6. Threats and opportunities to company's products and markets in the future (anticipate important developments in market and customer demands which may ultimately impact on the firm's activities
7. Pricing - the amount customers will have to pay to buy the product
8. Promotion and advertising - they are designed to communicate the attributes of products which help persuade the customer to buy. Promotional strategies may include the development and use of brands. Brands seek to differentiate products from other companies by providing an identity linked to attributes such as quality. If successful, brands and effective promotion result in price premiums, repeat sales, buyer confidence and increased market share

9. Distribution of a product - it refers to how the company makes that product available to the customer. In domestic markets this may be direct to the end user, such as builders. In export markets, large trading companies are often used who take over the responsibility of distributing products further. It is desirable however, to keep control of raw material as far along the distribution network as possible, provided that at each step, the company remains internationally cost competitive

Additional strategic initiatives in a company's marketing strategy can include marketing diversification, value chain analysis, strategic alliances, and joint-venture partnerships.

Important issues to be considered in this stage are related to both the supply of the product and the demand for the specific product. A steady supply of the product, with specific quality mix and quantity offered, is important. Another issue to be considered is competition. The number and qualities of possible substitutes need to be identified. This is crucial for gaining full value for the higher quality products. On the demand side, consumer preferences for a specific quality mix need to be identified in order to match them to the characteristics of the product. When considering customers needs it is important to understand to what degree does the customer perceive the quality change of the product and how much the customer is prepared to pay for this change. Willingness to pay for new products would reflect how much consumers know about the specific qualities of these new products, therefore, more quality-related and specific use-related information must be given for the new product.

In general, according to Edgar et al. (1992), supply/demand relationships for wood products are highly elastic, and they are constantly adjusting through the following factors: surplus log availability from other countries, commercialization of previously non-commercial species, improved efficiencies, new product developments and the increasing competitiveness of substitute products if wood prices rise, potential consumer resistance to wood-based products for environmental reasons.

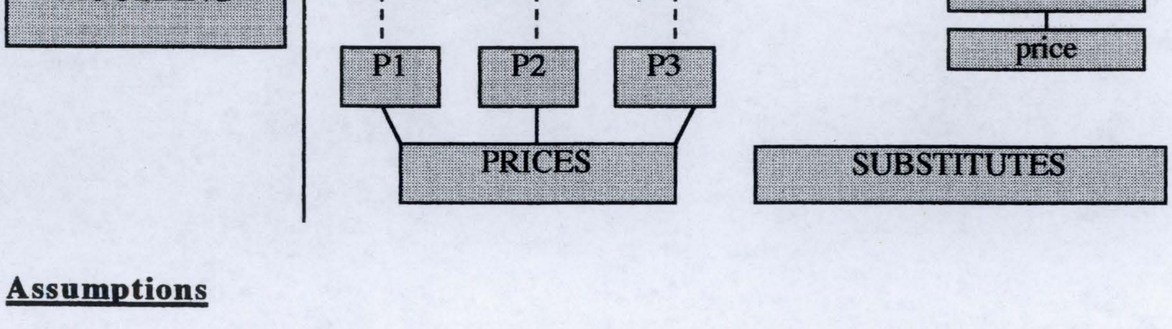
"It is critical that new products be individualized in ways that are perceived by buyers as being important. When the positively ranked attributes are consistently reinforced by a specific product, commitment to that product results. Consumer confusion persists when buyers are unable to place much confidence in their ability to rate a product on any attribute, which results not only in lowering predispositions towards a product line but also makes impersonal attributes the main influence on purchasing" (Sinclair, 1988). Thus product quality differentiation and positioning is very important for capturing the returns to value-adding. Strategies will also depend upon how well the product is aligned with consumer needs and preferences.

Some of the important product attributes are: strength/stiffness, price, product uniformity (surface/thickness), dimensional stability, durability, resistance to moisture, maximized performance/quality, light weight, eliminated delamination, workability (for nailing, cutting), favorable appearance, eliminated core voids, improved span ratings, skid resistant surface, smooth surface (Sinclair, 1988). The relative importance of the specific attributes varies according to the product, the market region and the consumer preferences.

On the other hand, for retailers, price and product availability are perceived as being of greatest importance when considering which particular brand of moulding to purchase. Retailers perceptions regarding the improvement of specific products in order to increase retail sales are: price reduction, improvement of dimensional stability, increased promotional/marketing support, increased moisture resistance, increased durability, improved tolerances across brands (thickness, uniform span rating system), increased strength/stiffness, greater variation in panel dimensions/sizes, improved product appearance, increased competitive product availability. These factors have been identified by considering the degree of consumer dissatisfactions (Sinclair, 1988).

According to Edgar et al. (1992), supply/demand relationships for wood products are highly elastic, and they are constantly adjusting through the following factors: surplus log availability from other countries, commercialization of previously non-commercial species, improved efficiencies, new product developments and the increasing competitiveness of substitute products if wood prices rise, and potential consumer resistance to wood-based products for environmental reasons.

Figure 10. Input-output scheme for the fourth stage of the model



<u>Assumptions</u>

1. Demand for high quality hardwood mouldings may increase. This could be due to several reasons: the growing Asian economies, the expanding American market, boom in

the construction industry, new "fashion" uses of mouldings, lower quality of substitutes, or simply the fact that the closest substitutes are softwood mouldings, etc.

2. Hardwood mouldings are likely to perform well in the market. Even though mouldings from other species are good substitutes, customers might be willing to pay a higher price for a product originated from a native hardwood. However, considering the regulatory restrictions for the use of native timber, plantation-grown tropical hardwood could be considered as the closest substitute. It could be assumed that the price for plantation hardwood products will be lower than the price for native hardwood products, but it will be higher than the price for softwood products.

3. The appearance characteristics of the new mouldings are better in terms of their smooth surface, colour, the lack of knots and fingerjointing (assuming that straighter logs produce mouldings in entire length). This is to say, mouldings are more likely to be produced from better quality boards.

Cost - Revenue Considerations

The costs of the new product include the overall cost of production up to the present stage of the value-adding chain, as well as the costs of distribution, advertising, and the acceptance of the product on the market place[96] (which vary according to the product and the targeted market).

Revenue is generated from selling the product in the market place. The quantity supplied, as well as the quality of the products will determine the price and the degree of quality premium captured.

6.2. Price / quality relationships

The purpose of the model is to establish marginal relationships between the improvement of the quality of eucalyptus trees (input) and the quality premium obtained from the mouldings (output), i.e. to focus on the economic meaning and justification for price differences related to quality. *What determines the change in quality? How much would price for the wood product change with a change in the quality of wood?*

[96] Radiata pine log pricing, for example, is significantly below the price from other sources, largely reflecting deeply held species preferences, and differences in basic quality/performance characteristics.

"Price differences based on quality are sometimes referred to as premiums or discounts. These price differences may change through time, but such variations are usually small relative to changes in the average level of prices for the commodity. The prices of all grades of a commodity tend to move up and down together, although price premiums and discounts between grades often change from season to season and may exhibit trends over time" (Tomek and Robinson, 1990) *(See Appendix 11)*.

When defining grades, the specific attributes of the product should be determined and a reasonable amount of information should be conveyed in order to inform potential buyers and sellers. The existence of grades is more likely to reduce marketing costs, and to minimize the problem of asymmetric information when quality is uncertain. On the other hand, the changes in the specific attributes are subject to specific quality mixes exhibited by the raw material. Thus, indirectly, the grade of a product would depend on the quality of the raw material used for producing this product.

The change in quality is due to changes in the genetic structure of the trees. Trees are re-engineered in order to improve their quality mix and performance, which further down the production process will suit customers' preferences for specific characteristics of the wood material (e.g. good appearance). However, how well will a quality improvement match the increase in value of the new product depends on the demand for better quality and the willingness to pay for it. It also depends on the suppliers ability to best represent the properties of the "new" product by establishing an appropriate grading system. Such a system should capture the quality differences between wood products. Outlining the structural or appearance differences is essential for establishing a grade ranking of products, and their respective prices. Prices of the products will be subject to the magnitude of improvement and quality differences. Each grade will have a different demand schedule and will perform differently in different niche markets (e.g. construction or furniture markets).

Finished products differ in terms of appearance attributes due to factors such as strength, colour, moisture contents, proportion of defects and impurities. The different attributes are valued differently due to the diverse final use of the products. In the case of mouldings[97], the appearance (defects free, entire (not finger-jointed)), the colour and the stiffness are the main determinants of quality, and depending on the different quality mixes (i.e. the degree of defects - e.g. knots) grades are allocated to differentiate between "good" and "bad" and their respective prices.

In the case of mouldings, different quality mixes are due to changes in the physical and genetic characteristics of the tree.

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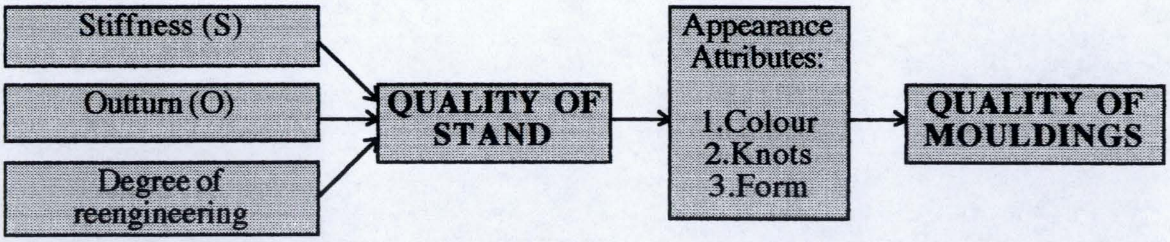
[97] A wood moulding is a detail of architectural design - a decorative strip of wood, milled with a plain or curved narrow surface which is continuous throughout its length (WM, 1996).

Figure 11. Links between wood properties and quality characteristics



The quality of mouldings, on the other hand is directly affected by the mix of desired appearance attributes. However, considering that appearance attributes are dependent on the quality of the stand, i.e. on the specific physical properties, a consumer who demands a moulding with specific appearance attributes, indirectly demands a mix of physical characteristics of the stand that was used to produce the product. Thus, if a consumer is willing to pay a price allocated to specific appearance mix (or grade), this will imply that indirectly the consumer will be willing to pay for a premium associated with achieving the desired appearance mix - a resource-to-customer chain.

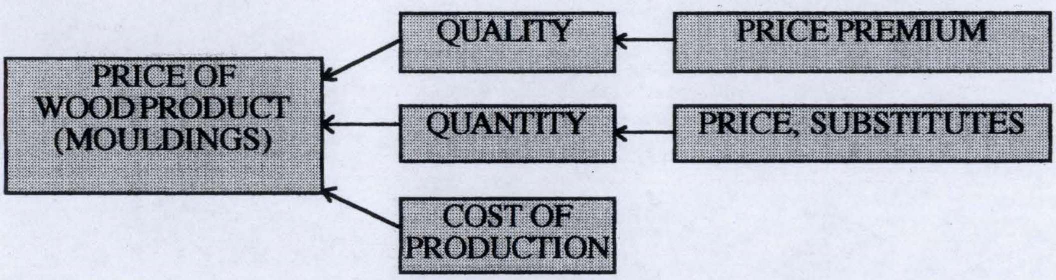
Solid interior wood paneling has a long history of representing quality. A wood paneled room adds warmth and makes a statement of elegance that cannot be achieved in any other way. "Mouldings have traditionally created interest and variety, highlighting architectural design. Not only do wood mouldings add to the aesthetic appearance of a structure, they employ function in protecting walls from the rigors of domestic or industrial usage. It has often been said that wood mouldings are among the most versatile of building products. An individual is only limited by his imagination when creating a design with wood mouldings" (WM, 1996).

This suggests that the appearance properties of mouldings are a function of the changing fashion designs in indoor paneling. Some of the main purposes of mouldings are - ceiling, flooring, door and window frames, hand and chair rails, base mouldings. "Many builders, looking for ways to add eye appeal, warmth and distinction to their homes, are turning to chair rails, picture mouldings, wide casings, heavy cornices, panel mouldings and 'built-up' combinations of these patterns to create even more elaborate profiles" (WM, 1996).

The elasticity of demand plays a crucial role in establishing the relationship between percentage changes in quality, quantity and prices. Price elasticity of demand as well as cross elasticity of demand are a way of approaching price/quality gradients. Cross elasticities are the ones that closely examine the relationship between different grades of products and thus different qualities (assuming that each grade represents a specific feature of quality that other grades don't have, and therefore, price varies according to the value put on this specific feature). The demand for the "new" products is more likely to be elastic, considering that there will be other similar products (i.e. substitutes). The degree of substitutability between the old and the new products will depend on how their attributes are defined, i.e. on the grading. In general, the degree of substitutability could be approached as substitutability across tree species, different wood products, and different grades.

Allocating the "right" price to the "new" final product is difficult considering the complexity of calculating the magnitude of the premium of enhanced quality and also the changes in prices caused by factors different than change in quality mix.

Figure 12. Determinants of the price for wood products with improved quality characteristics



Apart from changes in prices due to quality improvement, the quantity supplied of the product, as well as the existence of close substitutes and their prices, affect the final price of the wood product. Thus, when competing in markets with already established similar wood products[98] (i.e. substitutes - mouldings from species different than Eucalypts) the change in quality will be the main determinant for the marketability of the new product, assuming that customers have enough information about the product in order to value its specific characteristics.

Tomek and Robinson (1990) argue that there is great substitutability among grades of the same commodity, even though each has some unique characteristics. "Logic does not provide a clear guide as to whether the demand for high grades is, on average, more or less price-elastic that for lower grades. If one assumes that (1) the best grade has the largest income elasticity, (2) the sum of the cross elasticities is the same for all grades, and (3) the homogeneity condition with respect to elasticities prevails, then the demand for the best grades would tend to be more price elastic. But if the best grade typically has fewer close substitutes, then it has the (in absolute terms) price elasticity of demand" (Tome and Robinson, 1990).

Another important determinant of the success of the product is related to the stability of the supply flow. Moreover, when entering new, inexperienced markets (i.e. markets where

[98] Other substitutes are appearing on the international market and their value is increasing significantly - plywood, veneer and other processed products such as particle and fibreboard. These new processed products

customers have little if any experience with the product in order to stimulate specific behaviour for preference and demand), the quality of the product could be of little importance to the customer. High prices could then be explained by the existence of some sort of natural monopoly rather than quality improvement.

A price by grade incorporates changes in the quality of the resource, as each grade will exhibit different characteristics and will have different demand schedules. The size of changes in quality discounts and premiums depends on the size of shifts in demand and supply functions. "Generalizations about the price relationships among grades are difficult to make because of the many possible combinations of changes in relative supplies and demands by grades and of different slopes for the various functions" (Tomek and Robinson, 1990).

However, quality premiums are not always determined by competitive supply-demand relationships. Different prices could be charged between grades or qualities of products. Such price discriminating strategy is determined by sellers of industrial products or by those who market 'branded" commodities. "This situation usually occurs where the number of sellers is limited and/or firms have successfully differentiated their product from other products. Premiums or discounts in such cases may be based on quality or cost differences, but they also may simply reflect the ability of the seller to exploit consumer ignorance" (Tomek and Robinson, 1990), or the differences in demands among grades. Thus, two or more prices can be charged at the same time for the same product, depending on quantity, location of buyers, use of product, evenness of demand, future contracts and other factors, different from quality, considering that different markets have different elasticities of demand. For example, a domestic market may be protected by tariffs, implying a higher price for the product, but the same product may be accepted at a lower price in an export market (Hacking, 1986).

Moreover, quality improvements and the establishment of new grades have to be within the limits of quality standards. The question than is whether the wood products' quality standards are to be modified in order to accommodate for the new genetically transformed material. The improvement of the wood qualities of faster harvested logs is bound to alter the patterns of conventional grading of sawn logs. Normally, thinned trees, low quality logs, and degrade from sawn logs are used for pulping. However, with the improvement of wood characteristics, a greater proportion of the log could be used for processing, thus reducing the degrade and maximizing the quantity and quality of boards per cubic meter.

"The design of a grading scheme, therefore, should consider those quality attributes and defects that are economically important to buyers. But when a commodity has a variety of

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are the typical examples of value adding to the raw wood resource. Quality is the main concern, but it is achieved by the mixing low with high quality material, and adapting it to the specific consumer's demand.

uses and buyers place different values on particular attributes, a simple, consistent grading scheme may be difficult to design. [Generally speaking], if grades accurately reflect attributes demanded by consumers (and the defects they wish to avoid) reflect the demand for and supply of these attributes" (Tomek and Robinson, 1990).

CHAPTER 7

AN EVALUATION OF THE GAINS FROM USING BIO-REENGINEERED TREES IN PLANTATION FORESTRY

Previous chapters have briefly discussed the science, legislation, economics and commercialization developments of tree biotechnology. In Chapter 6 an exploratory model was developed in order to introduce the production stages in the forestry industry, and to provide specific assumptions regarding the input/output relationships embodied in each stage. The effects of the change of quality mix of trees due to selection and genetic engineering are present in each stage in the chain of production. The model provides only qualitative assumptions regarding such changes, and a more focused quantitative analysis is needed in order to capture the effects of such changes on the overall profitability of genetic engineering of purpose-selected and plantation-grown trees for the production of high quality wood products, e.g. mouldings.

The interest of the present thesis is focused on the gains from growing bio-reengineered *Eucalyptus* trees, and most of the assumptions made in the model are adapted to the specific characteristics associated with selection, engineering, growing and processing of eucalypts.

The evaluation is developed in such a way so as to be easily adapted to changing resource allocations and site-specific factors. The changes affecting the rate of return in the projects of interest are based on biotechnological developments and the socio-economic framework of New Zealand, but they can easily be altered to evaluate the gains in the case of Argentina. Considering that the availability, supply, and costs of factors of production differ across the two countries, a country-specific evaluation of gains of biotechnology needs to be undertaken.

For the purposes of analysis, the present evaluation is only indicative of the potential of the bio-reengineered resource, given the assumptions made, and hypothetical figures used, and thus, it doesn't necessarily reflect actual figures. The underlying assumptions of the evaluation are based on the details of the model.

7.1. The criteria for evaluation

The criteria for evaluation focuses on a comparison of the returns on investment of two main projects, and the efficient allocation of natural and financial resources for maximizing the gains from managing better trees. The two projects of interest are represented by the production, growing and processing of conventionally selected superior trees, and conventionally selected, superior and genetically engineered trees. The main difference in NPV terms between the two projects is represented by the process of genetic engineering and the extra research and development expenditure and time involved in it, as well as by the chosen silvicultural regimes and management approaches to tree maintenance and rotation length, accommodated for each project.

The economic evaluation is based on the conventional scheme for evaluating the stream of discounted costs and returns for a specific silvicultural regime, with a further modification to accommodate for the changes in the new genetic composition of the planted trees and specific management approaches towards their utilization. This implies that the change in the genetic mix of the tree will affect both the stream of costs and the level of benefits for growing the modified trees. Comparisons between unmodified trees and modified ones are made in order to offer a more comprehensive approach to the gains in NPV from growing genetically engineered material. Thus, initially the net present values and the internal rates of return of the two projects are evaluated, and the underlying assumptions are briefly presented. The predetermined discount rate for NPV calculations in the present evaluation is 10%, considering the choice of rotation length and the risk preferences for undertaking the projects.

When considering genetic engineering, however, a specific reference should be made on the trait of interest inserted or modified in the tree. The three traits of interest considered in the present evaluation are: insect resistance, herbicide resistance and lignin enhancement. Each trait implies different changes of the genetic mix of the tree and thus has a different impact on the cost-efficiencies of growing the tree. Thus, a specific evaluation and comparison of the NPV gains for each trait of interest is made. It should be noted that quality changes and superior performance of the trees allow for shorter rotation periods and greater product worth at harvest, and lead to increased NPV gains.

The sensitivity of trait-specific rates of return is also evaluated, where the changes in the rates of return are due to changes in the value of the underlying cost and return factors considered. The purpose of the sensitivity analysis is to make the evaluation more dynamic by showing a range of variation of the internal rate of return due to both endogenous as well as exogenous changes of the factors.

The fact that genetic engineering has been undertaken in order to improve the characteristics of trees (in terms of making them more resistant to specific pathogens or enhancing specific wood quality properties) implies that the price charged for a genetically engineered plant will be greater than the price charged for a conventionally improved, but unengineered plant. This is due to the higher costs of research and development, being internalized by the value of a royalty paid for the utilization of the technological innovation. The question of interest here is how more effectively to distribute the gain from royalty between those who produce the plant (technologists), and those who grow it (tree grower), in order to create an efficient redistribution of gains from producing and growing a superior and engineered tree and at the same time stimulate further research and development, and a greater demand for the modified tree. The timing of the royalty is of particular importance. Several schemes could be designed to capture the value of R&D, but in the present thesis only two scenarios are developed.

A brief reference is maid on the gains from utilization of genetically engineered trees for the purposes of processing and re-processing. The change in quality mix and the uniformity of logs, as well as their silvicultural regime, are the main determinants for maximizing the yield and outturn for each log type, and capturing a greater recovery in fall-down product. In general, the uniformity of the logs entering the mill changes the economics of processing further re-processing. Finally, possible shortcomings of the process and results of evaluation are given credit and the proposed emphasis for future analysis is highlighted.

7.2. The findings of the evaluation

The main focus of the present evaluation is to determine the attractiveness of a project which incorporates a high degree of research and development - the production, growing and utilization of bio-reengineered trees - considering that each step of the process is a combination of factors which affect the NPV gain and the internal rate of return of the overall project.

7.2.1. Comparison between NPV for unmodified and modified trees

The initial focus of the evaluation is directed towards the comparison of net present values of two projects - unmodified trees (improved, unengineered trees) and modified trees (improved, engineered trees). The main difference between the two project is represented by the length of their specific rotation periods, and by the nature and number of trees planted, and the associated costs per hectare for the maintenance of the growing tree (*See Appendix 12*).

Unmodified trees:

- The rotation length for unmodified trees is 25 years. The initial stock planted is 1,000 trees/ha and the number of trees harvested is 300 per hectare, representing a recoverable volume of 650 m^3/ha at harvest. Due to the greater density of planted stock trees are expected to be taller and thinner.
- Due to the rotation length and the nature of the trees, the cost scheme of silvicultural practices varies from the cost structure considered for modified trees:
    - the cost of seedling/planting reflects the price of the seedlings, which is assumed to be cheaper than in the case of modified plants,
    - costs of releasing are slightly higher, considering the quantity of initial stocking,
    - costs of pruning are higher, considering the greater density and number of planted stock,
    - costs of thinnings are also higher, considering the quantity of planted stock and the selected rotation length, which implies that various thinnings (including production thinning) should be undertaken before harvest.
- The revenue is collected in year 25 from selling the harvested logs:
    - each tree gives P1/P2 logs (30% of volume yield/tree), other logs (50% of volume yield/tree), and pulp and waste (20% of volume yield/tree),
    - each log type is characterized by different quality grades and thus has a different market value, respectively - $300, $160, $55.

Both costs and benefits are discounted to the initial year of investment (year 1). The discount rate used is 10%. Given the hypothetical numbers and assumptions adopted, the following was found:

UNMODIFIED TREES	
Net Present Value/ha (US$)	**Internal Rate of Return**
$3,053	15.263%

Note: The exchange rate used is 1 NZ$ = 0.60 US$

Modified trees:

- The rotation length for modified trees is 15 years. The initial stock planted is 600 trees/ha and the number of trees harvested is 300 per hectare (the same as in the case of unmodified trees), which represent a recoverable volume of 400 m^3/ha at harvest. In other words, genetic engineering has contributed to the growth potential of trees (by improving the quality of the tree and making it resistant to external factors), and thus, faster rotation periods are feasible. Given the greater spacing between trees, wood is allocated to the tree in a new technology fashion. This is to say, trees are expected to be shorter, but with greater diameter of the lower logs, which increase the product worth.
- Due to the rotation length and the nature of the trees, the cost scheme of silvicultural practices is the following:
    - the cost of seedling/planting reflects the price of seedlings, which is greater than the price for unmodified seedling, due to the underlying research and development undertaken for the production of the engineered plantlet, which increases the worth of the plant,
    - costs of releasing are slightly lower, considering the lower quantity of initial stocking,
    - costs of pruning are lower, considering the lower density of planted stock,
    - costs of thinnings are also much lower, considering the lower quantity of planted stock, as well as the fact that trees are harvested faster, and thus only production thinning is more likely to be undertaken,
    - the costs of weed control and forest protection (which includes insect control) are not changed in the present comparison. However, these costs will be altered later, when the gain of each genetically engineered trait is considered.
- The revenue is collected in year 15 from selling the harvested logs:
    - each tree gives the same yield and the same type of logs as in the case of unmodified trees,
    - each log type has the same market value as in the case of unmodified trees, respectively - \$300, \$160, \$55.

Both costs and benefits are discounted to the initial year of investment (year 1). The discount rate used is 10%. Given the hypothetical numbers and assumptions adopted, the following was found:

MODIFIED TREES	
Net Present Value/ha (US\$)	**Internal Rate of Return**
\$6,119	24.910%

The above results indicate that due to changes in the nature of the planted trees, the NPV of growing bio-reengineered trees is significantly greater than the NPV of growing unmodified trees. Given the assumptions made, this is due to the difference in the rotation length and the number of initial tree stocking per hectare, and the cost-effective performance of the trees on the field. All these factors are dependent on the nature of the tree grown, and engineered trees are bound to perform better in the above fashion given their enhanced quality and resistance to pathogens. The superior quality of wood implies a greater value of further utilization of logs for processing purposes and different end-uses.

In general, the gain in NPV terms associated with growing modified trees in a 15-year rotation schedule, rather than growing unmodified trees in a 25-year rotation schedule is $3,066 per hectare, which corresponds to 9.65% increase in the IRR (from 15.26% to 24.91%), or profitability of the tree growing enterprise.

The framework of the evaluation in this section (the assumptions made and results obtained) will be used as the base for analysis in the following sections. Thus, the estimated values below are based on the hypothetical values adopted for each cost and benefit factor use to evaluate the NPV and IRR for both unmodified and modified trees.

7.2.2. Comparison between gains in NPV for genetic traits of interest

The better performance of modified trees is based on the trait of interest inserted or modified in the tree genome. Thus, the NPV gain associated with modified trees varies according to the economics of the specific trait of interest. In the present section, NPV gains for the three main traits of interest are considered - herbicide resistance, insect resistance, and lignin enhancement.

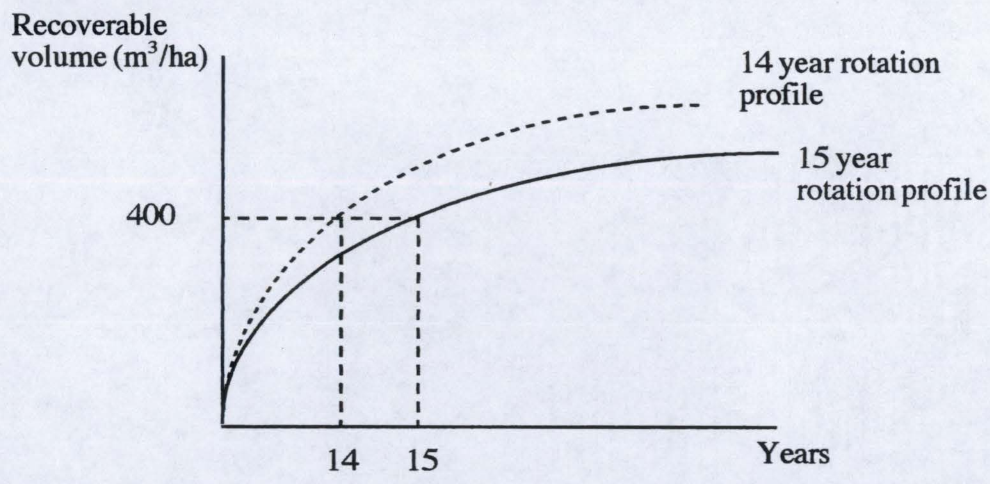
The starting point of evaluation of the gains for each trait of interest is the framework applied to evaluating the NPV of growing modified trees. Thus, the base rotation period is 15 years, and there is a number of generalized cost reductions (cost of releasing, pruning and thinning) that depend on the number of initial stocking. So, assuming that for each trait of interest initial stocking is the same (600 trees/ha), the above cost reductions apply for the evaluation of gains associated with each trait of interest.

NPV (US$)		**IRR (%)**	
15 year-rotation	***14 year-rotation***	***15 year-rotation***	***14 year-rotation***
$6,119	$6,917	24.91%	27.34%
NPV gain/ha - $798		**IRR change - 2.43%**	

The above NPV gain per hectare is found by comparing the change in NPVs of the two rotation schedules. An important thing to note here is that, even though the rotation period has been reduced by 1 year, the number of trees harvested, as well as the recovered volume per hectare at harvest stay the same, i.e. 300 trees/ha and 400 m^3/ha at harvest. The assumption here is that given the superior quality of growing trees and their tolerance to pathogens, trees grow faster and better, and thus by year 14 trees are more likely to exhibit the volume potential of a 15 year old modified tree.

Assuming that rotation length and underlying cost reductions are the same for each trait of interest, individual trait gains will be associated with the cost or revenue figure directly dependent on the change of the biological trait of interest.

Figure 13. The growth potential of a "modified" tree in terms of recoverable volume per hectare



Due to changes in the growth potential of modified trees induced by different genetically engineered traits of interest, trees would be able to achieve the same level of recoverable volume of m^3/ha as a 15 year-old tree, but in a shorter period of time. As it could be seen on the diagram, the gains will come not only from a reduced rotation period (from year 15 to 14), but also from a significant increase the recoverable volume of wood per hectare due to the "better" quality of the tree.

NPV gain for each trait of interest is characterized by the magnitude of quality improvement of grown trees (i.e. the product worth), as well as by the trait-specific cost reductions. For example, cost reduction figures regarding the application of agrochemicals vary among herbicide and insect resistant trees, and its effect on NPV gain depends on the number of trees grown per hectare, on the agrochemical regime undertaken, and on the overall rate of utilization and allocated expenditures of the specific agrochemical.

Herbicide resistance

Herbicide resistance means that trees are tolerant to the application of herbicides (e.g. Roundup). In other words, when herbicides are applied, they directly affect weeds (which compete for nutrients with the seedling, and slow down its growth) without affecting the integrity of the tree. Even though the costs of herbicide application are not likely to be reduced, the gains to be made originate from the fact that the utilized herbicide (Roundup) is cheap and tree-friendly, as well as it is applied on less trees per hectare. Thus, the overall cost per hectare of weed control is likely to be reduced. Moreover, considering that the integrity of herbicide resistant trees is not affected by the application of the herbicide, the trees are more likely to grow better and faster. Therefore, rotation length can be reduced to 14 years, assuming that the same amount and volume of trees per hectare will be harvested (300 trees/ha, representing a volume of 400 m^3/ha).

The assumption is that there is 60% saving in weed control, i.e. if previously the cost of weed control was $3.00/ha/yr., with herbicide resistant trees the cost for weed control will be reduced to $1.20/ha/yr. Thus, given the hypothetical numbers adopted in the previous section, the discounted cost savings from reduced weed control are $13.69 per hectare of planted trees. The gain in NPV/ha ($811) is represented by the difference in NPV values of modified trees grown for 15 years and herbicide resistant modified trees grown for 14 years ($798), to which the trait specific cost savings associated with weed control are added ($13.69). The NPV gain/ha thus represents the value captured by faster harvesting and the cost reductions in weed control.

Faster harvesting is feasible, given that trees are resistant to herbicide spraying and this allows better growth. Given that this gain is captured by planting 600 trees, and recovering 300 trees/ha and 400 m^3/ha at harvest, the following was found:

TRAIT - HERBICIDE RESISTANCE			
NPV gain /ha (US$)	**NPV gain /tree @ harvest (US$)**	**NPV gain/m^3 @ harvest (US$)**	**IRR (%)**
$812	$2.71	$2.03	27.40%

NOTE: The NPV/ha represents the NPV gain per hectare per year plus net cost savings per hectare per year.

Insect resistance

Insect resistance means that trees are not susceptible to attacks from insects (e.g. ants). In other words, the tree contains built-in toxins which affect the metabolism of insects and kill them. Thus, it is assumed that the application of chemical insecticides will be reduced due to the induced defense capacity of trees. This leads to reduction of costs for forest protection, as well as to a better and faster growth of trees. Therefore, rotation length is reduced to 14 years, and the costs per hectare associated with forest protection are significantly reduced.

The assumption is that there is 40% saving in forest protection, i.e. if previously forest protection cost $3.00/ha/yr., with insect resistant trees the cost for forest protection will be reduced to $1.80/ha/yr. Thus, given the hypothetical numbers adopted in the previous section, the discounted cost savings from reduced forest protection are $9.13 per hectare of planted trees. The gain in NPV is found by comparing discounted benefits for modified trees grown for 15 years and insect resistant modified trees grown for 14 years. The gain in NPV/ha ($807) is represented by the difference in NPV values of modified trees grown for 15 years and insect resistant modified trees grown for 14 years ($798), to which the trait specific cost savings associated with weed control are added ($9.13). The NPV gain/ha thus represents the value captured by faster harvesting and the cost reductions in forest protection.

Faster harvesting is feasible, given that trees are resistant to insects and this allows better growth. Given that this gain is captured by planting 600 trees, and recovering 300 trees/ha and 400 m^3/ha at harvest, the following was found:

TRAIT - INSECT RESISTANCE			
NPV gain /ha (US$)	**NPV gain /tree @ harvest (US$)**	**NPV gain/m^3 @ harvest (US$)**	**IRR (%)**
$807	$2.69	$2.02	27.38%

NOTE: The NPV/ha represents the NPV gain per hectare per year plus net cost savings per hectare per year.

Lignin enhancement

The difference between the above two traits of interest and the present one is the fact that in the case of the former two a foreign gene containing the trait of interest has been inserted into the tree genome to build resistance to external factors (herbicides, insects). In the case of the latter, no new genes have been inserted, but a specific characteristic of interest from the tree's own genome has been enhanced in order to improve the wood quality mix of the growing tree. The enhancement of lignin content has the purpose of increasing the wood density and thus allowing trees to be cut earlier without loss in terms of cubic meters of recovered volume. This leads to better and faster growth of trees, targeting a rotation length of 14 years.

Given the hypothetical numbers adopted, the NPV gain per hectare associated with lignin enhancement is captured by assuming that gains are due to rotation length as well as to the fact that a greater proportion of yield of the lower logs (P1/P2 log type) is likely. No trait specific savings are observed (the generalized cost savings scheme for modified trees holds), only revenue gain is embodied in the NPV gain of the trait. Thus, the gain in NPV is found by subtracting the NPV gains found for the above traits ($1,619) from the overall NPV gain associated with growing modified trees ($3,066). In other words, this gain corresponds to an increase of 4% in the yield of P1/P2 logs.

TRAIT - LIGNIN ENHANCEMENT			
NPV gain /ha (US$)	**NPV gain /tree @ harvest (US$)**	**NPV gain/m3 @ harvest (US$)**	**IRR (%)**
$1,447	$4.82	$3.62	28.13%

One reason that could be given in order to explain the difference between NPV gain of lignin enhancement and the NPV gain for the other two traits is the fact that the enhancement of lignin has direct effect on the wood properties of the tree (increases density), rather on the cost-effectiveness of the tree on the field. Thus, if trees are genetically modified to give greater proportion of mature wood at harvest, then even with shorter harvest profiles gains are made due to the increased volume of mature wood in logs of high monetary value (e.g. P1/P2 logs) and greater recovery potential at the mill. Thus, lignin enhancement is linked to the increase in net revenue, not only due to shorter rotation lengths, but also due to the increase in the yield recovered from lower logs.

A general comparison

Given that each trait affects the cost-effectiveness of the tree in a different way, the value of NPV will vary. If everything else is kept constant in the original evaluation (section 6.1), including the cost of seedlings (where each seedling is assumed to cost $0.50), the changes in NPV gain for each trait will depend on the following characteristics:

1. ***Herbicide resistance*** -
   - Total cost of weed control per hectare - it is needed in order to assess the cost-reduction potential of herbicide resistant trees. For example, if the cost of herbicides represents 70% of the cost of all other agrochemicals applied to the forest, then even a small reduction in the use of herbicides can have significant impact on cost reduction per hectare.
   - Rotation length;
   - Number of trees per hectare at planting.

2. ***Insect resistance*** - The same reasoning as for herbicide resistance, but applied to the weight of insecticides in the overall cost of agrochemicals applied. The length of rotation period, as well the number of trees planted per hectare are also of significant importance for cost reduction;

3. ***Lignin enhancement*** - Cost reductions are due to the reduced rotation periods and the lower number of planted trees. The main effect of this trait is on increasing returns due to a greater yield of P1/P2 logs per tree, which is to be expected given the genetically induced faster maturation of the tree. The proportion of the P1/P2 log yield would thus be crucial for the evaluation of NPV gain for this trait, as well as the gains associated with reduced rotation length.

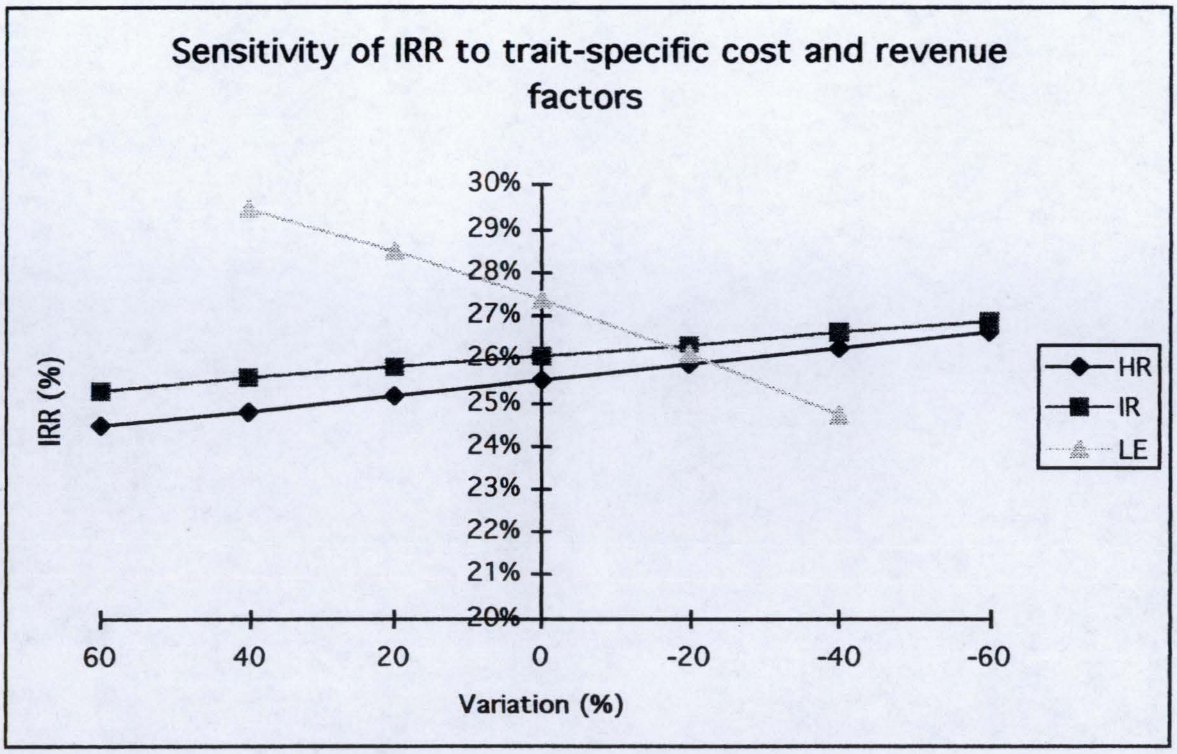
In general, assuming the hypothetical nature of the evaluation, NPV gains from herbicide and insect resistance are lower than the gain obtained from lignin enhancement. This, however, is not a general rule, and would depend on the significance of the costs of weed control and forest protection on the overall cost structure of growing the tree on the field. This is to say that if expenditures associated with herbicide purchase and application were a significant proportion of the overall cost structure, then a 60% reduction of these costs is more likely to increase the NPV gain/ha figure significantly.

7.2.3. Sensitivity analysis

A sensitivity analysis is conducted in order to capture the impact of variations in specific cost factors on the internal rate of return. In the trait specific evaluation it was emphasized that NPV gains/ha per trait a due to the shorter rotation period, and some specific cost reductions (in the case of herbicide and insect resistance) due to the nature of the tree. Thus, the magnitude of these cost reductions on the IRR is of particular interest.

Considering that in the hypothetical evaluation framework the costs associated with weed control and forest protection per hectare per year are very small and they are the same for both maintenance practices, it is difficult to detect the magnitude of changes in general and to distinguish between changes associated with a particular trait. Thus, for the purposes of analysis, greater and more easily distinguished cost figures are assumed for weed control and forest protection.

Figure 14. The sensitivity of IRR to trait-specific cost and revenue factors



Note: HR, IR, LE stand from respectively herbicide resistance, insect resistance, lignin enhancement

The sensitivity of the internal rate of return to changes in the cost and revenue factors is depicted by the slope of the lines. The steeper is the slope of the line, the more sensitive is the profitability of the project to that specific cost factor. From the figure some simple conclusions can be drawn:

- the positive slopes of the HR and IR lines represent the fact that as weed control and forest protection costs decrease, the IRR increases (percentage changes however are not equal, given that a 20% reduction in the cost of weed control, for example, increases IRR by 0.37%),
- the negative slope of the LE line indicates that as the percentage of yield per tree of P1/P2 logs decreases, so does the IRR, where a 20% reduction in the yield of P1/P2 logs (from 30% to 24%) leads to 1.23% reduction in the IRR.

In general, the profitability of the project is less sensitive to changes in the specific cost factors (weed control, forest protection) considered, while it is more sensitive to changes associated with the percentage of yield recovery of P1/P2 logs. In other words, the project seems to be more sensitive to changes in the underlying factors associated with lignin enhancement, rather than to changes of cost factors associated with herbicide or insect resistance.

7.2.4. The gains to technologist vs. the costs to grower

In the previous section, NPV gains for each trait of interest were found assuming that every factor in the initial evaluation for modified trees is kept constant except the specific cost reductions for each trait. Thus, the cost of seedling to the grower was also kept constant (at $0.50 per plant) for the purposes of the previous section. However, in the present section, the dynamics of this cost figure will be examined, considering that the cost per plant to the grower also represents the price charged for that plant from the technologist. For the purposes of the thesis, the technologist is considered to be the producer of the plant and plant grower, while the grower is the grower of the tree.

As previously mentioned, the price of a plant reflects the cost of research and development for engineering that plant, as well as the royalty paid for the utilization of the product of technological innovation, i.e. the right to benefit from the technologically improved plant. The optimal price range for selling modified plants depends not only on the cost of research and development involved, but also on the magnitude of the royalty. Thus, if the price per plant is $1.20, this means that $0.24 represents the cost of production, while the rest $0.96 are allocated for royalty payment. Thus, charging a higher price would increase the value of the royalty, given that cost of production is not altered.

It could be argued that the royalty captured in the price of the plant represents the profit of technological development for the technologist, while at the same time, it is the main factor which increases the cost per plant to the grower. In this case, even though the technologist will be willing to get a greater return from genetic engineering, the magnitude of such return will affect the cost to the grower. If the price charged per plant is very high, the grower will not buy the genetically engineered plant, and will look for a second-best option, i.e. purchase cheaper, improved, but unengineered plants.

Therefore, the magnitude of the royalty needs to be determined in a way so that the technologist gets enough return from genetic engineering to stimulate further investment for technological development, and the grower gets enough return from choosing to grow the modified trees.

Scenario 1 - Non-shared royalty

When the royalty is not shared between the technologist and the grower either one or the other captures the whole gain of bio-reengineered trees. What matters here however is the distribution of the gain between two periods - period one, when the plant is sold and period two when the tree is harvested. Thus, if the grower pays $0.24 to purchase a plant and pays nothing at harvest, the grower will capture the full value of the bio-reengineered tree. On the other hand, if the grower pays $0.24 to purchase a plant and pays another $34.07 per cubic meter at harvest, the whole gain will be appropriated by the technologist.

Table 2. NPV gains under a non-shared royalty scenario

Price / plant ($)	Net royalty value at harvest ($/m³)	NPV gain to grower	NPV gain to technologist
Full gain captured by the grower			
0.24	0	3,263	0
Full gain captured by the technologist			
0.24	34.07	0	3,263
0.36	33.32	0	3,263
0.60	31.82	0	3,263
1.20	28.06	0	3,263
1.80	24.30	0	3,263
2.40	20.54	0	3,263
3.00	16.78	0	3,263
3.60	13.02	0	3,263
4.20	9.26	0	3,263
4.80	5.50	0	3,263
5.40	1.74	0	3,263

Note: The prices are given in US$ terms.
The NPV gain in this section is different from the NPV gain presented in the previous sections ($3,066), because of differences associated with the cost per unmodified plant ($0.24) and the cost per modified plant ($0.60) assumed when evaluating the gains from growing the different trees. In this section, the initial cost per plant is assumed to be ($0.24) for both types of trees.

The problem however is represented by the fact that if the technologist captures the full gain, then the cost for a modified plant would be too high for the grower to bear, and the grower will be more likely to substitute genetically engineered plants with improved unengineered plants, which are cheaper. On the other hand, if the grower chooses to purchase a second-best plant, then the technologist will be left with no incentive to invest in genetic engineering.

Even though this scenario might seem desirable for the grower and the technologist individually, it is not a rational allocation of the royalty, considering that only one party will capture the returns for something that involves two parties to produce. The grower would not be able to achieve such gain in NPV without the technologist adding value to the genetic structure of the tree. On the other hand, the technologist would not be able to capture the gain from technological improvement unless the grower is willing to buy and grow the plants.

And as Hirshleifer (1989) describes it, a central problem considered in the economics of research and invention has been the conflict between the goals of achieving efficient use of innovation once produced versus providing ideal motivation for production of innovation. Under ideal conditions the efficient-use problem could be solved by charging perfectly discriminating fees to license (non-exclusively) all uses of a given innovation. If the discoverer were granted full property rights for the innovation, he in turn would have the optimal incentive to produce (search for) innovation. But in practice owners of patents cannot impose perfectly discriminating royalty-fee structures on licensees. A patentee might instead maximize returns by granting exclusive licenses or by imposing fee structures that distort the marginal production decisions of licensees.

Thus, some equilibrium needs to be established where both parties capture returns associated with their respective contribution for achieving of the magnitude of the NPV gain. A feasible distribution scheme will also imply that the grower would be willing to bear the higher cost of genetically transformed plants and the technologist will have the incentive to engage in further technological development.

Scenario 2 - Shared royalty in two periods

The present scenario considers the case of the royalty being shared between the technologist and the grower. The royalty is distributed in the following way:

- The technologist captures the gain from genetic engineering by selling the engineered plants to the grower in the initial year of investment and also by receiving a royalty per cubic meter of harvested trees.
- The grower captures the gain from growing the genetically engineered trees in the final year of investment, by paying a lower royalty per cubic meter of harvested trees.
- The values of royalty per plant sold and royalty per cubic meter harvested are such that make the NPV gain to the grower equal to the NPV gain to the technologist;

Within this scenario various approaches could be discussed. However, the table is limited to three possible schemes for sharing the gain from producing and growing bio-reengineered trees - 50/50, 60/40 and 40/60 splits and their respective values at planting and harvest.

Table 3. NPV gain under a shared royalty scenario

Price / plant ($)	Net royalty value at harvest ($/m³)	NPV gain to grower	NPV gain to technologist
Shared royalty - 50% gain to grower, 50% gain to technologist			
0.24	17.04	1,631	1,631
0.36	16.28	1,631	1,631
0.60	14.78	1,631	1,631
1.20	11.02	1,631	1,631
1.80	7.26	1,631	1,631
2.40	3.50	1,631	1,631
Shared royalty - 60% gain to grower, 40% gain to technologist			
0.24	13.63	1,957	1,305
0.36	12.88	1,957	1,305
0.60	11.37	1,957	1,305
1.20	7.61	1,957	1,305
1.80	3.85	1,957	1,305
2.40	0.10	1,957	1,305
Shared royalty - 40% gain to grower, 60% gain to technologist			
0.24	20.45	1,305	1,957
0.36	19.69	1,305	1,957
0.60	18.19	1,305	1,957
1.20	14.43	1,305	1,957
1.80	10.67	1,305	1,957
2.40	6.91	1,305	1,957
3.00	3.15	1,305	1,957

Assuming that the cost per plant is fixed, the royalty value at harvest is the critical figure in the above table. Under each sharing scheme, the grower is given a number of options to choose from in terms of sharing the value of the royalty with the technologist and doing so in two periods. This is to say that given that the 50/50 scheme is adopted, the grower can choose between paying $0.24 per plant when plants are bought and $17.04 per cubic meter when trees are harvested, or the grower might decide to buy each plant for $2.40, and pay $3.50 per cubic meter at harvest. Thus, the grower is not constrained to pay for the royalty in only one period. No losses are to be made by the technologist either, considering that the royalty values at the final year are discounted and presented in net present value terms (in the above table).

It should be noted that no matter in what proportion is the royalty shared between the technologist and the grower, there is an overall gain to the technologist and the grower from cooperating. Considering that each will get some proportion from the NPV gain, and various options exist to suit the financial and risk preferences of the grower, trade will be possible, i.e. the grower will be willing to pay the price of modified tree knowing that he will capture some of the royalty value, while the technologist will be willing to engage in further research and development given that some of the royalty will be captured by him.

However, the problem of royalty sharing does not end here. The question is who should get how much of the royalty if the royalty is to be shared. Considering the different set and magnitude of costs involved in producing the plant and growing the plant, the greater proportion of the royalty should be captured by whoever faces higher cost of handling the plant. The costs of research and development (including the cost of capital, labour and natural resources) as well as the patent protection of the developed technology represent significant cost bearing by the technologist. Thus, if the technologist gets only 40% of the royalty value, the incentives for further improvement of the plant are likely to be reduced.

A 60%-70% royalty share for the technologist is more likely to satisfy the needs for further technological development. On the other hand, the grower is more likely to be willing to pay a higher price for the modified trees (given that his royalty share will be 30%-40%), considering their improved quality and performance, and also assuming that by doing so, the grower will expect the technologist to further improve the genetic material. Thus, the royalty split represents a distribution of capital, as well as it is a non-binding agreement stimulating continuous research and development. Sharing the royalty is optimal, considering that both the technologist and the grower gain from it.

Generally speaking, the scenarios are two different ways of approaching the problem of royalty allocation. Other ways of sharing the royalty are also possible and would depend on the specific circumstances. The royalty can be shared between more than two parties involved in the production process, as well as it could be split between more than two periods. In the case of a vertically integrated company, for example, the technologist and the grower work together to maximize the value of the tree and royalty distribution would only be important if the company is to license the use of the trees to someone else.

7.2.5. The economics of processing

In the above sections greater attention was given to the gains associated with producing and growing modified trees. This section briefly examines the potential of modified trees in terms of their processing characteristics. In the model in Chapter 6 some specific assumptions were made concerning the quality of logs.

Briefly speaking, the variation in small end diameter between logs is greatly reduced considering the induced uniformity in the engineered trees. The goal, however, is not only to reduced such variation, but also to increase the actual small end diameter size up to around 45-50 cm. And this is where gains from genetic engineering can be realized. If trees have the characteristics to not only grow faster and be resistant to external pathogens, but also to generate a greater proportion of mature wood and thus increasing the size of small end diameter, this would bring significant gains associated with log utilization. Volume per modified tree does not to be greater than volume per unmodified tree. What matters is the fashion of wood distribution in the tree. Thus, total volume per tree might not change, but the proportion of wood from each log type might vary, and priority is given to capturing greater volume of wood from lower pruned logs.

On the other hand, the uniformity of logs implies cost reductions associated with log processing. Processing can be adapted to specific log sizes, forms and types, for the production of specific wood products. The uniformity of the input logs and their greater wood quality and the size of small end diameter are important characteristics that should lead to a greater percentage of outturn of output wood and its further conversion into high value wood products, such as mouldings.

A simple evaluation was undertaken in order to compare the potential of modified trees for processing, specifically addressing the processing and re-processing of mouldings. The main assumptions made are that total outturn of mouldings and timber from P1/P2 logs is greater (by 5%), and costs of milling are significantly reduced due to the higher quality and uniformity of logs. The overall net revenue gain from wood processing and re-processing for the production of mouldings was found to be $86 per total cubic meter of wood handled for unmodified trees, and $197 for modified trees (*See Appendix 13*). It is obvious that modified trees not only capture a gain on the field, but also significantly increase the gains from processing.

The limits to yield extend beyond recovery from the tree into recovery from the log, during its conversion. Different conversion processes use very different proportions of the wood in the log. This suggests that each type of log has an opportunity cost associated with its allocation for a specific wood product. In other words, the opportunity cost of log utilization is linked to the quality grade of the log and to the demand for specific wood products.

The factors most likely to influence opportunity cost considerations associated with good quality logs are:

- the volume of down-fall product from each alternative option (e.g. production of mouldings, plywood)
- the cost of producing alternative wood products
- the value of the wood product.

An evaluation of the opportunity costs of log utilization will determine the best allocation of logs of specific quality, given the capacity and purpose of the processing plant and the demand for the specific product.

7.3. General approach to the evaluation

The major shortcomings of the present analysis can be attributed to the lack of concrete data associated with the utilization of modified trees on different sites. This is mainly due to the 'new' nature of the tree and associated constraints on obtaining suitable numbers. More production data is needed about the effects of forest management practices on wood quality, e.g. effects of stocking, weed and pests control, thinning regimes, rotation lengths, yield of logs used for solid wood. The cost figures associated with implementing the specific silvicultural practices and the marginal returns received from those practices (costs of initial and intermediate treatment of forest stand, and the mill value of timber with a specified size, density or other characteristics) also need to be updated according to the specific site and the purposes of utilization of the harvested trees.

To accommodate for such limitations, the evaluation has been mainly based on qualitative assumptions about the characteristics and expected performance of the bio-reengineered trees. These assumptions are related to the specific biological characteristics of the trees, and the site- and purpose-specific silvicultural regime for growing such trees. Thus, how precisely the qualitative assumptions fit into the framework of quantitative cost and revenue factors is to be further examined.

The change in wood quality mix is an underlying factor broadly discussed in the model. Changes in wood quality mix associated with selection and genetic engineering are depicted in the evaluation by the marginal changes in the cost and revenue figures and mainly by the reduction of rotation length. In the future, when there is a greater knowledge of the performance of bio-reengineered trees, more objective assumptions can be made about the magnitude of changes in the quality mix and their impact on the growth potential of the tree in a shorter period of time, as well as on the values of different-quality logs. The present evaluation approximates the quality factor incorporated in the modified trees by considering the gains of the specific biological traits of interest, and by briefly discussing the gains associated with utilizing better wood in the mill.

At the present stage, the evaluation tries to link the unknown with the expected in order to give an indication of the potential gains involved in growing bio-reengineered trees for the purposes of commercial forestry and for their utilization in purpose-designed processing plants. However, without any solid data to provide for detailed analysis, the evaluation simply outlines a method for such analysis, and makes some assumptions to at least provide rough estimates of the economics of bio-reengineered trees.

CHAPTER 8

CONCLUSIONS AND FURTHER RECOMMENDATIONS

The present thesis was developed on the basis of a broad array of research, which when considered together form a rather exciting framework for analysis. Each topic discussed in the thesis has its own valuable characteristics and contributed to the formulation of the conclusions and of the directions for future research.

An outline of the focus points of the thesis

The scope of the thesis was extended beyond the academic framework for analysis to include specific private goals for research. This gave a more dynamic character to the issues discussed as well as it stimulated a more realistic approach to the current trends in plantation forestry. These were closely addressed by examining the strategies of a major (vertically-integrated) New Zealand-based forestry company - Fletcher Challenge Forests, regarding the potential for investing in new technological ventures and capturing the marginal gains from adapting the renewable natural resource (trees) to the specific market preferences for wood products. This real-life scenario opened up the possibility to examine how each step in the production process in the forestry industry contributes to the value adding to a final wood product of interest.

The main focus of the thesis rotates around the impact of bio-reengineered trees, and the changes in their quality mix associated with the alterations in their genetic composition, on the changes in the process of growing trees and further processing logs for producing specific wood products. The chain of production or value-adding starts with the process of genetic engineering.

A wide body of literature exists beginning from the characteristics of the science of biotechnology, and its conversion into an applied science, leading through its commercial application to specific industries, and finishing with the generation of 'new' and superior products for different markets. The developments of tree biotechnology have been of particular interest for the present thesis, and especially the applied genetic engineering research and results associated with *Eucalyptus grandis*. The scientific potential of genetic engineering for the insertion of new traits (by using Agrobacterium or Biolistic techniques) or for the enhancement of old quality traits into the tree genome, and their early control of expression (by the use of molecular markers) has proven to be significant. Added to the potential of genetic engineering are a number of multiplication systems (embryogenesis, organogenesis) which allow for the faster reproduction of superior clones. The superiority of the clones is represented by their specific quality characteristics (which are selected and further engineered for a specific trait) and their uniformity.

The selection and genetic engineering of trees adds value to the resource by making it more resistant to external pathogen factors, and thus maximizing its growth potential on the field, as well as by stimulating the improvement of wood quality. However, for the value which has been added in the first stage of the production process to be augmented specific silvicultural regimes have to be developed. Such regimes should be site-, species-, and tree-specific in order to increase the value of the tree for the next stage of the process of production. The superior quality of bio-reengineered trees suggests that they will be grown for the purposes of producing high-value, and a greater appearance quality, wood products. This on the other hand leads to the formulation of specific regimes which link the genetic quality of the tree with the appearance quality of the final wood product.

Generally speaking, bio-reengineered trees are more likely to be grown in much shorter rotation periods (15 or less years) than the conventionally adopted optimal harvesting profiles (25 or more years). This would be due to the greater growth potential of the tree, as well as to the underlying financial constraints regarding long term investment and difficulty to predict future prices. In order to allow for a greater growth in small end diameter of the trees and to maximize the amount of recovered volume of the high value log types in a shorter period of time greater initial spacing is more likely to be adopted (400-600 trees per hectare). Pruning regimes should be adapted to the shorter, but thicker trees. Also, due to the likely lower number of initial stocking and shorter rotation periods, only a production thinning would be needed. Silvicultural regimes are also country specific and the investment potentials in the Argentinean environment are briefly discussed.

The new nature of the tree will lead to changes not only in specific silvicultural practices, but also to associated cost reductions. The reduction in the costs per hectare will be mainly due to the changing intertemporal factors, such as shorter rotation periods and to the lower number of trees planted at initial stocking. Additional cost reductions are likely. They, however, will be linked to the specific genetic traits of resistance of the trees.

Altogether, significant gains in NPV terms can be made by growing bio-reengineered trees. In the present thesis it is suggested that NPV gains per hectare can reach about US$ 3,000 and an associated increase in IRR of around 10%. Such gains are achievable due to the above genetic and silvicultural factors. The contribution of the specific traits of interest to the broader scheme of NPV gains per hectare is also considered. Herbicide and insect resistant trees seem to capture similar NPV gains. This is due to the fact that their built-in resistance to respectively herbicides and specific insects (e.g. ants) is a factor which leads to the reduction of costs associated with the corresponding maintenance practices (weed control, forest protection), as well as to the greater growth potential of the tree and the possible further reduction in the rotation period.

The NPV gains associated with the enhancement of lignin content in the wood, however, are slightly greater that the NPV gains associated with the two other characteristics. The reasons for that can be found in the fact that genetic alterations associated with specific quality change (such as an increase in the proportion of lignins) aim at speeding up the formation of mature wood in the tree. This means that apart from the already discussed cost reductions from a lower initial stocking, this genetic trait will be represented by increasing the yield volume of the lower parts of the tree. Thus, the increase in yield in the higher-value logs of the tree will have great effects on the revenue from selling these logs for further processing, which will also increase the associated NPV gains per hectare.

Specific adaptations in the silvicultural regimes have to be made in order to add more value to the bio-reengineered trees. Considering that such adaptation leads to the allocation of wood in the tree in a new fashion (greater small end diameter size for P1/P2 logs), where trees are characterized by their genetic uniformity, further gains are to be captured from the processing of the logs. Processing techniques also need to be adapted to the 'new' nature of the log in order to allocate high quality logs to high quality wood products, and to do so in a greater outturn and product fall-down fashion. Due to the uniformity and higher quality of the logs, value can be added in a cost-minimizing and revenue-maximizing way.

The chain of value adding will end at the market place, where a price premium is likely to be captured for the higher quality wood product (e.g. mouldings). However, the magnitude of the price premium for the new product will depend on the market-specific demand and supply factors, as well as on the company's market entry strategies. In general, a successful entry in the United States mouldings market is feasible, considering that there is a limited number of high quality hardwood mouldings (different from mouldings from native hardwood) supplied, as well as to other previously discussed factors.

In brief, the explanatory model developed in the thesis, and its detailed break-down to four specific stages of the forestry industry production process, incorporates all the different areas discussed in each chapter. This has given the qualitative assumptions and judgments a more realistic approach, attempted to be captured in the quantitative evaluation undertaken.

The purpose of the thesis has been to explicitly present the main areas of interest associated with contemporary plantation forestry goals (the scientific, economic, political and legal environment for investment), to briefly discuss and critically analyze each of the outlined areas, to join them in the form of an explanatory model and to conduct an implicit evaluation, in order to determine the profitability of the originally established framework for the use of bio-reengineered trees. In general, the thesis has produced a detailed framework for analysis of the effects of bio-reengineered trees on the overall profitability of the process of production and value adding in the forest industry.

Directions for future research

Many of the areas emphasized in the thesis deserve more detailed attention and evaluation. Considering the novel nature of developments in tree biotechnology and their recent application to the specific purposes of plantation forestry, specific data associated with the changes in the intrinsic quality characteristics of the tree, the growth features, and the wood quality of logs is lacking, which gives present research an optimistic, if not a speculative, character. When more data regarding the characteristics of bio-reengineered trees is available, each stage of the explanatory model can be re-evaluated separately and more objective results can be drawn.

Generally speaking, there are five broad frameworks which should be addressed in more detail in future research regarding the underlying factors of biotechnology developments and their commercial application.

1. Scientific framework

The developments in genetic engineering, and specifically tree genetic engineering will allow for a greater understanding of the alterations associated with the new techniques and their effects on the intrinsic quality characteristics of the tree. An early and more precise specification of specific tree characteristics will also be possible thanks to molecular market techniques. This, on the other hand, will widen the scope of economic analysis and will make it possible to carried out at the early stages of tree development. Thus, specific quality characteristics of the tree will be more easily evaluated against their future grown and market potentials.

2. Regulatory framework

The developments in the formulation of regulatory frameworks associated with intellectual property rights (IPRs) and biosafety of the utilization and field testing of genetically modified organisms is another issue to be considered, given that presently, mainly regulatory constraints have been the main factor for the slowing down of commercial application of biotechnology. The evolution of science makes it necessary for regulations to be altered and updated, in order to safeguard the right and control the wrong involved with biotechnological re-engineering of living organisms, such as trees. A better protection of IPRs will stimulate further investment in research and development and will allow for better understanding of the process of genetic engineering for commercial purposes. Considering the private nature of patented biotechnological processes and products, a transparent licensing scheme needs to be developed in order to increase the scope and the associated returns from the utilization of technological innovation. Such a scheme has to represent both a legally enforced and market oriented binding agreement between the contracting parties, and it should be product or process specific.

A more rationalized and case-specific scheme for field testing of genetically engineered organisms is more likely to reduce the risks associated with GMOs. Such case-specific schemes will have the benefit of more focused understanding of the specific risk factors, thus making regulatory approaches more flexible across risk factors with different probabilities of occurrence. This will ease rather than constrain the field testing of GMOs, considering that a flexible regulatory approach will safeguard the potential of field testing and will allow for more correct identification of the boundaries of feasible risk. It could be argued that there is an option value associated with the testing of GMOs. Thus, if testing is restricted, the loss of option value could be grater than the estimated losses associated with testing the GMOs. The role of economic analysis in this area will be linked to estimating the risk probabilities and approaches to overcoming uncertainties associated with GMOs and their effects on the integrity of the natural and human environments.

An internationalization of the above regulatory frameworks might seem idealistic, but it will have significant effects for protecting the natural resources and the environment equally among countries, and will reduce the potential risks from exploiting regions with no such protections, and will allow for more controlled and sustainable way of exploring the opportunities associated with the 'new' natural resources.

3. Political framework

The developments in the legal environment discussed above are related to the country-specific political approaches to biotechnology. There are intra-, as well as inter-country differences associated with the development and application of biotechnology. The former are represented by the different nature of the goals in biotechnological research adopted by public and private sectors. This is mainly due to the cost associated with research and development in biotechnology, which is internalized by private companies by capturing monopolistic patent protection on their invention, but which on the other hand is hardly being able to be covered by poor government funding.

Inter-country differences are associated with the different involvement in biotechnological developments of developed and developing countries. This is due not only to differing financial constraints, but mainly to the differing views on the proprietary rights associated with biotechnology developments. The main debates are associated with who determines who owns the natural resources involved in genetic engineering of plants. *Ex-situ* conservation of germplasm has shifted its value away from its region of origin (more frequently a developing country) to the region where more value can be added to it (more frequently a developed country). The nature of the debate makes biotechnology an area of hostility rather than cooperation, even though recently technology transfer relationships have been more widely adopted.

The decision-making process for allocating resources for developments in biotechnology has its own framework of opportunity costs that need to be evaluated against the costs and benefits of alternative options for investment. Therefore, the economic analysis in this area can be focused on the political economy of research and development across sectors within each country, as well as across different countries.

4. Economics and trade framework

The economics of biotechnology can be evaluated from two main points of view - biotechnology as a mean of production and biotechnology as a research input into the production process. In both cases there are specific factors qualitative, as well as quantitative factors to be addressed. A range of opportunity costs should be considered when treating biotechnology as a process, while the weight of biotechnology as a research input on the characteristics and marketability of the output should also be identified.

The issue of trade is greatly related to the political economy of developments in biotechnology. Gains from trade associated with products generated by the use of biotechnology will certainly exist. The role of economic analysis will be to determine how big are these gains expected to be, who will appropriate the gains from trade, and what effects would the new nature of the products have on the comparative advantage of different countries.

5. Forestry industry framework

Each stage of the forest industry production process is associated with a wide range of interrelated factors which can be managed for achieving specific purposes. A change in the nature of the tree, in terms of its growth and quality potential, will have specific effects on each of the stages of the production process. The scope of economic analysis is therefore broadened in order to allow for more detailed evaluation of the marginal changes associated with the change in input. At the present, the lack of information has determined the formulation of qualitative assumptions regarding such changes. In the future, however, quantitative analysis should be undertaken in order to establish the specific relationships between quality change and marginal effects on growing the 'superior' trees, processing 'uniform' logs and marketing 'high-quality' wood products. Specific relationships within each stage should also be given separate attention, due to existent opportunity costs associated with different management decisions regarding the use of the bio-reengineered natural resource. The opportunity costs will be associated with the production capacity of the mill as well as with the quality of the entering logs. Considering that a greater volume of logs will be supplied, as well as a greater proportion of fall-down products is more likely to be achieved (due to the uniformity and higher quality of the logs), the result will be a significant reduction in post-harvest costs, which added to the higher-value of the final product, will maximize the gains from processing logs originated from "modified" trees.

APPENDICES

APPENDIX 1

The capacity (m^3/yr) and the wood products produced in the companies' sawmills and re-manufacturing plants

MILL	CAPACITY (m^3/yr)	WOOD PRODUCTS
Kawerau Sawmill	160,000	Kiln-dried machine stress graded framing, feedstock for laminating plant, packaging
Rainbow Mountain Sawmill	152,000	NZ domestic lumber, framing for Australia
Taupo Sawmill	160,000	American appearance grades, feedstock for mouldings plant, NZ domestic lumber
Waipa Sawmill	210,000	Douglas Fir lumber, appearance/structural/ industrial grades, feedstock for finger-jointed mouldings and millwork
Mt Maunganui Plywood Mill	16,000	Standard and treated structural plywood, Dried veneer
Kawerau Laminating Plant	16,000	Finger-jointed and laminated lumber for Japanese housing
Taupo Mouldings Plant	20,000	Solid lineal mouldings for North American homes
Waipa Remanufacturing Plant	9,000	Blanks and shook, edge-glued and face-glued laminates, panel products, door cores
Mt Maunganui Wood Processing	12,000	Blanks and mouldings
Sawmill (Argentina)	55,000	Eucalyptus grandis lumber
Plywood Mill (Argentina)	20,000	Eucalyptus grandis plywood

Source: Fletcher Challenge 1997 Annual Report - Forests

APPENDIX 2

Major markets for the Fletcher Challenge Forests' wood products (as a percentage of total sales in volume terms (m^3)

MARKET (by region)	SALES (% of total m^3)	PRODUCTS
New Zealand	42	Logs and lumber for building/ construction and industrial use
Australia	4	Lumber for building/construction
Japan	17	Logs for packaging, logs and laminated lumber for housing/construction
Korea	23	Logs and lumber for packaging and temporary construction
United States	3	Finished mouldings for housing
Asia and other	11	Logs and lumber for packaging and temporary construction

Source: Fletcher Challenge 1997 Annual Report - Forests

APPENDIX 3

Fletcher Challenge Forests - volume & composition of sales (1995-1997):

LOG SALES VOLUME (000 m^3)	June 1995	June 1996	June 1997
From Owned Estate:			
Pruned Radiata saw logs	81	95	97
Large unpruned Radiata saw logs	492	738	717
Small unpruned Radiata saw logs	809	633	999
Douglas Fir saw logs	38	36	34
Pulp logs/ Other species	573	694	588
Production thinnings	106	94	24
Total Owned Estate Volume	2,099	2,290	2,459
Total Log Sales Volume	2,990	3,223	3,614
Lumber Sales Volume:			
Mouldings			1
Laminated products			26
Lumber			441
Total Solid Wood Products			468

Source: Fletcher Challenge 1997 Annual Report - Forests
Note: Total log sales volume includes total owned estate volume, total managed estate volume, third party traded volume and intra-company sales.

APPENDIX 4

Mechanical properties of mature *E. grandis* wood @ 12% moisture content:

• Density	805-900 kg m^{-3}	(9 out of 10);
• Modulus of rupture	111-124 Mpa	(8+ out of 10);
• Modulus of elasticity	15500-17200 Mpa	(9 out of 10);
• Compression strength along grain	62.2-69.0 Mpa	(9 out of 10);
• Hardness value	7150-8000 N	(8 out of 10);
• Toughness value	15.9-18.1 Nm^{-1}	(7 out of 10);
• Strength group	S3, SD4;	
• Shrinkage	medium	

Source: Hillis and Brown (1988)

Note: The number in the parenthesis represents a ranking allocated out of 10. It can be seen that E. grandis performs very well in most of the above factors.

APPENDIX 5

The Pruned Log Index (PLI)

PLI Value	Pruned Log Quality
0 - 1.9	pruning ineffective
2 - 3.9	poor
4 - 5.9	satisfactory
6 - 7.9	good
8 - 9.9	very good
10 +	excellent

Source: Hammond, 1995

APPENDIX 6

Typical growing regimes and associated log type outturns for Radiata Pine

Direct pruned			**Pruned & thinned**			**Unpruned**		
Initial stocking - 1,000 stems / ha								
thin to waste 250 stems/ha, prune to 2.7 m (year 5); prune to 5.2 m (year 9)			thin to waste 500 stems/ha, prune to 2.7 m (year 5); prune to 5.2 m (year 9)			thin to waste 400 stems/ha no pruning		
Clearfelling (year 30)								
Log outturn								
Log type	m3/ha	%	Log type	m3/ha	%	Log type	m3/ha	%
P1/P2	155	26	P1/P2	125	20	P1/P2	0	0
S1/S2	80	13	S1/S2	150	24	S1/S2	230	31
L1/L2	220	37	L1/L2	110	18	L1/L2	50	7
S3/L3	115	19	S3/L3	110	18	S3/L3	210	28
R/T	30	5	R/T	130	20	R/T	260	34
Total	600	100	Total	625	100	Total	750	100

Source: Edgar, 1992

Note: T - thinnings

Silvicultural regimes and respective total recovery volume for log types (m^3/ha) of Radiata Pine

1. Silvicultural regime - intensively tended / no production thinning (i.e. stands which have been thinned to final crop stocking early, without extraction, and where at least half of the stems have been pruned prior to age 12)

		LOG PRODUCT TYPES (m^3/ha)				
Age (yr)	**TRV (m^3/ha)**	**P1/P2**	**S1/S2**	**L1/L2**	**S3/L3**	**Residual**
15	190	45	11	17	62	55
16	215	52	13	19	72	59
20	311	80	21	36	101	73
21	337	88	24	45	105	75
25	443	117	36	86	123	81
26	470	124	40	97	127	82

Source: Hammond, 1995

Note: TRV - total recoverable volume

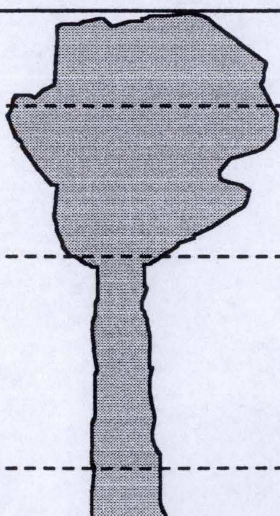
2. Silviculture regime - minimum tending / no thinning (i.e. stand which have not been thinned or pruned)

		LOG PRODUCT TYPES (m^3/ha)				
Age (yr)	**TRV (m^3/ha)**	**P1/P2**	**S1/S2**	**L1/L2**	**S3/L3**	**Residual**
15	211	0	25	11	100	75
16	236	1	33	13	112	77
20	347	1	64	29	153	100
21	376	1	73	36	162	104
25	487	1	112	67	188	119
26	514	1	123	75	194	121

Source: Hammond, 1995

APPENDIX 7

Proposed log outturn for a modified 15-year old Eucalyptus tree



	Height (m)	*Type of log*	*Under bark volume*	*Outturn (%)*
	6	R	0.40	13%
	12	L1/L2/L3	0.50	17%
	14	S1/S2	0.90	30%
	8	P1/P2	1.20	40%
Total:	40		3.00 m^3	100%

Achieved outturns from different log types for modified eucalypts:

Log type	Minimum sed (cm)	Volume (m^3)
Pruned plylog	30	114
Unpruned plylog	30	165
Large sawlog	24	110
Small sawlog	16	2
Pulp	10	79

Source: Fletcher Challenge Forests

Achieved outturns from different log types for unmodified conifers:

Log type	Log grade	Minimum sed (cm)	Typical outturn (%)	Maximum branch (cm)	Length (m)	$/$m^3$ at mill door
Pruned sawlog	P1	40	15	none	3 to 6	200-300
Pruned sawlog	P2	30	10	none	3 to 6	180-250
Large unpruned	S1, S2	25	30	7	3 to 6	140-200
Small Unpruned	L1, L2, L3	16	25	14	3 to 6	80-120
Pulpwood /chipwood	R	8	20	-	3 to 8	45-75

Source: Hammond, 1995

Notes:
* Standard lengths for sawn timber range from 1.8 m. to 6.0 m.*
* sed - small end diameter*
* P1/P2 — Logs for plywood, veneer, or clearwood (knot-free) for fine-finish / high-quality applications*
* S1/S2 — Logs for sawing into construction lumber and industrial uses (e.g. packaging)*
* L1/L2/L3 — Small diameter logs predominantly for industrial sawing use*
* R — Logs for pulp, paper, panels*

APPENDIX 8

Mill capacity

	Input (000m³)	Log Types	Output (000m³)	Capital cost NZ$ mil.	Comments
Small C-mill	100	pruned	54	45	clearwood mill (uses only P1/P2)
Large C-mill	200	pruned	109	60	clearwood mill (uses only P1/P2)
Plymill	132	pruned	60	75	uses only P1/P2
Large Sawmill	400	sawlogs	202	75	framing mill (uses S1/S2, L1/ L2/ L3)

Source: Edgar, 1992

Wood processing

Factors	Description	Hardboard mill	Plywood mill
Minimum economic size	Input Output	160,000 m^3/year 60,000 tonnes/year	170,000 m^3/year 80, 000 tonnes/year
Capital investment	Capital cost (+ working capital)	NZ$ 85 million (+/- 15%)	NZ$ 105 million (+/- 15%)
Labour input	Direct labour	90 in processing	200 in processing
Energy purchase	Electricity	20,000 MWh/year	20,000 MWh/year
Land area		10 ha	10 ha

Source: Edgar, 1992

An integrated Mill

Type of mill	Capital investment (NZ$ million)	Labour per shift	Production
Sawmill	20 - 30	20 - 35	70,000 - 100,000 m^3/yr/ shift
Heat plant	2	1	15,000 kW
Kilns	2	9	60,000 - 80,000 m^3/yr
Planing mill	2	9	60,000 - 80,000 m^3/yr
Remanufacturing	3	30 - 40	10,000 m^3/yr
Treatment plant	1	3	10,000 m^3/yr
Shipping	-	8	-

Source: Edgar, 1992

Note: Integrated saw mills are a combination of dimension and cutting mill (high speed mills producing standard framing dimensions). Machines are designed to handle small logs economically. Six or more logs, as small as 150 mm in diameter can be processed per minute. However, because of high capital costs and large production capacities associated with these sawmills, they require a large wood resource to be economic.

APPENDIX 9

Estimated volume of Western Softwood Lumber Production (USA) - by Grade (Mouldings and Better) and Species (in thousand board feet)

	Ponderosa Pine	Sugar Pine	White Fir (Hem-Fir)	Douglas Fir	Douglas Fir/Larch	Incense Cedar	White Woods	Western Red Cedar	Hemlock (Hem-Fir)	Idaho White Pine	Sitka Spruce	Total Species
1992	175,778 (5.46)	30,254 (10.69)	24,601 (1.09)	23,386 (0.41)	14,028 (0.61)	8,252 (4.25)	4,928 (0.44)	3,263 (0.47)	3,087 (0.2)	1,363 (1.89)	127 (1.06)	289,067 (1.66)
1993	134,344 (4.57)	18,898 (8.83)	19,726 (0.98)	15,892 (0.32)	13,560 (0.67)	7,894 (4.56)	2,069 (0.18)	3,935 (0.64)	3,545 (0.2)	1,545 (2.31)	255 (2.5)	221,663 (1.41)
1994	119,106 (4.2)	16,692 (8.83)	15,582 (0.78)	16,099 (0.31)	9,123 (0.47)	6,573 (3.61)	1,468 (0.13)	3,015 (0.47)	3,135 (0.17)	917 (1.64)	159 (0.88)	191,870 (1.19)
1995	90,653 (3.83)	10,160 (7.26)	11,523 (0.64)	14,745 (0.3)	6,143 (0.35)	5,326 (3.08)	907 (0.1)	2,881 (0.4)	2,801 (0.17)	655 (1.64)	35 (0.27)	145,828 (1.00)

Source: Western Wood Products Association's Statistics for Analysis (1996).

Notes:
* The number in the brackets represents the proportion of the total volume of lumber production of the species in each year which is allocated to moulding (volume of mouldings(species) / total volume of produced lumber(species).
* The general trend across species in the time period of 1992-1995 is that the volume of production of mouldings has been falling. This could be due to a number of characteristics, such as the production of mouldings from other species (such as Eucalypts, for example), i.e. greater competition and substitutability of mouldings from different species; or the ability to alter rapidly the quality mix of mouldings in order to suit specific customer preferences.
* In species such as Sugar Pine, Ponderosa Pine, Incense Cedar, production of mouldings represents a greater proportion of total lumber production per species than in the other species used for the production of mouldings (identified in the table). This could mean that in these species selects are valued more, and thus relying on good inputs (good logs) would bring greater return of the produced output.

APPENDIX 10

Proportion of total Western Softwood Lumber Production (USA) by grade category (in % of total thousand board feet)

	1989	1990	1991	1992	1993	1994	1995
SELECTS	3.56	3.80	3.63	3.30	2.47	2.12	1.87
E GRADE	0.02	0.03	0.03	0.02	0.00	0.01	0.00
SHOP	9.67	10.17	10.05	9.83	8.78	7.71	6.93
COMMONS	14.79	15.34	15.61	15.72	16.11	15.29	16.26
DIMENSION	52.93	52.36	52.62	53.36	54.28	56.84	56.75
STUDS	12.23	11.39	10.89	11.47	11.99	11.81	11.61
TIMBERS	6.12	6.31	6.48	5.69	5.95	5.91	6.19
EXPORT COMMONS	0.69	0.61	0.69	0.61	0.41	0.31	0.39

Source: Western Wood Products Association's Statistics for Analysis (1996).

Notes:

* Mouldings form part of the "Selects" category, and they represent the greatest proportion of the total volume of lumber production of this grade category.
* The general trend of the proportion of selects in the total volume of lumber production is declining in the time period 1992-1995. This could be due to both input and output factors. On the input side, the lack of good logs for processing and re-processing could cause the decline in the production of selects. On the output side - the changing nature of consumer preferences might have altered demand for selects, i.e. increasing preferences for other have caused a decline in demand for selects.

APPENDIX 11

Product prices in the US market

Price range (1996) for Radiata Pine Mouldings and Better in the USA:

- 350 - 375 $US/m3
- 1,200 - 1,400 $US/mbf

Source: Fletcher Challenge 1997 Annual Report - Forests

Pricing schedule for solid wood mouldings sold into the US market

Type of moulding	Price range (US$/100 lineal feet)	Use
Casing	20 - 73	trim inside and outside door and window openings
Chair rail	27 - 29	prevent chairs from marking walls; a key decorative detail in traditional designs
Crown	25 - 49	cover large angles (where walls and ceiling meet)
Base	20 - 45	protect walls from kicks, bumps, furniture

Source: Fletcher Challenge Forests and Wood Mouldings and Millwork Producers Association

APPENDIX 12

Cost and revenue factors in the evaluation of NPV and IRR for unmodified trees

Recoverable Volume - 650 m3/ha														
Initial stocking - 1000 trees/ha														
Year		1	2	3	4	5	6	7	8	9	10	11	12	13
COSTS														
Site Preparation	$/ha	$200												
Land	$/ha	$900												
Seedling/Planting	$/ha	$400												
Releasing	$/ha		$15	$15	$15	$15	$15	$15	$15	$15	$15			
Pruning	$/ha						$300	$300	$300	$300	$300			
Thinning	$/ha							$70	$70	$70	$70			
Fertilizer (post-p.)	$/ha	$75												
Harvest Roading	$/m3													
Log and Load	$/m3													
Production Thinning	$/m3												$1,000	
Transport	$/m3													
Harvest Fee Mngt	$/m3													
Project Mngt	$/ha/yr	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25
Rates	$/ha/yr	$6	$6	$6	$6	$6	$6	$6	$6	$6	$6	$6	$6	$6
Insurance	$/ha/yr	$12	$12	$12	$12	$12	$12	$12	$12	$12	$12	$12	$12	$12
Maintenance	$/ha/yr	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5
Weed Control	$/ha/yr	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5
Animal Control	$/ha/yr	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5
Forest Protection	$/ha/yr	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5
Total Costs		$1,638	$78	$78	$78	$78	$378	$448	$448	$448	$448	$63	$1,063	$63
REVENUE	yield/tree													
P1/P2 Logs	30%													
Other Logs	50%													
Pulp & Waste	20%													
Total Revenue														
Cash Flow		($1,638)	($78)	($78)	($78)	($78)	($378)	($448)	($448)	($448)	($448)	($63)	($1,063)	($63)
Discount fct @10%		0.9091	0.8264	0.7513	0.6830	0.6209	0.5645	0.5132	0.4665	0.4241	0.3855	0.3505	0.3186	0.2897
Discounted Net Benefits		($1,489)	($64)	($59)	($53)	($48)	($213)	($230)	($209)	($190)	($173)	($22)	($339)	($18)
NPV (NZ$)		$5,088												
NPV (US$)		$3,053												
IRR		15.263%												

											650	
14	15	16	17	18	19	20	21	22	23	24	25	
											$1,500	
											$10,400	
											$11,700	
											$3,900	
$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	$25	
$6	$6	$6	$6	$6	$6	$6	$6	$6	$6	$6	$6	
$12	$12	$12	$12	$12	$12	$12	$12	$12	$12	$12	$12	
$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	
$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	
$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	
$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	$5	
$63	$63	$63	$63	$63	$63	$63	$63	$63	$63	$63	$27,563	
											$58,500	$300
											$52,000	$160
											$7,150	$55
											$117,650	
($63)	($63)	($63)	($63)	($63)	($63)	($63)	($63)	($63)	($63)	($63)	$90,087	
0.2633	0.2394	0.2176	0.1978	0.1799	0.1635	0.1486	0.1351	0.1228	0.1117	0.1015	0.0923	
($17)	($15)	($14)	($12)	($11)	($10)	($9)	($9)	($8)	($7)	($6)	$8,315	

APPENDIX 13

Net revenue gains associated with processing "modified" logs

	Unmodified trees		Modified trees	
Volume of Logs to Mill	m3/ha	yield/log	m3/ha	yield/log
P1/P2 Logs	195	30%	120	30%
Other Logs	325	50%	200	50%
Pulp & Waste	130	20%	80	20%
Total	650		400	
		outturn		outturn
Volume of P1/P2 Logs to Mill	195	48%	120	53%
Total Timber & Mouldings Outturn	94		64	
Outturn from Mill				
Mouldings	39	20%	35	25%
Other Timber	55	28%	39	28%
Waste	101	52%	66	47%
Total P1/P2 Logs	195		140	
Costs to Mill				
P1/P2 Logs	$300		$300	
Other Logs (Timber)	$160		$160	
Pulp & Waste	$55		$55	
Milling Costs/m3	$94		$47	
Moulding Making/m3	$188		$94	
Prices at Mill Gate				
Mouldings (100 lineal feet)	$35		$40	
Mouldings (cubic metres)	$1,167		$1,400	
Other Timber	$480		$480	
Waste	$55		$55	
Revenue				
From P1/P2 Logs				
Mouldings	$45,513		$49,000	
Other Timber	$26,208		$18,816	
Waste	$5,577		$3,619	
From Other Logs (Timber)				
Timber Logs	$156,000		$96,000	
Pulp Logs	$7,150		$4,400	
Total Revenue	**$240,448**		**$171,835**	
Costs				
Log Purchase				
P1/P2 Logs	$58,500		$36,000	
Other Logs	$52,000		$32,000	
Pulp & Waste	$7,150		$4,400	
Other Costs				
Milling Costs	$30,550		$9,400	
Moulding Making	$36,660		$11,280	
Total Costs	**$184,860**		**$93,080**	
Net Revenue	**$55,588**		**$78,755**	
per total cubic metre handled	**$86**		**$197**	
Benefit Cost Ratio	1.30		1.85	

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