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KHAMOUI, THAO

AN ECONOMIC FEASIBILITY ANALYSIS OF WOODCHIP PRODUCTION ON THE ISLAND OF HAWAII FOR EXPORT TO JAPAN

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# AN ECONOMIC FEASIBILITY ANALYSIS OF WOODCHIP PRODUCTION ON THE ISLAND OF HAWAII FOR EXPORT TO JAPAN

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE
UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT
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By

Thao Khamoui

Dissertation Committee:

Harold L. Baker, Chairman
Charles H. Lamoureux
Frank S. Scott, Jr.
Gary R. Vieth
Yeong-Her Yeh

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## ABSTRACT

The chipping of sawmill residues and the transportation of woodchips to distant pulpmills began in Canada in 1955. Since then there have been considerable development and dramatic changes in the production and transportation of woodchips. The transocean shipment of Douglas fir woodchips from Oregon to Japan in 1965 initiated a new area of international trade. Today Japan and the United States are the world's two largest trading partners in woodchips.

According to the F.A.O., the world trade of woodchips in 1976 was 11 million cubic meters, with 9.6 million cubic meters, or 86 percent, going to Japan. In that year the United States and Australia, respectively, supplied 60 and 23 percent of total Japanese imports of woodchips to supplement domestic supplies demanded by Japanese pulp and paper industry.

The objectives of this study are twofold: (1) to examine the future pulpwood requirements in Japan and the market potential for Hawaii-produced eucalypt woodchips and the comparative advantages for Hawaii in the export market and (2) to analyze the economic feasibility of sustaining a private woodchip production on the Island of Hawaii.

The supply, demand and the availability of woodchips for export were analyzed in great detail in five sub-regions in the Pacific: Japan, North America, Oceania, Southeast Asia, and the Soviet Union. It was estimated that Japan would have to import 1.2 million cubic meters of pulpwood, mostly in the form of woodchips, from nontraditional sources to meet her requirements in 1990. The importance of hardwood in Japan's total imports has increased significantly, from 19,000 cubic meters in 1960 to 4.8 million

cubic meters in 1977, the latter figure including 2.8 million cubic meters of eucalypt woodchips from Australia. In terms of total pulpwood imports, hardwood represented 9.8 percent in 1960 and 34.7 percent in 1977.

Hawaii is in a good position to supply some of Japan's deficit because it has the required forest resources. Furthermore, Hawaii has three comparative advantages: (1) proximity to the Japanese market, (2) a relatively fast growth rate of eucalyptus trees and (3) the recent and current exchange rates that make exports from the United States competitive in the world market.

Woodchip price determination was analyzed in terms of technical and economic factors, which included wood properties, pulp yield, pulp quality, freight and processing costs, and pulpwood market structure in the Pacific region, especially in Japan. The alternative use of woodchips for biomass energy and the substitutability of plastic, a petroleum byproduct, for paper were also discussed. They affect the availability of woodchips for export and woodchip prices.

A 25-year plantation model was constructed for the economic feasibility analysis. The Faustmann formula was applied to determine the break-even price for stumpage. Net present value, internal rate of return, and benefit-cost ratio were used as analytical tools for the feasibility study. Sensitivity analysis was also conducted to find out the effects of changes in pulpwood yields and changes in input and output prices. It was found that it is economically feasible to operate a woodchip project as a single business entity but it is infeasible for a tree grower to supply stumpage to a chipper at the current price of $3 per bone-dry ton.

The criteria for the economic feasibility of woodchips were based on private costs and benefits. Social costs and benefits have not been included due mainly to lack of reliable quantitative data. However, a full benefit-cost analysis is warranted as more data become available and more efficient analytical techniques are developed.

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| B/C | Benefit-cost ratio |
| BDT | Bone-dry ton (2,000 lbs) |
| BDU | Bone-dry unit (2,400 lbs) |
| C.I.F. | Cost, insurance and freight |
| F.A.O. | Food and Agriculture Organization of the United Nations |
| F.A.S. | Free alongside ship |
| F.O.B. | Free on board |
| IRR | Internal rate of return |
| NPV | Net present value |

CHAPTER I

# INTRODUCTION AND THE PROBLEM

## Introduction

Hawaii has about 2 million acres of forest land which, constitutes almost half of the 4.1 million acres of land area in the state. For classification purposes there may be overlap between forest land and grazing lands. Approximately one million acres are considered commercial forest land capable of growing marketable timber crops and not reserved for restricted uses such as parks, natural areas and critical watersheds. However, the term "commercial forest land" does not imply that every acre of forest land that is capable of producing timber crops should or will be devoted to that purpose. On the contrary, under the concept of multiple use, many areas are considered to be more valuable as watersheds, scenic area or some combination of uses to attain increased yields of multiple goods and services (48). Detailed information on Hawaii's forest land is given in Table 1.

Table 2 shows that roughly only one-fourth, or 238,000 acres, of the total commercial forest land is currently growing timber stands that are presently or potentially of commercial use. Of this commercial forest land, only some 46,000 acres are in plantations. The islands of Hawaii and Maui have 18,000 and 10,600 acres, respectively. Various species of eucalyptus occupy about 17,000 acres of the current commercial plantations, as shown in Table 3. The other three-fourths, or 664,000 acres, are mostly occupied by native species, although these areas have soils and climate suited to growing commercial timber crops (80). An intensification of the forestry effort in Hawaii would use some of these lands as well as marginal grazing and agricultural lands.

TABLE 1

AREA BY LAND CLASS AND ISLAND, STATE OF HAWAII, 1970

(In thousand acres)

| Land Class | State Total | Hawaii | Kahoolawe | Kauai | Lanai | Maui | Molokai | Niihau | Oahu |
|---|---|---|---|---|---|---|---|---|---|
| Forest Land: | | | | | | | | | |
| Commercial | | | | | | | | | |
| Plantations | 46.1 | 18.1 | — | 5.6 | 1.0 | 10.6 | 2.6 | — | 8.2 |
| Native & naturalized forests | 901.7 | 551.3 | — | 140.3 | 3.5 | 56.9 | 31.4 | — | 118.3 |
| Total | 947.8 | 569.4 | — | 145.9 | 4.5 | 67.5 | 34.0 | — | 126.5 |
| Noncommercial | | | | | | | | | |
| Productive reserved | 114.4 | 71.5 | — | 2.3 | — | 30.3 | .3 | — | 10.0 |
| Unproductive | 924.2 | 511.6 | 15.8 | 71.7 | 39.4 | 142.0 | 43.8 | 31.1 | 68.8 |
| Total | 1,038.6 | 583.1 | 15.8 | 74.0 | 39.4 | 172.3 | 44.1 | 31.1 | 78.8 |
| Total Forest Land | 1,986.4 | 1,152.5 | 15.8 | 219.9 | 43.9 | 239.8 | 78.1 | 31.1 | 205.3 |
| Total Nonforest Land* | 2,123.4 | 1,431.2 | 13.0 | 131.3 | 45.4 | 226.2 | 88.9 | 13.4 | 174.0 |
| Total All Land Classes | 4,109.8 | 2,583.7 | 28.8 | 351.2 | 89.3 | 466.0 | 167.0 | 44.5 | 379.3 |

*Includes areas of water less than 40 acres in size defined by the Bureau of Census as land.

Source: State of Hawaii, Dept. of Land and Natural Resources, Dept. of Planning and Economic Development, and U.S. Forest Service Region 5, Forestry Potentials for Hawaii, 1976, p. 7.

TABLE 2

AREA OF COMMERCIAL FOREST LAND IN NATIVE AND NATURALIZED FORESTS
BY FOREST TYPE AND OWNER GROUP, HAWAII, 1970

(In thousand acres)

| Forest Types | State | | | Island of Hawaii | | | All Other Islands | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | Public | Private | Total | Public | Private | Total | Public | Private |
| Commercial: | | | | | | | | | |
| Ohia | 174.1 | 95.3 | 78.8 | 174.1 | 95.3 | 78.8 | — | — | — |
| Koa | 18.6 | 2.7 | 15.9 | 18.6 | 2.7 | 15.9 | — | — | — |
| Ohia-koa | 43.2 | 23.1 | 20.1 | 43.2 | 23.1 | 20.1 | — | — | — |
| Monkey-pod | 2.2 | — | 2.2 | 2.2 | — | 2.2 | — | — | — |
| Total | 238.1 | 121.1 | 117.0 | 238.1 | 121.1 | 117.0 | — | — | — |
| Noncommercial: | | | | | | | | | |
| Kukul | 6.3 | 6.3 | — | 6.3 | 6.3 | — | — | — | — |
| Ohia-koa | 382.9 | 185.3 | 197.6 | 247.1 | 141.5 | 105.6 | 135.8 | 43.8 | 92.0 |
| Other tree types | 13.0 | 12.4 | .6 | — | — | — | 13.0 | 12.4 | 0.6 |
| Shrub types | 261.4 | 98.1 | 163.3 | 59.8 | 15.4 | 44.4 | 201.6 | 82.7 | 118.9 |
| Total | 663.6 | 302.1 | 361.5 | 313.2 | 163.2 | 150.0 | 350.4 | 138.9 | 211.5 |
| Total All Forest Types | 901.7 | 423.2 | 478.5 | 551.3 | 284.3 | 267.0 | 350.4 | 138.9 | 211.5 |

Source: State of Hawaii, Dept. of Land and Natural Resources, Dept. of Planning and Economic Development, and U.S. Forest Service Region 5, Forestry Potentials for Hawaii, 1976, p. 9.

TABLE 3

AREA OF FOREST PLANTATIONS FOR ALL OWNERSHIPS
BY ISLAND AND FOREST TYPE, HAWAII, 1970

| Islands | Total All Types | Total Non-Commercial Types | Total Commercial Types | Commercial Types | | | |
|---|---|---|---|---|---|---|---|
| | | | | Eucalyptus | Other Hardwoods | Conifers | Unclassified |
| Hawaii | 18,060 | 2,691 | 15,369 | 6,367 | 6,591 | 384 | 2,027 |
| Kahoolawe | — | — | — | — | — | — | — |
| Kauai | 5,588 | 2,164 | 3,424 | 1,698 | 475 | 1,251 | — |
| Lanai | 1,064 | 470 | 594 | 262 | 55 | 80 | 197 |
| Maui | 10,624 | 4,561 | 6,063 | 3,465 | 492 | 2,106 | — |
| Molokai | 2,636 | 533 | 2,103 | 1,267 | 30 | 806 | — |
| Niihau | — | — | — | — | — | — | — |
| Oahu | 8,188 | 2,139 | 6,049 | 3,615 | 1,025 | 195 | 1,214 |
| All Islands | 46,160 | 12,558 | 33,602 | 16,674 | 8,668 | 4,822 | 3,438 |

Source: State of Hawaii, Dept. of Land and Natural Resources, Dept. of Planning and Economic Development, and U.S. Forest Service Region 5, Forestry Potentials for Hawaii, 1976, p. 13.

The annual precipitation of forest land at varying elevations in Hawaii is given in Table 4. There is a large acreage of commercial forest land having an elevation of 4,000 feet or less with an annual rainfall ranging between 75 to 200 inches.

Slightly over 60 percent of all the potential commercial forest land is on the Island of Hawaii. The potential commercial forest land is fairly evenly divided statewide between public holdings, 47 percent or 423,000 acres, and private holdings, 53 percent or 479,000 acres. The State of Hawaii owns 97 percent of the public holdings. Corporate owners hold 59 percent or 283,000 acres and individual owners occupy 41 percent or 195,000 acres of privately owned commercial forest lands.

Few native stands contain as much as 2,000 cubic feet per acre, yet the volume in some planted stands exceeds 9,500 cubic feet per acre. This is because native stands in Hawaii contain a very high proportion of cull trees (82). Unlike the planted forests, the native forests have not provided an attractive resource base for sustained large industrial operations mainly due to the low quality and the low yield of sawtimber per acre. Therefore, the additional development of forests is essential to the growth of a forest-based industry in Hawaii.

Hawaii now imports practically all of its lumber needs, approximately 98 percent, from the United States West Coast, Canada, and the Orient (47). However, there is a chipping operation, Capitol Chip Company, located at Kawaihae on the Island of Hawaii.[1] Established in 1973, this operation has been the only woodchip producer in Hawaii. The company purchases

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[1]According to the Honolulu Star Bulletin, August 28, 1980, the Capitol Chip Company has filed for a bankrupcy following the fire which destroyed the woodchip production plant in June.

TABLE 4

AREA OF COMMERCIAL FOREST LAND IN NATIVE AND NATURALIZED FORESTS BY ELEVATION AND PRECIPITATION, HAWAII, 1970

| Average annual precipitation (inches) | Elevation (feet) | | | | |
|---|---|---|---|---|---|
| | Total | 00-2000 | 2000-4000 | 4000-6000 | 6000+ |
| | Thousand acres | | | | |
| 30 | 41.2 | 19.7 | 16.1 | 4.4 | 1.0 |
| 40 | 71.4 | 32.5 | 16.9 | 17.2 | 4.8 |
| 50 | 157.2 | 70.5 | 45.8 | 35.3 | 5.6 |
| 75 | 108.0 | 32.5 | 41.4 | 31.0 | 3.1 |
| 100 | 217.7 | 94.0 | 64.3 | 50.4 | 9.0 |
| 150 | 152.6 | 53.7 | 54.6 | 43.6 | .7 |
| 200 | 87.6 | 28.1 | 46.0 | 13.3 | .2 |
| 250+ | 66.0 | 8.7 | 40.4 | 6.0 | 10.9 |
| Total | 901.7 | 339.7 | 325.5 | 201.2 | 35.3 |

Source: Melvin E. Metcalf, et al., Hawaii's Timber Resources - 1970, p. 8.

timber primarily from the state, but also buys from private owners. According to the records of the U.S. Department of Commerce in Honolulu, the company's export earnings have grown from $577,317 in 1975 to $3,012,200 in 1980. The woodchips are used to make fine stationery and coated paper for magazines in Japan.

The export of forest products is not new to Hawaii. Hawaii's sandalwood was shipped to Canton, China during the first four decades of the nineteenth century (90). The fragrant oily heartwood of sandalwood was in great demand in China. Thus the current export of woodchips is a revival of an old industry in Hawaii.

The Problem

Hawaii's economy has been in the past, and is expected to be in the foreseeable future, reliant on a few major industries. These include tourism, Federal expenditures, and such agricultural products as sugar, pineapple, papaya, macadamia nuts and livestock and dairy products. The tourist industry is by far the largest single source of civilian jobs in Hawaii. In 1979, 23,735 people were employed by hotels (50). Other indirect services such as communication, transportation, construction and restaurants also employ a large number of people. Tourism and federal government spending provided approximately 53 percent of the state's total income in 1978 (9).

These two activities, however, are extremely sensitive to national and international economic fluctuations and political climate. This fact means that Hawaii's economy is highly vulnerable to swings in the business cycle and changes in political conditions that originate elsewhere. Therefore, there is the risk of frequent widespread unemployment. Due to its large share of the state's income and its degree of influence, fluctuation in tourism would cause serious secondary repercussions in the construction industry and other related activities in Hawaii.

Although the growth in the tourist industry is projected to continue, it is expected to be at a decreasing rate. Hawaii had 171,588 visitors staying overnight or longer in 1958 and 1,314,571 in 1968, a 766 percent increase in 10 years. In 1978 there were 3,679,297 visitors in Hawaii, a 279 percent increase since 1968. It has been estimated that in 1990 Hawaii would have 6,432,000 visitors, a 175 percent increase from 1978 (50). It seems that the growth in the tourist industry might someday stop, although it is not known when this time might occur.

In view of the aforementioned problems, the Hawaii State Plan of 1978 emphasized a gradual lessening of the dependence on tourism while setting priorities to stabilize and diversify Hawaii's economy, to maintain a healthy visitor industry, to protect, encourage and diversify agricultural activities, to promote public and private investment on the neighbor islands, and to protect and preserve Hawaii's natural environment (49).

With ample available forest land, producing woodchips for export seems to provide a possible alternative that would meet the priority directions set forth by the state with the available forest land. This industry can, to some extent, help to stabilize Hawaii's economy.

Objectives

Given the economic situations, woodchip production is a possible alternative which might make Hawaii's economy a little stronger and more diversified. Consultations and comments from a knowledgeable forester[2] in the U.S. Forest Service have indicated two important points for consideration:

1) Capitol Chip is presently cutting trees that were planted at low cost in the period from 1910 to 1935 and are not being carried as an investment by their owners. There is no investment history on which to base a valuation for this timber, the owners generally consider this

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[2]Personal communication with Dr. Roger G. Skolmen.

timber as "free". Currently Capitol Chip is paying $1 per bone-dry ton (BDT)[3] to the state and $3 per BDT to private owners.

2) If tree growers are now considering planting trees specifically to supply chips, it is very different from the present situation. They now have to consider the costs involved in growing this crop and how they can be recovered. They have to determine if the venture would be feasible.

Although the present forest resource situation indicates some areas which offer opportunities to diversify Hawaii's economy, two conditions must be fulfilled: (1) evidence that tree growing can be a profitable enterprise and (2) evidence that an adequate supply of good quality crops can be and will be grown on a sustained basis. Therefore, the objectives of this study are twofold. The first objective is to examine the future pulpwood requirement in Japan and the market potential for Hawaii-produced woodchips and Hawaii's comparative advantages in woodchip export. The second one is to analyze the economic feasibility of sustaining private woodchip production in Hawaii.

## Methodology

Typically, forest investment projects are usually characterized by heavy expenditures for stand establishment followed by fairly low expenditures for stand maintenance; occasional small revenues, if any, from thinning; heavy expenditures for harvesting; and, finally, a large revenue from sales. Pulpwood plantation management may be viewed as a point-jnput, point-output activity. Most costs are incurred at the time

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[3]One BDT is one ton of dry wood at zero percent moisture content. It must be made clear whether it means metric ton, short ton, or long ton. See Appendix E for conversion. Short ton is used in this study.

of plantation establishment. Limited inputs are required to maintain the plantation during the growth period. Without thinning, income is received only when trees are harvested.

Time is an important element, especially because forest production is a biological process requiring many years to complete. A typical approach for evaluating forestry ventures involves the consideration of a representative site to which all projected expenditures and returns are based. Discounting is then applied to bring the cash flow to a common point of time, and the project is evaluated by one or more of three standard analyses. These are the benefit-cost ratio (B/C), net present value (NPV) and internal rate of return (IRR). These financial appraisal methods outlined below are widely applied in Australia woodchip projects in Tasmania (5), New South Wales (22), Western Australia (3), and in Papua New Guinea (96).

The benefit-cost ratio is expressed as:

$$\frac{B}{C} = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+i)^t}}$$

Where:

$B_t$ = gross private benefits in the t-th year

$C_t$ = gross private costs in the t-th year

n = number of years

i = interest rate

and let the discount rate at t-th year be

$$D = 1/(1+i)^t$$

The equation simply states that the B/C ratio is the sum of the present value of the benefits received during each year of the life of the investment project divided by the sum of the present value of the cost incurred during the project life. In short, the present value of gross benefits is divided by the present value of gross costs. If the ratio is greater than one, the project is said to be feasible.

The second method is determination of net present value:

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t}$$

It is the sum of the differences between total benefits and total costs in terms of present value for each year of the life of the investment project. A project is feasible or profitable if NPV is positive and is just at the break-even point if NPV is zero.

The internal rate of return or sometimes called marginal efficiency of investment (MEI) is expressed as:

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t} = 0$$

The IRR is the interest rate at which the NPV is zero. In other words, it is defined as the discounting rate which equates discounted revenue with discounted expenditure, i.e., the rate at which NPV equals zero and B/C ratio equals one. If the IRR is greater than the interest rate charged on invested capital (IRR>i) the project is feasible. The difference between them can be viewed as a return to uncertainty (58).

These methods have both advantages and disadvantages but each is a useful supplement to the other. An evaluation of their financial appraisal capability is included in Chapter VI. A computer program of the woodchip production feasibility based on the formulae and data presented in Chapter V is given in Appendix A.

The Faustmann formula, derived in 1849 by a German forester, is applied to estimate the stumpage value (19, 36). The formula expresses the present net worth per acre as a function of the revenues and costs, appropriately discounted over a series of rotations.

$$L = [\sum_j \sum_t p_j y_{jt}(1+i)^{r-t} - \sum_t c_t(1+i)^{r-t} - a\{(1+i)^r - 1\}/i]/\{(1+i)^r - 1\}$$

Where L denotes the present net worth per acre, ($\$ac^{-1}$);

$j = i, \ldots n$ denotes the $j^{th}$ product;

$t = o, \ldots r$ denotes the year since start of clearing;

r denotes the rotation length (years);

$p_j$ denotes the price of the $j^{th}$ product ($\$ BDT^{-1}$);

$y_{jt}$ denotes the yield of the $j^{th}$ product in the $t^{th}$ year (BDT log volume $ac^{-1}$);

$c_t$ denotes a cost incurred in the $t^{th}$ year ($\$ac^{-1}$);

i denotes the rate of discount (decimal);

a denotes a constant annual cost ($\$ac^{-1}$ $year^{-1}$)

The time lag involved in forestry programs, whether for commercial harvesting and regeneration, or for long term environmental preservation, mean that adequate allowances should be made for risk and uncertainty in appraisals of the consequences of alternative forest policies (103).

The question of risk and interest rate determination are rather closely related. Once the interest rate is determined, risk becomes a matter of subjective judgment. Common risks involved in forest plantations are fire, insects, disease and other natural disasters such as typhoon, flood, earthquake and, in Hawaii, new lava flows from volcano eruptions.

A procedure for dealing with risk is the use of a risk discount factor, $\delta$. For instance, suppose the actual rate of interest is 10 percent, the rate used in discounting might be increased by a "risk factor" of, say, 1 percent to a total of 11 percent for a low risk investment, but we might add a risk factor of 5 percent to a total of 15 percent for a high risk project (11).

Such a risk discount factor always reduces the value of the discount rate, D, because now $D = 1/(1+i+\delta)<1/(1+i)$. In other words, the higher the risk, the more we lower our evaluation of a given expected return. To state it differently, if the discount rate is now defined as $D = 1/(1+i+\delta)$, the values of B/C ratio, NPV and IRR will be smaller because D has become smaller.

The risk-discounted method has some desirable properties and is relatively easy to manage. However, its basic difficulty is that it comes with no explicit instructions to permit us to determine the appropriate value of the risk factor, $\delta$, and it must usually be estimated on the basis of some sort of subjective judgment or intuition (11).

Many factors, which must be taken into consideration in developing a viable woodchip industry in Hawaii, are socio-economic in nature and cannot be quantified in purely financial terms. The major social benefits such as watershed protection, erosion control, better road network for forest-fire control, recreation, habitat for wildlife and aesthetics are almost impossible to quantify. On the other hand, there are social costs involved such as pollution and other forms of possible damage to the environment. However, this feasibility study is not directly involved in the complex issue of social costs and benefits which are in the field of welfare economics. The evaluation of social costs and benefits should better be left to the process of socio-political judgment, although some economic recommendations could be made for consideration.

Cost data used in the analysis is largely obtained from the recent study on biomass energy for Hawaii (107). Data used in analyzing Japan's future demand on pulpwood is mainly from the Food and Agriculture Organization (F.A.O.), Australian statistics, the Industrial Bank of Japan, and Pulp and Paper Statistics published by the Japan Paper Association.

# CHAPTER II

# INTERNATIONAL TRADE OF WOODCHIPS AND JAPAN'S FUTURE REQUIREMENTS

During the last quarter century there have been considerable development and dramatic changes in the production and long distance trade of woodchips. Long distance transport makes it possible to supply wood as raw material to pulp and paper mills all over the world.

The chipping of sawmill residues and the transportation and the sale of the woodchips to distance pulp mills started in Canada in 1955. In the following years the trade in woodchips obtained from both sawmill residues and roundwood developed and woodchips within and between the United States and Canada became important for pulp and paper industries. Owing to technological changes, woodchips are now considered a better pulping material than roundwood.

## Factors Influencing Trade in Forest Products

The Heckscher-Ohlin theory of the emergence of trade assumes that countries are characterized by differences in relative factor endowments and differences in factor intensities between products (51, 85). However, Johnson argued that it is not necessarily true that a country will export the commodity which uses relatively intensively the factor with which the country is relatively heavily endowed (67).

Many countries import and export forest products simultaneously. Some are major importers despite their rich forest resource endowment, while others have become major exporters with very limited forest resources. Therefore, resource surpluses and deficiencies alone are not the sole determinants of trade in forest products. In fact, there are many complex factors that determine the world trade patterns. These include resource base, market capacity, processing and transportation efficiencies, the nature of demand in importing countries, and, in some instances, institutional barriers superimposed on free trade. In other words, the most important factor of international trade in forest products is the principle of comparative advantage. Therefore, trade in forest products is not simply the movement from countries with surpluses to those with insufficient natural resources. A few examples are given here.

Scandinavian countries such as Finland and Sweden import large volumes of pulpwood from Europe and the USSR and then export large quantities of pulp and paper products all over the world. This is clear evidence that processing efficiency can compensate for transportation costs and resource deficits. Obviously the conversion efficiency in these countries is greater than that of the log producing or end-product consuming countries. Otherwise, the intermediate conversion would take place at either end of the production-consumption point. If transportation costs were to increase to the extent that they outweighed the higher efficiency, the intermediate processing countries would lose their role in international trade (16).

South and Central American countries, on the other hand, are net importers of forest products despite their extensive forest resources and proximity to the major markets of North America and Western Europe. This is due mainly to lack of capital investments and processing inefficiency of domestic industry.

Finally, the size of the Japanese market, its relative processing efficiency of the domestic pulp and paper industry, and its highly efficient long-distant chips carriers all have enabled Japan to import large volumes of woodchips and maintain its competitiveness in international trade of pulp and paper products.

A good example of trade barrier is found in North America. While the United States has been the largest softwood exporter, it is also the largest softwood sawntimber importer. One important reason is that the subsidized Tran-Canada rail freight has enable British Columbia to service the United States Mid-West and the East Coast more cheaply than can the U.S. West Coast. The other reason is the Jones Act of 1931 that makes Oregon-New York freight costs more expensive than Vancouver-New York rates, with a longer distance. Currently, Hawaii is shipping its woodchips to Japan on foreign carriers at a lower rate. Due to the Jones Act, it is not economically feasible to ship to the United States Mainland at higher rates charged by domestic carriers.

History of Woodchip Trade

Since World War II the Japanese manufacturers whose existence and expansion were threatened by raw material shortage and its high costs began looking overseas for wood supplies. The export of Douglas fir woodchips by Weyerhaeuser Co. from Coos Bay, Oregon to Japan in 1965 started a new area in international trade. A cord of Douglas fir contains 2,400 pounds of oven dry wood; this is the origin of the bone-dry unit (BDU)[4]

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[4]One BDU is 2,400 lbs. of dry wood at zero percent moisture content. The BDU is a transaction unit for the transport of woodchips by ship. It is not concerned with the original green weight nor the volume of woodchips required to make the 2,400 lbs. dry wood. Species with high specific gravity (or basic density) will normally require less volume than lighter species. Note the differences between BDU and BDT; the latter contains only 2,000 lbs. of dry wood for short ton. See Appendix E for metric ton and long ton conversions.

which is widely used in the international trade of woodchips. Prior to 1965, Japanese pulp mills imported only pulpwood and carried out woodchipping operations by themselves. Now Alaska, California, and Washington States are among the major exporters of woodchips to Japan.

Today Japan is the world's largest importer of woodchips. The world trade of woodchips in 1976 was 11 million cubic meters, with 9.6 million cubic meters, or 86 percent, going to Japan (32). In that year the United States and Australia, respectively, supplied 60 and 23 percent of total Japanese imports of woodchips to supplement domestic supplies demanded by Japanese pulp and paper industry.

It has been observed that in the past two decades there are substantial interregional trade flows of pulpwood and significant shifts have occurred in pulpwood trade. Round pulpwood exports by North America to Europe diminished greatly in the 1960's, while woodchips—largely made from residues—became a major export to Japan. Japan also draws on the Soviet Union and the South Pacific for a good portion of its pulpwood, both as direct imports and as residues derived from processing of imported logs.

In regard to the three components of pulpwood trade, namely, roundwood, chips and residues, the following major streams may be observed, each reflecting regional supply-demand situations (61).

1) Roundwood: From the USSR to Eastern Europe, Western Europe and Japan.
From Canada to the United States and Western Europe.

2) Chips: From the United States, Southeast Asia, Oceania and the USSR to Japan.
From Canada to the United States.

3) Residues: Interchange among European countries.

In 1969, rubberwood chips from Malaysia and pine chips from New Zealand were exported to Japan. In 1970, mangrove chips were produced in Sarawak and exported to Japan. In 1971, Japan started importing a large volume of eucalypt chips from Tasmania, Australia, one of the world's most important sources of hardwood chips. The Soviet Union also has signed a contract to export pulpwood and woodchips to Japan, amounting to 12.8 million cubic meters over ten years from 1972. Since 1974 Japan has imported some mixed tropical hardwood chips from Papua New Guinea. There are reports on the possibility of Japan importing eucalypt woodchips from South Africa and from Brazil. India and some Pacific Islands have also been mentioned as possible chip suppliers.

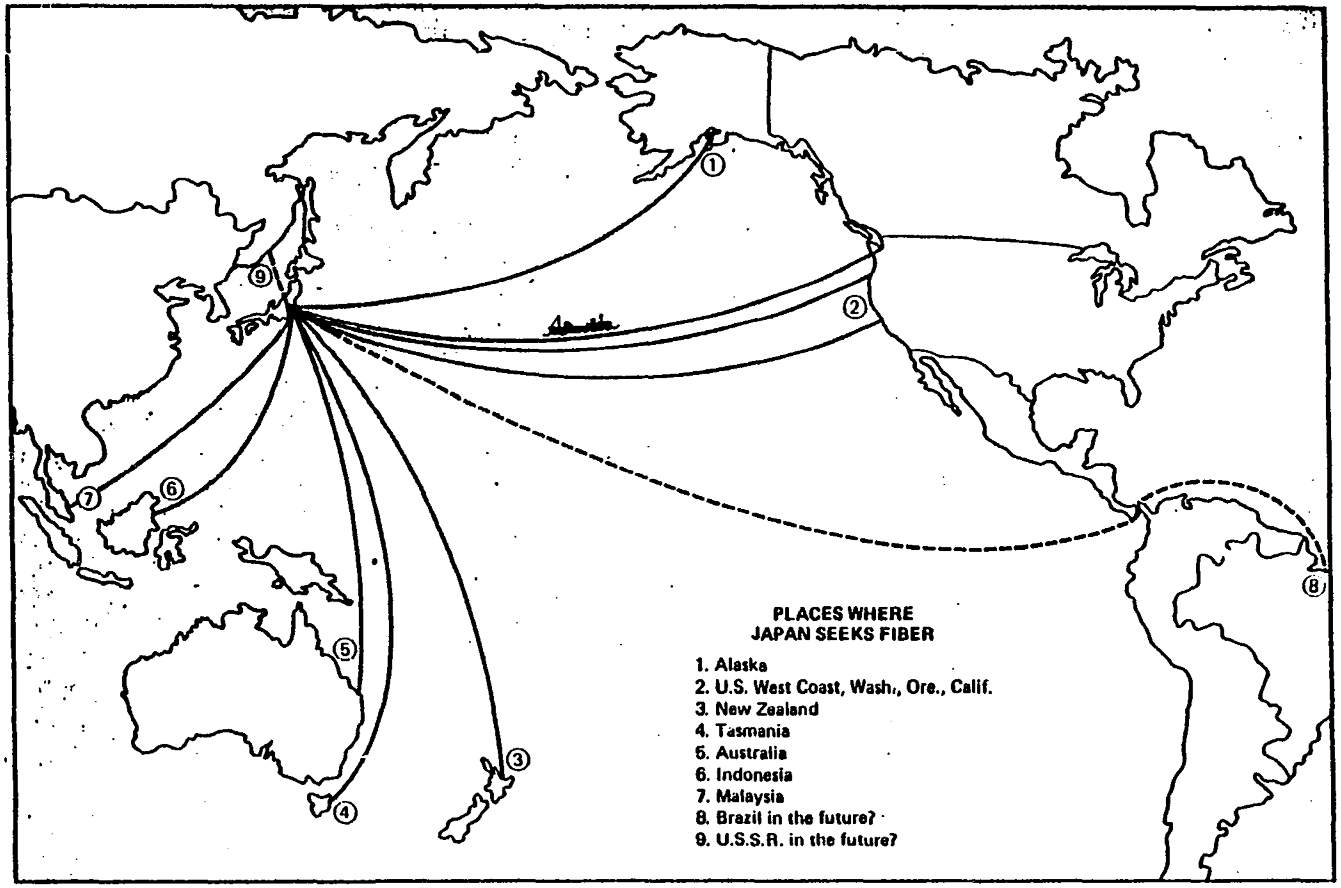
Figure 1 shows the major suppliers and potential sources of woodchips to Japan. They can be divided roughly into four regions, namely, North America, Oceania, Southeast Asia, and the USSR. The future availability of pulpwood from each region is the subject of this chapter and will be examined fully in the following sections.

China is not considered in this regional trade analysis due to lack of statistical data. According to the F.A.O., the last Chinese export of pulpwood was in 1971; Japan was the destination of the 35,300 cubic meters of pulpwood (32). It appears unlikely that China will export pulpwood in the near future.

## JAPAN

### Japan's Forest Resources

Japan's forest land covers 25.3 million hectares, or nearly 70 percent of the total land area. Of the total, 59 percent is privately owned and 41 percent is publicly owned. The land is comprised of natural and plantation forests, 57 percent and 37 percent respectively, while the remaining 6 percent is classified as "others". Afforested areas declined




Figures 1. Places Where Japan Seeks Fiber

Source: Vernon S. White, "Japan's Quest for Fiber Has Worldwide Impact," Pulp and Paper, Vol. 46, No. 9, Aug. 1972, p. 83.

from 402,000 hectares in 1966 to 288,000 hectares in 1976. A total of 76 percent of the stands are young as the result of heavy harvesting shortly after World War II. Tree stands are owned by companies, groups, shrines, temples, etc., with 90 percent of them owning less than 5 hectares; the average is 2.6 hectares (77).

Total Japanese forest resources are estimated at 2.1 billion cubic meters; approximately half are coniferous species and half are broad leaved. Sixty-one percent of forests are located on the main island of Honshu, 22 percent on Hokkaido, 11 percent on Kyushu and 6 percent on Shikoku. With the exception of the densely forested areas in northeastern Hokkaido, forest found throughout the whole country are separated into small units by steep slopes and valleys.

TABLE 5

ESTIMATED COMMERCIAL FOREST RESOURCES IN JAPAN

| | 1975 | 1985 | 2005 |
|---|---|---|---|
| Area (million ha.) | 25 | 25 | 25 |
| Growing Stock (million $m^3$) | 2000 | 2000 | 2500 |
| Increment (million $m^3$) | 80 | 90 | 1000 |
| Removals (million $m^3$ RWE*) | 110 | 130 | 170 |
| Removals as % of Growing Stock | 5.5 | 5.9 | 6.8 |
| Removals as Ratio of Increment | 1.38 | 1.44 | 1.70 |

*Roundwood equivalent

Source: A. J. Leslie, "An Australian Strategy for Planning Future Wood Production," New Zealand Journal of Forestry, Vol. 20, No. 2, 1975, p. 260.

In Table 5 the projected rates of removals in years 1985 and 2005 are greater than the increment of growing stock. This indicates that Japan's forest resources are depleting.

Japan's Future Pulpwood Requirements

Due to the scope of the subject matter and the imprecise nature of the data, the main thrust of the analyses in this chapter is concerned more with qualitative considerations rather than detailed quantitative analyses. However, the F.A.O. ten-year projection model (29) will be discussed to gain a better understanding, and the results obtained will be compared with other projections in this paper. The F.A.O. consumption model is presented here.

10-YEAR PROJECTIONS OF APPARENT CONSUMPTION OF PAPER AND PAPERBOARD
(Based on cross-section analyses of data for 1963-1965 and 1973-1975 for 127 countries)

Equation: $Cf = e^{a} C^{b} I_{f}^{c} I^{d}$

Where $Cf$ = future consumption metric tons per 1,000 capita

$C$ = present consumption metric tons per 1,000 capita

$e$ = base of natural logs

$I$ = present gross domestic product per capita (1975 US$)

$I_f$ = future gross domestic product per capita (1975 US$)

Due mainly to the energy crisis in mid-1970's, Japan's growth rate of gross domestic product (GDP) declined from the annual average of 11.6 percent in 1965-1970 period to 5.3 percent in 1970-1975 (29). The F.A.O. has projected that the future trend will be 5.8 and 5.5 percent average annual growth rate for 1980-1985 and 1985-1990 periods respectively. It seems clear that Japanese economy is unlikely to resume the high levels of growth which characterized it before the energy crisis.

TABLE 6

OUTLOOK FOR PAPER AND PAPERBOARD CONSUMPTION IN JAPAN

(In million tons)

| Year | Newspring | Other Pring and Writing Paper | Other Paper and Paperboard | Total Paper and Paperboard |
|---|---|---|---|---|
| 1973-75 | 2.2 | 2.7 | 9.9 | 14.8 |
| 1980 | 2.6-2.8 | 3.7-4.0 | 12.5-13.5 | 19.0-20.0 |
| 1985 | 3.2-3.6 | 4.8-6.0 | 16.0-18.0 | 24.0-27.0 |
| 1990 | 4.0-4.6 | 6.0-8.2 | 19.5-22.0 | 30.0-34.0 |

Source: F.A.O., World Pulp and Paper Demand, Supply and Trade-1, 1977, p. 23.

Table 6 presents a range of estimates on paper consumption based on different assumptions made by the F.A.O. They indicate that paper consumption in every category in Japan, except newsprint, will more than double from 1975 to 1990, even at the lower range.

The low estimates are generally in line with the recent thinking of many economists and international agencies. These will later be compared with estimates of production in order to draw attention to possible constraints on consumption and to their implication for trade. It is stressed, however, that projections are trends and do not attempt to allow for cyclical fluctuations.

A graphical presentation of Japan's consumption outlook for total paper and paperboard is presented in Figure 2. The average annual growth rate for 1975-1990 is projected to be 4.7 percent, a substantial declined from an annual rate of 8.7 percent since 1960. The total tonnage consumption

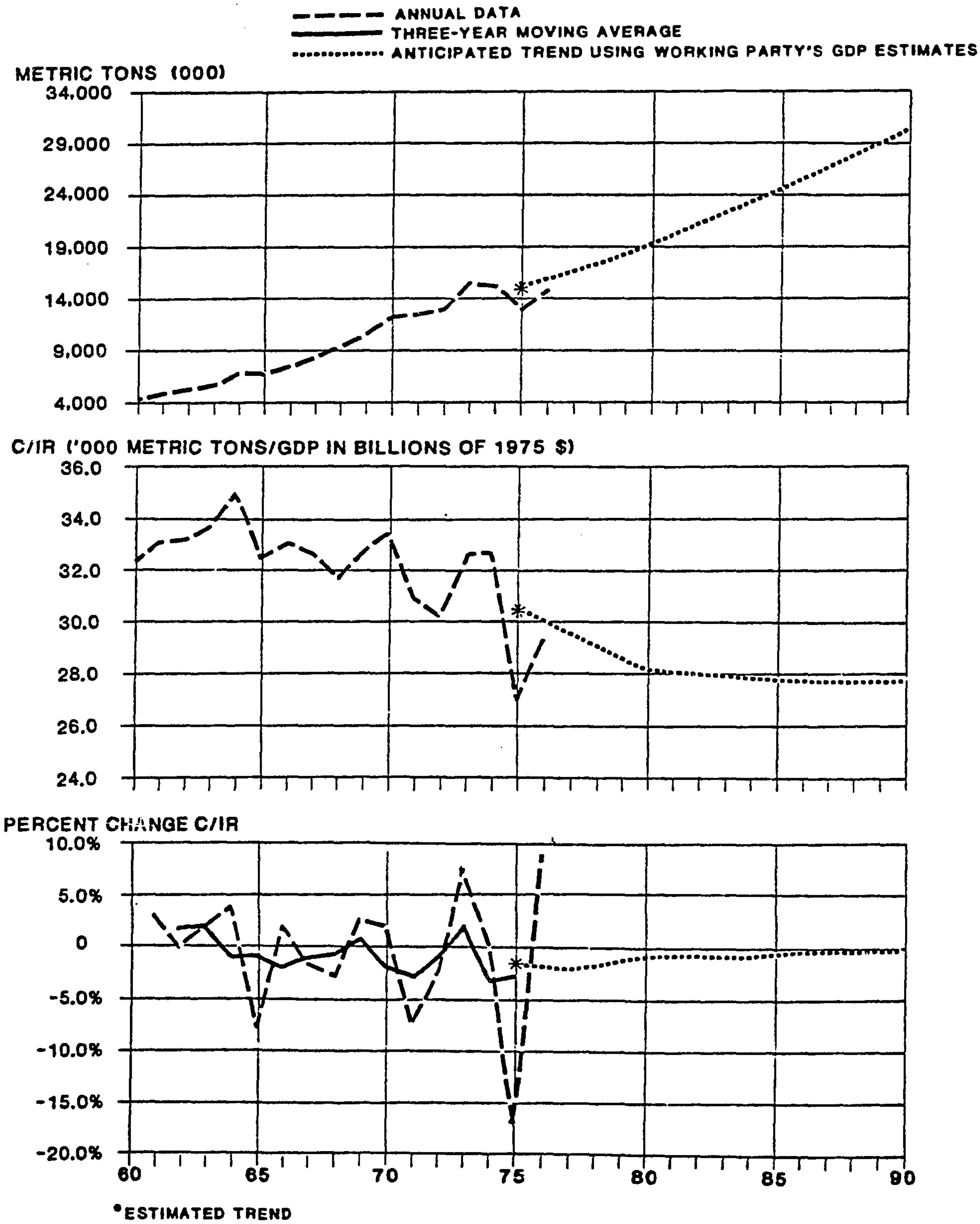



Figure 2. Consumption Outlook For Total Paper & Paperboard

Source: F.A.O., World Pulp and Paper Demand, Supply and Trade-1, 1977, p. 126.

of paper and paperboard will have an upward trend up to 1990 in absolute terms. However, there will be a decline in consumption in relation to gross domestic production.

The pulp and paper capacity survey issued in 1977 by the F.A.O. provides an indication of possible future production expansion as presented in Table 7. Based on this survey, a set of self-sufficiency estimates were derived from dividing the projected productions by the midpoint values of the projected consumptions presented in Table 6.

According to the self-sufficiency ratios presented in Table 8, Japan will remain a net exporter of printing and writing papers. This is of particular importance for eucalypt woodchip exporting countries because these chips are used mainly to manufacture fine printing and writing papers in Japan. For a fiber-deficit nation such as Japan to maintain its self-sufficiency in printing and writing papers, it will have to continue to import large quantities of woodchips as raw material for its pulp and paper production.

The estimated production of mechanical and semi-chemical pulps in 1990 was projected to be 6.5 million tons and chemical pulp to be 11.6 million tons. Total estimated pulpwood requirements presented in Table 9 were derived using approximate conversion ratio of 2.1 cubic meters raw wood material for one ton of mechanical or semi-chemical pulps and 3.7 cubic meters of pulpwood per ton of chemical pulp (29). This amounts to a requirement of 57 million cubic meters of pulpwood for paper, as shown in the table.

This estimate indicates that in 1990 Japan will have to import some 17 million cubic meters of pulpwood, assuming that domestic removals will supply 30 million cubic meters and another 17 million cubic meters would

TABLE 7

A TENTATIVE FUTURE PRODUCTION ALTERNATIVE
FOR PAPER AND PAPERBOARD IN JAPAN

(In million tons)

| Year | Newspring | Printing and Writing | Other Paper and Paperboard | Total Paper and Paperboard |
|---|---|---|---|---|
| 1973-75 | 2.17 | 2.8 | 10.06 | 15.07 |
| 1980 | 2.85 | 4.3 | 13.7 | 20.9 |
| 1990 | 4.3 | 7.8 | 21.4 | 33.5 |

Source: F.A.O., World Pulp and Paper Demand, Supply and Trade-1, 1977, p. 26.

TABLE 8

JAPAN'S SELF-SUFFICIENCY RATIOS* FOR PAPER AND PAPERBOARD

| | 1960 | 1965 | 1970 | 1975 | 1980 | 1990 |
|---|---|---|---|---|---|---|
| Newsprint | 1.01 | 1.00 | 0.97 | 1.04 | 1.05 | 1.00 |
| Printing and Writing Papers | 1.10 | 1.10 | 1.09 | 1.06 | 1.12 | 1.10 |
| Other Paper and Paperboard | 1.03 | 1.03 | 1.03 | 1.04 | 1.05 | 1.03 |

*Production divided by apparent consumption; actual for historical data; for 1980 using production (proportional to capacity estimates by regions) adequate to match world consumption estimates; assumed for 1990.

Source: F.A.O., World Pulp and Paper Demand, Supply and Trade-1, 1977, p. 72.

TABLE 9

PULPWOOD REQUIREMENTS AND SUPPLY FOR 1990

(In million cubic meters)

| | Requirements | | | Inter-regional Trade* | Supply | | |
|---|---|---|---|---|---|---|---|
| | For Paper Pulp | For Dissolving Pulp Particle Board Fireboard | Total | | Total | Removals | Residues |
| Developed Regions | 559 | 136 | 695 | -27 | 668 | 502 | 166 |
| North America | 358 | 42 | 400 | +10 | 410 | 310 | 100 |
| Western Europe | 136 | 84 | 220 | -26 | 194 | 150 | 44 |
| EEC | 25 | 55 | 80 | -21 | 59 | 42 | 17 |
| Nordic Countries | 81 | 14 | 95 | -5 | 90 | 70 | 20 |
| Other Western Europe | 30 | 15 | 45 | — | 45 | 38 | 7 |
| Japan | 57 | 7 | 64 | -17 | 47 | 30 | 17 |
| Oceania | 8 | 3 | 11 | +6 | 17 | 12 | 5 |
| Developing Regions | 55 | 20 | 75 | +18 | 93 | 62 | 31 |
| Latin America | 37 | 5 | 42 | +3 | 45 | 30 | 15 |
| Near East, North Africa | 3 | 4 | 7 | -2 | 5 | 4 | 1 |
| Africa (South of Sahara) | 6 | 5 | 11 | +2 | 13 | 8 | 5 |
| Far East | 9 | 6 | 15 | +15 | 30 | 20 | 10 |
| Centrally Planned Economies | 104 | 50 | 154 | +9 | 163 | 123 | 40 |
| WORLD TOTAL | 716 | 206 | 923 | — | 921 | 684 | 237 |

*Trade in roundwood, chips and residues: - denotes net import, + denotes net exports.

Source: F.A.O., World Pulp and Paper Demand, Supply and Trade-1, 1977, p. 37.

TABLE 10

PULPWOOD IMPORTS BY ORIGINS AND SPECIES 1960-1977

(In thousand cubic meters)

| Year | U.S.A. | U.S.S.R. | Australia | Southeast Asia and Other | | | | | TOTAL | Percent of total pulpwood consumption |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Malaysia | New Zealand | Indonesia | Other | Total | | |
| 1960 | | | | | | | | | | |
| Total | - | 192 | | | | | | 1 | 193 | 2 |
| of which softwood | - | 173 | | | | | | 1 | 174 | 2 |
| of which hardwood | - | 19 | | | | | | - | 19 | 0 |
| 1965 | | | | | | | | | | |
| Total | 253 | 167 | | 26 | | 9 | 6 | 41 | 461 | 3 |
| of which softwood | 253 | 142 | | | | | | 22 | 417 | 5 |
| of which hardwood | - | 25 | | | | | | 19 | 44 | 0 |
| 1970 | | | | | | | | | | |
| Total | 4,090 | 256 | - | 572 | 158 | 25 | 183 | 938 | 5,284 | 19 |
| of which softwood | 4,072 | 143 | - | - | 153 | - | 30 | 183 | 4,398 | 37 |
| of which hardwood | 18 | 113 | - | 572 | 5 | 25 | 153 | 755 | 886 | 5 |
| 1973 | | | | | | | | | | |
| Total | 7,501 | 418 | 2,048 | 664 | 301 | 194 | 97 | 3,304 | 11,223 | 34 |
| of which softwood | 7,409 | 195 | 3 | - | 239 | - | 50 | 292 | 7,896 | 52 |
| of which hardwood | 92 | 223 | 2,045 | 664 | 62 | 194 | 47 | 3,012 | 3,327 | 19 |
| 1974 | | | | | | | | | | |
| Total | 8,729 | 579 | 2,674 | 1,020 | 383 | 374 | 293 | 4,744 | 14,052 | 42 |
| of which softwood | 8,296 | 403 | - | 36 | 332 | - | 76 | 444 | 9,143 | 57 |
| of which hardwood | 433 | 176 | 2,674 | 984 | 51 | 374 | 217 | 4,300 | 4,909 | 29 |
| 1975 | | | | | | | | | | |
| total | 7,533 | 723 | 2,033 | 702 | 389 | 88 | 323 | 3,535 | 11,791 | 41 |
| of which softwood | 7,103 | 464 | - | - | 358 | - | - | 358 | 7,925 | 56 |
| of which hardwood | 430 | 259 | 2,033 | 702 | 31 | 88 | 323 | 3,177 | 3,866 | 26 |
| 1976 | | | | | | | | | | |
| Total | 8,528 | 768 | 2,441 | 515 | 369 | 85 | 573 | 3,983 | 13,279 | 42 |
| of which softwood | 7,964 | 528 | - | - | 359 | - | 20 | 379 | 8,871 | 57 |
| of which hardwood | 564 | 240 | 2,441 | 515 | 10 | 85 | 553 | 3,604 | 4,408 | 27 |
| 1977 | | | | | | | | | | |
| Total | 8,750 | 890 | 2,830 | 435 | 421 | 59 | 552 | 4,297 | 13,937 | 44 |
| of which softwood | 8,114 | 588 | - | - | 388 | - | - | 388 | 9,090 | 57 |
| of which hardwood | 636 | 302 | 2,830 | 435 | 33 | 59 | 552 | 3,909 | 4,847 | 30 |

Source: Japan Paper Association, Pulp and Paper Statistics 1978, p. 14.

be derived from residues as indicated in Table 9. Whether Japan can actually increase its domestic supply to the projected 47 million cubic meters in 1990 will remain to be seen.

In this projection, North America and Oceania, mainly the United States and Australia, will respectively have 10 and 6 million cubic meters of pulpwood available for exports in 1990 as presented in Table 9.

The F.A.O. estimate of 17 million cubic meters deficit in Japan, despite Japan's slower economic growth rates in recent years, seems to be rather conservative compared to other estimates and the recent trend on pulpwood imports. Table 10 shows that Japan's total pulpwood imports increased from 5.3 million cubic meters in 1970 to 14 million cubic meters in 1977. These volumes, respectively, represent 19 and 44 percent of total pulpwood consumption in those two years. Furthermore, a recent projection made by a Japanese bank indicates that Japan's pulpwood deficit will reach 17.4 million cubic meters in 1980, ten years ahead of the projection made by the F.A.O. The deficit will increase to 23 million cubic meters in 1985, as shown in Table 11.

TABLE 11

RECENT AND ESTIMATED PULPWOOD BALANCE IN JAPAN

(In thousand cubic meters)

| Year | Demand | Supply | Balance |
|---|---|---|---|
| 1970-72 | 29,300 | 22,200 | -7,100 |
| 1975 | 32,400 | 21,000 | -11,400 |
| 1980 | 37,900 | 20,500 | -17,400 |
| 1985 | 43,200 | 20,000 | -23,200 |

Source: The Industrial Bank of Japan, Japanese Finance and Industry, Quarterly Survey, Oct.-Dec., 1975, No. 30, pp. 30-31.

TABLE 12

PULPWOOD SUPPLY AND CONSUMPTION 1960-1977

(In thousand cubic meters)

| Year | Total Supply | | | | | | | Consumption | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Domestic Supply | | | Imports | | | Grand Total | | | |
| | Softwood | Hardwood | Total | Softwood | Hardwood | Total | | Softwood | Hardwood | Total |
| 1960 | 6,520 | 4,502 | 11,022 | 174 | 19 | 193 | 11,215 | 7,861 | 4,481 | 12,342 |
| 1965 | 7,617 | 8,535 | 16,152 | 417 | 44 | 461 | 16,613 | 7,956 | 8,893 | 16,849 |
| 1970 | 7,206 | 15,320 | 22,616 | 4,398 | 887 | 5,285 | 27,901 | 12,018 | 16,325 | 28,343 |
| 1973 | 7,143 | 14,015 | 21,158 | 7,896 | 3,327 | 11,223 | 32,381 | 15,131 | 17,784 | 32,915 |
| 1974 | 7,449 | 14,126 | 21,575 | 9,143 | 4,909 | 14,052 | 35,627 | 15,913 | 17,162 | 33,075 |
| 1975 | 6,636 | 10,360 | 16,996 | 7,925 | 3,866 | 11,791 | 28,787 | 14,217 | 14,595 | 28,812 |
| 1976 | 7,030 | 11,652 | 18,682 | 8,871 | 4,408 | 13,279 | 31,961 | 15,617 | 16,231 | 31,848 |
| 1977 | 6,904 | 11,194 | 18,098 | 9,010 | 4,858 | 13,868 | 31,966 | 15,900 | 15,939 | 31,839 |

Source: Japan Paper Association, Pulp and Paper Statistics 1978, p. 13.

Based on the recent trend of pulpwood imports presented in Table 12 and the aforementioned projections, it is reasonable to expect that Japan's pulpwood deficit in 1990 will be greater than 17 million cubic meters projected by the F.A.O. How much greater will depend on the levels of future domestic supply. Whether Japan can increase its domestic pulpwood supply from an annual average of 22 million cubic meters in 1973-75 period to 47 million cubic meters in 1990 as projected by the F.A.O. will remain to be proven (29).

Composition of Pulpwood Imports

According to the F.A.O. statistics (32), 86 percent of Japan's total pulpwood imports in 1977 are in woodchips, rising from 38 percent in 1966. Detailed information on pulpwood imported into Japan has been given in Table 10. The United States is by far the most important woodchips supplier, exporting some 8.75 million cubic meters to Japan in 1977. This amounts to 63 percent of the total imports of 14 million cubic meters, increased from 461,000 cubic meters in 1965. This clearly demonstrates Japan's increasing dependence on imported raw fibers.

The Soviet Union is Japan's most important source of pulp logs as indicated in Table 13. Export of woodchips from the USSR to Japan is relatively insignificant in terms of Japan's total imports. Other suppliers of pulpwood include Malaysia, New Zealand, Indonesia and Papua New Guinea.

In recent decades, there has been an increased proportion of non-coniferous species used for pulpwood. The rapid growth in the relative proportion of hardwood species for pulping has also been made possible by recent technical developments in pulp and paper manufacturing processes. Hardwood imports increased from 19,000 cubic meters in 1960 to 4.8 million

TABLE 13

MAJOR SUPPLIERS OF PULP LOGS TO JAPAN

(In thousand cubic meters)

| | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 |
|---|---|---|---|---|---|---|---|
| World | 1119 | 1163 | 1358 | 1345 | 1064 | 776 | 1244 |
| USSR | 745 | 957 | 1131 | 823 | 809 | 658 | 1161 |
| USA | | 2 | 3 | 132 | 23 | | |
| Asia | 351 | 187 | 194 | 241 | 87 | 66 | 41 |
| Oceania | 9 | | 15 | 126 | 145 | 47 | 42 |
| Others | 14 | 16 | 15 | 23 | | 5 | |

Source: F.A.O., Yearbook of Forest Products 1966-1977, 1979.

cubic meters in 1977, while softwood increased from 417,000 cubic meters to 9 million during the same period (Table 12). In 1977 Australia alone exported 2.8 million cubic meters of eucalypt woodchips to Japan (Table 10). This accounted for 53 percent of Japan's total hardwood imports, or 20 percent of total pulpwood imports. According to Table 10, hardwoods represent 9.8 and 34.7 percent of total pulpwood imported in 1960 and 1977, respectively. Obviously, the importance of hardwood in Japanese paper industry and the proportion of hardwood in Japan's total imports have increased significantly.

It can be concluded that the United States is Japan's largest woodchips supplier, mostly coniferous, while Australia is the largest supplier of hardwood eucalypt chips. Woodchip exports from Malaysia have been limited by the availability of wood of suitable pulping quality, while Canadian exports are constrained by quotas.

The importance of hardwood in Japanese pulp and paper industry can also be analyzed in terms of total pulpwood consumption. As presented in Table 12, hardwood comprised 4.5 million cubic meters or 36 percent of total pulpwood consumption in 1960 and increased to 16 million cubic meters or 50 percent in 1977. It has been projected that Japan's hardwood pulpwood and chip demand will be 29 million cubic meters in 1985 and 48 million cubic meters in 2000 (13). In terms of total pulpwood demand, they represent 60 and 64 percent, respectively. These figures provide potential hardwood woodchips producers with some indications on market potential in Japan.

## NORTH AMERICA

### Canada

Canadian forests include some 588 million acres of forest land suitable and available for timber production, or 18 percent more area than the commercial timberlands of the United States.

Canada is a major exporter of forest products. According to the F.A.O. statistics (32), in 1977 Canada exported 8.6 million metric tons, or 71 percent, of its paper and paperboard products, and 6.1 million metric tons of wood pulp. In the same year the United States exported 2.6 and 2.4 million metric tons of the two products, respectively. Canada's important markets include the United States, Western Europe, Japan and Australia.

Canada, however, exports a relatively insignificant and decreasing volume of pulpwood. From 1970 to 1977 it declined from 4.1 to 2.4 million cubic meters as shown in Table 14. Most of these exports found their markets in the United States, especially Washington State, as presented in Table 15.

TABLE 14

NORTH AMERICA PULPWOOD EXPORTS

(In thousand cubic meters)

| Year | Canada | United States | Total |
|---|---|---|---|
| 1970 | 4066 | 3711 | 7777 |
| 1971 | 3356 | 3116 | 6472 |
| 1972 | 2803 | 3965 | 6768 |
| 1973 | 2602 | 5235 | 7837 |
| 1974 | 2328 | 6074 | 8402 |
| 1975 | 1827 | 5040 | 6867 |
| 1976 | 2242 | 6095 | 8337 |
| 1977 | 2420 | 6152 | 8554 |

Source: F.A.O., Yearbook of Forest Products 1966-1977, 1979

## The United States Forest Resources

Some 754 million acres, or one third of the 2.3 billion acres of land in the United States, were classified as forest lands in 1970. About 500 million acres were classified as commercial timberland. Nearly three-quarters of the commercial timberland is located in the eastern half of the United States, about equally divided between the North and South sections. The remaining one-quarter of the Nation's commercial timberland is located in the West and is concentrated in Oregon, Washington, California, Montana, Idaho and Colorado.

In 1970, an estimated 2.8 billion cubic feet of slabs, sawdust, veneer cores, and other similar material resulting from the manufacture of lumber and other wood products was used for pulp, particleboard, fuel, or other

TABLE 15

VOLUME AND AVERAGE VALUE OF PULPWOOD IMPORTS
FROM CANADA INTO THE WASHINGTON CUSTOMS DISTRICT
1965 - 1979

| | Chipped Pulpwood | | Roundwood Pulpwood | |
|---|---|---|---|---|
| Year | Short tons | Dollars | Cords | Dollars |
| 1965 | 783,723 | 8.06 | 243 | 19.91 |
| 1966 | 821,814 | 7.87 | 10,789 | NA |
| 1967 | 1,182,581 | 9.31 | 3,529 | NA |
| 1968 | 1,047,384 | 7,60 | 3,720 | NA |
| 1969 | 581,167 | 7.78 | 3,174 | NA |
| 1970 | 795,044 | 8.44 | 17,501 | NA |
| 1971 | 1,157,444 | 9.57 | 3,944 | 19.47 |
| 1972 | 909,926 | 9.87 | 2,300 | 47.56 |
| 1973 | 1,085,124 | 11.19 | 16 | 97.06 |
| 1974 | 623,830 | 15.55 | 31,998 | 60.08 |
| 1975 | 493,761 | 23.36 | 11,517 | 42.90 |
| 1976 | 877,550 | 20.98 | 1,967 | 32.14 |
| 1977 | 1,056,102 | 18.59 | 16,674 | 91.19 |
| 1978 | 1,215,483 | 16.37 | — | — |
| 1979 | 1,039,458 | 17.19 | — | — |

NA = Not Available.

Source: Florence K. Ruderman, Production, Prices, Employment, and Trade in Northwest Forest Industries, Forth Quarter, 1979, U.S.D.A., Forest Service, Portland, Oregon. Data are compiled from U.S. Dept. of Commerce records at the end of each quarter. Value is declared value at port of entry.

products. Almost 1.8 billion cubic feet (about 22 million cords) was used for pulp in 1970, including nearly 2 million cords of chip exports to Japan. Use of such material for pulping increased nearly 18-fold between 1952 and 1970 (97).

In spite of the rapid growth in use of wood byproducts, in 1970 almost one billion cubic feet (more than 12 million cords) of material was left unused at sawmills and other primary manufacturing plants. About two-thirds of this unused material was softwood, 40 percent of which was chippable residues including slabs, edgings, and other coarse material (97); most of this volume was on the Pacific Coast.

## Woodchip Exports

Except for Europe, Japan will remain the world's largest consuming country, continuing to depend heavily on imported pulpwood to support the increasing demands of its pulp and paper industry. It has been pointed out in the preceding section that the United States is Japan's most important overseas source of long-fibered pulpwood which accounted for 63 percent of Japan's total imports in 1977. Australia's exports were entirely short-fibered eucalypt woodchips.

According to the F.A.O. statistics, over 95 percent of pulpwood exports from the United States is in the form of woodchips (32). Woodchip exports to Japan increased from 2.4 million short tons in 1970 to 4.1 million short tons in 1979, as shown in Table 16. This accounts for over 95 percent of total woodchip exports from the United States, and almost all of these exports are from the West Coast, namely, Oregon, Washington, California, and Alaska, as presented in Table 17.

TABLE 16

U.S. WOODCHIP EXPORTS TO JAPAN 1970-1977

| Year | Short Tons | Dollars | $/Short Tons |
|---|---|---|---|
| 1970 | 2,317,389 | 36,611,341 | 15.80 |
| 1971 | 1,975,262 | 41,041,056 | 20.78 |
| 1972 | 2,509,436 | 56,799,433 | 22.63 |
| 1973 | 3,442,233 | 84,551,908 | 24.56 |
| 1974 | 3,808,965 | 113,025,468 | 29.67 |
| 1975 | 3,045,622 | 109,519,327 | 35.96 |
| 1976 | 3,808,258 | 147,733,968 | 38.79 |
| 1977 | 3,822,611 | 169,177,692 | 44.00 |
| 1978 | 3,436,226 | 148,109,596 | 43.10 |
| 1979 | 4,128,974 | 180,628,825 | 43.75 |

Source: U.S. Department of Commerce, U.S. Exports, FT610/Annual

The combination of concentrations of deep water ports, productive forest lands, and railroad development in U.S. Pacific Northwest gives excellent access to Japanese pulpwood importers. The Pacific Northwest, therefore, is the logical center for present and future North America woodchip export activity to Japan. For these reasons, it has been suggested that the price of international trade on softwood chips will be based on the rate for North America, namely the West Coast of the United States.

The United States West Coast softwood chip values have risen rapidly since 1972 as the lumber and plywood mill residual base bacame fully exploited and woodchip suppliers had to begin supplementing supplies with

TABLE 17

VOLUME (IN SHORT TONS, OVENDRIED BASIS) AND AVERAGE VALUE (IN DOLLARS PER SHORT TON) OF CHIPS EXPORTED FROM THE WASHINGTON, OREGON, SAN FRANCISCO, AND ALASKA CUSTOMS DISTRICTS, 1965-79*

| Year | Washington Customs District | | Oregon Customs District | | San Francisco Customs District | | Alaska Customs District | |
|---|---|---|---|---|---|---|---|---|
| | Volume | value | Volume | Value | Volume | Value | Volume | Value |
| 1965 | - | - | 91,646 | 19.74 | - | - | - | - |
| 1966 | - | - | 219,181 | 19.68 | - | | - | - |
| 1967 | - | - | 603,314 | 19.75 | 38,291 | NA | - | - |
| 1968 | 112,132 | 22.23 | 1,102,669 | 20.25 | 77,381 | 15.90 | - | - |
| 1969 | 160,165 | 24.52 | 1,460,669 | 21.10 | 83,520 | 15.16 | - | - |
| 1970 | 238,757 | 19.56 | 1,605,062 | 19.31 | 267,347 | NA | - | - |
| 1971 | 229,237 | 17.87 | 1,504,169 | 20.94 | 467,400 | NA | 19,600 | 28.06 |
| 1972 | 168,725 | 19.56 | 2,081,032 | 22.12 | 253,401 | 24.76 | 20,185 | 25.76 |
| 1973 | 272,196 | 21.84 | 2,778,829 | 24.85 | 369,403 | 24.41 | - | - |
| 1974 | 390,370 | 28.62 | 3,177,465 | 26.50 | 242,017 | 30.69 | 34,828 | 28.99 |
| 1975 | 326,083 | 38.56 | 2,436,807 | 34.74 | 257,735 | 28.96 | 32,399 | 48.51 |
| 1976 | 457,801 | 33.39 | 2,881,577 | 39.90 | 366,678 | 34.76 | 107,652 | 37.89 |
| 1977 | 281,540 | 49.17 | 2,892,333 | 43.33 | 519,444 | 42.91 | 107,429 | 51.67 |
| 1978 | 299,140 | 46.16 | 2,650,423 | 42.98 | 412,107 | 40.82 | 31,827 | 37.20 |
| 1979 | 346,209 | 50.05 | 3,125,103 | 42.55 | 603,989 | 44.69 | 83,706 | 48.62 |

NA = Not available

*Data through 1969 were compiled in cords and value per cord and converted to bone-dry tons and value per bone-dry ton using the following formula:

Number of cords x 1.2 = Number of short tons.

Dollars per cord x 0.8333 = Dollars per short ton.

Source: U.S. Department of Commerce except for San Francisco data for 1970 and 1971 which were obtained from the Port of Sacramento. The valuation definition used in the export statistics is the value at the seaport or border port of exportation. It is based on the selling price (or cost if not sold) and includes inland freight, insurance, and other charges to the port of exportation. Washington Customs District includes all ports in the State of Washington, except Longview and Vancouver. Oregon Customs District includes all Oregon ports and Longview and Vancouver, Washington. San Francisco Customs District includes all coastal and inland ports in the State of California from Monterey north. The Alaska Customs District is the State of Alaska.

high-cost fiber log chips. In 1965, woodchip exports from the West Coast totalled only 160,000 cubic meters, and they were entirely lumber and plywood manufacturing residues. By 1970 volume had grown to 3.5 million cubic meters and 12 percent of the volume was coming from higher cost fiber log chipping. In 1975, 24 percent of the ten million cubic meters came from roundwood source which cost 2.5 times as much to collect and chip (13).

As indicated in Table 9 in the earlier section, the F.A.O. has estimated that North America will have 10 million cubic meters of pulpwood available for export in 1990. However, only the volume produced by the United States will be available for the Japanese pulp and paper industry because Canada currently does not and probably will not export pulpwood to Japan due to its export restriction. Assuming that the United States will maintain its recent proportion of North America pulpwood exports (approximately 70 percent as presented in Table 14), Japan will be able to import only 7 million cubic meters from the United States in 1990. However, the actual level of supply will depend, among other factors, on the price of woodchips at that time.

The activities in the construction industry in the United States will affect the price and availability of woodchips to a certain extent since the residues from lumber and plywood mills provide the least cost source of woodchips. Price increases in energy may also affect the availability of woodchips for pulp to some extent.

## The United States Trade Policy

There is no doubt that North America has the physical capacity to supply increasing Japanese pulpwood needs in the foreseeable future. It has the soil, climate and infrastructure which can increase forest production levels. These are the very factors that draw back forest productivity in the Soviet Union despite its huge inventories. However, the nature of the trade and the U.S. trade policies could change under changes in political climate and thus could affect the availability of pulpwood.

Due to rising domestic demand for lumber and other wood products in the late sixties, the export of raw material, especially to Japan, generated strong public opposition in the United States. As a result, an administrative export restriction was imposed in 1968, requiring that all timber harvested from Federal lands in Oregon and Washington be given primary manufacture in the United States. The primary purpose of the legislation was not to preserve lumber for domestic consumption but to protect local sawmills unable to compete for the raw material. The legislation did not restrict the export of lumber, only logs. Furthermore, some of the species preferred by the Japanese, such as hemlock and cedar, traditionally have had little market in the United States. If they were not exported, some of these species would not be sold domestically but would either be left unharvested or disposed of as slash (89).

Although the aforementioned development did not directly affect the exportation of woodchips, a semi-processed product, it did restrict the export of pulp logs. Woodchip trade would be affected if further processing were required as in the case of Alaska when Japanese investment was made in Alaska Pulp Company in 1953. Initially Japan planned to import Alaskan timber principally as pulpwood. However, when American regulations required that timber be locally processed, a pulpmill was constructed; almost all of the pulp output has been delivered to the

Japanese paper industry (60). The restriction on log exports from Alaska then was aimed at supporting local industry and the desirability of stimulating Alaskan development.

It is the Jones Act of 1931, together with the proximity of Alaska to Japan, which is responsible for the shipment of forest products to Japan. It also hampers shipment from Alaska to the rest of the nation. The inefficiency arising from this act makes it cheaper to import Canadian timber than to transport it to the East Coast from the Pacific Northwest.

This export restriction has not affected Hawaii's woodchip exports to Japan for two main reasons. The first reason is that woodchips, unlike pulplogs, are semi-finished product. And secondly, they were not harvested from federal land in Hawaii where federal forest holding is extremely small.

A possible impact of further trade restrictions has been clearly stated by Nelson (83).

> Any curtailment of exports can only cause Japan to look to other sources for the supply it believes it needs. In this case, it would almost surely mean larger purchased from British Columbia which would, in turn, reduce the availability of Canadian lumber for export to the United States. The fact that the U.S. exports logs, whereas British Columbia insists on some degree of fabrication, is largely irrelevant in this connection. While there would not be a one-to-one correspondence between a curtailment of U.S. exports to Japan and a reduction of imports from Canada, they would no doubt substantially offset each other. Moreover, there are so many delicate factors involved in U.S. trade relations with Japan that any further moves to reduce log exports could entail quite serious penalties on other fronts.

Zivnuska (110) pointed out a very interesting fact about the United States' imports of Canadian wood. Canada has some 20 percent greater forest area and wood volume, but it has about 10 percent of the United States' population. Inevitably, the Canadians turn primarily to the export market where the United States constitutes its single largest market. In fact, the United States consumes about 50 percent more wood from Canada annually than do the Canadians. Moreover, the two nations share the same species and forest types, common technology, similar cost patterns, and, in many cases, the same corporate control.

Unlike Japan, the United States has not depended heavily upon international trade. Trade with the world has accounted for only a small percentage of its gross national product. For this reason, not until the Arab oil embargo did the American general public really realize that the United States is part of the world economy. It would be unimaginable for the United States to call for a free international movement of raw materials which it needs while restricting the exports of basic commodities it produces. Better policies in the long run should instead call for more efficiency in both production and consumption of raw materials.

## OCEANIA

### Australia's Forest Resources

Forest resources in Oceania can roughly be classified as eucalypts in Australia, softwoods in New Zealand, and mixed tropical hardwoods in Papua New Guinea.

Australia is a very dry continent; only 15 percent of the land was forested at the time of European settlement. Today less than 6 percent is forested, as seen in Figure 3.

The total area of forest in Australia is 44 million hectares. Of this area, 35.5 million hectares are on publicly owned land and 8.5 million hectares are on privately owned land. Of the publicly owned forest, 35 percent is permanently dedicated for timber production, 60 percent is used for timber production but is not permanently dedicated, and 5 percent is reserved for non-timber values such as national parks. Table 18 presents detailed statistics by each state.


Figure 3. Distribution of Forests-Australia
(Excluding cypress pine forests and woodlands)

Source: Dept. of Industry and Commerce, Australia, The Australian Wood Pulp Industry: Supply Potential, Canberra, Australia, 1979, p. 15.

## TABLE 18

LAND AREAS, CLASSIFIED BY VEGETATION COVER GROUPS, 30 JUNE 1978
AUSTRALIA, STATES AND TERRITORIES

(In thousands of hectares)

| Vegetation cover group | State or Territory | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NSW | VIC | QLD | SA | WA | TAS | ACT | NT | Total* |
| Forest† | 16,300 | 6,200 | 11,900 | 100 | 3,200 | 2,800 | 60 | 3,270 | 44,000 |
| Woodland§ | 3,300 | 2,900 | 28,200 | 900 | 20,600 | 2,100 | 5 | 7,000 | 65,000 |
| Total Land Area | 80,160 | 22,760 | 172,720 | 98,400 | 252,550 | 6,780 | 240 | 134,620 | 768,000 |
| Forest† | (19.4) | (27.2) | (6.9) | (0.1) | (1.3) | (40.8) | (27.9) | (2.4) | (5.6) |
| Woodland§ | (4.1) | (9.2) | (16.3) | (0.9) | (8.2) | (31.0) | (2.1) | (5.2) | (8.3) |

*Rounded to nearest million hectares.

†Includes native forest with existing or potential stand height of 20 meters or more, cypress pine forest in commercial use regardless of stand height, and forest plantations.

§Approximately defined as vegetation having a top stratum of trees 10 meters or more in height and crown cover between 10 and 30 percent per unit land area occupied.

Note: Figures in brackets are percentages of total land area for each State or Territory.

Source: Department of Primary Industry, Australian Forest Resources 1978, Canberra, 1979, p. 2.

TABLE 19

AREAS OF EUCALYPT FOREST IN AUSTRALIA

(In hectares)

| State | Ownership | | | Total |
|---|---|---|---|---|
| | Public | National Park | Private | |
| Queensland | 7679000 | 197000 | 1158000 | 9034000 |
| New South Wales (including A.C.T.) | 7795300 | 809600 | 4603900 | 13208800 |
| Victoria | 5108000 | 128100 | 549500 | 5785600 |
| Tasmania | 1227300 | 94400 | 973500 | 2295200 |
| Western Australia | 2303100 | 34000 | 688400 | 3025500 |
| Northern Territory | 2144000 | 306400 | — | 2450400 |
| Australia | 26256700 | 1568500 | 7973300 | 35799500 |

Source: Report of Panel No. 2, Appendix 3, FORWOOD Conference, Canberra, Australia, 1974.

The native forest, mostly eucalypts, comprises 99 percent of the total forest area in Australia. Coniferous and braodleaved plantations total only 1 percent of the forest area. Areas of eucalypt forest are presented in Table 19.

The eucalypts are possessed of great powers of regeneration. Even if nothing had been done by man to encourage regeneration, the remarkable eucalypts would have quickly produced natural regeneration or second growth resulting from four main sources. These are the coppice from cut stumps, shoots from lignotubers, some seedling growth and the flushing of dormant buds on seemingly fire-killed trees to produce epicormic shoots, which will keep the tree alive until it has been able to re-establish a crown (100).

Australia's Pulp and Paper Industry

In 1976-77, 23 percent of Australia's total forest products consumption was in the form of paper products, as indicated in Table 20, while only 9 percent of total wood removals from Australia's forest was used in papermaking. Therefore, Australia has to import large quantities of pulp, paper and paper products.

Being a net importer of pulp, paper and paper products, it does not mean that Australia has inadequate forest resources. In fact, Australia exports large quantities of eucalypt woodchips to Japan as raw material for papermaking. The present level of hardwood pulpwood removal in Australia is 4.6 million cubic meters per year, of which 3.5 million cubic meters are exported (6). In addition, the availability of low cost electrical energy generated from Australia's extensive coal reserves is particularly important in the manufacture of mechanical pulps.

Despite these favorable conditions, Australia has not been self-sufficient in paper products. Ferguson has suggested that capital formation, risk and profitability are three interrelated and critical determinants of future investment in the pulp and paper industry (38).

While a typical woodchip venture can be established for around $20 million, a pulpmill to process the same amount of wood, between one and 1.5 million cubic meters, could cost over $200 million (6). Financing investment of this scale may be difficult. A 25 percent increase in the total capital cost has also been quoted for environmental protection which further exacerbates the problem (76).

Besides large capital requirements, there are uncertainties regarding investments in new capacity. Ferguson observed that an optimal scale is so large that a new plant may represent a significant additional production

TABLE 20

REMOVAL, PRODUCTION AND USAGE OF AUSTRALIAN PULPWOOD 1972-1977

| Item | Unit | 1972-73 | 1973-74 | 1974-75 | 1975-76 | 1976-77 |
|---|---|---|---|---|---|---|
| Total Wood Removal | 1,000 $m^3$ | 12,586 | 13,699 | 13,771 | 12,872 | 13,889 |
| Estimated Removals of Pulpwood | 1,000 $m^3$ | 2,441 | 3,985 | 4,295 | 3,677 | 4,831 |
| Woodchip Exports | 1,000 $m^3$ | 1,709 | 2,930 | 2,822 | 2,565 | 3,557 |
| Estimated Pulpwood for Australia Papermaking | 1,000 $m^3$ | 732 | 1,055 | 1,473 | 1,102 | 1,274 |
| Pulpwood for Australian Papermaking as Proportion of Total Wood Removals | % | 6 | 7.7 | 10.7 | 8.6 | 9.2 |
| Log Equivalent of All Forest Products Consumed | 1,000 $m^3$ | 16,413 | 15,735 | 16,030 | 14,826 | 15,559 |
| Log Equivalent of Paper and Paper Consumed | 1,000 $m^3$ | 4,434 | 3,907 | 4,384 | 3,052 | 3,561 |
| Paper Products as Proportion of All Forest Products Consumed | % | 27 | 25 | 27 | 21 | 23 |

Source: Department of Primary Industry, Australian Forest Resources 1977, Canberra, Australia, 1978, Tables 5, 6, pp. 40-41, and Table 30, p. 66.

to local markets. The gestation period from investment decision to commencement of production often takes more than three years and markets can fluctuate widely during this period (38). Prices tend to be volatile because stocks of market pulp are generally small relative to international trade (16). In other words, it is the price instability and low profit that make it difficult to finance capital improvements and new construction. In addition, the surplus resource of eucalypt fibers is not consistent with Australian requirements of long fiber conifers. In the absence of any apparent shortage of short-fibered pulp in Australia relative to papermaking capacity at present, the output of an additional pulpmill would presumably be export oriented.

However, it has been cautioned that if production for export were planned to be a large proportion of total production, a failure of anticipated exports would be likely to significantly depress returns to producers (16). Therefore, unless profitable export markets can be found for supplies in excess of domestic pulp and paper requirements, Australia's woodchips will continue to be exported since the profitability of woodchip exports seems considerably more assured than for a pulpmill, especially considering the far greater capital investment required by the latter.

Currently, there are five woodchip operations in Australia, three in Tasmania, one in Western Australia and another one at Eden, New South Wales, as shown earlier in Figure 3. In order to have a clear understanding of Australia's woodchip exports, it is important to examine the role of Australian Federal and State Governments. The operations of woodchip companies are subject to a number of administrative arrangements and regulations.

## Government Controls on Australian Woodchip Exports

The authority and responsibility of states regarding woodchips obtained from publicly owned forests are clearly spelled out in the Australian Parliamentary Paper No. 116, as quoted here (3).

> Management and control of the publicly owned forest resources in the States are the responsibility of the State Governments. The State Governments determine whether a pulpwood concession area of Crown land should be developed and by whom it should be developed, the conditions of sale of the pulpwood, including such aspects as volume, royalty payable and responsibility for roading are determined by the State forest services. The forest services are also responsible for regenerating logged publicly-owned forest areas in all existing woodchip concessions and have an overall responsibility to ensure that harvesting is carried out in accordance with the conditions set out in the special licenses issued to woodchip companies.

Although State Governments control and allocate the publicly owned state forest, it is the Australian government that has overriding power by refusing to grant an export license, thus preventing the development of a woodchip project. The export of woodchips is controlled under the Customs (Prohibited Exports) Regulations and an export approval must be obtained from the Australian Minister of Agriculture. This requirement and the associated controls were initially introduced to ensure that adequate prices are received for woodchips exported and that a reasonable degree of further processing in Australia be investigated and implemented if found feasible. Therefore, the export woodchip industry is considered to be a transition state in development of an expanded domestic pulp and paper industry.

Exports will not be permitted unless the contract price reached by a woodchip company is equivalent to or above ruling world market prices, taking into account the quality of woodchips and other relevant factors. Ferguson and Parke suggested that prices in Australia have tended to follow those for exports of woodchips in the United States, but increases have been erratic because of the longer terms offered by the Australian contracts (37). Another objective of the control over prices negotiated is to ensure that contracts contain adequate provision for price escalation over time.

There are, however, few State Government controls over the use of privately owned forest. It has been estimated that about one-third of the forest area to be affected by logging operations under existing approved licenses is in privately owned forest (3); a very large proportion of this area is in Tasmania. Under this situation, the Australian government may impose certain conditions deemed necessary in granting an export license. For example, an approval granted to a company in Tasmania producing woodchips from privately owned pulpwood resources was conditional on the company carrying out a reforestation program on private lands of 2,000 hectares per annum from 1977. Woodchip areas granted to the existing companies and quantities of woodchips approved for export are presented in Table 21.

Eucalypt Woodchip Exports and Their Future Availability

Detailed information on woodchip exports to Japan is presented in Table 22. In comparing Tables 22 with 23, it is noted that the contract periods run concurrently with export approvals, 5 to 20 years. Volumes contracted range from 3.4 to 8.7 million green tons. Tasmania is Australia's forest state where three out of five of Australia's woodchip companies are located. In 1977-78 its exports accounted for approximately two-thirds of three million tons of Australian woodchip exports to Japan as shown in Table 24

The Australian Parliament in 1975 made a very comprehensive study on the prospects of the export hardwood woodchip industry (3). It also

TABLE 21

WOODCHIP AREAS AND QUANTITIES OF WOODCHIPS APPROVED FOR EXPORT*

| Export Woodchip Companies | Forested Concession Area Excluding National Parks | Estimated Area Cut-over | Forest License | Export Approval† |
|---|---|---|---|---|
| | (hectares) | (hectares p.a.) | (tonnes p.a.) | (tonnes p.a.) |
| New South Wales | | | | |
| Harris-Daishowa (Aust) Pty Ltd (Export approved 1970-76) | 255,000 | 5,500 | 508,000 | 610,000§ |
| Tasmania | | | | |
| Tasmanian Pulp and Forest Holdings Ltd (Exports approved 1971-1988) | 350,000 | 5,100 | 508,000 | 710,000 |
| Associated Pulp and Paper Mills Ltd | | | | |
| (Exports approved 1972-1983) | 326,000 | 5,300 | 508,000 | 610,000 |
| (Exports approved 1973-1978) | 136,000 | | 255,000 | 365,000 |
| Northern Woodchips Pty Ltd (Exports approved 1972-1986) | — | — | — | 710,000 |
| Western Australia | | | | |
| W. A. Chip and Pulp Co. Pty Ltd (Exports approved for 15 years after first woodchip export) | 519,000 | 10,000 | 680,000 | 750,000 |
| Total | 1,586,000 | 15,900 | 2,459,000 | 3,755,000 |

*Columns 1,2 and 3 relate only to eucalypt forests on publicly-owned land.

†The difference between quantity approved for export and the quantity obtainable from publicly-owned land under the forest licence is derived from sawmill residues and operations on private property.

§ The company has a separate licence to export an additional 152,000 tonnes of woodchips annually derived solely from sawmill residues.

Note: In view of the differing time periods of forest licences and export approvals, caution must be exercised in using the total figures presented in this table.

Source: The Parliament of the Commonwealth of Australia, Economic and Environmental Aspects of the Export Hardwood Woodchip Industry, Parliamentary Paper No. 116, 1975, p. 24.

TABLE 22

AUSTRALIAN CHIP EXPORT INDUSTRIES

| Company | Harris-Daishowa (Australia) Pty. Ltd. | Tasmanian Pulp & Forest Holdings Pty. Ltd. | Associated Pulp & Paper Mills Ltd. (Tamar Division) | Northern Woodchips Pty. Ltd. |
|---|---|---|---|---|
| Location | Eden, N.S.W. | Triabunna, Tas. | Long Reach, Tas. | Long Reach, Tas. |
| Total quantity of chips under contract (million tonnes, green) | 3.4 | 7.7 | 8.7 | 5.8* |
| Contract period (years) | 20 | 15 | 1. 11½<br>2. 5½ | 15 |
| Annual export quantity (tonnes, green) | 610,000** | 610,000† | 915,000†† | 710,000§ |
| Number of ships and capacity (tonnes) | 1x24,000<br>1x54,000 | 2x31,000 | 3x41,000 | 1x20,000<br>2x38,500§§ |
| Number of sailings per year | 18 | 20 | ca. 25 | ca. 18 |
| Date exports commenced | 1970 | 1971 | 1972 | 1972 |
| Purchasing Company | Daishowa | Jujo | Sanyo-Kokusaku<br>Mitsubishi | Taio |
| Chip destination | Suzakawa mill | Isinomaki mill | Iwakuni mill<br>Hachinohe mill | Iyomishima mill |

*The company has options to increase this quantity to 9.3 million tonnes.

**Includes 100,000 tonnes of chips to be supplied by Gippsland Pulp and Paper Ltd.

†About 80% from Crown lands, remainder from private forest and sawmill residues.

††Two contracts involved (1) — 1972 to 1983 for 610,000 tonnes/year and (2) — 1973 to 1978 for 310,000 tonnes/year. About 8% of the chips exported are purchased from sawmills.

§All wood from private forests and sawmill residues.

§§One ship expected mid-1973 and one later, possibly to replace the smaller vessel.

Source: H. G. Higgins and F. H. Phillips, "Technical and Economic Factors in the Export of Woodchips from Australia and Papua New Guinea," Australian Forest Industries Journal, Vol. 39, No. 2, March 1973, p. 35.

TABLE 23

DURATION AND EXPIRY DATE OF WOODCHIP COMPANY APPROVALS

| Woodchip Areas | State Forest Licence | | Export Approval | |
|---|---|---|---|---|
| | Duration (Years) | Expiry Date | Duration (Years) | Expiry Date |
| Harris-Daishowa | 20 | 1989 | 6 | 1976 |
| TPFH | 18 | 1989 | 18 | 1989 |
| APPM (1)* | 11 | 1983 | 11 | 1983 |
| APPM (2)† | 5½ | 1978 | 5½ | 1978 |
| Northern Woodchips | not applicable | | 15 | 1987 |
| W. A. Chip & Pulp Co. | 15 | 1991 | 15 | 1991 |

*Initial approval to export 610,000 tonnes of woodchips per annum

†A Further approval for the export of 365,000 tonnes of woodchips per annum.

Source: The Parliament of the Commonwealth of Australia, Economic and Environmental Aspects of the Export Hardwood Woodchip Industry, Parliamentary Paper No. 116, 1976, p. 12.

TABLE 24

EXPORT OF WOODCHIPS BY STATE 1977-1978*

(In thousand tonnes. Percentage of total shown in brackets)

| Year | N.S.W. & W.A. | TASMANIA | TOTAL AUSTRALIA |
|---|---|---|---|
| 1973-1974 | 514 (19.3) | 2,150 (80.7) | 2,664 |
| 1974-1975 | 405 (15.8) | 2,161 (84.2) | 2,566 |
| 1975-1976 | 643 (27.5) | 1,693 (72.5) | 2,336 |
| 1976-1977 | 1,099 (34.0) | 2,135 (66.0) | 3,234 |
| 1977-1978† | 1,091 (34.8) | 2,041 (65.2) | 3,132 |

*Australia totals are actual exports from A.B.S. Overseas Trade Bulletins, 1976-1977 is unpublished and 1977-1978 is preliminary.

Tasmanian exports have been assumed to be identical with actual Tasmanian production for export. A.B.S. Sawmilling, Woodchipping, etc., Statistics, reference 8203.6.

N.S.W. and W.A. exports are a residual.

†Proportionate f.o.b. values allocated for 1977-1978 would be N.S.W. and W.A. $29 million, Tasmania $54 million, Australia $82 million.

Source: Australia, Submission by the Government of Tasmania to the Senate Standing Committee on Trade and Commerce Inquiry, Forestry and Forestry Based Industries, March 1979.

TABLE 25

PROJECTIONS OF AUSTRALIA'S POPULATION AND PER CAPITA GROSS NATIONAL PRODUCT

| Year | G.N.P. per capita (1966-67 dollars) | Population (million) |
|---|---|---|
| 1980 | 2,947 | 15.1 |
| 1990 | 3,656 | 18.2 |
| 2000 | 4,551 | 21.5 |
| 2010 | 5,694 | 25.2 |

Source: FORWOOD Conference, "Panel Reports and Recommendations," Australian Forest Industries Journal, Vol. 40, No. 5, June 1974, p. 65.

projected the potential Japanese demand for Australian forest products and Australia's availability of woodchips for export to the year 2010. Part of the study that is important in future trade on woodchips will be discussed in this section. Projection of population and per capita gross national product up to the year 2010 are given in Table 25.

Estimates of the supply and demand balance for eucalypt pulpwood in Australia under existing forest management and approved planting programs are shown in Table 26. From the figures presented, it would appear that there will be a surplus of eucalypt pulpwood potentially available for export up to the year 2010. However, the volume will decrease from 3.5 million cubic meters in 1980 to 1.9 million cubic meters in 2010. It also has been suggested that future technological progress may well permit the substitution of eucalypt pulp for coniferous pulp, thereby helping to reduce Australia's deficit of coniferous pulp. The surplus of eucalypt pulpwood available for export will also be reduced as a result.

TABLE 26

AUSTRALIA'S SUPPLY/DEMAND BALANCE FOR EUCALYPT PULPWOOD UNDER PROPOSED FOREST MANAGEMENT REGIMES

(In thousand cubic meters roundwood equivalent)

| Item | 1980 | 1990 | 2000 | 2010 |
|---|---|---|---|---|
| Supply of Eucalypt Pulpwood | | | | |
| Pulplogs economically available for domestic consumption | 6056 | 6371 | 6287 | 6341 |
| Sawlog residues | 481 | 856 | 985 | 1248 |
| Recycled waste paper | 1032 | 1560 | 2084 | 2640 |
| Total | 7569 | 8787 | 9356 | 10229 |
| Demand for Eucalypt Pulpwood | | | | |
| Poles and posts | 272 | 240 | 240 | 240 |
| Hardboard | 362 | 432 | 479 | 514 |
| Newsprint | 590 | 760 | 970 | 1200 |
| Printing and writing | 836 | 1254 | 1672 | 1944 |
| Industrial papers and packages | 1980 | 2700 | 3546 | 4410 |
| Total | 4040 | 5386 | 6907 | 8308 |
| Potential surplus available for export as woodchips or pulp | 3529 | 3401 | 2449 | 1921 |

Source: A Survey of Australian Forestry and Wood-based Industires: Production Forestry Development Plan: FORWOOD Conference, Canberra, November 1974, pp. 37-38.

The potential demand for Australian pulpwood by Japan will depend on the growth rate of Japanese paper consumption which in turn will be affected by the growth rate of gross national product. A fairly close, positive relationship between these two growth rates is well established (29). However, factors such as strict pollution control, availability of capital and raw material can also influence future paper production.

The study concluded that it is unlikely that the composition of Japanese raw material import will shift significantly towards pulp over the next 10 to 15 years. It is possible that Australia's ability to satisfy the Japanese demands for pulp will not be as great over this period as the ability to meet their woodchip requirements; this is because of the capital commitment necessary for a pulp mill.

Furthermore, the estimated rate of increase in potential Japanese demand is much greater than the rate of increase in potential Australian export supply. In fact, the latter is negative as indicated in Table 26, and it is, therefore, very likely that a situation of excess demand for these resources will arise. The actual amounts by which the potential increase in Japanese demand becomes translated into effective Australian export volumes is difficult to estimate. Much will depend on the supplies of pulpwood that will become available from other countries, especially those in the Pacific region. At the present, too little is known about the economic potential of the forest resources in Asia and the Soviet Union. The study further suggested that the implication of these expected supply and demand movements is that the real value of Australian-produced pulpwood can be expected to increase over the next 15 to 20 years.

## New Zealand

During 1937-1960, New Zealand's exotic forest increased by an average of only 2,000 hectares per year. By 1970 the annual rate of increase had risen to 18,000 hectares. By the mid-1970's the rate had more than doubled to 40,000 hectares per year and was recommended to be increased to 55,000 for the remainder of the century. The total volumes that would be available are presented in Table 27.

The production level could reach as high as 36 million cubic meters per year within the next 30 years. However, because of the very low rates of planting in the period between the mid-1930's and the mid-1960's, there is little scope for expansion of the wood supply until about 1990. According to Sutton (95), after the year 2000 the volume available for export will increase over the present level by more than 20 million cubic meters, accounting for over 70 percent of the wood supply.

Between 1995 and 2010, New Zealand will probably have sufficient additional pulpwood available to supply 20 new pulpmills each of 500,000 tons per year capacity (35). O'Neill, however, suggested that it may not be possible to muster the capital resources to build the mills and associated facilities to process this material (86). For this reason it is essential that New Zealand's access to markets for wood such as logs and chips is kept open even at the cost of the loss of some export earnings over the intervening period.

A woodchip project has been established in the neighborhood of Christchurch for the chipping slabwood from private forests to supply 1.5 million tons to the Marubeni Corporation of Japan for a ten-year period from 1973. New Zealand has been exporting relatively insignificant quantities of woodchips, increasing rather slowly from 183,000 cubic meters

TABLE 27

PREDICTED YIELD FROM EXOTIC FORESTS IN NEW ZEALAND

(In million cubic meters)

| | Planting Rates | | | |
|---|---|---|---|---|
| | 1969 | 1972 | 1974 | |
| Year | 21000 ha. | 28500 ha. | 40000 ha. | 55000 ha. |
| 1976-1980 | 5.5 | 9.0 | 8.5 | 8.5 |
| 1981-1985 | 8.5 | 10.0 | 9.6 | 9.6 |
| 1986-1990 | 9.6 | 11.0 | 10.7 | 10.7 |
| 1991-1995 | 10.3 | 13.0 | 11.9 | 11.9 |
| 1996-2000 | 11.8 | 16.0 | 16.4 | 18.5 |
| 2001-2005 | — | 18.7 | 24.8 | 30.8 |
| 2006-2010 | — | — | 28.8 | 36.1 |

Source: G. M. O'Neill, "Forestry Production and Planting Targets," New Zealand Journal of Forestry, Vol. 20, No. 1, p. 80, 1975.

TABLE 28

EXPORT OF WOODCHIPS FROM NEW ZEALAND

(In thousand cubic meters)

| Year | Chips and Particles |
|---|---|
| 1970 | 183 |
| 1971 | 217 |
| 1972 | 204 |
| 1973 | 237 |
| 1974 | 309 |
| 1975 | 379 |
| 1976 | 329 |
| 1977 | 498 |

Source: F.A.O., Yearbook of Forest Products 1966-1977, 1979.

in 1970 to 498,000 cubic meters in 1977, as shown in Table 28. One reason is the government policy encouraging exports of pulp and paper products rather than raw pulpwood. In fact, New Zealand has already announced that after current contracts with the Japanese expire no more woodchips will be exported (105).

Papua New Guinea

About 40 million hectares of the land area of Papua New Guinea is covered by trees. Only a little over a third of this, however, is regarded as accessible commercial forest. The topography is generally mountainous and the rainfall high. The greatest part of the forest areas now being exploited are the lowland rainforests. There is a wide variety of forest types and species mixtures. Some 200 species have economic potential but at present only one quarter of these account for the bulk of merchantable timber now harvested. The total growing timber volume on the operable forests in Papua New Guinea is estimated to about 500 million cubic meters (88).

Much has been written about the heterogeneity of the tropical forests and the difficulties of utilizing the wide range of species. However, an intensive study of pulping behaviour and suitability for various end products of mixed tropical hardwoods from the rainforests of Papua New Guinea has recently been carried out and their use has been found technically feasible (88). Tests undertaken in America, Australia, Europe and India have also confirmed the suitability of this rainforest resource for the manufacture of paper and it is further supplemented by positive production experience in the Philippines (30).

It is very doubtful, however, that use of the tropical forests can be developed economically, based on removal of pulpwood alone because of large investments required. Therefore, removal of pulpwood will very likely be tied in with an integrated forest products complex of plywood and sawntimber (2).

The world's first mixed woodchip export project was started in 1974 at Madan, Papua New Guinea. The forest areas included in the timber permit cover 83,000 hectares. The project included a chipmill, a sawmill and a veneer mill with an annual intake of almost 0.4 million cubic meters. The existing rainforest is expected to sustain this cut for about 20 years (52). Other woodchip projects under consideration are listed in Table 29.

Fourteen possible areas for export woodchip production in Papua New Guinea have been identified. Assuming optimistically that all these areas will give rise to woodchip export projects, Papua New Guinea's maximum possible supply to Japan is projected to be 1.9 million BDT in 1985. The export trend is presented in Table 30 and Figure 4. However, woodchip possibilities are severely limited by the number of suitable anchorages available, and hydrographic information is very sketchy. Therefore, it is reasonable to rule out several of these areas as unsuitable (25).

## Southeast Asia

The major sources of Japan's import of pulpwood from Southeast Asia are Malaysia and Indonesia. Export of pulpwood from the Philippines is nil since there is a pulp and paper industry in that country. According to Table 31, pulpwood exports from Southeast Asia to Japan are declining rapidly. In Malaysia it decreased from one million cubic meters in 1974 to 435,000 cubic meters in 1977. Woodchip exports from Malaysia were

TABLE 29

PAPUA NEW GUINEA FOREST RESOURCES UNDER CONSIDERATION FOR CHIP EXPORT

| Location | Area of forest (hectares) | | Net merchantable log volume (million cubic meters) | Suitable material for chips (million cubic meters) | Investigating company |
|---|---|---|---|---|---|
| | Total | Merchantable | | | |
| Gogol Timber Area* | 47,800 | 32,000 | 1.3† | 4.5 | Japan New Guinea Timber Co. Ltd. |
| Adjoining areas | 36,200 | 30,200 | 1.2† | 1.9 | |
| Vanimo Timber Area | 298,000 | 239,000 | 10.6 | 7.1 | West Sepik Timber Development Pty. Ltd. |
| Open Bay Timber Area | 183,000 | 104,000 | 7.0§ | 4.6 | Thiess-Sobu Adachi Co. Ltd. |
| Tiaru Pandi | — | 51,000 | 2.6† | 0.7 | |
| Kumusi Timber Area | 44,000 | 24,000 | 1.9† | 1.7 | — |
| Saiho | 3,200 | 1,400 | 0.09† | 0.08 | |
| Saiho extension | 12,000 | 3,300 | 0.2† | 0.2 | |
| Ioma Block 5 | 131,000 | 31,000 | 2.5† | 2.4 | |
| Sagarai-Gadaisu Timber Area | 160,000 | 58,000 | 3.3 | 4.3 | — |

*Under Development.

§Includes 0.08 million cubic meters of Eucalyptus deglupta (kamarere).

†All species, 1.5m girth and greater, including defect which could be appreciable in some cases.

Source: H. G. Higgins and F. H. Phillips, "Technical and Economic Factors in the Export of Woodchips from Australia and Papua New Guinea," Australian Forest Industries Journal, Vol. 39, No. 2, March 1973, p. 39.

TABLE 30

MAXIMUM PROJECTED ANNUAL CHIP PRODUCTION
FROM PAPUA-NEW GUINEA

(In thousand units)

| Year | Bone Dry Tons | Cubic Meters |
|---|---|---|
| 1973 | 210 | 475 |
| 1974 | 280 | 634 |
| 1975 | 530 | 1200 |
| 1976 | 730 | 1650 |
| 1977 | 990 | 2240 |
| 1978 | 1180 | 2670 |
| 1979 | 1370 | 3100 |
| 1980 | 1460 | 3300 |
| 1981 | 1680 | 3800 |
| 1982 | 1810 | 4100 |
| 1983 | 1870 | 4230 |
| 1984 | 1930 | 4370 |
| 1985 | 1930 | 4370 |

Source: N. D. Endacott, "Implication of the Wood Chip Industry As It Affect the New Guinea Scene," The Australian Timber Journal, Vol. 37, No. 4, May 1971, p. 55.

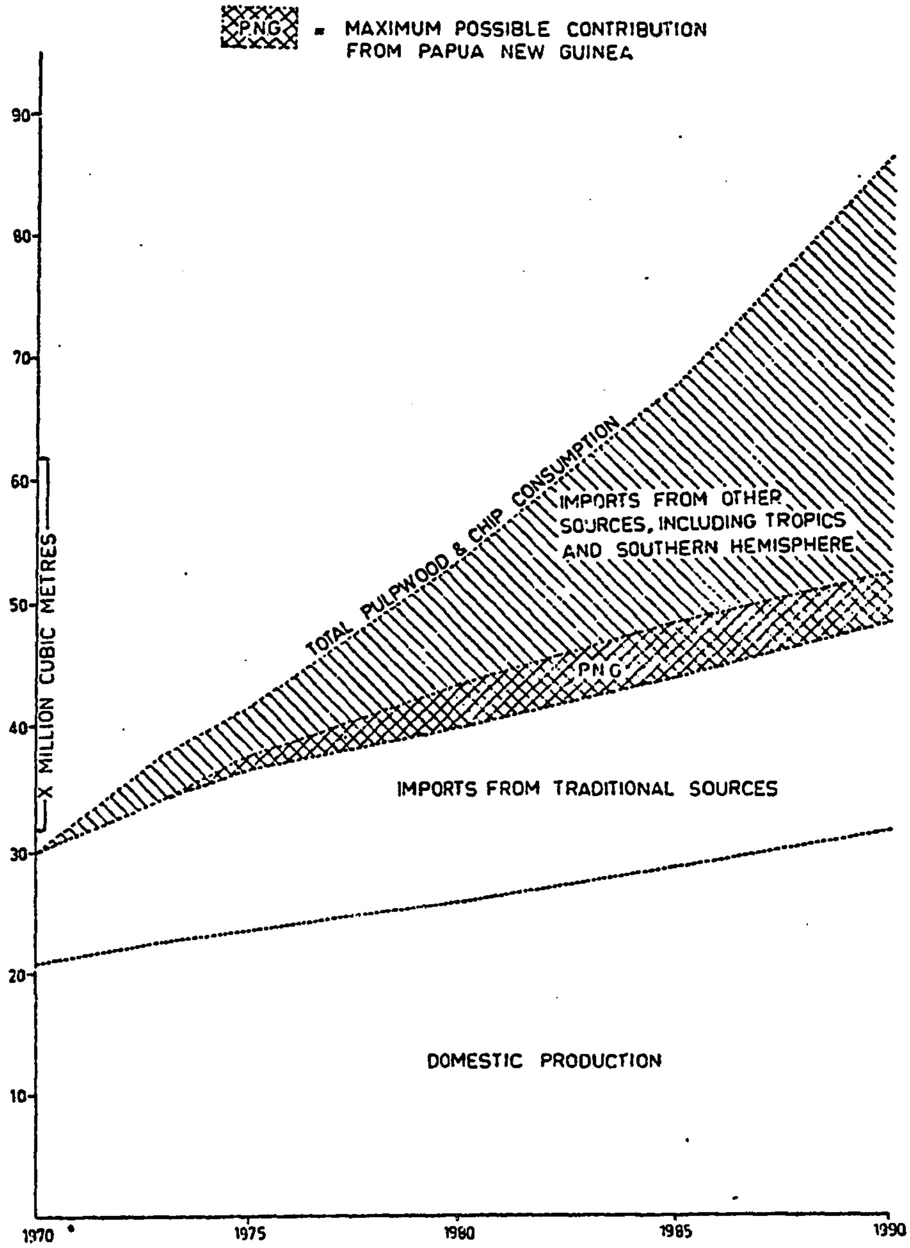



Figure 4. Japanese Pulpwood and Chip Demand/Supply Projections

Source: N. D. Endacott, "Implications of the Wood Chip Industry As It Affects the New Guinea Scene," Australian Forest Industries Journal, Vol. 37, No. 4, May 1971, p. 55.

TABLE 31

JAPAN'S IMPORTS OF PULPWOOD FROM SOUTHEAST ASIA

(In thousand cubic meters)

| Year | Malaysia | Indonesia | Total |
|---|---|---|---|
| 1965 | 26 | 9 | 35 |
| 1970 | 572 | 25 | 597 |
| 1973 | 664 | 194 | 858 |
| 1974 | 1020 | 373 | 1393 |
| 1975 | 702 | 88 | 790 |
| 1976 | 515 | 85 | 600 |
| 1977 | 435 | 59 | 494 |

Source: Japan Paper Association, Pulp and Paper Statistics 1978, p. 14.

probably mainly from clearing of rubber trees and some mangrove forest operation. Their quality of pulpwood is rather low, but they grow in a pretty segregated condition, yielding themselves to massive and low cost production (61). Their utilization has already increased the region's pulpwood supply to some extent. Any further substantial increase in this supply will depend on the possibility of utilizing mixed tropical hardwoods which are presently used as fuelwood.

Only since 1972 have forest products from Indonesia become a significant export commodity and generated the much needed foreign currency. However, the Indonesian government now emphasizes the establishment of more wood processing plants and reduction of allowable log export has already begun. The government has recognized the benefits that could be gained from their forests. Despite efforts to eliminate the log export

TABLE 32

WOOD PULP PRODUCTION AND TRADE IN SOUTHEAST ASIA

(In thousand metric tons)

| Year | Indonesia | | | Malaysia | | | Philippines | | |
|---|---|---|---|---|---|---|---|---|---|
| | Prod. | Imp. | Exp. | Prod. | Imp. | Exp. | Prod. | Imp. | Exp. |
| 1973 | 1 | 3 | - | - | 2 | - | 174 | 55 | 11 |
| 1974 | 3 | 7 | - | - | 3 | - | 146 | 85 | 3 |
| 1975 | 1 | 8 | - | - | 2 | - | 99 | 27 | - |
| 1976 | 1 | 19 | - | - | 3 | - | 149 | 44 | - |
| 1977 | 1 | 40 | - | - | 3 | - | 181 | 47 | - |

Source: F.A.O., Yearbook of Forest Products 1966-1977, 1979.

trade in favor of higher valued processed forms, Indonesia still is a major log exporter while the Philippines and Malaysia have been quite successful in converting their export industry to dealing in more processed forest products.

While the Philippines produces an increasing quantity of wood pulp for its own domestic consumption in paper production, pulp production in Indonesia is almost non-existent and Malaysia has no pulp production at all. Consequently, Southeast Asia imports a large volume of paper products. This situation is clearly exihibited in Table 32.

There is a possibility of further decline in the availability of pulpwood for export from Southeast Asia if a pulp and paper development program for this region suggested by the F.A.O. in its recent study can be implemented (30). It will assure the Association of South East Asian Nations (ASEAN) an attainment of approximately 70 percent of its total projected paper demand by 1990, and rising to 80 percent by 1995.

However, the capital requirements for the proposed program appear to be very high. The allocation of funds for the development of the pulp and paper industry will largely depend on the expected return in this industry compared to other alternative investment opportunities. Currently, rates of return for private investors do not appear to be sufficiently attractive. However, international development institutions may find the program feasible with relatively lower rates of interest normally charged on development projects.

## The Soviet Union

While the USSR only occupies 16.5 percent of the world's land surface, it has 27 percent of the world's forest area, 24 percent of the world's total wood volume and 60 percent of the world's softwood resource. Since the Soviet Union has only about 6.5 percent of the world's population, these figures suggest that the Soviet Union could be a major world source of forest products.

The major problem in an analysis of the Soviet Union forest resource is not a lack of information *per se* but rather of interpretation. The footnotes on Table 33 show that some of the discrepancies can be explained by variations in assumptions and definitions, while other differences have arisen because of changes in the size and conditions of resources between assessments.

About 70 percent of the Soviet Union supply of timber resources comes from the European and the southern parts of the country due to accessibility. The forest land in these regions, however, is already overexploited. Any increase in supply from these regions can hardly be expected. On the other hand, Siberia's forest land remains mostly undeveloped but contains little

TABLE 33

ESTIMATES OF THE USSR'S FOREST RESOURCES

| Authority | Reference year | Forest Area Total* (million ha) | Accessible (million ha) | Actually in use (million ha) | Volume (million $m^3$) Total Reserve |
|---|---|---|---|---|---|
| FAO (1955) | 1953 | 743 | 425 | 350 | 58,700 |
| FAO (1960) | 1956 | 1131 | 836** | 459 | 69,847 |
| Vasil`ev (1961) | 1956 | 836 (722)† | 836 | 398 | 77,900 (42,800)†† |
| Tseplyaev (1965) | 1956 (?) | 681 | | | 75,085 |
| FAO (1966) | 1963 | 910 (738)† | | 318 | 79,000 |
| Vasil`ev (1973) | 1966 | 916 (626)§ | | 328 | 79,700 (53,400)§§ |

*May include area not actually covered by forest.

**excludes accessible unproductive forest.

†value in brackets is area actually covered by forest.

††value in brackets are for forests actually in use.

§value in brackets is the area with timber producing species.

§§value in brackets is the volume of mature timber in centrally managed forests.

Source: W. R. J. Sutton, "The Forest Resources of the USSR; Their Exploitation and Their Potential," Commonwealth Forestry Review, Vol. 54, No. 2, 1975, p. 111.

commercial forest which is potentially exploitable. Of the 515 million hectares of forests in Siberia and the Far East, only 205 million hectares can be regarded as exploitable (61). Nearly all of the areas in which future development can take place are characterized by an absence of people, means of transportation and other factors.

Although the Soviet Union has a greater forest area and a greater amount of standing timber than any country, the situation in respect to large scale woodchip export to Japan is apparently fraught with some difficulties (53). These include the wood requirements of the USSR for internal industrial growth, the remoteness of many forests from centers of population and the consequent long transport hauls. Furthermore, many of the northern ports are shallow and ice-free for only four months of the year (52). In Japan the main consuming areas are in the east, so that a small inefficient ship must make a fairly long voyage and be handicapped by a short season.

Sutton (94) has estimated that the total internal demand for wood in the Soviet Union would reach 560-600 million cubic meters per year by the year 2000. However, projection of total production for around 1995 is in the neighborhood of 510 million cubic meters. Unless the Soviet Union produces considerably more, (which, based on their past record, seems unlikely) or demands considerably less than is predicted, it is unlikely that it will have an exportable surplus around the end of the century.

Furthermore, Soviet export policy is often determined either by the need to acquire foreign currency to pay for imports or by the political desire to assist countries within the Soviet sphere of influence. Export to acquire currency has been mainly in the less processed wood products, including pulpwood, while exports to countries within the Soviet block have been mainly pulp and paper products. The export of wood pulp, for example, to serve the Soviet block is presented in Table 34.

Under F.A.O. classification, exports of pulpwood include roundwood, chips and particles, and wood residues as presented in Table 35. According to the table, woodchips and particles represented a small proportion of the total pulpwood export from the Soviet Union in 1977. They accounted for about 3 percent, while pulp logs and residues exports comprised of 79 and 18 percent, respectively. The volume of Japan's recent pulpwood imports from the Soviet Union has been presented in Table 10.

The study by Sutton suggests that the Soviet Union has limited scope for increased exports, and, even if there is any surplus, it will only be in the region of Eastern Siberia and the Far East and in low quality species of larch and birch. The price of internationally traded wood products from the USSR can be expected to rise not only because of the pressure of supply and demand but also because of the higher costs of management, harvesting, production and transport in Eastern Siberia and the Far East.

In addition to bad climate, poor soil productivity and internal need, the present lack of rail transportation development, and an ice-free port in the Asian Soviet Union limit access to export markets.

TABLE 34

EXPORT OF WOOD PULP FROM THE SOVIET UNION

(In thousand metric tons)

| | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 |
|---|---|---|---|---|---|---|---|
| World | 467 | 501 | 520 | 491 | 515 | 632 | 680 |
| Cuba | 17.7 | 16 | 17 | 14 | 25 | 23 | 27 |
| Bulgaria | 69.9 | 62 | 61 | 66 | 70 | 93 | 85 |
| Czechoslovakia | 51.8 | 51 | 55 | 51 | 55 | 57 | 54 |
| France | 23.4 | 44 | 41 | 28 | 22 | 45 | 47 |
| Germany DR. | 69.2 | 65 | 72 | 70 | 76 | 80 | 70 |
| Hungary | 79.5 | 84 | 86 | 83 | 97 | 84 | 85 |
| Poland | 92.4 | 96 | 90 | 106 | 119 | 125 | 123 |
| Others | 63.1 | 83 | 98 | 73 | 51 | 125 | 189 |

Source: F.A.O., Yearbook of Forest Products 1966-1977, 1979

TABLE 35

EXPORT OF PULPWOOD FROM THE SOVIET UNION IN DIFFERENT FORMS

(In thousand cubic meters)

| Year | Chips and Particles | Pulpwood (round and split) | Wood Residues |
|---|---|---|---|
| 1968 | 19 | 4742 | 940 |
| 1969 | 11 | 5376 | 603 |
| 1970 | 27 | 5982 | 561 |
| 1971 | 19 | 5560 | 744 |
| 1972 | 23 | 5247 | 617 |
| 1973 | 22 | 6662 | 1040 |
| 1974 | 51 | 6844 | 1270 |
| 1975 | 226 | 6186 | 1499 |
| 1976 | 226 | 6784 | 1499 |
| 1977 | 226 | 6561 | 1499 |

Source: F.A.O., Yearbook of Forest Products 1966-1977, 1979.

# CHAPTER III

# HAWAII'S COMPARATIVE ADVANTAGES, MARKET POTENTIAL AND MARKET ENTRY IN JAPAN

Some explanations have been given in the preceding chapter as to why resource surpluses and deficiencies alone are not the sole determinants of the direction of trade in forest products. Various forms of comparative advantage play important roles because they are desirable bases for trade. This chapter is devoted to the analysis of the market potential in Japan, the examination of Hawaii's comparative advantages concerning woodchip production for export, and market entry in Japan.

## Market Potential for Pulpwood in Japan

It is evident that Japan will continue to dominate the Pacific region as a major importer for woodchips. Some countries in this region have taken positive action to develop their pulpwood industry for potential export.

The Japanese major overseas subsidiaries are presented in Table 36. Obviously, the Japanese have been making a major long-term effort to establish softwood and eucalyptus plantations in Malaysia, Indonesia, Australia, New Zealand and Papua New Guinea where political stability is found and foreseen.

Japan's interest in these areas is greatly influenced by the desire of its business and political leaders to avoid dependence upon any raw material source which could be cut off. Since the Japanese have no proprietary interest in the United States woodchip sources, they have become uneasy. However, the U.S. produces higher quality woodchips than can be obtained from other foreign sources.

TABLE 36

JAPANESE OVERSEAS SUBSIDIARIES PRODUCING PULPWOOD OR CHIPS

| Japanese Parent Companies | Host Countries | Overseas Subsidiaries | Date of Founding | Japanese Investment Amount | Japanese Investment Ratio | Main Area of Operation | Product Lines | Capacity |
|---|---|---|---|---|---|---|---|---|
| Daishowa Paper Mfg. Co.,Ltd. Shigyo Co., Ltd. | Malaysia | Daishowa(M) Wood Products Sdn Bhd | Sept. 1967 | M$5,700,000 | 95 | Port Swettenham | Waste rubber tree chips | Hardwood chips 600,000 cm/y. |
| Kohjin Co., Ltd. | Malaysia | Sarawak Wood Chip Co. Sdn Bhd | Oct. 1967 | M$51,000 | 51 | Rejang Sarawak | Mangrove chips | Hardwood chips 150,000 cm/y. |
| MDI (Kohjin, Jujo, Kansaki, Sanyo-Kokusaku and Nippon Pulp) | Malaysia | Sharikat Bakau Sabak Sdn Bhd | Mar. 1970 | M$51,000 | 51 | Tawau Sabah | Mangrove chips | Hardwood chips 150,000 cm/y. |
| MDI (Kohjin, Jujo, Kanzaki, Sanyo-Kokusaku and Nippon Pulp) | Malaysia | Jaya Chip Sdn Bhd | Nov. 1972 | M$51,000 | 51 | Sandakan Sabah | Mangrove chips | Hardwood chips 150,000 cm/y. |
| Sanyo-Kokusaku Pulp Co., Ltd. | Indonesia | P.T. Zedsko Indonesia | Oct. 1968 | US$200,000 | 50 | Malili Mamdju Sulawesi | Pulpwood chips | Pulpwood 64,000 cm/y. |
| Oji Paper Co., Ltd. Mitsui & Co., Ltd. | Indonesia | P.T. Triomas Forestry Development | May 1969 | US$325,000 | 85 | Selat Pandjang Sumatra | Hard pulpwood | Pulpwood 120,000 cm/y. |
| Daishowa Paper Mfg. Co., Ltd. C. Itoh & Co., Ltd. | Australia | Harris Daishowa(A) Pty Ltd. | Dec. 1967 | A$2,700,000 | 100 | Eden New South Wales | Eucalypts chips | Hardwood chips 900,000 cm/y. |
| Tokai Pulp Co., Ltd. | New Zealand | Nelson Pine Forest Ltd. | Mar. 1970 | US$420,000 | 25 | Nelson South Island | Pine beech chips | Sofwood/hardwood chips 400,000 cm/y. |
| Honshu Paper Co., Ltd. | New Guinea | Jant Pty Ltd. | Nov. 1971 | US$2,000,000 | 100 | Gogol Madan N.E. New Guinea | Chips, pulpwood | Hardwood chips 150,000 cm/y. |
| Oji Paper Co., Ltd. | Gabon | Societe Gabon aise de Cellalase Sogacel | Oct. 1969 | US$18,200 | 10 | Libreville Gabon | On-site survey | — |
| Oji Paper Co., Ltd. | Malaysia | Oji Malaysia Plantation Sendirian Berbad | Mar. 1971 | M$219,900 | - | Johol Malaysia | Forestry testing | — |
| 10 Manufacturers Incl. Oji and Jujo C. Itoh & Co. | Brazil | — | — | — | - | Espirito Santo | Eucalypts chips | Hardwood chips 6,000,000 cm/y. |

Source: The Industrial Bank of Japan, Japanese Finance and Industry, Quarterly Survey, July-September, 1975, p. 42.

British Columbia refuses to export woodchips, insisting on obtaining economic benefits of pulping in its own province. Australia, New Zealand, and Canada can be expected in the long run to insist on keeping payrolls home by pulping in their countries. The industries based on pulpwood add more value to the original raw material than any of the other industries based on wood. The greatest returns to governments in the form of taxation is also made by industries based on pulpwood (64). The extent of timber export controls by some countries are summarized in Table 37. Export of roundwood is prohibited in all countries cited.

Strictly from an economic point of view, the Japanese prefer to import pulp logs as the first choice, followed by chips and pulp. This preference will maintain most of the manufacturing functions in Japan and provide employment at home. According to Table 38, 78,900 people were employed in pulp, paper and paperboard production in 1977. This objective is further implemented by the upward investment trends in Japan's pulp and paper mills, as presented in Table 39.

On the other hand, there will be increasing social and legal requirements for higher standard of environmental protection of the atmosphere, water, and land. The first two directly relate to emission from pulp and paper mills and the latter to the disposal of waste papers and packaging materials.

Despite the aforementioned dual restrictions of environmental concerns and raw material shortages, it is believed that new major mills will continue to be developed in Japan, probably at a slower rate, in areas specifically designated for this type of industry. Furthermore, the existing industrial capacity, the high efficiency and the upward investment trends in pulp and paper production, the strong economic growth compared

TABLE 37

RESTRICTIONS ON TIMBER EXPORTS

| Countries | Applicable Resources | Extent of Control |
| --- | --- | --- |
| USA | Roundwood from federally owned forests west of 100 degrees Western Longitude. | Exports prohibited with few exceptions. |
| Canada | Roundwood from provincial forests of British Columbia. | Exports prohibited with few exceptions. |
| Philippines | All domestically produced roundwood. | Exports are limited to 80 percent of the allowable level of removal. |
| Malaysia | Roundwood from Western Malaysia. | Exports prohibited with few exceptions. |
| Brazil | Roundwood and sawnlogs, 76mm or more in thickness. | Exports prohibited with few exceptions. |

Note: The restrictions listed above represent those enforced in March, 1975.

Source: The Forestry Agency of the Japanese Government and The Industrial Bank of Japan, Japanese Finance and Industry, Quarterly Survey, Oct.-Dec., 1975, No. 30, p. 6.

TABLE 38

NUMBER OF REGULAR EMPLOYEES ENGAGED IN PULP, PAPER AND PAPERBOARD PRODUCTION IN JAPAN, 1965-1977

| Year | Pulp | Paper | Paperboard |
|---|---|---|---|
| 1965 | 24,335 | 58,807 | 23,581 |
| 1970 | 19,817 | 55,038 | 22,332 |
| 1975 | 16,794 | 47,651 | 20,451 |
| 1976 | 16,038 | 46,806 | 19,256 |
| 1977 | 15,381 | 45,101 | 18,418 |

Source: Japan Paper Association, Pulp and Paper Statistics 1978, p. 20.

TABLE 39

INVESTMENT TRENDS IN PULP AND PAPER INDUSTRY IN JAPAN

(In billions of U.S. dollars)

| | 1970 | 1975 | 1976 | 1977 | 1978 | 1982 |
|---|---|---|---|---|---|---|
| Pulp and paper mills | 0.6 | 0.8 | 0.9 | 0.9 | 0.9 | 1.2 |
| Pulp & paper products manufacturing | 0.2 | 0.3 | 0.3 | 0.3 | 0.4 | 0.5 |

Source: U.S. Department of Commerce, U.S. Export Opportunities to Japan, 1978, p. 167.

to other developed nations, and the "lifetime" employment philosophy and practices in Japan have all made it extremely difficult to change its current structure of pulp and paper industry. Therefore, it seems very likely that Japan will continue to import large quantities of pulpwood, particularly in the form of woodchips although increasing emphasis will be placed on imports of more processed materials especially pulps.

It is difficult to estimate the potential supply of pulpwood from the USSR and Southeast Asia. As noted in the preceding chapter, the Soviet Union's trade policy is often motivated by political considerations. On the other hand, it is difficult to develop tropical forests in Southeast Asia aimed at removal of pulpwood alone because of large investments required. Pulpwood production will likely be integrated with plywood and sawntimber.

Table 40 provides some estimates of pulpwood supply and demand in countries where Japan obtains its pulpwood imports. It has been projected that Southeast Asia will have a surplus of 1.6 and 2.5 million cubic meters in 1980 and 1985, respectively; not all surpluses, however, are available for Japan. The Soviet Union, for example, trades most of its surplus in Europe.

However, based on estimates in the preceding chapter and assuming that in 1990 the USSR and Southeast Asia can double their exports to Japan over their 1970-1977 average export levels, as presented in Table 10, Japan will have to import 1.2 million cubic meters of pulpwood in 1990 from non-traditional sources. Estimated levels of supplies from major pulpwood producers to Japan are given in Table 41 assuming that Japan can increase its domestic production from an annual average of 22 million cubic meters in 1973-1975 period to the projected 47 million cubic meters in 1990 (29).

TABLE 40

ESTIMATED FUTURE SUPPLY AND DEMAND OF PULPWOOD IN COUNTRIES EXPORTING PULPWOOD TO JAPAN

(In million cubic meters)

| | 1980 Demand | 1980 Supply | 1980 Balance | 1985 Demand | 1985 Supply | 1985 Balance |
|---|---|---|---|---|---|---|
| Japan | 37.9 | 20.5 | -17.4 | 43.2 | 20.0 | -23.2 |
| USA | 195.7 | 202.6 | 6.9 | 218.6 | 223.7 | 5.1 |
| Oceania | 7.2 | 10.5 | 3.3 | 10.5 | 14.6 | 4.1 |
| USSR | 42.1 | 53.0 | 10.9 | 56.1 | 70.5 | 14.4 |
| S.E. Asia | 3.9 | 5.5 | 1.6 | 7.2 | 9.7 | 2.5 |

Source: The Industrial Bank of Japan, Japanese Finance and Industry, Quarterly Survey, Oct.-Dec., 1975, No. 30, p. 31.

TABLE 41

POTENTIAL PULPWOOD SUPPLIERS TO JAPAN IN 1990

(In million cubic meters)

| | |
|---|---|
| Japan's import requirement | 17 |
| From United States | 7.0 |
| Oceania | 6.0 |
| Southeast Asia | 1.6 |
| U.S.S.R. | 1.2 |
| Remaining Deficit | 1.2 |

There is no doubt, of course, that Japan will import more pulp. Imports will increase from 2.4 million cubic meters of wood equivalent of pulp in 1975 to 5.2 million cubic meters in 1990 (29). However, it is likely that the increase in pulp imports will be used to satisfy part of the increase in Japan's growing pulp consumption rather than replacing the current domestic pulp production. It has been unmistakenly pointed out by a prominent papermaker (13) in the United States that Japan's existing papermaking industry is not threatened by the increasing volumes of pulp and paperboard imports. These imports will be incremental to, not competitive with, Japanese production in the long-term trend.

It is important to realize that Japanese pulp manufacturers also enjoy a tariff protection of 15 percent against imported pulps (79). Therefore, it is not surprising that a number of major developments in Japan are based primarily on imported woodchips.

## Hawaii's Comparative Advantages

Comparative advantage is measured by the economic ability of an area to compete with other areas in the production of particular goods or services. Certain comparative advantages stem from natural resource endowment, while others involve favorable institutional arrangements, locations and transportation costs. It is not uncommon to ignore the importance of differences in spatial location. However, all of the above set of factors must be considered in the calculation of comparative advantage (10).

Basically, Hawaii has three comparative advantages in woodchip export to Japan. These are proximity to the Japanese market, relatively fast growth rate of eucalyptus trees in Hawaii, and exchange rates that make exports from the United States competitive in world market.

Table 42 and 43 provide some general ideas on the favorable growth rates of Eucalyptus saligna in Hawaii as compared to growth rates of eucalypt species in some countries. The growth rate in Hawaii is as high as 21.9 dry tons per acre per year, while growth rates in Kenya and Portugal are 8.7 and 17.9 dry tons per acre per year. Even with the conservative annual growth rates of 23.3 green tons or 11.6 BDT per acre used in the feasibility analysis in Chapter V, these rates are still higher than the rates in Italy, Indian and Brazil as presented in Table 43. Growth rates in Australia are generally lower than those overseas although eucalypts are Australia's native trees. The main reasons could be the conditions of soil and climate.

The exchange rate is another important factor in international trade. As long as U.S. dollars remain weak relative to other currencies, exports from the United States are relatively cheaper. So are the costs of woodchips from Hawaii compared to Australia's exports. Therefore, as long as the U.S. dollar continues to devalue relative to the Japanese yen, while other currencies such as Australian dollars remain relatively stable, export of woodchips from Hawaii will be more competitive in the Japanese market. It must be realized, however, that exchange rates do fluctuate from time to time. Therefore, the extent of this comparative advantage will also vary.

For example, Japan's annual imports in 1973 amounted to 50,000 million yen in pulpwood (of which woodchips accounted for 43,000 million yen), 32,000 million yen in paper pulp and 3,000 million yen in waste paper and

TABLE 42

YIELDS OF EUCALYPTUS SPECIES

| | |
|---|---|
| California | 13.4 dry tons/acre-yr |
| California | 24.1 dry tons/acre-yr |
| Spain | 8.9 dry tons/acre-yr |
| Kenya | 8.7 dry tons/acre-yr |
| South Africa | 12.5 dry tons/acre-yr |
| Portugal | 17.9 dry tons/acre-yr |
| Hawaii (*Eucalyptus saligna*) | |
| Maui, 8 x 8 ft spacing | 14.1 dry tons/acre-yr |
| Maui, 10 x 10 ft spacing | 9.7 dry tons/acre-yr |
| Hawaii, 6 x 6 ft spacing | 21.9 dry tonx/acre-yr |

Source: Christine Yang, et al. (Eds.), *Biomass Energy for Hawaii, Volume IV Terrestrial and Marine Plantations*, Institute for Energy Studies, Stanford University, California, 1977, p. 78.

TABLE 43

SOME SELECTED STEM WEIGHT AND VOLUME YIELDS OF EUCALYPTUS SPECIES

| Species | Location | Age (Yrs.) | Mean Annual Increment Stem Vol. ($m^3$/ha) | Mean Annual Increment Stem Wt. (t/ha) | Specific gravity |
|---|---|---|---|---|---|
| Eucalyptus grandis | Qld., Australia | 8 | 33.3 | 15.8 | .47 |
| " " | Qld., Australia | 10 | 15.7 | 7.4 | .47 |
| " " | N.S.W., Australia | 6 | 14.9 | 7.0 | .47 |
| " " | Brazil | 11 | 19.6 | 9.2 | .47 |
| Eucalyptus saligna | Brazil | 10 | 27.2 | 12.8 | .54 |
| Eucalyptus globulus | Italy | 6 | 32.5 | 16.9 | .52 |
| " " | Italy | 6 | 39.4 | 20.5 | .52 |
| " " | Vic., Australia | 2 | 2.9 | 1.5 | .52 |
| " " | India | 15 | 48.5 | 32.5 | .67 |
| Eucalyptus nitens | Vic., Australia | 4 | 13.1 | 5.8 | .44 |
| Eucalyptus regnans | Vic., Australia | 24 | 33.8 | 14.2 | .42 |
| " " | Vic., Australia | 60* | 30.1 | 18.1 | .60 |
| Eucalyptus obliqua | Vic., Australia | 51* | 5.8 | 4.5 | .77 |
| Eucalyptus pilularis | Qld., Australia | 47* | 11.9 | 10.5 | .88 |
| " " | Qld., Australia | 32 | 8.9 | 7.8 | .88 |

*denotes regrowth native forests, remaining entries plantations.

Source: D. I. Bevege, "A Green Revolution in the High Yield Forest: Rational Silviculture or New Technology?" Australian Forestry, Vol. 39, No. 1, 1976, p. 43.

other material. Due to the revaluation of dollars in February of 1973 the total import value was reduced by some 12,000 million yen (60). The terms of trade for Japan were improved because it enabled them to purchase a larger quantity of imports for a given volume of exports.

Although the Japanese will seek new sources of chips, freight rates and other difficulties will limit them primarily to the Pacific area and North America. The handling and transport of chips may represent as much as 50 percent of the cost, insurance, and freight (C.I.F.) value of the goods, depending, of course, on the transport distance (29).

Since there are positive costs involved in the transfer of a commodity from one region to the other trade will not completely equalize commodity prices. Instead the prices in different regions will move toward each other until they differ exactly by the cost of transfer (14). Whether this theory has relevance to real market depends largely on the homogeneity of the products under consideration, the availability of knowledge on market conditions, and how close the real market is to the perfect market assumptions.

Von Thunen's model of concentric land-use zone strongly reflects the influence of transportation costs (10). Producers closer to the market often benefit from their ability to move products to market at lower cost, in less time and in better condition than their competitors. Savings in transportation allow these producers to compete favorably.

Japan is the major woodchip importer in the Pacific, in fact the market center. Based on Von Thunen's theory, woodchip producing countries closer to Japan will receive a higher price for their product assuming a uniformed product and perfectly competitive world market. Theoretically, therefore, Hawaii should be able to obtain a higher price due to its proximity to the Japanese market. Available price statistics seem to confirm it.

Prices of Hawaii-produced eucalypt woodchips during 1975-1980 are given in Table 44. In 1978 the price was $52.64 per BDT in free alongside ship (F.A.S.) value. Australia's 1977-1978 export price of eucalypt woodchips was A$26.32 per green ton in free on board (F.O.B.) value, as presented in Table 45. After making allowance for moisture content in Australia's green eucalypt chips (approximately 50 percent), adjustment for foreign exchange rates, and differences between Hawaii's unbarked chips and Australia's debarked chips and between F.A.S. and F.O.B. prices, it appears that Hawaii has captured a relatively high price with a relatively small volume of export based on the calculation below. The reported cost of approximately $7 for loading a BDT of woodchips into a freighter at Kawaihae is used in the calculation (107).

Calculation:

| | |
|---|---|
| 26.32 | 1978 Australian export price/green ton in F.O.B. value |
| x 2 | Conversion factor based on 50% moisture content |
| 52.64 | Approximate A$/BDT |
| x 1.15 | 1978 annual average A$-U.S.$ exchange rate |
| 60.54 | U.S.$/BDT |
| - 5.26 | Price adjustment for 10% bark content per BDT of chips |
| 55.28 | U.S.$/BDT equivalent to Hawaii's unbarked chips in F.O.B. |
| - 7.00 | Less loading cost/BDT |
| 48.28 | U.S.$/BDT in F.A.S. value |

The difference in freight charges between Southern Australia and Japan and between New Guinea and Japan could be in the order of $5 to $7 per BDU (25). Hawaii is also closer to Japan than Tasmania (see Figure 5), the major woodchip producing island state of Australia.

TABLE 44

HAWAII'S WOODCHIP EXPORT TO JAPAN 1975-1979

| Year | Short Ton | Dollars | $/STN |
|---|---|---|---|
| 1975 | 9,339 | 577,317 | 61.82 |
| 1976 | 33,488 | 1,330,029 | 39.72 |
| 1977 | 20,887 | 1,243,023 | 59.51 |
| 1978 | 48,083 | 2,531,264 | 52.64 |
| 1979 | 30,164 | 1,517,854 | 50.32 |
| 1980 | 36,626 | 3,012,200 | 82.24 |

Source: U.S. Department of Commerce, Honolulu.

TABLE 45

AUSTRALIA'S WOODCHIP EXPORT 1972-1978

| Year | Green tonnes (1000) | A$ (1000) | A$/Tonne |
|---|---|---|---|
| 1972-1973 | 1,553 | 23,040 | 14.84 |
| 1973-1974 | 2,664 | 39,748 | 14.92 |
| 1974-1975 | 2,566 | 46,437 | 18.10 |
| 1975-1976 | 2,336 | 50,551 | 21.64 |
| 1976-1977 | 3,234 | 79,497 | 24.58 |
| 1977-1978 | 3,132 | 82,420 | 26.32 |

Source: Australian Bureau of Statistics (S.I.T.C. No. 6318301)


Figure 5. Map of the Pacific Region

Therefore, the $4.32 price differential between the calculated price of $48.28 for the Australian woodchips and the Hawaii's export price of $52.60 could largely be attributed to the differences in the transportation costs. The average price of $50 per BDT in the feasibility analysis in Chapter V is also higher than the calculated price for Australian woodchips. It is suggested in Chapter IV that freight cost is one of the most important factors in woodchip price determination.

It will be discussed in Chapter IV that a given volume of normally dense eucalyptus chips contain substantially more wood than the same volume of less dense softwood chips. This also gives Hawaii a comparative advantage over softwood chip export from Washington and Oregon to Japan, in addition to a shorter shipping distance.

## A Dual Market

Eucalyptus chips could be exported as pulp chips for papermaking or supplied to a local utility company as energy chips. However, there are differences in price structure, supply-demand relationship and risk in these markets. The market for pulp chips is well developed internationally, while the market for energy chips would depend on the willingness of a utility or other company to take a risk on this new source of energy supply. Assurance of steady supply is one of the most critical factors in constructing or modifying a power plant which would consume woodchips. Moreover, a power plant designed to burn both woodchips and fuel oil would incur an incremental cost of $6.60/BDT over a plant designed to burn only oil as estimated in 1976 (107). Therefore, before woodchips would become an economic fuel, the price of oil would have to increase significantly enough to bid woodchips away from the pulp market.

It has often been suggested that woodchips would become an economic fuel if the price of oil increases by a certain percentage. It must not be overlooked, however, that when the price of oil increases, the price of plastic, a petroleum byproduct, also rises (see Figure 8 in Chapter IV). When the price of plastic rises, the demand for paper, a substitute for plastic, and thus woodchips, would both increase. This would result in a price increase for woodchips due to a greater demand.

The oil equivalency value of the eucalyptus woodchips has been determined to be $55.75 per ton in 1980 (68). This value includes the costs of energy used in woodchip drying operations to reduce the moisture content to 25-30 percent before burning. This means that the net value for green woodchips is lower. On the other hand, the annual average export price for pulp woodchips in 1980 is $82.24 per BDT as presented earlier in Table 44. Without government subsidies or intervention concerning energy policy, it appears that woodchips would continue to be exported for pulp.

Even in the study of giant leucaena (kao haole) for energy tree farms for the Island of Molokai, Brewbaker has pointed out that the pulp market is a very lucrative option for the island with deep-water harbors (15).

Alternatively, a eucalyptus plantation could supply both the energy and pulp markets. High-quality woodchips would be exported as pulp chips for higher price while low-quality woodchips would be consumed as fuel.

Market Entry

The problem of language, differences in customs and complexities of distribution in most foreign markets require a minimum level of investment. One way of reducing the required investment in the early stage of market entry in Japan is to locate a capable trading company for utilization as a distributor in the Japanese market. Duplicating the extensive services of the trading companies would be prohibitively expensive.

The origin of trading companies dates back to the 1870's when Japan resumed international trade. Trading companies were set up to provide needed expertise in seeking export opportunities, finding sources of raw material, and assisting in the transmission of technology to promote industrial development.

Almost 6,000 corporations in Japan are classified as trading companies, engaging primarily in exporting, importing or a combination of these two activities. There are 400 trading companies dealing with logs and lumber. The ten largest trading companies, presented in Table 46, are called general trading companies, with a minimum annual trunover of $6 billion. In 1974, all trading companies handled 67 percent of total Japanese exports, while the largest ten trading firms accounted for 57 percent. Total imports going through all trading companies was 70 percent, with major trading companies handling 58 percent. Because of the volume of the business handled, the trading companies are able to realize economies of scale in transportation, warehousing and other areas related to the marketing of imports and exports.

Trading companies are not simply import-export companies. They generally perform the following six important functions (65):

1) Trade intermediaries. They provide trade information, handle peperwork for importers and exporters, obtain necessary foreign exchange, and arrange for transportation, insurance and storage.

TABLE 46

SALES OF THE TOP 10 TRADING COMPANIES IN JAPAN

(In trillion yen)

| Company | Annual Turnover | Company | Annual Turnover |
|---|---|---|---|
| Mitsubishi | 9.1 | Nissho-Iwai | 4.0 |
| Mitsui | 7.9 | Tomen | 2.3 |
| Marubeni | 5.8 | Kanematsu-Gosho | 2.3 |
| C. Itoh | 5.6 | Ataka | 2.0 |
| Sumitomo | 5.5 | Nichimen | 1.7 |

Note: Sales for the 12-month period ended March 1976, p. 28.
Source: Japan External Trade Organization (JETRO) Marketing Series 2.

2) Trade flows. For example, a trading company located iron ore mines in Australia, invested in mining, exported iron ore to Japanese steel manufacturers, then pruchased some steel for export as well as supplying the domestic market.

3) Finance. One example is in the paper and wood industry where trading companies have traditionally borrowed from banking sources to finance imports of logs and woodchips for pulp production. This raw material is then provided to secondary processors on short-term credit. Trading companies have also assisted in financing development of raw material resources overseas and processing facilities both overseas and in Japan. Trading companies are often better informed on the actual credit standing of their client firms than most financial institutions because of their close day-to-day contact with them.

4) Risk absorption. Trading companies absorb risk through the variety of products which they handle, the variety of markets where they operate and the sheer size of their business. The top ten trading companies handle as many as 20,000 different items. Except during the most severe recessions, it is unlikely that demand for all of these products will decline at once. General trading companies can thus usually finance losses in one field with the profit obtained in other areas. Another important way in absorbing risk is through risk hedging operations for foreign exchange. Generally, trading companies have both export and import contracts dominated in dollars. If dollars depreciate, for example, there are losses in export contracts but there are gains in import contracts; these tend to offset each other in the long run.

5) Resource development. Because of their ability to provide finance for development projects and provide reasonable guarantees of a future market, trading companies have come to play an increasingly important role around the world in the development of new sources of raw materials. For example, one major trading company has engaged in a major agriculture development project in Brazil involving 20,000 hectares of farmland producing wheat and soybeans.

6) Offshore trade. Offshore trade refers to trade among third countries not involving Japan. One example involved the sale of raw cotton from the U.S., and the sale of wool from Australia and New Zealand to the People's Republic of China. These transactions were arranged by general trading companies, utilizing their existing customer relationship in these nations.

To penetrate the Japanese woodchip market, products must enter via established trade channels. Woodchip exports from Australia, New Zealand, Papua New Guinea, Indonesia and Malaysia all go through, or are financed by, one of the ten general trading companies. Table 36 and 46 (pages 74 and 91) indicate that some trading companies have overseas subsidiaries producing woodchips.

Marubeni Corporation, one of the general trading companies, is presently importing woodchips from Hawaii. Being a new marekt entrant and a small producer, it is financially advantageous for Hawaii to negotiate a long-term contract with a Japanese trading company.

In 1975, Marubeni Corporation and Oji Paper Company of Tokyo were interested in establishing a wood pulp plant on more than 40,000 acres of privately held land in the Hamakua District of the Island of Hawaii. The Japanese hope to lease the land, log off the existing trees and then replant the acreage in fast-growing eucalyptus. The deal did not go through, however, probably because of concerns for air and water pollution. A pulp plant will require large quantities of water and energy; depending on the process, pulp mills use a maximum of 34,650 gallons of water per ton of kraft and 62,700 gallons per ton of sulfite pulp produced (1).

With the combination of financial capability and incentives to create trade flows from a new source of raw material, trading companies appear to be in a unique position to contribute to development and assist in expansion of woodchip exports form Hawaii. Expanded forestry development then can be operated with corporate or contractual agreement through some sort of joint venture. Such a contract will assure Hawaii of a constant long-term demand. This kind of arrangement on woodchip projects has been proven successful in other countries.

# CHAPTER IV

# PAPERMAKING AND WOODCHIP PRICE DETERMINATION

Papyrus, from which the word paper is derived, was used in the fourth millenium in Egypt. Papyrus is a laminated mat of unseparated plant fibers made from a sedge (Cyperus papyrus) growing at the banks of the Nile River. Paper, the writing substance, is a manufactured product of Chinese origin. It was invented in 105 A.D. by using fibers from the bark of the paper mulberry (Broussonetia papyrifera) tree (78). The Arabs learned and improved the papermaking process. It was not until early in the eleventh century that paper was first made in Europe from linen rags. Paper was not made successfully from wood until the middle of the nineteenth century (91).

The principle ingredient in paper is cellulose fiber found in many plant materials. By far the most important commercial fiber is wood, followed by waste paper. Some agricultural materials give comparable yields to woods, but many give very much lower yields of fiber and may, in addition, consume more cooking chemicals than wood. Obviously, only those materials which approach wood in regard to pulp yield and chemical consumption can be economically viable. Limited amounts of paper are still made from rags, straw, cane bagasse, bamboo and kenaf.

## Pulping Processes

The first stage in the preparation of a papermaking fiber, irrespective of origin, is to separate and reduce the raw material to a pulpy mass. There are basically two types of pulping processes—chemical and mechanical; between them are a range of processes. An appropriate process will depend on the end use of paper, cost of the ingredients used and their availability.

Mechanical pulping processes are characterized by high pulp yield with lignins remaining in the pulp, high energy consumption and comparatively little use of water. Chemical pulping processes involve removing the lignins from woodchips in chemical solutions. They are characterized by relatively low pulp yield, low energy consumption and high water consumption. They also produce a comparatively high level of pollution (6).

Mechanical pulp is well suited for newsprint and for tissue papers. Chemical pulps are required where strength is important and it is essential that they contain a high proportion of long fibers. On the other hand, short fibers give papers with smooth surfaces and high opacity and are highly desirable for printing grades.

The low extractives content in fast grown young *Eucalyptus saligna* found in Portugal (56) suggested a low chemical requirement needed to dissolve the extractives in cell lumen and cell walls (40). In South Africa and Brazil, *Eucalyptus saligna* has been manufactured into various paper products including printing and writing papers (71, 81).

## Factors Affecting The Value of Woodchips

The most important factors affecting the quality of woodchips are basic density, extractives content and uniformity. These factors will significantly affect pulp yield, pulp quality, freight costs, and processing costs and, therefore, the price of woodchips. Table 47 presents some technical and operational factors related to the quality and value of woodchips. Higgins and Phillips have analyzed these factors in great detail (54).

This method of price determination refers to evaluation of a proposed wood resources in comparison with the established or referenced

TABLE 47

TECHNICAL FACTORS RELATED TO QUALITY AND VALUE OF CHIPS

| Primary Factor | Component Factors |
|---|---|
| Freight | Basic density of wood<br>Shipping distance<br>Size of ship<br>Distance of port to pulp mill |
| Pulp Yield | Basic density of wood*<br>Extractive content of wood<br>Lignin content of wood<br>Processing variables<br>Uniformity of chips<br>Freedom from rot |
| Pulp quality | Basic density of wood*<br>Bleachability<br>Cleanliness of wood<br>Beating response<br>Runnability on paper machine<br>Mechanical properties<br>Optical properties<br>Surface properties<br>Structural properties |
| Processing | Chemical requirements<br>Heat requirements<br>Digester productivity<br>Processing efficiency by existing plant |
| Environmental | Adaptability to new processes to meet environmental regulations.<br>Relative deterioration in store environment<br>Corrosivity to plant and handling equipment |

*Some of subsequent factors listed correlate closely with basic density.

Source: W. G. H. Meadows and C. M. Saul, "Eucalypt Chips for Export," Australian Forest Industries Journal, Vol. 38, No. 9, Oct. 1972, p. 81.

resources of known value. Higgins and Phillips suggested that if the factors influencing the price of woodchips include wood quality, freight costs, pulp yield, pulp quality and processing cost, then the price of woodchips from a new source, in dollar per BDU, is given by:

$$p_n = p_e + \Delta p_w + \Delta p_f + \Delta p_y + \Delta p_q + \Delta p_c$$

where

$p_n$ = F.O.B. price of new woodchips

$p_e$ = F.O.B. price of established woodchips

$p_w$ = dollar value of wood quality

$p_f$ = dollar value of freight cost

$p_y$ = dollar value of pulp yield

$p_q$ = dollar value of pulp quality

$p_c$ = dollar value of processing costs

Therefore, $\Delta p_w$, $\Delta p_f$, $\Delta p_y$, $\Delta p_q$, and $\Delta p_c$ are the amounts in dollars per BDU by which the value of woodchips from the new resource differs from the established resource. The quantities are positive when a specific factor favors the new resource and negative when it favors the established resource.

Higgins and Phillips further argued that the effect of freight and pulp yield on F.O.B. price is considerably greater than the other factors, even collectively, and in most circumstances these are the ones which can be calculated most readily. Hawaii's comparative advantage on freight cost have been discussed in the preceding chapter.

Pulp yield must be established for the woodchips from both the new and established resources. This would normally be done on the basis of laboratory experiments and the difference can be evaluated in monetary terms either from the difference in the weight of oven dry wood required to produce the same amount of pulps, or from the difference in the amount of slush pulp produced from the same weight of oven dry wood from the two resources.

The technical factors that affect the value of woodchips will be discussed in more detail in the following sections.

## Freight Costs

Freight differences for woodchips from two resources are not determined only by the distance of shipment, and raw material weight and volume, but also by type, size and the nationality of the vessels and wood basic density.

Woodchips are of relatively low value and therefore their transportation across the ocean is economical only on a large scale. Currently, a bulk carrier of at least 24,000 tons capacity is regarded as the minimum, and such vessels require a deep water anchorage berth.

According to the F.A.O., there were about 50 Japanese chip carriers in service in 1974, ten years after the first transocean shipment of woodchips. Most of the carriers were in the deadweight class of 20,000 to 40,000-ton, carrying a chip volume of 40,000 to 100,000-cubic meters (28).

Basic density is a measure of the weight per-unit-volume of the wood fiber, excluding moisture. Basic density is one of the most important factors in woodchip trade and papermaking because it affects freight costs, pulp yield and pulp quality, as indicated in Table 47.

Moisture content is defined as a percentage weight loss based on undried weight. In the oven scale test, usually used to determine the moisture content of a sample of wood, the material is dried at elevated temperatures until the weight no longer changes and then the weight loss is compared to the wet weight (75). The moisture content and basic density of a woodchip load is dependent on wood species, season of logging, and storing time and conditions (28).

The oven-dry weight of woodchips which can be stored in a given volume is directly proportional to the basic density of the solid wood, the connecting factor being the volume occupied by the wood itself. The stowage factor may be expressed in cubic feet per green long ton of woodchips at a given moisture content. The stowage factor, therefore, is inversely proportional to the basic density. For transport of woodchips by ship, the following stowage factors (cubic feet/long ton) were suggested by the F.A.O. (28).

| | |
|---|---|
| Woodchips from North America (softwood): | 100-120 cf/LT |
| Woodchips from Malaysia (rubber tree): | 100 cf/LT |
| Woodchips from Tasmania (eucalyptus): | 80 cf/LT |
| Woodchips from New Zealand (pine): | 100-110 cf/LT |
| Woodchips from New Zealand (beech): | 80 - 90 cf/LT |

As a result, the freight cost per BDU will vary with the stowage factor but will vary inversely with the basic density. This can have a large effect in intercontinental transport of woodchips. Hardwoods in general, and the eucalypts, in particular, offer a major advantage in bulk shipping costs due to their substantially higher basic density. Therefore, the economic disadvantage of lower yields attributable to the relatively high basic density of the eucalypts is offset by decreased transport costs which result from the greater amount of fiber per unit volume which can be accommodated in a ship's hold (4).

Pulp Yield

Pulp yield is affected by factors such as basic density, extractive content, uniformity and purity of woodchips. Low density wood normally produce superior pulp to that of high density wood. Wood basic density is related to fiber cell wall thickness, which is an important influence on the conformability and bonding property of fibers. Basic density is also affected by other factors such as the proportion of vessels in the wood and the presence of extractives. Within a range of eucalypts, pulp yield has been found to decline with increasing basic density. For any one species, an increase in tree age is generally associated with an increase in basic density and extractive content, which causes low pulp yield (54) and high usage of chemicals.

At a given age level, different species produce different basic density wood and different pulp strength properties. In general, differences among species are more pronounced than differences in age, although age of the wood also has a marked influence on wood and pulp properties (46).

Since there are strong correlations indicating reduced pulp yield with increasing basic density and increasing chemical consumption with increasing basic density, pulping and papermaking properties of the eucalypts and other hardwoods are substantially better in those species having the lowest densities (79).

Chip uniformity, in respect to species and dimensions, also has significant effects on pulp yield. Insufficient penetration of the pulping liquors due to oversized chips or over-cooking for smaller chips will reduce pulp yield (54). For these reasons, uniformity is desirable and can be achieved by chip specification; analysis of chip dimensions is commonly done by screening.

Initially, before the mill is in operation, the buyer submits a fairly rigid specification. Chip quality specifications set up by purchasers vary considerably because they reflect, among other things, the type of digester available, the pulping process used, and the pulp grades manufactured. Assessment of woodchip quality is usually maintained by the prospective buyer, so a rigid quality standard has to be observed by the woodchip producer. It consists of making certain that species mix lies within agreed proportions, bark and foreign matter do not exceed the agreed percentage, charcoal is unacceptable and chip dimensions are observed. Proper quality control has to be maintained continuously because the buyer is in a position to impose penalties. If the proportion of oversized chips, pin chips, and bark is above agreed upon limits, this will reduce the woodchip price. By other agreements, the excess weight proportion of such fractions may be deducted from the load weight.

The chip size distribution is quite appreciably altered by the handling that the chips receive at various points in the operation. The main cause of the size variation is believed to be the crushing by bulldozers while stockpiling the chips and ship loading. Damage also occurs in the reclaim conveyor where chips rub against the side and bottom of the conveyor, and against each other.

It has been suggested that longer initial chips be produced because from the time the log is chipped until the time they go into the digester in Japan, chips can be handled on up to twenty-six occasions so the larger initial size improves the chances of achieving a more acceptable chip size at the pulp plant (69).

Traditionally, paper has been made from conifers, the bark of which does not make good paper because it contains a low proportion of cellulose fibers; thus it yields little pulp. This could be the reason for demanding a low proportion of bark in woodchips. However, the barks of eucalypts and most other hardwoods contain large proportions of cellulose fiber, and seem much more promising for papermaking (24).

The unbarked Eucalyptus viminalis pulpwood, grown on ratation of less than ten years, can be pulped to produce paper not requiring high strength (84). Species with similar bark characteristics to Eucalyptus viminalis could save the high cost of debarking. Eucalyptus globulus, Eucalyptus grandis, and a number of other species have both good growth rates and bark similar to that of Eucalyptus viminalis (17). It has also been pointed out earlier that Eucalyptus saligna differs morphologically from Eucalyptus grandis only in subtle details difficult to appreciate outside its country of origin (27). The information above seems to explain the acceptance of Hawaii-produced unbarked Eucalyptus saligna woodchips by the Japanese.

Tests by the U.S.D.A. Forest Products Laboratory at Madison, Wisconsin have indicated that increases in fiber yields can be produced with the use of unbarked woodchips. Strength, brightness, and contaminant levels remained comparable with debarked fiber samples. The net yield of acceptable pulp per rough cord will be at least four percent higher. In addition, another five to ten percent gain in yield could be realized because of little or no white wood loss usually incurred during the barking operation (59).

In most species the younger, smaller trees have an appreciably greater percentage of bark by volume than do older trees (66). Therefore, the yield would be increased if species with the most acceptable bark for pulping were planted. This would result not only in a saving of debarking and disposal costs, but bark utilization is also a potential way to eliminate or at least lessen pollution caused by bark disposal. A lower production cost is thus anticipated.

## Pulp Quality

The quality of pulp is related to specific end uses. It may be evaluated in terms of the behavior of the pulp in subsequent operations such as bleaching, beating, paper or board making, corrugating or printing of paper made from it (54). The relation between these operations and the quality of the pulp is briefly discussed below.

Bleachability and good optical properties may sometimes be impaired by the occurrence of a particular type of extractive which may resist pulping and subsequent bleaching operations.

The beating response is good for kraft pulps from eucalypts compared with those from softwoods or mixed tropical hardwoods. Maximum pulp strength is developed with the expenditure of less energy.

Runability or freeness on the paper machine depends primarily on drainage characteristics. These properties govern the speed of the paper machines and hence determine the productivity of the papermaking process. The runability of hardwood pulp can be improved by incorporating softwood pulp in the furnish (a mixture of various fibrous and non-fibrous raw material from which any given paper is made).

The requirements for fine printing and writing paper are adequate strength property, high brightness and opacity, good formation, smooth surface, compressibility and good surface strength. Many of these properties can be obtained with hardwood pulps.

The emphasis on the use of eucalypts is mainly in the context of fine opacity and good formation. Good formation is an inherent advantage of all short fiber hardwoods. Short fiber is required to fill in the spaces between the long fibers to provide a better and smoother writing and printing surface (70).

Eucalypts characteristically give bleached pulps of good opacity but, nevertheless, opacity depends on cell wall thickness which varies more or less directly with basic density. Thus pulps derived from woods of intermediate to high density can effectively increase opacity (79).

Vessels and their fragments and tylosses of a large size can cause picking and affect the quality of printing and writing papers. Vessel picking is to be encountered in most hardwood pulps. The vessel picking problem and poor surface strength can usually be overcome by application of starch (53).

### Processing Costs

Some woods require more chemicals than others under specific pulping conditions. High chemical requirements are usually accompanied by lower pulp yield and thus reduce the value of woodchips. High pulping temperatures may sometimes be used for additional steam requirements. Beating requirements can also be measured in terms of the energy required to beat the pulp to a specified freeness.

However, processing costs can only be determined at a particular mill in the light of the prevailing conditions. In other words, the calculation on the value of woodchips must be mill-specific. It may be difficult to evaluate some of them accurately and to relate differences between pulps from different woods to a price differential in dollars per BDU of woodchips. However, even when the aforementioned factors in the preceding sections are taken collectively, their effects are likely to be much smaller than that of differences in pulp yield and freight costs (54).

## Market Structure

Besides these technical factors, economic factors such as supply, demand and market structure of Japanese pulp and paper industry also have important influence in woodchip price determination. Exports and imports of woodchips are far removed from the model of free trade where there are no institutional barriers to interfere with trade based entirely on economic forces. They also depart far from the model of perfect competition where there are large number of buyers and sellers and no one has a large enough market share to influence the market performance.

In fact, the international trade of woodchips operates on contractual arrangements between buyers and sellers. Given the price levels on the international trade of woodchips and the heterogeneity of wood quality, the actual prices reached will depend upon the market information, locations, volume of trade and, more importantly, the bargaining power each party has. It is likely that small exporters will have a limited knowledge of the market in which they operate.

One important characteristic of the Japanese pulp and paper industry is that there are only a handful of integrated producers with their own pulp and paper production mills, although there are a relatively large number of paper producing companies. The industry relies heavily on imported pulpwood and woodchips for raw materials. In 1977, imports met 46 percent of total domestic demand of 30 million cubic meters of pulpwood and woodchips (99). However, the suppliers of woodchips in Australia and the United States are also concentrated. Furthermore, the Australian Government has control over its export prices because it can deny the issuance of an export license.

Unlike the Australian contracts which run between 5 to 20 years, most American woodchip contracts are between 5 to 10 years. Some have annual renegotiation clauses on price, while others are locked up or include periodic upward price escalation clauses (23).

It has been suggested, as a general guideline, that the softwood chip price will be based on the rate for North American woodchips and the hardwood on that for Australian woodchips, since they are two major exporters of these chips (28).

Table 48 provides some ideas on the complexity of pulpwood pricing. Comparison is difficult to make because prices are sometimes given in F.O.B., C.I.F., or pulpmill delivery prices, as explained in the footnotes. There are also price differences in softwoods, hardwoods, roundwoods and woodchips; after all, pulpwood is not a homogeneous product. Price differences were quite significant, as shown in Figure 6, between Hokkaido and Chugoku areas. According to the graphs, in 1975 hardwood chips prices were approximately 7,000 yen per cubic meter in Hokkaido and 11,000 yen in Chugoku. The differences could have arisen from transportation costs. However, four kinds of pulpwood in Hokkaido, for some unexplained reasons, were sold for about the same price, 7,000 yen per cubic meter in 1975.

TABLE 48

LOCAL PULPWOOD PRICES IN JAPAN IN 1972

(In Japanese yen per cubic meter)

| Country | Species | Prices |
|---|---|---|
| USA (the state of Washington) | Softwood roundwood | 3,600 |
| USA (the state of Washington) | Softwood residue chip | 3,000 |
| USA (the state of Washington) | Softwood chip for Japan | 4,900 |
| USA (the South) | Hardwood roundwood | 3,200 |
| Canada (national average) | Softwood roundwood | 3,800 |
| Canada (national average) | Softwood residue chip | 2,800 |
| Sweden (national average) | Softwood roundwood | 4,000 |
| Brazil | Eucalyptus roundwood | 2,600 |
| Australia | Eucalyptus chip for Japan | 6,600 |
| USSR | Softwood chip for Japan | 6,000 |
| Japan (national average) | Softwood roundwood | 6,090 |
| Japan (national average) | Hardwood roundwood | 5,090 |
| Japan (national average) | Softwood chip | 5,750 |
| Japan (national average) | Hardwood chip | 4,980 |

Note: a) The prices in USA, Canada, Sweden and Brazil are all delivery prices at pulpmills.

b) The roundwood prices in Japan are on an F.O.R. basis, while the chip prices are pulpmill delivery prices.

c) The American and Australian chip prices for Japan are F.O.B. prices, while the USSR price of chips for Japan are on a C.I.F. basis.

Source: The Industrial Bank of Japan, Japanese Finance and Industry, Quarterly Survey, Oct.-Dec., 1975, No. 30, p. 13.

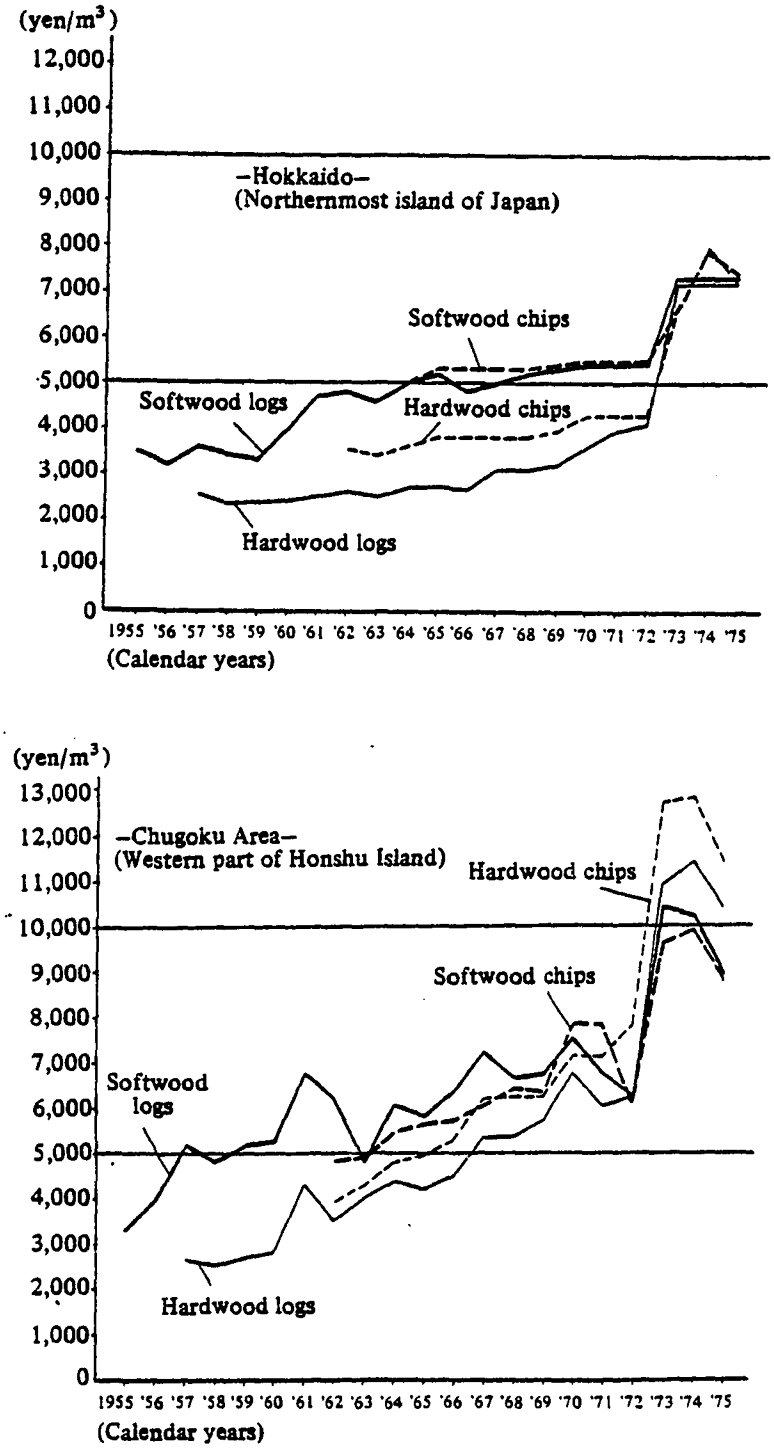



Figure 6. Trends of Pulpwood Prices in Hokkaido and Chugoku Areas

Source: The Industrial Bank of Japan, Japanese Finance and Industry, Quarterly Survey, Jan.-June, 1977, No. 34, p. 45.

The rate of change in pulpwood prices also varies from country to country. In general, it is observed that the rate of change is more rapid in pulpwood deficit countries such as Japan and Sweden than the surplus countries such as Canada and the United States. The changes in pulpwood prices in these countries are graphically presented in Figure 7.

A price ceiling on woodchips is imposed by the reality of plastic paper. Technically, synthetic resin films can be used as substitutes for paper and paperboard. Japan imports a large volume of petroleum from the Persian Gulf and has plenty of raw material for petrochemical pulp. Japan's experiments have shown that plastic is economically feasible for some very fine grade papers. However, chemists do not foresee that petrochemical pulp will become competitive with wood pulp, costwise, for most paper grades. Nevertheless, it means that price of woodchips cannot rise indefinitely (104). The effectiveness of the presumably high ceiling imposed by plastic is also questionable because the price of petroleum has been skyrocketing since the energy crisis. A sudden price rise on petrochemical products occurred in 1973 when the Arabs embargoed oil exports; Figure 8 shows an upward trend since then. In addition, plastic paper and synthetic pulp are not considered attractive because of the difficulties involved in their disposal.

## Hardwood Pulping in Japan

The growth of Japan's pulp and paper industry has been as rapid as that of the Japanese economy itself, and Japan is now the world's second largest producer of paper and paperboard, following the United States. Despite the relative scarcity of domestic forest resources, Japan has been able to attain its present position in pulp and paper production

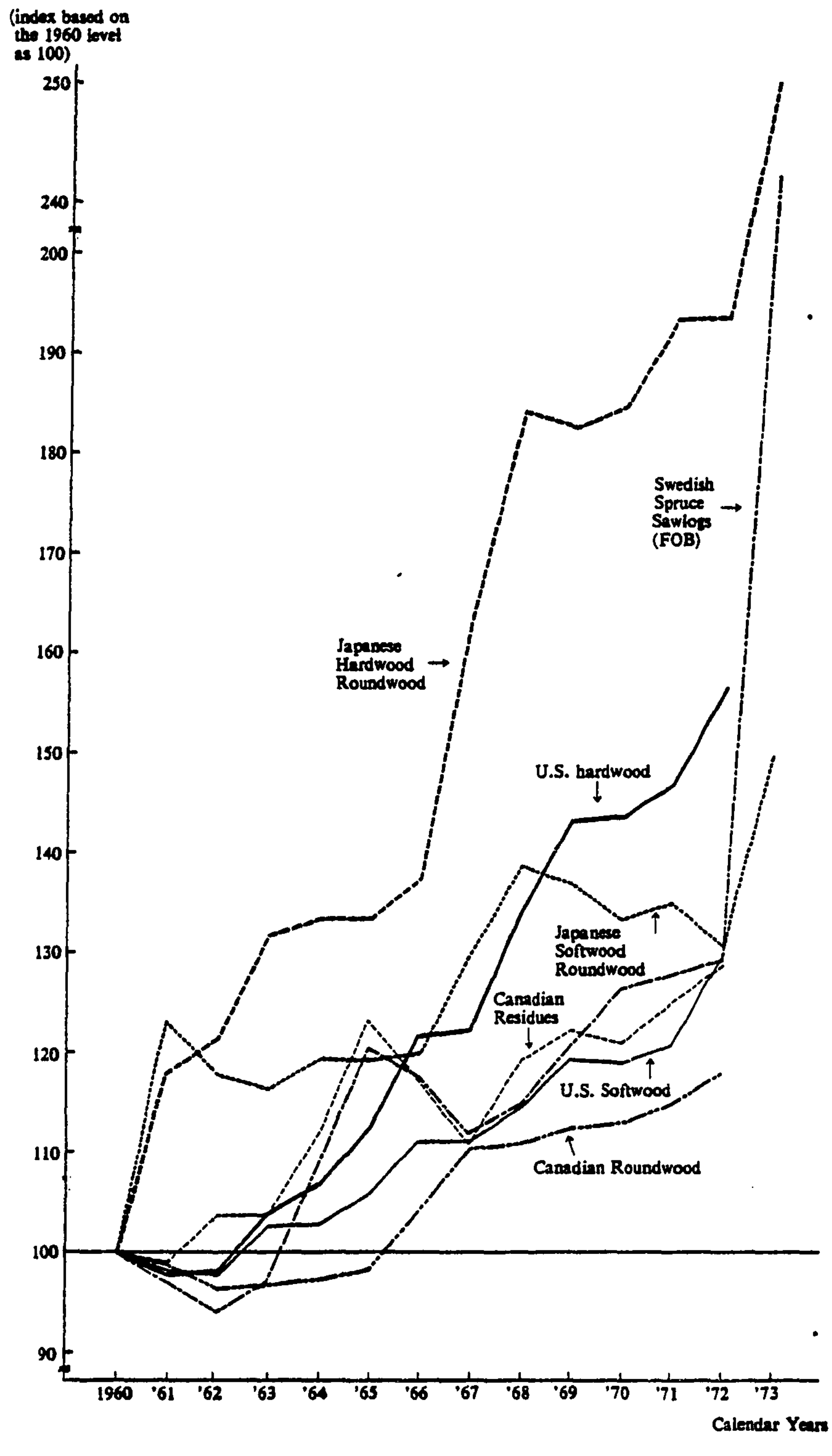



Figure 7. Changes in Pulpwood Prices in Several Countries

Source: The Industrial Bank of Japan, Japanese Finance and Industry. Quarterly Survey, Oct.-Dec. 1975, No. 30, p. 14.

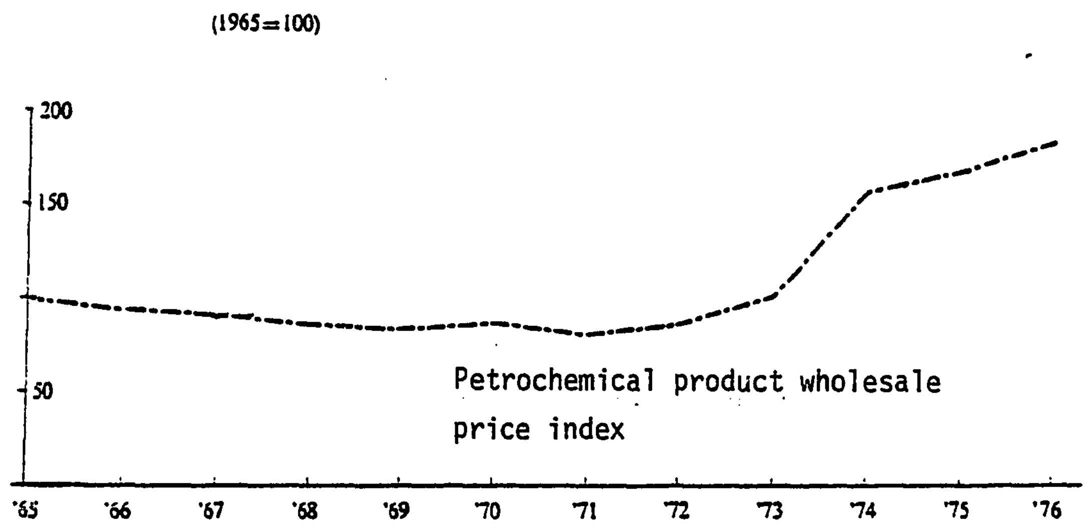



Figure 8. Trends in Petrochemical Prices

Note: The petrochemical product wholesale price index used here is a weighted average of the Bank of Japan's wholesale price indices for "organic industrial chemicals" and "plastics."

Source: The Industrial Bank of Japan, Japan Finance and Industry, Quarterly Survey, Jan.-June, 1977, No. 34, p. 16.

by overcoming the problem of pulpwood shortage, which has threatened the existence of the Japanese industry. In the 1950's, the Japanese industry developed technology to utilize hardwoods as pulpwood, thereby overcoming the shortage of softwood supplies. In the 1960's, the industry was faced with a shortfall in the domestic supply of pulpwood, but this problem was resolved by bulk importation of woodchips. This new transportation method was instrumental in averting a shortage in the supply of pulpwood and saving the Japanese pulp and paper industry.

Japan has led the world in the use of hardwoods and other species previously considered unusable or undesirable for pulping. The Japanese industry is experienced in techniques of papermaking with predominantly short fiber furnishes due to its indigenous forest being heavily endowed with hardwoods. For this reason, the Japanese purchasers have been seeking similar raw materials to supplement their requirements, particularly in the areas of fine printing and writing papers. The Japanese industry has demonstrated that the kraft pulping conditions applicable to Japanese domestic hardwood (a mixture of caustic soda and sodium sulphide) are virtually identical to those for eucalypt woodchips (79).

Many pulp and paper mills in Japan that are users of imported woodchips are already accustomed to using a wide variety of raw materials ranging from domestic hardwood to pines, spruce, Douglas fir, hemlock, eucalypts and rubberwood. It is common to find a range of pulping processes and paper products being manufactured by one firm. This diversity in materials, processes and products allows opportunities for mixed pulping, mixing of pulping liquors or for pulp blending.

The industrial possibilities for mixing woodchips, pulps and liquors and the technical effects produced are very relevant factors in properly evaluating a new raw material which is to be introduced into the system. If a particular type of raw material is defective in any way, the undesirable effects can usually be minimized or eliminated. The diversity of processes and products means that a new material can be readily diverted to the most appropriate end use (53).

The significance of these considerations as far as the woodchip exporting countries are concerned is that a change in technology towards more hardwood fibers and blending with softwood fibers would presumably tend to enhance the value of the hardwood. The potentialities of hardwood could be more fully realized.

# CHAPTER V

# THE ECONOMIC FEASIBILITY

This chapter will analyze the economic feasibility of woodchip production in Hawaii. Sensitivity analysis of changes in production costs, woodchip prices and pulpwood yields is also performed at the end of the chapter. Break-even prices for stumpage are estimated.

Cost data used in this feasibility analysis are in 1976 dollars[5] and is largely obtained from the recent study on biomass energy for Hawaii (107). Data on revenues is based on Hawaii's exports of *Eucalyptus saligna* woodchips as reported by the U.S. Department of Commerce. Data on land lease is derived from the Department of Land and Natural Resources, State of Hawaii.

## Eucalyptus Saligna for Pulpwood Plantation in Hawaii

Although there are many different species of eucalypts, about 500 in all, as a group they have many likenesses. On the order of 100 species are regularly used for timber production and papermaking throughout Australia (39).

Eucalypt planting in Hawaii occurred sporadically from about 1850. After a world tour in 1881, King Kalakaua instigated the planting of a wide variety of many seeds, and the decendants of these plantings may be

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[5]Attempts have not been made to update the cost data because prices in 1979-80 have increased so rapidly due to high inflation rates of approximately 12 percent and a record high of 21 percent prime interest rate in 1980. However, the effects of input price increases will be tested in a sensitivity analysis at the end of this chapter.

found on almost every island in the group (108). Eucalyptus saligna was introduced to Hawaii in the 1880's and has been widely planted since 1960's for watershed protection and timber production. Hawaii and Oahu have the most Eucalyptus saligna.

Some foresters have questioned the identity of Eucalyptus saligna in Hawaii. Many of these trees are probably hybrids of Eucalyptus saligna and Eucalyptus grandis, while some may in fact be Eucalyptus grandis. A similar situation has been found in South Africa where the name Eucalyptus saligna is commonly applied to trees of the related species Eucalyptus grandis, Eucalyptus saligna and also to trees of the many transitional forms between them (81). It also has been suggested that Eucalyptus saligna differs morphologically from Eucalyptus grandis only in subtle details difficult to appreciate outside its country of origin (27). Whatever their genotype, the trees grow very rapidly on favorable sites averaging annual increments of one inch in diameter and 10 feet in height (92).

A recent study on biomass energy for Hawaii has pointed out some advantages, listed below, of growing Eucalyptus saligna plantations in Hawaii (107).

1) Rapid growth and good yields are attainable on non-agricultural land with little or no cultivation.

2) Extensive plantings are present in Hawaii, indicating adaptability to soil and climate conditions.

3) In spacing and fertilizer trials on sites and soils very similar to those potentially available for plantations, Eucalyptus saligna showed acceptable sustained yields in the absence of extensive follow-up after planting, precisely the growth qualities required for a forest-type plantation.

4) No problems concerning insect or fungal pests have arisen since eucalyptus has been planted in Hawaii.

The high incidence of growth stresses in eucalyptus trees hinders the utilization of the wood as building material because special milling techniques are required. This defect does not affect its use for pulpwood.

The potential of eucalypts as plantation species throughout the world is being increasingly recognized. Because of the fast growth rate they are often preferred for short rotation crops. Harvesting ages of five to ten years are common in Africa, South America and Mediterranean countries. The advantages of short rotation cropping include a reduction in interest charges and a reduced expectancy of loss for a given crop as a result of fire or other depredation. Therefore, the choice of a species, such as *Eucalyptus saligna*, which can regenerate by coppicing should ensure a reduction of re-establishment costs and a greater yield due to the physiologically older root system. The practices of coppicing, mechanical harvesting, the utilization of bark of some species and perhaps even complete trees utilization should enable greater production from forests in the future.

## Price and Revenue

In this analysis the 1975-1979 average export price of $50 per BDT F.A.S. is assumed. Prices of Hawaii-produced eucalypt woodchips during 1975-1980 have been presented in Table 44 (page 86). Gross revenue will vary depending on whether the harvest is from the initial planting or from coppice crops due to differences in yields. Yields will also differ from coppice to coppice. The differences are discussed in a later section in this chapter.

The revenues used in this analysis are assumed to be maximum potential revenues in that they were obtained from the full utilization of the plantation by the private owner. Whether or not this volume of output is itself optimal will depend on the existence of economies of scale and technological changes over the planning period (3).

## Site Selection and Land Lease

In any particular plantation, costs of growing and harvesting the crop are dependent on plantation design and establishment techniques. Costs vary widely depending on condition of the area prior to preparation for planting, climate, topography and soil type.

Although experimental plantings have been sited in the Islands of Hawaii and Maui with an annual rainfall of between 80-150 inches per year, a minimum annual rainfall of 75 inches per year is believed necessary for good tree growth, depending on tree species chosen (107). A rainfall map of the Island of Hawaii is presented in Figure 13 in Appendix B.

Due to competition with other uses of prime agricultural land on the Island of Hawaii, marginal agricultural and grazing lands must necessarily be located and considered. Plantations established on non-forested grazing and marginal agricultural lands will not only minimize initial site preparation costs but will preserve the native ecosystem as well. Some possible sites and their brief descriptions are presented in Appendix B. All costs in this analysis are based on the representative sites.

A total of 15,000 acres will be required for an operable plantation. Thirteen thousand acres will be used for planting and the remaining 2,000 acres will be used for roads and cleared areas. It is proposed that one-fifth of the total acreage requirement be leased during the first year of start-up and planting. An increment of 3,000 acres will be added to the total leaseholding each year until the entire 15,000 acres are acquired. It is not necessary for all 15,000 acres to be contiguous.

Average annual lease rates for publicly owned pasture land on the Island of Hawaii are given in Table 49, $3.65 per acre in 1976. State tax for agricultural land runs slightly more than $3.00 per acre per year. Therefore, land lease in 1976 was close to $7.00 per acre per year. However, accumulating such a large tract of land may be difficult without paying a premium rate above the lease rate of state land. Therefore, a combined lease and tax rate of $26.00 per acre is assumed (107). Land costs then become $78,000 for the first year and increase by this amount annually to $390,000 for the fifth and subsequent years and then gradually decrease from the twenty-second year.

Plantation Layout, Spacing and Pulpwood Yield

The number of seedlings to be planted per acre depends upon the morphological and biological characteristics of the species selected, the physio-chemical and biological characteristics of the site, the forest products derived and the silvicultural treatment proposed. According to the F.A.O., if one assumes that a plantation owner wishes solely to obtain the maximum yearly volumetric yield, without consideration of quality or end-use, the general rule is that maximum average annual yield will be obtained by using a rotation varying inversely with the density per acre (27).

*Eucalyptus saligna* has been planted on a 9-feet by 9-feet spacing in South Africa. However, Luckhoff suggested in his study that a closer spacing is likely to give a higher pulpwood yield (74). He also pointed out that a good and uniform initial stocking is particularly important in *Eucalyptus saligna* stands grown on a short rotation without thinning, and in which coppice regeneration will be utilized for several successive crops.

TABLE 49

PASTURE LAND LEASES, ISLAND OF HAWAII 1970-1979

| Year | Acres | Annual Rental | Average Rental/Acre | No. Leases |
|---|---|---|---|---|
| 1970 | 282,171 | $472,300 | $1.67 | 95 |
| 1971 | 279,223 | 526,149 | 1.88 | 95 |
| 1972 | 274,386 | 508,898 | 1.85 | 86 |
| 1973 | 176,826 | 118,395 | 0.67 | 53 |
| 1974 | 132,045 | 61,457 | 0.47 | 37 |
| 1975 | 131,951 | 60,342 | 0.46 | 35 |
| 1976 | 173,327 | 633,237 | 3.65 | 54 |
| 1977 | 173,339 | 633,337 | 3.65 | 55 |
| 1978 | 172,032 | 631,858 | 3.67 | 48 |
| 1979 | 172,100 | 633,708 | 3.68 | 48 |

Source: Department of Land and Natural Resources, State of Hawaii, Report to the Governor, various years.

In 1961, the U.S. Forest Service and the Hawaii Division of Forestry began a joint study to determine the optimum spacing for Eucalyptus saligna; the study site was on the Koolau Forest Reserve on the Island of Maui. In five years, the study trees had shown extremely rapid growth rates— rates not likely to be equalled by any other species in the United States (102). According to Table 50, 8-feet by 8-feet spacing not only grew more trees per acre, but yielded 3,800 cubic feet per acre at five years compared to other spacings.

Based on Tamimi's study on the growth of Eucalyptus saligna at Paauilo planted in six-foot-square spacing, a stand volume of 5,900 cubic feet per acre at five years was reported (107). This seems to confirm the study by Luckhoff and the suggestion by the F.A.O. that a volumetric yield can be increased on a short rotation pulpwood crop with a denser spacing.

A proposed plantation layout and spacing of trees for this feasibility study are presented in Figures 9 and 10. Assumptions and pulpwood yield are given below (107).

- minimum stem to stem spacing of 6 feet to achieve growth rate for Eucalyptus saligna similar to the Tamimi test plots.
- minimum equipment clearance of 15 feet between alternating rows.
- pineapple spacing scheme which results in the maximum tree/acre density (see Figure 10), 720 trees/planted acre.
- survival rate of seedlings = 90%
- harvest = 647 trees/planted acre
- density of wood on green volume basis = 74 lb/cu ft at a moisture content of 50%
- tree growth period = 5 years.
- diameter at cut = 6.3 inches (6 in. diameter breast height)
- height = 60 feet

TABLE 50

TREE SURVIVAL, BASAL AREA, HEIGHT, AND DIAMETER OF SALIGNA EUCALYPTUS AT FIVE YEARS, BY SPACING, IN HAWAII

| Spacing | Stand Density | Tree Survival | Basal Area | Stand Volume | Height | Diameter Breast Height |
|---|---|---|---|---|---|---|
| | | | | | (all trees) | |
| feet | trees/acre | percent | sq.ft./acre | cu.ft./acre | feet | inches |
| 8 by 8 | 599 | 88 | 142 | 3800.0 | 76 | 6.2 |
| 10 by 10 | 384 | 88 | 112 | 2956.0 | 72 | 7.0 |
| 12 by 12 | 248 | 82 | 88 | 2214.0 | 75 | 7.4 |
| 14 by 14 | 178 | 80 | 70 | 1833.0 | 76 | 7.9 |

Source: G. A. Walters and T. H. Schubert, "Saligna Eucalyptus Growth in a Five-Year-Old Spacing Study in Hawaii," Journal of Forestry, Vol. 67, No. 4, Apr. 1969, p. 233.

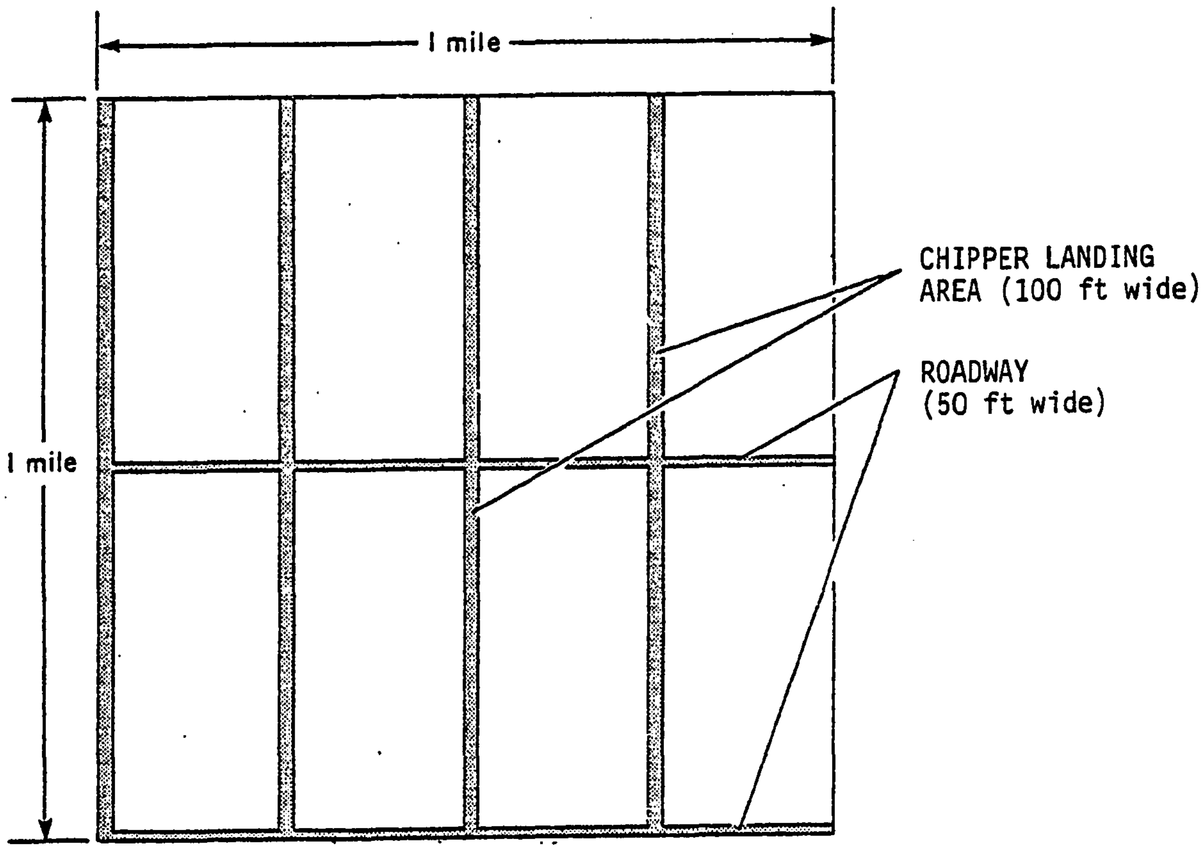


Figure 9. Plantation Layout for One Mile Sector

Source: Christine Yang, et al. (Eds.), Biomass Energy for Hawaii, Volume IV Terrestrial and Marine Plantations, Institute for Energy Studies, Stanford University, California, 1977, p. 42

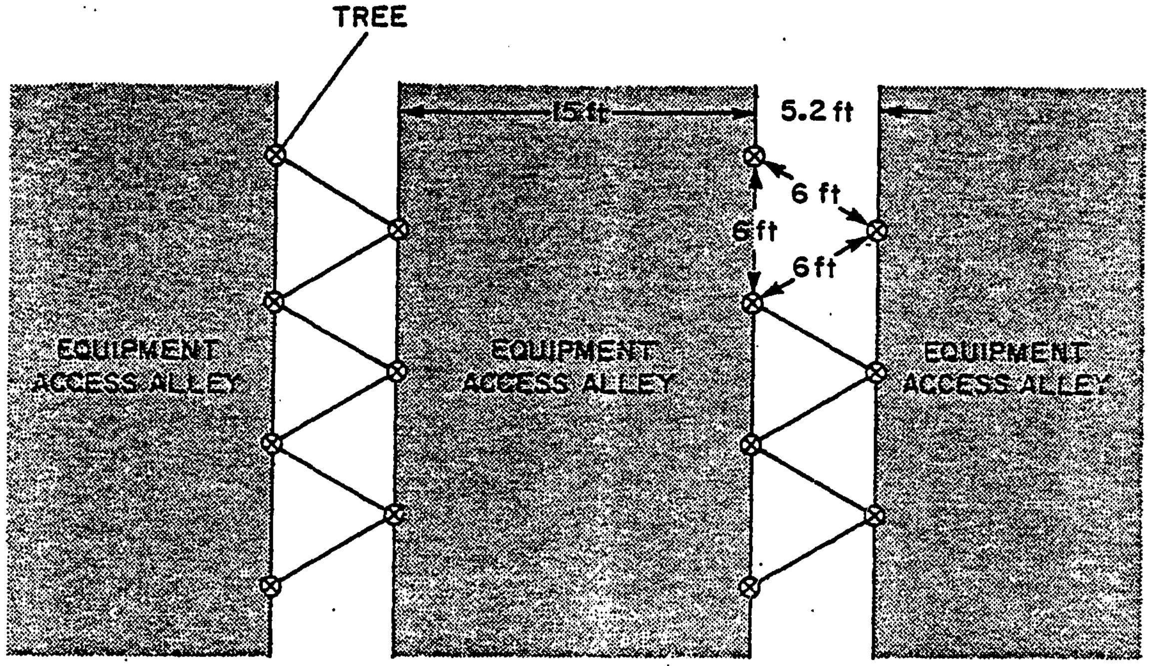


Figure 10. Planting Arrangement

Source: Christine Yang, et al. (Eds.), Biomass Energy for Hawaii, Volume IV Terrestrial and Marine Plantations, Institute for Energy Studies, Stanford University, California, 1977, p. 114.

Calculation:

| | |
|---|---|
| 4.44 | Tree trunk volume (cone), cu ft |
| + .43 | Volume of limbs and leaves (10%), cu ft |
| 4.87 | Total tree volume, cu ft/tree |
| x 74 | Wood density (green), lb/cu ft |
| 360 | Tree weight, lb/tree |
| x 647 | Trees/planted acre |
| 116.6 | Green tons/planted acre |
| ÷ 5 | Crop rotation every five years |
| 23.3 = | Yield Green tons/acre-yr |
| or 11.6 | Bone-dry ton/acre-yr |

Seedlings

Eucalypt seedlings can be ordered from the state nursery at Kamuela on the Island of Hawaii. Containerized eucalyptus seedlings have been quoted for 4 cents each. Containerized seedlings are considered in this study because of their high survival rate. Two million seedlings will be needed annually for the first five years; they will cost $80,000 a year. This analysis assumes that the state will be able to provide the needed seedlings to encourage silviculture as a means of developing its forest resources and at the same time diversify its economy. Without starting its own nursery, a plantation can cut down the early investment that is otherwise required. The savings on interest charge in the early stage will result in lower production cost.

Soil Preparation and Planting

The initial step in land development is to clear the land. Sites selected for eucalyptus plantations will require some degree of preparation before the plantation operation can start. The method of clearing and the equipment needed will obviously vary from site to site and will depend on such factors as soil, climatic and topographic conditions, and type and density of vegetation. For nonforested grazing and marginal agricultural lands, however, harrows may be used to incorporate the vegetation into the top six to eight inches of soil. The material then decays either before the seedlings are planted or during tree growth (107).

Soils which are either naturally poor or have been exhausted by cropping are characteristically low in both nitrogen and organic matter. Dramatic increases in the early growth rate of eucalypts can be obtained by the addition of moderate quantities of nitrogen and phosphorus (21). The cultivation of herbage legumes will also ensure nitrogen and organic enrichment (106). In addition to the fixation of organic nitrogen, if a legume cover crop is planted immediately after planting or harvesting operations, the soil will soon be covered with vegetation capable of holding the soil and reducing erosion while at the same time decreasing the need for weed control. The need for environmentally hazardous herbicides is therefore avoided. Within a year or two, the fast-growing eucalyptus trees should develop a canopy capable of shading out the legume undergrowth; without sufficient sunlight for growth, the legume will die and be incorporated into the plantation soil (107). This concept, however, is yet to be tried.

Assumptions on soil preparation and planting and their costs are given below and in Tables 51, 52, 53 in the following pages.

Assumptions:

- preparation of grazing land with no tree clearing.
- sequence of preparation:
  1) disc harrow to chop up weeds and incorporate grass into top 6-8 inches of soil, after which seedlings are planted; and

2) seed with legume crop immediately after each planting or harvest to check erosion and fix nitrogen.

- the above sequence occurs in the order described with two different working crews not including planting crew.
- prepare 13,000 acres for planting over 5 years.
- prepare 2,600 acres/yr.
- (250 work days/yr) (8-hr/work day) = 2,000 work hrs/yr.
- prepare 10.5 acres/operating day.
- supervisor oversees all soil preparation and planting operations.

Disc Harrow:

- necessary only beginning of project over first 5 years.
- one track-type prime mover with 7-foot offset disc width has production rate of 1.6 acres/hr (12.8 acres/day); therefore, require 1 tractor-harrow unit.
- require one operator/tractor

Planting:

- plant 13,000 acres over 5 yr.
- planting operations are repeated after third coppice crop is harvested.
- there are three dry months in summer when survival rate of trees is too low to justify planting.
- 16 days/yr when weather conditions do not permit planting.
- 180 planting days/yr.
- 5-day work week, 8-hour day.
- plant 2,600 acres/yr = 14.6 acres/planting day.
- 720 trees/acre = 10,500 trees/day
- 6-foot spacing between trees along a row.
- 5.2-foot spacing between rows with alternate tree spacing along rows.

- planted rows are 0.125 mile long= 660 ft/row

- mechanical planter (modified Quickwood ® planter) plants 2 rows at a time.

- planter will cost twice as much as single-row planter.

- 110 seedlings/row = 220 trees/planter pass.

- planter plants 800 seedlings/hr = 4.5 sec/seedling.

- 13.1 planting hr/day.

- two planters are used, each having an actual planting time of 6.55 hr/day; this leaves 1.45 hr/day for refilling.

- one 10-gm fertilizer pellet is inserted along with the seedling at time of planting.

- fertilizer is 20% nitrogen, 10% phosphoric acid, 5% potash, 2.6% calcium.

- fertilizer cost as delivered to dock in California is $0.0175/pellet.

- $0.018/fertilizer pellet delivered to Hawaii.

- require 1,890,000 fertilizer pellets and seedlings/yr.

- one truck is used to bring fuel, fertilizer, and seedlings to field each day (travel 50 mi/day).

- two track-type prime movers are required.

- one operator/prime mover and two laborers/planter.

- operators paid 196 days/yr.

- supervisor to oversee soil preparation and planting operations (requires truck at 60 mi/day).

- supervisor works 250 days/yr.

- some seedlings may need to be replanted in second year after planting.

Legume Seeding:

- seed legume immediately after each planting and harvest.

- 1 lb <u>Desmodium intortum</u> (greenleaf) seed/acre.

- 2625 lb legume seed/year
- use same truck that transports seedlings to field for transporting seed to field.
- require one track-type prime mover and one seeder.

TABLE 51

EXPENDITURES FOR DISC HARROWING

| Capital Costs | Life (yrs.) | Number Required | Unit Cost | Total Cost | Annual Depreciation |
|---|---|---|---|---|---|
| Prime Mover (Caterpillar D-6) | 5 | 1 | $80,000 | $80,000 | $16,000 |
| Disc Harrow | 5 | 1 | $ 6,135 | $ 6,135 | $ 1,227 |
| Totals | | | | $86,135 | $17,227 |

Source: Christine Yang, et al. (Eds.), Biomass Energy for Hawaii, Volume IV Terrestrial and Marine Plantations, Institute for Energy Studies, Stanford University, California, 1977, p. 121.

Annual Operating Costs

| | | |
|---|---|---|
| Prime Mover (D6)-one unit | | |
| Fuel consumption: 5.0 gal/hr @$0.50/gal | $ 5,000 | |
| Labor: one operator @ $7.93/hr | 15,860 | |
| Labor Overhead: 35% of labor | 5,551 | |
| Insurance: 1% of average value | 600 | |
| Maintenance/Repair: 5% of initial capital cost | 4,000 | |
| Subtotal | | $31,011 |
| Disc Harrow | | |
| Insurance: 1% of average value | $ 46 | |
| Maintenance/Repair: 5% of initial capital cost | 307 | |
| Subtotal | | $ 353 |
| Total Annual Operating Costs | | $31.364 |

TABLE 52

EXPENDITURES FOR PLANTING

| Capital Costs | Life (yrs.) | Number Required | Unit Cost | Total Cost | Annual Depreciation |
|---|---|---|---|---|---|
| Prime Mover (Caterpillar D4D SA LGP) | 5 | 2 | $36,750 | $ 73,500 | $14,700 |
| Planter (Modified Quickwood) | 5 | 2 | 8,600 | 17,200 | 3,440 |
| Truck for fuel fertilizer, seedlings | 5 | 1 | 20,000* | 20,000 | 4,000 |
| Supervisor's Truck | 5 | 1 | 8,000* | 8,000 | 1,600 |
| Totals | | | | $118,700 | $23,740 |

*Estimated by Stanford University study team.

Note: All equipment prices include tax and shipping costs, average value = 0.75 x initial capital cost)

Source: Christine Yang, et al. (Eds.), Biomass Energy for Hawaii, Volume IV Terrestrial and Marine Plantations, Institute for Energy Studies, Stanford University, California, 1977, p. 123.

Annual Operating Costs

| | | |
|---|---|---|
| Prime Mover (D4D SA LGP)-two units | | |
| Fuel consumption: 5.6 gal/hr @ $0.50/gal | $ 8,064 | |
| Labor: two operators @ $7.93/hr | 24,868 | |
| Insurance: 1% of average value | 551 | |
| Maintenance/Repair: 5% of initial capital cost | 3,676 | |
| Subtotal | | $ 37,159 |
| Planter (Modified Quickwood)-two units | | |
| Labor: four operators @ $3.87/hr | 24,273 | |
| Insurance: 1% of average value | 129 | |
| Maintenance/Repair: 5% of initial capital cost | 860 | |
| Subtotal | | 25,262 |
| Truck for fuel, fertilizer, seedlings-one unit | | |
| Fuel consumption: 5 mpg @ $0.65/gal | 1,170 | |
| Labor: one operator @ $4.66/hr | 7,307 | |
| Insurance: 2% of average value | 300 | |
| Maintenance/Repair: 5% of initial capital cost | 1,000 | |
| Subtotal | | 9,777 |
| Supervisor's Truck-one unit | | |
| Fuel consumption: 15 mpg @ $0.65/gal | 650 | |
| Labor: one supervisor @ 8.23/hr | 16,460 | |
| Insurance: 2% of average value | 120 | |
| Maintenance/Repair: 5% of initial capital cost | 400 | |
| Subtotal | | 17,630 |
| Fertilizer Costs | | |
| 1,891,980 fertilizer pellets @ $0.018/pellet | | 34,055 |
| Labor Overhead-35% of Labor | | 25,518 |
| Total Annual Operating Costs | | $149,401 |

TABLE 53

EXPENDITURES FOR LEGUME SEEDING

| Capital Cost | Life (yrs.) | Number Required | Unit Cost | Total Cost | Annual Depreciation |
|---|---|---|---|---|---|
| Prime Mover (Caterpillar D4D SA LGP) | 5 | 1 | $36,750 | $36,750 | $7,350 |
| Seeder | 5 | 1 | $ 5,000 | $ 5,000 | $1,000 |
| Totals | | | | $41,750 | $8,350 |

Source: Christine Yang, et al. (Eds.), Biomass Energy for Hawaii, Volume IV Terrestrial and Marine Plantations, Institute for Energy Studies, Stanford University, California, 1977, p. 120.

Annual Operating Costs

| | | |
|---|---|---|
| Prime Mover (D4D SA LGP)-one unit | | |
| Fuel consumption: 5.6 gal/hr @ $0.50/gal | $ 5,600 | |
| Labor: one operator @ $7.93/hr - 2,000 hr/yr | 15,860 | |
| Labor Overhead: 35% of labor | 5,551 | |
| Insurance: 1% of average value | 275 | |
| Maintenance/Repair: 5% of initial capital cost | 3,675 | |
| Subtotal | | $30,961 |
| Seeder-one unit | | |
| Insurance: 1% of average value | $ 38 | |
| Maintenance/Repair: 5% of initial capital cost | 250 | |
| Subtotal | | $ 288 |
| Seed Costs (Desmodium intortum-Greenleaf) | | |
| 2625 lbs @ $6.50/lb | | 17,062 |
| Total Annual Operating Costs | | $48,311 |

## Coppicing

When some hardwoods, including the great majority of the eucalypts, are cut down, shoots grow freely from dormant buds on the stumps; regeneration produced in this way is known as coppicing. The coppice system is the oldest form of systematic silviculture. It was practice by the Greeks and Romans, and was of great importance when wood was the main industrial fuel.

The coppice shoots can draw on an established root system, and they have much greater vigor than the seedling shoots. The young coppice shoots develop quickly after the old forest is felled because they are supported by the root system of the mature trees. The number of shoots reaching utilizable size from each stump in unthinned coppices averages between two and three only (63).

In South Africa and South America, *Eucalyptus grandis* and *Eucalyptus saligna* are managed on rotations of five to eight years for pulpwood. Three out of four crops are harvested from coppice which develops vigorously from the stumps (18).

The yields for three coppice crops in this analysis are based on 120 per cent, 90 per cent and 80 per cent of the yield of the initial planting, following a study by the F.A.O. (27). This variation in yields will obviously affect gross revenues.

A summary of the sequence of plantation operations is presented in Table 54.

## Harvesting and Chipping

Many factors influence production of any logging operation. Logging costs per unit of output depend not only upon the productivity of the

TABLE 54

SUMMARY OF SEQUENCE OF PLANTATION OPERATION

| Year | Plant 3,000 acres | Plant legume cover crop* | Apply time-release fertilizer pellet | Harvest crop from year | Allow stump to coppice |
|---|---|---|---|---|---|
| 1 | x | x | x | | |
| 2 | x | x | x | | |
| 3 | x | x | x | | |
| 4 | x | x | x | | |
| 5 | x | x | x | | |
| 6 | | x | x | 1 | x |
| 7 | | x | x | 2 | x |
| 8 | | x | x | 3 | x |
| 9 | | x | x | 4 | x |
| 10 | | x | x | 5 | x |
| 11 | | x | x | 6 | x |
| 12 | | x | x | 7 | x |
| 13 | | x | x | 8 | x |
| 14 | | x | x | 9 | x |
| 15 | | x | x | 10 | x |
| 16 | | x | x | 11 | x |
| 17 | | x | x | 12 | x |
| 18 | | x | x | 13 | x |
| 19 | | x | x | 14 | x |
| 20 | | x | x | 15 | x |
| 21 | | | | 16 | |
| 22 | | | | 17 | |
| 23 | | | | 18 | |
| 24 | | | | 19 | |
| 25 | | | | 20 | |

*Legume shaded out by eucalyptus canopy after two years.

labor and the efficiency of equipment but also upon the topography, climatic conditions and the density and size of trees being logged. Therefore, any consideration of production costs must be tied to the area being logged.

The total output of chipping depends very much on the organization of work. The most common practice is to chip into a transporting vehicle. Stoppages vary according to the type of chipper. They include preparatory work of the chipping site, movements of chipper within and between chipping sites, servicing and repairs. The waiting time of trucks covers the most effective time lost (26).

The cost of field chipping is slightly higher than chipping at the mill because of maintenance and power cost. It is cheaper, however, to receive and handle woodchips at the millyard than to receive roundwood which requires double handling. Moreover, woodchip storage is cheaper than roundwood because less land is required (12).

A feller-buncher is essential because it makes it possible to deliver an adequate quantity of material to the chipper; it efficiently cuts and accumulates small diameter (six to seven-inch) trees. The feller-buncher consists of a large crawler with a tree shear mounted on the end of an articulated boom. The shear head clamps and shears trees off a few inches above ground level if a coppicing crop is desired for the next harvest or at ground level if replanting is planned. However, if trees were shear felled and bunched by a feller-buncher and then topped and delimbed in bundles, the shearing forces could cause loss of productivity in later coppice crops due to damage to the stumps (17).

After felling, chain saws are used to buck off limbs and leaves from the trees, leaving them on the ground to reduce erosion and improve soil conditions. Leaving green matter in the field would return a large portion of nitrogen and other minerals to the soil because leaves, bark and branches are the wood-components highest in nutrients (107). Once the trees are accumulated, a skidder grabs the ends of six to nine trees with its grapple and drags them to a chipper.

The design and layout of the plantation outlined earlier dictates the equipment to be chosen so that each piece of equipment is fully utilized. All equipment will be selected on the basis of supplying each chipper with the appropriate amount of trees. Assumptions and costs of harvesting are given below and in Table 55.

Assumption:

- will harvest 1,200 green tons (45-50 percent moisture content) per operating day or 300,000 green tons per year.
- daily operations will be run on a 10-hour work day with two hours of paid overtime.
- 250 operating days per year.
- longest skidding distance will be 0.125 miles.
- with a five-year crop rotation individual trees will be 60 feet in height and 6.36 inches at cutting level (6 inches d.b.h.).
- tree density (green weight, 50 percent moisture content) is 74 pounds per cubic feet.
- tree weight 360 pounds.

There are basically two kinds of chippers with different cutting knives: disc chippers and drum chippers. Disc chippers are best suited for the production of high quality industrial chips (26). Morbark Total Chiparvestor Model 22 has a 3-knife disc capable of producing 200 to 300 tons per day (28)

The Morbark Model 22 Chiparvestor is highly maneuverable and requires only ten minutes for set-up when moved to a new landing. This is an

TABLE 55

EXPENDITURES FOR HARVESTING EQUIPMENT

| | Life (yrs.) | Number Required | Costs Unit | Costs Total | Annual Depreciation |
|---|---|---|---|---|---|
| Harvesting: | | | | | |
| Chipper, Morbark #22* | 10 | 4 | $104,520 | $ 418,080 | $ 41,808 |
| Chain saws | 1 | 12 | 400 | 4,800 | 4,800 |
| Feller-buncher-Drott 40LC | 10 | 9 | 69,432 | 624,888 | 62,489 |
| Skidder-John Deere | 5 | 12 | 46,246 | 554,952 | 110,990 |
| Supervisor's truck | 5 | 3 | 8,000 | 24,000 | 4,800 |
| | | | | $1,626,720 | $224,887 |
| Trucking: | | | | | |
| Truck tractors | 10 | 14 | 46,800 | 655,200 | 65,520 |
| Truck trailers | 10 | 13 | 20,200 | 262,600 | 26,260 |
| Trailer dumper | 10 | 2 | 44,200 | 88,400 | 8,840 |
| | | | | $1,006,200 | $100,620 |

*Reference to a trade name does not imply endorsement or recommendation of the product. It is used solely to provide specific information.

Note: All equipment prices include tax and estimated freight costs. One additional tractor/trailer is purchased after five years.

Source: Christine Yang, et al. (Eds.), Biomass Energy for Hawaii, Volume IV Terrestrial and Marine Plantations, Institute for Energy Studies, Stanford University, California, 1977, p. 55.

Annual Operating Costs

| | | |
|---|---|---|
| **Chipper-4 units** | | |
| Fuel consumption: 30 gal/hr, 8 hr/day, 4 units and 250 working days = 240,000 gal/yr @ $0.50/gal | $120,000 | |
| Labor: 4 operators @ $7.83/hr | 86,130 | |
| 4 buckers @ $6.16/hr (10-hr day @ 1.5 overtime) | 67,760 | |
| Labor Overhead: 35% of labor | 53,862 | |
| Insurance: 1% of average value | 3,136 | |
| Maintenance/Repair: 5% of original cost | 20,904 | |
| Subtotal | | $ 351,792 |
| **Feller-Buncher Drott 40C-9units** | | |
| Fuel Consumption: 4 gal/hr, 9 hr/day, 9 units and 250 working days = 81,000 gal/yr @ $0.50/gal | $ 40,500 | |
| Labor: 9 operators @ $7.93/hr | 196,268 | |
| Labor Overhead: 35% of labor | 68,964 | |
| Insurance: 1% of average value | 5,757 | |
| Maintenance/Repair: 5% of original cost | 31,244 | |
| Subtotal | | 342,463 |
| **Skidders, JD544B-12units** | | |
| Fuel consumption: 3.3 gal/hr, 9 hr/day, 12 units and 250 working days = 89,100 gal/yr @ $0.50/gal | $ 44,550 | |
| Labor: 12 operators @ $7.93/hr | 261,696 | |
| Labor Overhead: 35% of labor | 91,594 | |
| Insurance: 1% of average value | 3,901 | |
| Maintenance/Repair: 5% of original cost | 27,748 | |
| Subtotal | | 429,489 |
| **Supervisor Trucks-3 units** | | |
| Fuel Consumption: 8 gal/day, 3 units and 250 working days = 6,000 gal/yr @ $0.50/gal | $ 3,000 | |
| Labor: 3 supervisors @ $8.23/hr | 67,898 | |
| Labor Overhead: 35% of labor | 23,764 | |
| Insurance: 1% of average value | 1,500 | |
| Maintenance/Repair: 5% of original cost | 1,200 | |
| Subtotal | | 97,362 |
| Total Annual Operating Costs | | $1,221,106 |

important feature because it allows the chipper to be moved frequently without substantial loss of operating time. As a consequence, skidding distances, which are the major component of the operating cost, can be reduced. The total daily production level of 1,200 green tons can be met with four Morbark Chiparvestors, each processing about 40 green tons per hour, with the majority of lost time due to periodic changing of knife blades and waiting time for the return of the chip vans. A combined operating time loss of two hours per day appears reasonable for the plantation. Each chipper and support equipment must then be operated over a ten-hour shift to harvest 300 green tons per day (107). A woodchip processing flow chart is presented in Appendix C.

Two feller-bunchers will be required, each cutting 112 trees per hour. It must be capable of shearing trees at ground level or higher. When cutting the six-inch stems typical of the proposed plantation, it has a capacity of 150 trees per operating hour. This represents about 34 percent spare capacity, which will cover downtime, adverse weather conditions and difficult terrain (107).

Three wheeled skidders were selected to supply each chipper with 40 green tons per hour or 6.7 tons every ten minutes. A total of twelve skidders with a grapple capacity of 6.5 tons will be required for the four chippers. Wheeled equipment will be used because it will be more maneuverable around the stumps left after cutting. Skidder capacity is highly dependent on the total skidding cycle time, which is the time required to pick up the bunched load of trees, skid them to the chipper and return to the feller-buncher.

With three skidders operating, approximately 6 tons of material can be moved to the chipper every 6.25 minutes. Average cycles show this capacity can meet the 6.7 tons per 10 minutes chipper requirement, with about 43 percent extra capacity to cover downtime, adverse weather conditions and difficult terrain (107).

## Trucking and Road Construction Costs

The amount of trucking capacity required to accept woodchips from the four chippers and transport the daily output of 1,226 green tons to Kawaihae Harbor depends on carrying load, loading and unloading time, total daily operating time and most importantly, the total distance traveled. The annual operating costs for the required 13 trucks based on the following assumptions are given below (107).

Assumptions:

- Round trip distance is 50 miles from plantation site to Kawaihae Harbor
- Shift time is 12 hours per day.
- Average traveling speed is 30 miles per hour.
- Wages are $7.38 per hour
- Loading and unloading times are 30 minutes each.
- Legal load limit for an 18-wheel van is 24 tons.

Calculations:

$$\text{Number of trips required} = \frac{\text{1200 green tons/day}}{\text{24 tons/trip}} \cong \text{50 trips/day}$$

50-mile round-trip distance will require a total cycle time of 180 minutes.

$$\text{Number of trips per day} = \frac{\text{720 minutes}}{\text{180 minutes}} \cong \text{4 trips per trucks.}$$

$$\text{Required number of trucks} = \frac{\text{50 trips/day}}{\text{4 trips/truck}} \cong \text{13 trucks.}$$

Expenditures for Trucking Requirements

Capital Costs have been given in Table 5.

Annual Operating Costs:

| | | |
|---|---|---|
| Truck Tractors-14 units with 1 used as a spare | | |
| Fuel consumption: 4 mpg, 200 mi/day, 13 units and 250 working days = 162,500 gal @ $0.50 | $ 81,250 | |
| Labor: 13 operators @ $7.38/hr (1.5 overtime) | 335,790 | |
| Labor Overhead: 35% of labor | 117,526 | |
| Insurance: 2% of average value | 9,828 | |
| Road taxes: @ $1,000/yr-truck | 14,000 | |
| Maintenance/Repair: 5% of original cost | 32,760 | |
| Subtotal | | $591,154 |
| Truck Trailers-13 units | | |
| Insurance: 1% of average value | $ 1,969 | |
| Maintenance/Repair: 5% of original cost | 13,130 | |
| Subtotal | | 15,099 |
| Trailer Dumper-2 units | | |
| Labor: 2 operators @ $7.38/hr (1.5 overtime) | $ 51,660 | |
| Labor Overhead: 35% of labor | 18,081 | |
| Insurance: 1% of average value | 663 | |
| Maintenance/Repair: 5% of original cost | 4,420 | |
| Subtotal | | 74,824 |
| Total Annual Operating Costs | | $681,077 |

After every 5 years of harvesting, an additional tractor and trailer are purchased to back up the old ones. The annual operating costs will increase proportionately to $716,000.

A good road system is essential to keep logging costs down. Hawaii is fortunate in this respect because the road system in and around the sugar cane and pineapple plantations either goes past or close to forest plantations that currently have timber of commercial size or constitute potential timber growing sites. To develop new forest plantation areas,

TABLE 56

ROAD COST ESTIMATES

| | Type | Distance(mi) | $/mi | Total |
|---|---|---|---|---|
| Road Construction: | | | | |
| | Primary | 5 | 70,000 | $ 350,000 |
| | Secondary | 145 | 16,000 | 2,322,000 |
| | Total Construction Cost for 5 Years: | | | $2,672,000 |
| | Annual Road Cost: $534,000 | | | |
| Road Maintenance: | | | | |
| | Assumes $2,000/mi-yr average | | | |
| | Annual Road Maintenance: $300,000 | | | |

Source: Christine Yang, et al. (Eds.), Biomass Energy for Hawaii, Volume IV Terrestrial and Marine Plantations, Institute for Energy Studies, Stanford University, California, 1977, p. 43.

new heavy-duty main haul roads and secondary haul and skid road systems will have to be developed (8).

The construction of approximately 145 miles of secondary roads and five miles of primary roads to provide access for the chip van loading sites for the chippers is not necessary until late in the fifth plantation year, just prior to harvesting. Road construction will then proceed slightly ahead of the harvesting phase. Delaying the road construction has the advantage of allowing plantation revenues to finance this very expensive start-up activity. These roads are not necessary for the site preparation and planting phase performed earlier.

Secondary roads for a eucalyptus plantation operation will cost about $16,000 per mile. Road costs are highly dependent on site terrain and the availability of a close supply of cinder rock for a road base. Quotes on primary roads range from $70,000 to $100,000 per mile for subcontracted work as indicated in Table 56. The total maintenance cost would be about $300,000. The maintenance cost will increase by one-fifth of the total cost from the sixth year as the plantation gradually approaches full production level. On the other hand as the project comes to an end the maintenance cost starts to decline because less mileage requires maintenance.

## Storage and Chip Loading

Before giving the cost of storing woodchips, it is important to review some past studies involving woodchip storage.

On the U.S. West Coast, pulpwood chips have been stored outdoors in large piles since the early 1950's. However, deleterious processes may take place during chip storage, leading to loss of wood substance, increased consumption of cooking or bleaching chemicals, increased fines content, wood discoloration, or a decline in paper strength (33). In some instances, however, woodchip storage may have a beneficial effect on the pulping process, for example, by providing conditions for a higher rate of reduction of the resin content, compared with logs (55).

Damage to woodchips is greatest in the outer few feet of the sides of piles and develops faster in hardwoods, such as gum and oak, than in pines (73). Large chip piles may incur a lower loss in wood substance on storage because the outer zones of the pile, which constitute a greater proportion of the total volume in a smaller chip pile, are the most affected (55).

A sufficient rise in temperature may also cause spontaneous ignition of the pile. It is also possible to ignite the surface of the pile from outside sources such as a grass fire, flying brands, or spilled flammable liquids. Moisture content of the woodchips and wind velocity are the major factors which affect surface fires (45).

A study has been made of the microbial ecology of mixed tropical hardwood chips stored for two and four months in equatorial Papua New Guinea in experimental conical-shaped piles. Biodeterioration in the form of discoloration and loss in wood substance occurred; loss in wood substance increased from 2 percent at two months to 7 percent after four months. Deterioration in chip piles overseas varies slightly from country to country and among wood species, but, on the whole, the figures compare well with this result (43). The loss of wood substance, therefore, does not appear to be a major problem. However, the length of woodchip storage time depends on climate, wood species and pulping processes (28).

It is assumed in this study that 150,000 BDT of woodchips will be exported annually to Japan in four or five shipments. Therefore, severe loss in wood substance is not expected because storage time will be short. This will also reduce the risk of fire due to heat build-up.

Wheeled chip loaders are often the major chip-handling equipment used for chip pile build-up and reclaiming. Many mills have found it advantageous to use a rubber-tired loader which travels relatively gently on the chip pile (7); chip damages are minimized as a result.

For this reason, a wheeled front-loader with snowplow attachment will be used to push chips. The loader will need to be replaced every 10 years. Capital and annual operating costs are given below.

Capital Costs:

| | |
|---|---|
| A wheeled front-end loader with snowplow | $50,000 |

Annual Operating Costs:

| | |
|---|---|
| Land lease: Storage at Kawaihae Harbor | 300 |
| Heavy equipment operator: $7.93/hr | 16,494 |
| Labor overhead: 35% of labor | 5,773 |
| Fuel consumption: 3.3 gal/hr (6600 gal/yr) | 3,300 |
| Insurance: 1% or average value | 500 |
| Maintenance/Repair: 5% of original cost | 2,500 |
| Total Annual Operating Costs | $28,867 |

Existing sugar loading facilities in Kawaihae, on the Island of Hawaii, are used for woodchips loading. This minimizes early heavy investment and makes for better utilization of the existing facilities. Since revenues are derived from F.A.S. prices, the Japanese importer will absorb the loading expenses.

Taxes

Corporate ownership is assumed. The ordinary income tax is a composite of the federal coporate tax rate of 48 percent and the state income tax rate of 6.45%. The composite rate is given by:

$$6.45\% + (1 - 0.0645)\ 48\% \quad = \quad 51.35\%$$

The capital gains tax rate is assumed to be 30 percent, so that the capital gains tax = (Net Capital Gains) x 30%.

The value of the eucalyptus woodchips can be broken down into two components (98):

1) the value of the free-standing timber, and

2) the value added to the free-standing timber when it is processed—harvested, chipped and trucked.

The former value is taxed at the capital gains rate while the latter is taxed at the ordinary income rate. A value added to the free-standing timber during the harvesting and chipping operations has been estimated to be $16.88 per BDT. For a sale price of $50 per BDT, this amounts to 34 percent of the price of the chips. Therefore, the value of the free-standing timber accounts for about 66 percent of the sale price of the woodchips which is taxed as capital gains rate. Tax tables are presented Tables 63 and 64 in Appendix D.

The assumptions and calculation that lead to the above conclusion are given below.

Assumptions:

- woodchip selling price = $50/BDT
- require 20% rate of return before taxes
- 10-yr life for trucks and harvesting equipment
- harvest 150,000 BDT/yr

Annual Operating Costs:

$ 681,077 (trucking)
1,221,100 (harvesting)

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$1,902,177

Capital Expenditures:

$1,006,200 (trucking)
1,626,720 (harvesting)

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$2,632,920

Capital Recovery Factor @20%, 10-yr life = 0.239

Annual Return on Capital = ($2,632,920/yr) (0.239) = $629,270/yr

Total Costs = $1,902,177 + $629,270 = $2,531,447/yr

$$\text{Value Added/Ton Harvested} = \frac{\$2,531,447/\text{yr}}{150,000/\text{BDT/yr}} = \$16.88/\text{BDT}$$

$$\text{Value Added/Selling Price} = \frac{\$16.88/\text{BDT}}{\$50.00/\text{BDT}} = 0.34$$

Under accounting procedures, depreciation is written off at the end of fiscal year. For cost analysis purposes, the straight line method of depreciation is most satisfactory (101). This method depreciates the capital investment over the period of years of its anticipated useful life in equal installments.

Capital investments cover the equipment costs of the harvesting, trucking, and storage operations. It also includes the cost of road construction. Capital investments are fully depreciable expenses deductible from the plantation's ordinary income. The salvage or residue value is assumed to be zero because land will be leased and the highly specialized equipment will be fully depreciated for tax purposes. The economic life of the equipment coincides with the length of the project itself. Should the project continue replacement would be required.

Ordinary expenses cover expenditures for management and overhead, and operating expenses for harvesting, road maintenance, trucking, and woodchip storage. Management and overhead include two full-time managers at full production, office leasing, legal and secretarial fees, engineering consultant fees, stores and supplies, miscellaneous and contingency expenses. Ordinary expenses are deductible from the ordinary income of the plantation's gross revenues (98).

Expenses such as site preparation, planting, seedlings and land lease expenditures are considered as capitalized costs (98). The depletion basis in the calculation represents an annual average of the five-year capitalized expenses that were used to grow the trees. Therefore, these costs are not deductible until the trees are sold. In this case the trees are harvested, chipped, transported, and then sold. Only then is the depletion basis deducted from the capital gains portion of the incoming revenues.

## Sensitivity Analysis

So far, it has been implicitly assumed that all input and output prices will remain constant or change at the same rate over time and therefore will not change the relative values. Such an assumption would yield reliable results only if all costs and revenues would change uniformly by the same proportion.

However, uncertainty is inherent in project analysis. Estimates of costs and revenues are approximate, even for the present, and uncertainty increases when those estimates are projected into the future, as the analysis requires. Actual value may deviate even from the best estimates or expected values. A question, therefore, is how this uncertainty is to be taken into account. In traditional analytical practice, sensitivity analysis is a standard part of project analysis (93).

An analysis which does not take account of price changes is over-simplified and unrealistic. One of the most obvious factors affecting future prices is inflation. It would be very difficult to forecast the future rate of inflation but it is not helpful to set aside the problem altogether by varying all costs, revenues and interest rates in real terms. A careful economic and financial analysis must test whether a proposed project is still feasible if some events occur unexpectedly. Sensitivity analysis is concerned with the effects on the outcome of the analysis of changes in the values of particular variables. In other words, how sensitive are a project's internal economics to a particular event?

Although there are more elaborate risk analysis techniques, sensitivity analysis is a rather straightforward and a quite efficient means to deal with the question of risk and uncertainty in project analysis. Of course, a sensitivity analysis is quite subjective. Decisions are made on which variables in the calculation are most critical and most uncertain, and testing to see how sensitive the calculated present value is to likely change in the value of these variables (11).

In agriculture and silviculture there are generally two main kinds of sensitivity analyses which should be considered. The first one is changes in relative input and output prices and the second one is changes in the level of yields (41).

Results

Interest rates charged by banks on long-term business loans in 1976 are given in Table 57. Allowing for risk and uncertainty, a 10 percent real interest rate is assumed in this study.[6] It is important to remember that all costs and revenues are in 1976 dollars.

A summary of expenses, taxes, and revenues is presented in Table 58. The results of the economic feasibility and the sensitivity analysis of the changes in costs, yields and woodchip prices are presented in Table 59. Since the selection of the appropriate interest rate for financial analysis raises difficult and subjective questions, the standard practice is followed here in presenting results from a range of interest rates for practical and comparison purposes.

With a 10 percent real interest rate, the results of the economic feasibility analysis of the woodchip project show a NPV of 11.79 million dollars, a B/C ratio of 1.53 and an IRR of 31.2 percent. On one extreme, when a real interest rate is 16 percent, yields are 20 percent lower and price and costs are, respectively, 10 and 20 percent higher than estimated, the NPV is 3.12 million dollars, the B/C ratio is 1.22 and the IRR is 27.40. These results indicate the feasibility of producing woodchips on the Island of Hawaii for export to Japan under the conditions of this study.

Results of changes in costs, yields and prices at different percentages can be obtained if they are needed.

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[6]Since interest rates fluctuated widely during 1979-1980, real interest rates, not nominal rates, are applied. The difference is: real rate of interest = nominal rate of interest - rate of inflation. Experienced a record high of 21 percent prime interest rate in 1980, a 10-percent real interest rate applied may seem very low. It is reasonable, however, when a 12-percent inflation rate is considered.

TABLE 57

LONG TERM INTEREST RATES CHARGED BY BANKS ON BUSINESS LOANS IN 1976

(In percent per annum)

| Size of Loan ($1,000) | New York City | | | | West Coast | | | |
|---|---|---|---|---|---|---|---|---|
| | Feb. | May | Aug. | Nov. | Feb. | May | Aug. | Nov. |
| 100-499 | 8.01 | 8.45 | 8.05 | 7.93 | 8.85 | 7.73 | 8.81 | 8.31 |
| 500-999 | 7.25 | 8.51 | 8.44 | 8.06 | 9.12 | 8.29 | 10.00 | 7.78 |
| 1000 and over | 7.68 | 7.76 | 8.56 | 7.26 | 8.28 | 8.26 | 8.46 | 8.03 |

Source: Federal Reserve Bulletin, Sept. 1976, p. A26, and Jan. 1977, p. A26

TABLE 58

SUMMARY OF EXPENSES, TAXES AND REVENUE

(In thousands of dollars)

| Year | Land lease and tax | Seedlings | Site Preparation and Planting | | Roads | | Harvesting | | Trucking | | Storage | | Management & overhead | Taxes | Revenue |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Capital | Operating | Capital | Operating | Capital | Operating | Capital | Operating | Capital | Operating | | | |
| 1 | 78 | 80 | 247 | 229 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 150 | -77 | 0 |
| 2 | 156 | 80 | 0 | 229 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 150 | -77 | 0 |
| 3 | 234 | 80 | 0 | 229 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 150 | -77 | 0 |
| 4 | 312 | 80 | 0 | 229 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 150 | -77 | 0 |
| 5 | 390 | 80 | 0 | 229 | 534 | 0 | 1627 | 0 | 1006 | 0 | 50 | 0 | 150 | -77 | 0 |
| 6 | 390 | 0 | 42 | 48 | 534 | 60 | 0 | 1221 | 0 | 681 | 0 | 29 | 300 | 1234 | 7500 |
| 7 | 390 | 0 | 0 | 48 | 534 | 120 | 0 | 1221 | 0 | 681 | 0 | 29 | 300 | 1203 | 7500 |
| 8 | 390 | 0 | 0 | 48 | 534 | 180 | 0 | 1221 | 0 | 681 | 0 | 29 | 300 | 1172 | 7500 |
| 9 | 390 | 0 | 0 | 48 | 534 | 240 | 0 | 1221 | 0 | 681 | 0 | 29 | 300 | 1141 | 7500 |
| 10 | 390 | 0 | 0 | 48 | 0 | 300 | 603 | 1221 | 67 | 681 | 0 | 29 | 300 | 1110 | 7500 |
| 11 | 390 | 0 | 128 | 80 | 0 | 300 | 0 | 1221 | 0 | 716 | 0 | 29 | 300 | 1663 | 9000 |
| 12 | 390 | 0 | 0 | 80 | 0 | 300 | 0 | 1221 | 0 | 716 | 0 | 29 | 300 | 1663 | 9000 |
| 13 | 390 | 0 | 0 | 80 | 0 | 300 | 0 | 1221 | 0 | 716 | 0 | 29 | 300 | 1663 | 9000 |
| 14 | 390 | 0 | 0 | 80 | 0 | 300 | 0 | 1221 | 0 | 716 | 0 | 29 | 300 | 1663 | 9000 |
| 15 | 390 | 0 | 0 | 80 | 0 | 300 | 1627 | 1221 | 1006 | 716 | 50 | 29 | 300 | 1663 | 9000 |
| 16 | 390 | 0 | 42 | 48 | 0 | 300 | 0 | 1221 | 0 | 716 | 0 | 29 | 300 | 810 | 6750 |
| 17 | 390 | 0 | 0 | 48 | 0 | 300 | 0 | 1221 | 0 | 716 | 0 | 29 | 300 | 810 | 6750 |
| 18 | 390 | 0 | 0 | 48 | 0 | 300 | 0 | 1221 | 0 | 716 | 0 | 29 | 300 | 810 | 6750 |
| 19 | 390 | 0 | 0 | 48 | 0 | 300 | 0 | 1221 | 0 | 716 | 0 | 29 | 300 | 810 | 6750 |
| 20 | 390 | 0 | 0 | 48 | 0 | 300 | 603 | 1221 | 67 | 716 | 0 | 29 | 300 | 810 | 6750 |
| 21 | 390 | 0 | 0 | 0 | 0 | 300 | 0 | 1221 | 0 | 716 | 0 | 29 | 300 | 428 | 6000 |
| 22 | 312 | 0 | 0 | 0 | 0 | 240 | 0 | 1221 | 0 | 716 | 0 | 29 | 300 | 483 | 6000 |
| 23 | 234 | 0 | 0 | 0 | 0 | 180 | 0 | 1221 | 0 | 716 | 0 | 29 | 300 | 537 | 6000 |
| 24 | 156 | 0 | 0 | 0 | 0 | 120 | 0 | 1221 | 0 | 716 | 0 | 29 | 300 | 591 | 6000 |
| 25 | 78 | 0 | 0 | 0 | 0 | 60 | 0 | 1221 | 0 | 716 | 0 | 29 | 300 | 645 | 6000 |

TABLE 59

EFFECTS OF CHANGES IN COSTS, YIELDS AND PRICES ON THE WOODCHIP PROJECT'S ECONOMIC FEASIBILITY BASED ON 1976 DATA

| Cost | Yield | Price | Net Present Value (million dollars) | | | | Benefit-Cost Ratio | | | | Internal Rate of Return |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 10% | 12% | 14% | 16% | 10% | 12% | 14% | 16% | |
| Estimated* | Estimated† | Estimated§ | 11.79 | 8.85 | 6.64 | 4.96 | 1.53 | 1.48 | 1.42 | 1.37 | 31.20 |
| 10% Higher | 10% Lower | 10% Higher | 11.71 | 8.69 | 6.43 | 4.72 | 1.48 | 1.43 | 1.37 | 1.32 | 29.30 |
| 20% Higher | 20% Lower | 10% Higher | 7.85 | 5.83 | 4.30 | 3.12 | 1.32 | 1.29 | 1.25 | 1.22 | 27.40 |

*See Table 58.

†11.6 bone-dry tons per acre per year.

§$50 per bone-dry ton.

Break-Even Prices for Stumpage

So far the woodchip project has been treated as a vertically integrated operation. It starts from growing young seedlings to harvesting mature trees and finally producing woodchips. The entire process is run by a single business entity. On the other hand, the whole process can be performed by different people. A wood chipper may have contracts to purchase all required pulpwood from different sources. A wood chipper may also operate his own plantation to produce pulpwood while obtaining additional requirements from other tree growers.

A potential tree grower, who can be an individual, a corporation or even the state itself, may be interested in finding out the feasibility of growing pulpwood. Estimating the break-even price for pulpwood stumpage is important in this respect.

Assuming that marginal agricultural or pasture land is acquired, the investment in a eucalyptus plantation would only be economical if the net present value derived from the equation is equal to or greater than zero. Therefore, to determine the break-even price for stumpage, the Faustmann formula presented in the methodology section in Chapter I is set equal to zero and solve. It gives:

$$p_b = [a\{(1+i)^r-1\}/i+\sum_t c_t(1+i)^{r-t}]/[\sum_t y_t(1+i)^{r-t}]$$

where $p_b$ denotes the break-even price (\$/BDT) for stumpage.

For an output level of 150,000 BDT per year, \$150,000 is needed for management and overhead costs. This amount is half of the total required for producing 150,000 BDT of woodchips if the entire operations are vertically integrated. This amounts to a constant annual cost of \$10 per acre. Land lease, seedling cost, and site preparation and planting costs are as presented earlier in Table 58 and yields are as previously projected.

The break-even prices for stumpage of a pulpwood stand and the results of a sensitivity analysis due to changes in costs and yields are presented in Table 60. The break-even prices range from \$6.32 to \$11.72 per BDT depending on the rate of interest, cost of production and pulpwood yields. Assuming a 10 percent real interest rate with projected costs and yields, the break-even price is \$6.32 per BDT. It will raise to \$11.72 per BDT if the real interest rate is 16 percent, cost of production is 20 percent higher and pulpwood yields are 20 percent lower than expected. A tree farmer can figure out his break-even price in this general framework.

Currently, it is infeasible for a tree grower to supply stumpage to a chipper at the current rate of \$3 per BDT reportedly paid to private forest owners on the Island of Hawaii. Obviously, the current rate is underpriced if reforestation is planned.

TABLE 60

EFFECTS OF CHANGES IN COST, YIELD AND PRICE ON BREAK-EVEN PRICES FOR STUMPAGE

(In Dollars per bone-dry ton)

| Cost | Yield | Interest Rates | | | |
|---|---|---|---|---|---|
| | | 10% | 12% | 14% | 16% |
| Estimated* | Estimated† | 6.32 | 6.87 | 7.46 | 8.12 |
| 10% Higher | 10% Lower | 7.57 | 8.22 | 8.93 | 9.72 |
| 20% Higher | 20% Lower | 9.12 | 9.91 | 10.77 | 11.72 |

*See Table 58.

†11.6 bone-dry tons per acre per year.

# CHAPTER VI

# CONCLUSION AND EVALUATION

The success of a project, be it agriculture or forestry, is dependent on a reasonable chance of making an adequate financial return on the investment. According to macroeconomic analysis, the needed capital investment for new plantations must be obtained in competition with other sectors of the economy based merely on the expected economic returns. On the other hand, if forest plantations were partially subsidized by the public, such support should be justifiable on the basis that forestry development would contribute to the society by producing other public goods and services. These basically should be the factors determining the selected form of land use for a particular area, excluding , of course, watersheds, recreation and conservation areas.

## Conclusion

Japan's hardwood imports increased from 19,000 cubic meters in 1960 to 4.8 million cubic meters in 1977 which included 2.8 million cubic meters of eucalypt woodchips from Australia. In terms of total pulpwood consumption, hardwood represented 36 percent in 1960, 50 percent in 1977 and will, according to estimates, represent 60 percent by 1985. Obviously, the importance of hardwood in Japanese paper industry and the proportion of hardwood in Japan's total imports has increased significantly.

The F.A.O. has estimated that Japan will import 17 million cubic meters of pulpwood in 1990 based on the projection that domestic supply will increase from an annual average of 22 million cubic meters in the period of 1973-1975 to 47 million cubic meters by 1990. While the level of domestic production seems to be optimistically high, the level of import seems to be conservative because the current trend of pulpwood imports shows a faster rate of increase (see Table 12). A recent projection made by a Japanese bank also indicates that Japan's pulpwood deficit will reach 17.4 million cubic meters in 1980, ten years ahead of the projection made by the F.A.O. It is reasonable, therefore, to expect that Japan's pulpwood deficit in 1990 will be greater than 17 million cubic meters. How much greater will depend on the levels of future domestic supply. Furthermore, since part of the domestic pulpwood supply comes from residues of the processing of imported timber and logs, further reduction in log exports by other countries will also decrease the availability of pulpwood in Japan. As a result, Japan will have to import more pulpwood. While the U.S. West Coast, Oceania, Southeast Asia and the Soviet Union will supply most of Japan's requirement, it will have to import 1.2 million cubic meters of pulpwood from other sources in 1990. Although Japan will seek new sources of woodchips, freight costs and other difficulties will limit it primarily to the Pacific region and North America.

Despite the increasing concern for air and water pollution, it is extremely difficult for Japan to change its pulp and paper industrial structure because of the present large production capacity, the upward investment trends, the strong economic growth compared with other industrial nations, and the "lifetime" employment practices. Therefore, it is very likely that Japan will continue to import large volumes of pulpwood, mostly in the form of woodchips. Japan will also import more pulp; the increase will be used to satisfy part of the increase in Japan's growing pulp consumption rather than to replace the current domestic production.

The statistical information just presented indicates that there is a market potential for Hawaii-produced eucalypt woodchips in Japan. Hawaii is in a good position to supply some of Japan's pulpwood deficits because it has the required forest resources and some comparative advantages such as market proximity, a relatively fast growth rate of eucalyptus trees, and currently a favorable exchange rate for exports from the United States. It has been determined in this study that the $4.32 price differential between Hawaii's and Australia's woodchip exports to Japan could be attributed to the differences in transportation costs since Hawaii is closer to Japan.

The review of forest resources in Chapter I indicates the availability of commercial forest land on the Island of Hawaii. However, to find out whether it is profitable to start a woodchip enterprise from scratch, a 25-year plantation model was constructed for a feasibility study.

The results from the benefit-cost analysis and sensitivity analysis in Chapter V have provided some indications of the profitability of the 25-year woodchip export project on the Island of Hawaii. Assuming a real interest rate of 10 percent, and woodchip price, production costs and pulpwood yields as estimated, the NPV is 11.79 million dollars, the B/C ratio is 1.53 and the IRR is 31.2. By sensitivity analysis, assuming a real interest rate of 16 percent, yields 20 percent lower, and price and costs respectively, 10 and 20 percent higher than estimated, the NPV would be 3.12 million dollars, the B/C ratio 1.22 and the IRR 27.4. This sensitivity analysis should, to some extent, compensate for the fact that cost data have not been updated. Results of further changes in costs, yields and prices at different rates can also be obtained if they are needed.

Although an integrated woodchip project in this study has been found economically feasible, it does not necessarily mean that such a venture is financially attractive. Whether the woodchip project is worth undertaking under the projected profitability outlook would depend on a comparison with alternative investment opportunities available to a prospective investor. Moreover, each investor is likely to have a different set of investment opportunities. Therefore, it is beyond the scope of this study to suggest in isolation the worthiness of a woodchip project.

In this study, the break-even prices for stumpage have also been determined for tree growers, ranging from $6.32 to $11.72 per BDT depending on costs, yields and interest rates as presented in Chapter V. It is, therefore, unprofitable for an independent tree grower to supply stumpage to a chipper at the current rate of $3 per BDT. This rate is obviously too low if reforestation is considered because the lowest replacement cost, the break-even price, is $6.32 per BDT.

### Appraisal Capability of Benefit-Cost Analysis

Each financial appraisal method applied in this economic feasibility analysis has both advantages and disadvantages, but each is a useful supplement to the other.

The efficiency with which a project will use its capital cannot be determined from NPV. NPV gives no weight to different sizes of projects which, obviously, require different levels of investments. For example, a NPV of one million dollars derived from a ten-million or a twenty-million dollar project is theoretically indifferent under this method, which is not practically true. Therefore, direct comparison of net present values among projects cannot be meaningfully made.

Furthermore, when there are limitations to a firm's borrowing ability and it is forced to choose among projects, no such simple and categorical judgment can be offered, for in that case there is no well-defined current interest rate (11). In other words, there is no appropriate rate of interest for the determination of NPV. The interest rate which the firm happens to pay on the borrowed funds does not necessarily measure the true opportunity value of cash to the firm. For example, if the capital market is imperfect and an investor is limited in the funds he can borrow, he would be unable to undertake a project capable of returning, say, 30 percent on investment. Therefore, the real loss is not the going market rate of interest, but the 30 percent profit foregone on the investment opportunities from which he is precluded.

The IRR, on the other hand, bears no relationship to the size of the project. This method permits direct comparison between the interest rate charged on the project and its IRR. It measures the efficient use of capital. However, problems arise when this method gives multiple values of IRR.

Since there are some theoretical difficulties inherent in the IRR concept, B/C ratio is, in general, a preferred measure of financial efficiency. The B/C ratio is also independent of the size of the project. This method is widely used in both public and private project analysis in various countries, including the United States, because of its simplicity and its indication of the relative efficiency with which the capital resources are used. However, like IRR, it has also been criticized on the ground that it provides no indication of the level of profits or losses involved.

Any combination of these partially valid criteria, therefore, should give an improved assessment. Hence the best approach to the criterion problem would seem to be to use NPV which indicates the level of profit or loss in conjunction with some criterion such as IRR or B/C ratio which measures the relative efficient use of capital.

## Social Versus Private Costs and Benefits

The criteria for investment feasibility of woodchips have been discussed in terms of private costs and benefits, which are the cash revenues and the cash outlays, and opportunity costs that can be directly attributed to the project. Social costs and benefits have not been considered but must be put in perspective.

Costs and benefits often go beyond monetary measurement. They can include values that are not, or are only partially, measurable in monetary terms. Therefore, it is almost impossible to accurately estimate the social costs and benefits associated with the use of forest resources because intangibles are difficult to quantify or even identify, in some instances.

The divergences between private and social costs and benefits exist when economic agents do things which benefit others in such a way that they receive no payment in return, or when their actions are detrimental to others and involve no commensurate cost to themselves (11). These divergences could lead to a misallocation of resources either by over-production or under-production.

According to Coase's Theorem, externalities represent sources of social gain or loss that do not get translated in the market place (20). This theorem, which has been widely accepted by the students of law and economics, basically states that the fundamental source of the externality is an inappropriate assignment or simply an absence of property rights. Therefore, government interference is justifiable since externalities usually involve a large number of people and thus the transaction costs to solve such disputes would be prohibitively high.

A corrective tax placed on the generation of a harmful externality would tend to reduce the amount it imposed on others. Correspondingly, a corrective subsidy would usually induce a greater level of beneficial externality activity (57). These are possible remedies for closing or at least narrowing the gap between social and private costs and benefits.

The use of legal and similar measures to internalize the externalities and thus force the responsible firm to bear the costs associated with them or with preventive treatments, will help to alleviate some of the problems of social cost measurement. However, problems associated with measuring beneficial externalities remain unsolved.

Opinions may differ as to relative emphasis to place on economic valuation in relation to externalities. This applies particularly to projects which might have important irreversible economic and environmental consequences. This is one reason why the final decision on vital land-use issues is often made by society, albeit through an imperfect democratic process (34).

Very often implicit weights are used which merely reflect the analyst's own value judgment. The weighing applied to the goals of public welfare is anything but simple and the present stage of art is far from satisfactory. It is unsatisfactory because the weights are mostly subjective and yet cannot be easily identified by others (34). In this respect, economists are in danger of usurping the functions of politicians, whose role in making their decisions is to assess the weight society accords to differing impacts (42).

This is not an argument for using a partial analysis based only on woodchip production values. However, before any claims can be made about the net benefit from forestry programs in any given region, a great deal more needs to be known in quantitative terms about the physical and biological effects on ecosystem, and about the socio-economic relationships between the forests and the community. A full benefit-cost analysis is warranted as more information become available and more efficient analytical techniques are developed. As an interim measure then, supplementing financial analysis of woodchip production projects with qualitative statements of social effects might seem to be a reasonable compromise (72).

In the absence of a satisfactory analytical technique which would allow the evaluation of environmental and economic factors, ultimate decisions on the export woodchip industry would be made on the basis of economic evidence. On the other hand, public decision makers will continue to make judgments with little or no quantitative basis with respect to the non-monetary costs and benefits involved and will have the final responsibility for weighing society's preferences for the allocation of forest resources for environmental preservation or woodchip production.

Imperfect as it is, benefit-cost analysis is an analytical tool for decisionmaking. The fact that benefit-cost analysis is an aid to decision-making and not a substitute for it suggests that non-economic considerations need to be taken into account in applying the results of benefit-cost analysis.

## APPENDIX A

### COMPUTER PROGRAM AND OUTPUT

```
      REAL LCOST(100),SDCST(100),PCOST(100),RCOST(100),HCOST(100),
     -TCOST(100),SCOST(100),MCOST(100),GREV(100),CFLOW(100),PVCFLO(100),
     -PVGB(100),PVGC(100),GCOST(100),XPVGB(100),XPVGC(100),ATPVCF(100),
     -TAXES(100),NREV(100)
      N=25
      DR=0.10
      READ (5,12) (LCOST(I),SDCST(I),PCOST(I),RCOST(I),HCOST(I),
     -TCOST(I),SCOST(I),MCOST(I),GREV(I),TAXES(I),I=1,N)
   12 FORMAT(10F5.0)
      TLCOST=0.
      TSDCST=0.
      TPCOST=0.
      TRCOST=0.
      THCOST=0.
      TTCOST=0.
      TSCOST=0.
      TMCOST=0.
      TTAXES=0.
      TGREV=0.
      DO 14 I=1,N
      TLCOST=TLCOST+LCOST(I)
      TSDCST=TSDCST+SDCST(I)
      TPCOST=TPCOST+PCOST(I)
      TRCOST=TRCOST+RCOST(I)
      THCOST=THCOST+HCOST(I)
      TTCOST=TTCOST+TCOST(I)
      TSCOST=TSCOST+SCOST(I)
      TMCOST=TMCOST+MCOST(I)
      TTAXES=TTAXES+TAXES(I)
      TGREV=TGREV+GREV(I)
   14 CONTINUE
C EVALUATE
      TGCOST=0.
      TNREV=0.
      TCFLOW=0.
      TPVCF=0.
      TPVGB=0.
      TPVGC=0.
      DO 16 I=1,N
      DF=((1.+DR)**I)
      GCOST(I)=LCOST(I)+SDCST(I)+PCOST(I)+RCOST(I)+HCOST(I)+TCOST(I)
     -+SCOST(I)+MCOST(I)
      TGCOST=TGCOST+GCOST(I)
      NREV(I)=GREV(I)-TAXES(I)
      TNREV=TNREV+NREV(I)
      CFLOW(I)=NREV(I)-GCOST(I)
```

```
      TCFLOW=TCFLOW+CFLOW(I)
      PVCFLO(I)=CFLOW(I)/DF
      TPVCF=TPVCF+PVCFLO(I)
      ATPVCF(I)=TPVCF
      PVGB(I)=NREV(I)/DF
      TPVGB=TPVGB+PVGB(I)
      PVGC(I)=GCOST(I)/DF
      TPVGC=TPVGC+PVGC(I)
   16 CONTINUE
C RATIO OF GROSS BENEFIT TO GROSS COSTS
      BC=TPVGB/TPVGC
      IF(TPVGC.GT.0) GO TO 18
      BC=0
   18 CONTINUE
C CALCULATE INTERNAL RATE OF RETURN
      XRATIO=0.
      XERR=9999
      XIRR=DR
   20 XTPVGB=0.
      XTPVGC=0.
      IF(BC.GT.1.) GO TO 22
      XIRR=XIRR-.001
      IF(XIRR.LT.0.) GO TO 24
      GO TO 26
   22 XIRR=XIRR+.001
   26 DO 28 I=1,N
      XDF=((1.+XIRR)**I)
      XPVGB(I)=NREV(I)/XDF
      XTPVGB=XTPVGB+XPVGB(I)
      XPVGC(I)=GCOST(I)/XDF
      XTPVGC=XTPVGC+XPVGC(I)
   28 CONTINUE
      RATIO=XTPVGB/XTPVGC
      ERROR=ABS(RATIO-1.)
      IF(BC.GT.1) GO TO 30
      IF(RATIO.LT.XRATIO) GO TO 32
   30 IF(ERROR.GT.XERR) GO TO 34
   32 XERR=ERROR
      XRATIO=RATIO
      XXRR=XIRR
      GO TO 20
   24 XXRR=0
   34 ERROR=XERR
      XIRR=XXRR*(100.)
      RATIO=XRATIO
```

```
      WRITE(6,60)
   60 FORMAT(///T35,'A FEASIBILITY STUDY OF A WOODCHIP PROJECT IN HAWAII
     -')
      WRITE(6,61)
   61 FORMAT (///T43,'PROJECT COST AND REVENUE ($1000)',///T2,'YEAR',
     -T16,'LCOST',T25,'SDCST',T34,'PCOST',T43,'RCOST',T52,'HCOST',
     -T61,'TCOST',T70,'SCOST',T79,'MCOST',T90,'TAXES',T103,'GREV')
      DO 62 I=1,N
   62 WRITE(6,63) I,LCOST(I),SDCST(I),PCOST(I),RCOST(I),HCOST(I),
     -TCOST(I),SCOST(I),MCOST(I),TAXES(I),GREV(I)
   63 FORMAT(T3,I2,T12,F9.1,T21,F9.1,T30,F9.1,T39,F9.1,T48,F9.1,
     -T57,F9.1,T66,F9.1,T75,F9.1,T86,F9.1,T98,F9.1,T111,F9.1)
      WRITE(6,64)
   64 FORMAT(/T2,'TOTAL')
      WRITE(6,65) TLCOST,TSDCST,TPCOST,TRCOST,THCOST,TTCOST,TSCOST,
     -TMCOST,TTAXES,TGCOST
   65 FORMAT (T12,F9.1,T21,F9.1,T30,F9.1,T39,F9.1,T48,F9.1,T57,F9.1,
     -T66,F9.1,T75,F9.1,T85,F10.1,T97,F10.2)
      WRITE (6,66)
   66 FORMAT (/////T35,'PROJECTED NET REVENUE AND AFTER-TAX CASH FLOW
     -($1,000)',///T2,'YEAR',T17,'NREV',T37,'GCOST',T60,'CFLOW',
     -T81,'PVCFLO',T104,'ATPVCF')
      DO 67 I=1,N
   67 WRITE (6,68)  I,NREV(I),GCOST(I),CFLOW(I),PVCFLO(I),ATPVCF(I)
   68 FORMAT (T3,I2,T12,F9.2,T33,F9.2,T56,F9.2,T78,F9.2,T101,F9.2)
      WRITE (6,69)
   69 FORMAT (/T2,'TOTAL')
      WRITE (6,70)  TGREV,TGCOST,TCFLOW,TPVCF
   70 FORMAT (T12,F9.2,T33,F9.2,T56,F9.2,T78,F9.2)
      WRITE(6,71)
   71 FORMAT(///T10,'NET PRESENT VALUE',T40,'TOTAL PRESENT VALUE GROSS
     -BENEFIT',T85,'TOTAL PRESENT VALUE GROSS COST')
      WRITE(6,72) TPVCF,TPVGB,TPVGC
   72 FORMAT(T12,F10.3,T48,F10.3,T94,F10.3)
      WRITE(6,73)
   73 FORMAT(//T10,'BENEFIT/COST RATIO',T40,'INTERNAL RATE OF RETURN')
      WRITE(6,74) BC,XIRR
   74 FORMAT(T12,F10.2,T47,F7.2)
      WRITE(6,75)
   75 FORMAT(1H1,9X,'YEARS OF PROJECT LIFE = 25',
     -/10X,'INTEREST RATE              = 0.10')
      WRITE (6,76)
   76 FORMAT (10X,'LCOST = LAND LEASE COST')
      WRITE (6,77)
   77 FORMAT (10X,'SDCST = SEEDLING COST')
      WRITE (6,78)
   78 FORMAT (10X,'PCOST = PLANTING COST')
```

```
      WRITE (6,79)
   79 FORMAT (10X,'RCOST = ROAD CONSTRUCTION AND MAINTENANCE COST')
      WRITE (6,80)
   80 FORMAT (10X,'HCOST = HARVESTING COST')
      WRITE (6,81)
   81 FORMAT (10X,'TCOST = TRUCKING COST')
      WRITE (6,82)
   82 FORMAT (10X,'SCOST = STORAGE COST')
      WRITE (6,83)
   83 FORMAT (10X,'MCOST = MANAGEMENT AND OVERHEAD COST')
      WRITE (6,84)
   84 FORMAT (10X,'TAXES = ORDINARY AND CAPITAL GAINS TAXES')
      WRITE (6,85)
   85 FORMAT (10X,'GCOST = GROSS COSTS')
      WRITE (6,86)
   86 FORMAT (10X,'GREV = GROSS REVENUE')
      WRITE (6,87)
   87 FORMAT (10X,'NREV = NET REVENUE (GROSS REVENUE - TAXES)')
      WRITE (6,88)
   88 FORMAT (10X,'CFLOW = CASH FLOW')
      WRITE (6,89)
   89 FORMAT (10X,'PVCFLO = PRESENT VALUE CASH FLOW')
      WRITE (6,90)
   90 FORMAT (10X,'ATPVCF = ACCUMULATED TOTAL PRESENT VALUE CASH FLOW')
      STOP
      END
```

## PROJECT COST AND REVENUE ($1000)

| YEAR | LCOST | SDCST | PCOST | RCOST | HCOST | TCOST | SCOST | MCOST | TAXES | GREV |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 78.0 | 80.0 | 476.0 | 0.0 | 0.0 | 0.0 | 0.0 | 150.0 | 0.0 | 0.0 |
| 2 | 156.0 | 80.0 | 229.0 | 0.0 | 0.0 | 0.0 | 0.0 | 150.0 | 0.0 | 0.0 |
| 3 | 234.0 | 80.0 | 229.0 | 0.0 | 0.0 | 0.0 | 0.0 | 150.0 | 0.0 | 0.0 |
| 4 | 312.0 | 80.0 | 229.0 | 0.0 | 0.0 | 0.0 | 0.0 | 150.0 | 0.0 | 0.0 |
| 5 | 390.0 | 80.0 | 229.0 | 534.0 | 1627.0 | 1006.0 | 50.0 | 150.0 | 0.0 | 0.0 |
| 6 | 390.0 | 0.0 | 90.0 | 594.0 | 1221.0 | 681.0 | 29.0 | 300.0 | 1234.0 | 7500.0 |
| 7 | 390.0 | 0.0 | 48.0 | 654.0 | 1221.0 | 681.0 | 29.0 | 300.0 | 1203.0 | 7500.0 |
| 8 | 390.0 | 0.0 | 48.0 | 714.0 | 1221.0 | 681.0 | 29.0 | 300.0 | 1172.0 | 7500.0 |
| 9 | 390.0 | 0.0 | 48.0 | 774.0 | 1221.0 | 681.0 | 29.0 | 300.0 | 1141.0 | 7500.0 |
| 10 | 390.0 | 0.0 | 48.0 | 300.0 | 1824.0 | 748.0 | 29.0 | 300.0 | 1110.0 | 7500.0 |
| 11 | 390.0 | 0.0 | 208.0 | 300.0 | 1221.0 | 716.0 | 29.0 | 300.0 | 1663.0 | 9000.0 |
| 12 | 390.0 | 0.0 | 80.0 | 300.0 | 1221.0 | 716.0 | 29.0 | 300.0 | 1663.0 | 9000.0 |
| 13 | 390.0 | 0.0 | 80.0 | 300.0 | 1221.0 | 716.0 | 29.0 | 300.0 | 1663.0 | 9000.0 |
| 14 | 390.0 | 0.0 | 80.0 | 300.0 | 1221.0 | 716.0 | 29.0 | 300.0 | 1663.0 | 9000.0 |
| 15 | 390.0 | 0.0 | 80.0 | 300.0 | 2648.0 | 1722.0 | 79.0 | 300.0 | 1663.0 | 9000.0 |
| 16 | 390.0 | 0.0 | 90.0 | 300.0 | 1221.0 | 716.0 | 29.0 | 300.0 | 810.0 | 6750.0 |
| 17 | 390.0 | 0.0 | 48.0 | 300.0 | 1221.0 | 716.0 | 29.0 | 300.0 | 810.0 | 6750.0 |
| 18 | 390.0 | 0.0 | 48.0 | 300.0 | 1221.0 | 716.0 | 29.0 | 300.0 | 810.0 | 6750.0 |
| 19 | 390.0 | 0.0 | 48.0 | 300.0 | 1221.0 | 716.0 | 29.0 | 300.0 | 810.0 | 6750.0 |
| 20 | 390.0 | 0.0 | 48.0 | 300.0 | 1824.0 | 783.0 | 29.0 | 300.0 | 810.0 | 6750.0 |
| 21 | 390.0 | 0.0 | 0.0 | 300.0 | 1221.0 | 716.0 | 29.0 | 300.0 | 428.0 | 6000.0 |
| 22 | 312.0 | 0.0 | 0.0 | 240.0 | 1221.0 | 716.0 | 29.0 | 300.0 | 483.0 | 6000.0 |
| 23 | 234.0 | 0.0 | 0.0 | 180.0 | 1221.0 | 716.0 | 29.0 | 300.0 | 537.0 | 6000.0 |
| 24 | 156.0 | 0.0 | 0.0 | 120.0 | 1221.0 | 716.0 | 29.0 | 300.0 | 591.0 | 6000.0 |
| 25 | 78.0 | 0.0 | 0.0 | 60.0 | 1221.0 | 716.0 | 29.0 | 300.0 | 645.0 | 6000.0 |
| TOTAL | 8190.0 | 400.0 | 2484.0 | 7470.0 | 28880.0 | 16291.0 | 680.0 | 6750.0 | 20909.0 | 71145.00 |

## PROJECTED NET REVENUE AND AFTER-TAX CASH FLOW ($1,000)

| YEAR | NREV | GCOST | CFLOW | PVCFLO | ATPVCF |
|---|---|---|---|---|---|
| 1 | 0.0 | 784.00 | -784.00 | -712.73 | -712.73 |
| 2 | 0.0 | 615.00 | -615.00 | -508.27 | -1220.99 |
| 3 | 0.0 | 693.00 | -693.00 | -520.66 | -1741.66 |
| 4 | 0.0 | 771.00 | -771.00 | -526.60 | -2268.26 |
| 5 | 0.0 | 4066.00 | -4066.00 | -2524.68 | -4792.93 |
| 6 | 6266.00 | 3305.00 | 2961.00 | 1671.42 | -3121.52 |
| 7 | 6297.00 | 3323.00 | 2974.00 | 1526.14 | -1595.38 |
| 8 | 6328.00 | 3383.00 | 2945.00 | 1373.87 | -221.50 |
| 9 | 6359.00 | 3443.00 | 2916.00 | 1236.68 | 1015.18 |
| 10 | 6390.00 | 3639.00 | 2751.00 | 1060.64 | 2075.81 |
| 11 | 7337.00 | 3164.00 | 4173.00 | 1462.63 | 3538.44 |
| 12 | 7337.00 | 3036.00 | 4301.00 | 1370.45 | 4908.88 |
| 13 | 7337.00 | 3036.00 | 4301.00 | 1245.86 | 6154.74 |
| 14 | 7337.00 | 3036.00 | 4301.00 | 1132.60 | 7287.34 |
| 15 | 7337.00 | 5719.00 | 1618.00 | 387.34 | 7674.68 |
| 16 | 5940.00 | 3046.00 | 2894.00 | 629.83 | 8304.50 |
| 17 | 5940.00 | 3004.00 | 2936.00 | 580.88 | 8885.38 |
| 18 | 5940.00 | 3004.00 | 2936.00 | 528.07 | 9413.45 |
| 19 | 5940.00 | 3004.00 | 2936.00 | 480.07 | 9893.52 |
| 20 | 5940.00 | 3674.00 | 2266.00 | 336.83 | 10230.35 |
| 21 | 5572.00 | 2956.00 | 2616.00 | 353.51 | 10583.86 |
| 22 | 5517.00 | 2818.00 | 2699.00 | 331.57 | 10915.43 |
| 23 | 5463.00 | 2680.00 | 2783.00 | 310.81 | 11226.23 |
| 24 | 5409.00 | 2542.00 | 2867.00 | 291.06 | 11517.31 |
| 25 | 5355.00 | 2404.00 | 2951.00 | 272.37 | 11789.68 |
| TOTAL | 146256.00 | 71145.00 | 54196.00 | 11789.68 | |

| NET PRESENT VALUE | TOTAL PRESENT VALUE GROSS BENEFIT | TOTAL PRESENT VALUE GROSS COST |
|---|---|---|
| 11789.680 | 34078.953 | 22289.250 |

| BENEFIT/COST RATIO | INTERNAL RATE OF RETURN |
|---|---|
| 1.53 | 31.20 |

YEARS OF PROJECT LIFE = 25
INTEREST RATE = 0.10
LCOST = LAND LEASE COST
SDCST = SEEDLING COST
PCOST = PLANTING COST
RCOST = ROAD CONSTRUCTION AND MAINTENANCE COST
HCOST = HARVESTING COST
TCOST = TRUCKING COST
SCOST = STORAGE COST
MCOST = MANAGEMENT AND OVERHEAD COST
TAXES = ORDINARY AND CAPITAL GAINS TAXES
GCOST = GROSS COSTS
GREV = GROSS REVENUE
NREV = NET REVENUE (GROSS REVENUE - TAXES)
CFLOW = CASH FLOW
PVCFLO = PRESENT VALUE CASH FLOW
ATPVCF = ACCUMULATED TOTAL PRESENT VALUE CASH FLOW

# APPENDIX B

## DESCRIPTIONS OF REPRESENTATIVE SITES ON THE ISLAND OF HAWAII

To minimize initial site preparation costs and preserve native forests, a eucalyptus plantation should be established on acreage that is currently non-forested, such as marginal grazing or agricultural land.

Twelve possible plantation sites on the Island of Hawaii were investigated by the Stanford University-University of Hawaii Biomass Energy Study Team (107). The investigation included an examination of each location, current ownership, soil properties, rainfall, terrain, and access. Although the selected areas in Figure 11 are delineated by straight and solid lines, they do not represent proposed boundaries, merely local regions of similar climate and soil properties containing enough area for a biomass plantation.

Of the twelve regions evaluated, seven sites were classified as conservation areas and five sites were zoned for agriculture. Only sites VII and VIII, both along the Hamakua Coast, were found to have the most desirable combination of attributes for a plantation. Both are composed of non-forested grassland which once supported tree growth but was cleared for grazing. Site VIII, located near Kawaihae Harbor and just south of Waipio Bay and Honokaa, was considered a representative site for an economic analysis.

A summary of site characteristics for those zoned for agriculture is presented in Table 61. Ownership and rainfall of the Island of Hawaii are presented in Figures 12 and 13. Ownership of the parcels in these localities is complex and land acquisition may present some difficulties.

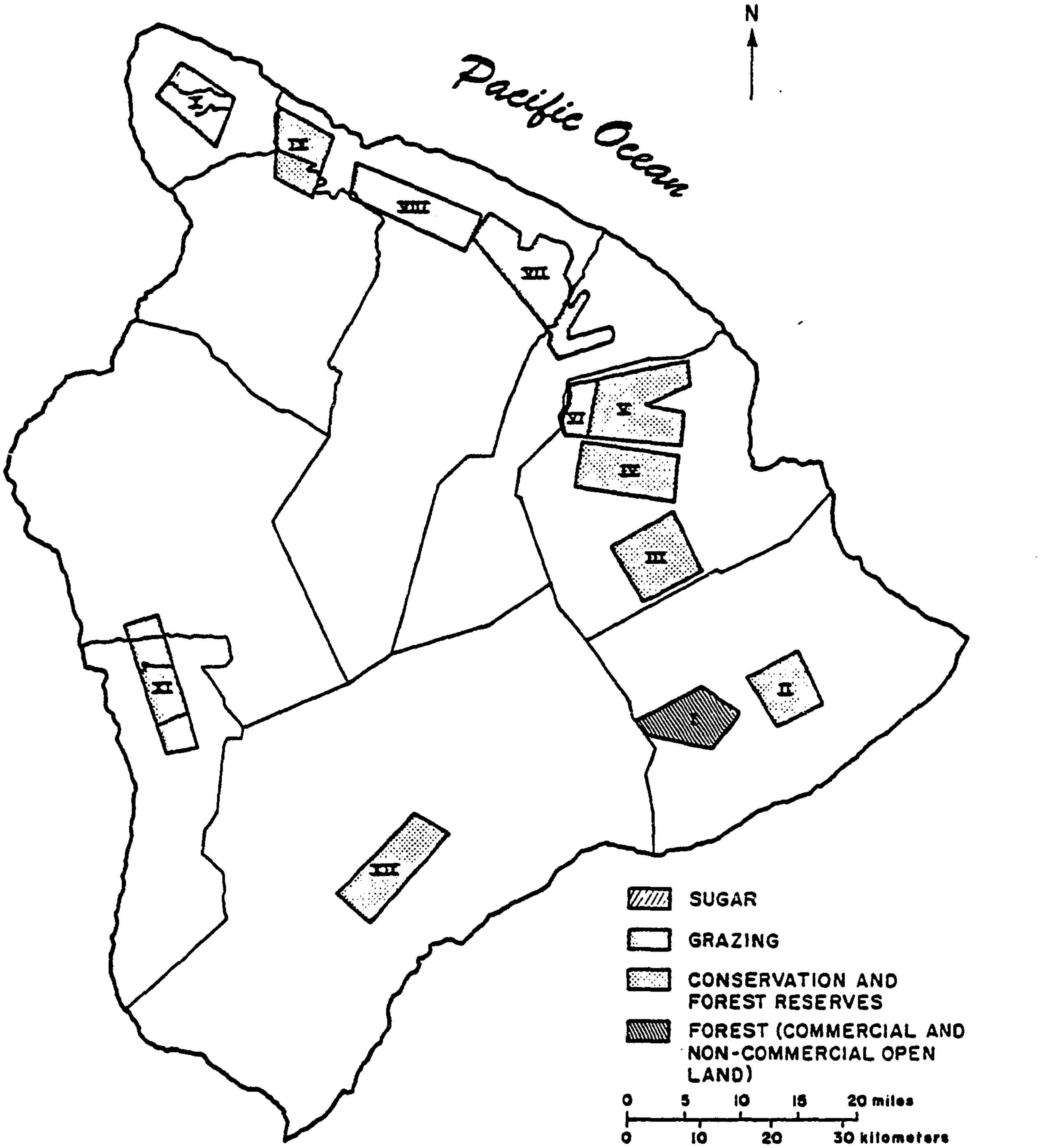



Figure 11. Land Use for Some Selected Sites, Island of Hawaii

Source: Christine Yang, et al. (Eds), Biomass Energy for Hawaii Volume IV Terrestrial and Marine Plantations, Institute for Energy Studies, Stanfore University, Stanford, California, 1977, p. 6-35.

TABLE 61

SUMMARY OF PLANTATION SITE CHARACTERISTICS

| Site | Cover type | Land use* class | Elevation (feet) | Rainfall (in/yr) | Ownership and comments |
|---|---|---|---|---|---|
| VI | Non-forest grassland (grazing) | A | 5400-6600 | 65-150 | Small area, owned by W. H. Shipman, Inc. |
| VII | Non-forest grassland (grazing) | A | 2600-5000 | 100-150 | Mixture of parcels, fair access and owned by Theo. H. Davies, Bishop Estate and state of Hawaii |
| VIII | Non-forest grassland (grazing) | A | 1800-3000 | 75-150 | Close to Port of Kawaihae, good access, owned by Theo. H. Davies, Parker Range and state of Hawaii |
| X | Mixture of intensive<br>agriculture, non-forest<br>grassland and, commercial<br>forest, ohia/ohia-koa | <br>A<br>A<br>C | 0-3000 | 75-125 | Owned by Castle and Cooke and Parker Range |
| XI | Non-forest grassland and,<br>commercial forest,<br>ohia/ohia-koa | A<br><br>C | 2400-4600 | 75-100 | Owned by W. H. Greenwell, Kealakekua Range, Bishop Estate, McCandless Heirs and state of Hawaii |

*A denotes agriculture and C denotes conservation.

Source: Christine Yang, et al. (Eds.), Biomass Energy for Hawaii, Volume IV Terrestrial and Marine Plantations, Institute for Energy Studies, Stanford University, Stanford, California, 1977, p. 6-38.

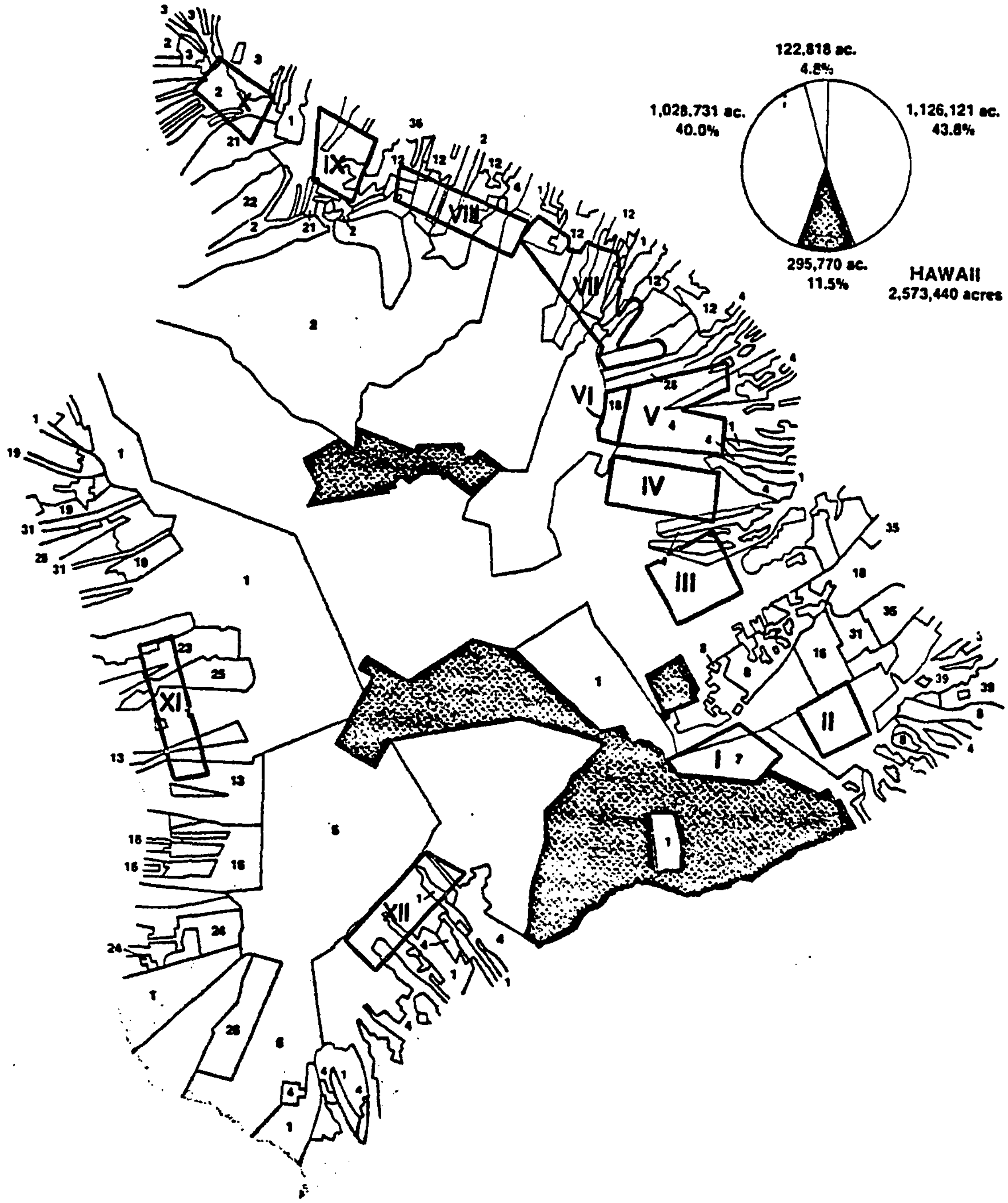



Figure 12. Land Ownership of Some Selected Sites, Island of Hawaii
(see key to land ownership on the following page)

Source: Christine Yang, et al. (Eds), Biomass Energy for Hawaii, Volume IV Terrestrial and Marine Plantations, Institute for Energy Studies, Stanford University, Stanford, California, 1977, p. 6-36.

TABLE 62

LAND OWNERSHIP

| | | |
|---|---|---|
| State of Hawaii | acreage | 1,590,532 |
| Federal Government | | 402,084 |
| Major Private Landowners | | |
| 1 | Bernice P. Bishop Estate | 369,462 |
| 2 | Richard S. Smart (Parker Ranch) | 185,940 |
| 3 | Castle and Cooke, Inc. | 153,912 |
| 4 | C. Brewer and Co., Ltd. | 145,147 |
| 5 | Samuel M. Damon Estate | 143,842 |
| 6 | Alexander and Baldwin, Inc. | 126,790 |
| 7 | James Campbell Estate | 81,549 |
| 8 | Amfac Inc. | 81,417 |
| 9 | Molokai Ranch, Ltd. | 73,975 |
| 10 | Gay and Robinson | 55,800 |
| 11 | Niihau Ranch | 46,065 |
| 12 | Theo H. Davies and Co., Ltd. | 43,490 |
| 13 | McCandless Heirs | 37,622 |
| 14 | Haleakala Ranch Co. | 33,041 |
| 15 | Grove Farm Co., Inc. | 22,616 |
| 16 | Yee Hop, Ltd. | 21,830 |
| 17 | Ulupala Kua Ranch, Inc. | 21,557 |
| 18 | W. H. Shipman, Ltd. | 20,599 |
| 19 | Thelma K. Stillman Trust (Huehue Ranch) | 15,438 |
| 20 | Puu-O-Hoku Ranch (G. W. Murphy) | 14,262 |
| 21 | Kahua Ranch, Ltd. | 14,013 |
| 22 | Queen's Hospital | 13,065 |
| 23 | W. H. Greenwell, Ltd. | 12,149 |
| 24 | Dillingham Investment Corp. | 11,471 |
| 25 | Kealakekua Ranch (S. Greenwell) | 11,136 |
| 26 | Hawaiian Ocean View Estate | 10,642 |

TABLE 62 (continued) LAND OWNERSHIP

| | | |
|---|---|---|
| 27 | Kaupo Ranch, Ltd. | 10,037 |
| 28 | Queen Liliuokalani Trust | 9,794 |
| 29 | Kaonoulu Ranch Co., Ltd. | 8,813 |
| 30 | Estate of H. K. L. Castle (Kaneohe Ranch) | 8,606 |
| 31 | Frank R. Greenwell (Palani Ranch) | 6,917 |
| 32 | Zion Securities Corp. | 6,514 |
| 33 | Francis H. Ii Brown, et al | 6,164 |
| 34 | Eric A. and August F. Knudsen Trust | 5,879 |
| 35 | Hawaiian Paradise Park Corp. | 5,503 |
| 36 | Bernice P. Bishop Museum | 5,257 |
| 37 | Austin Heirs | 5,255 |
| 38 | Capital Investment Co., Ltd. | 5,182 |
| 39 | Kapoho Land & Development Co., Ltd. | 5,174 |
| Small private landowners (less than 5000 acres) | | 257,059 |

Source: Atlas of Hawaii, The University Press of Hawaii, Honolulu, 1974, p. 141.

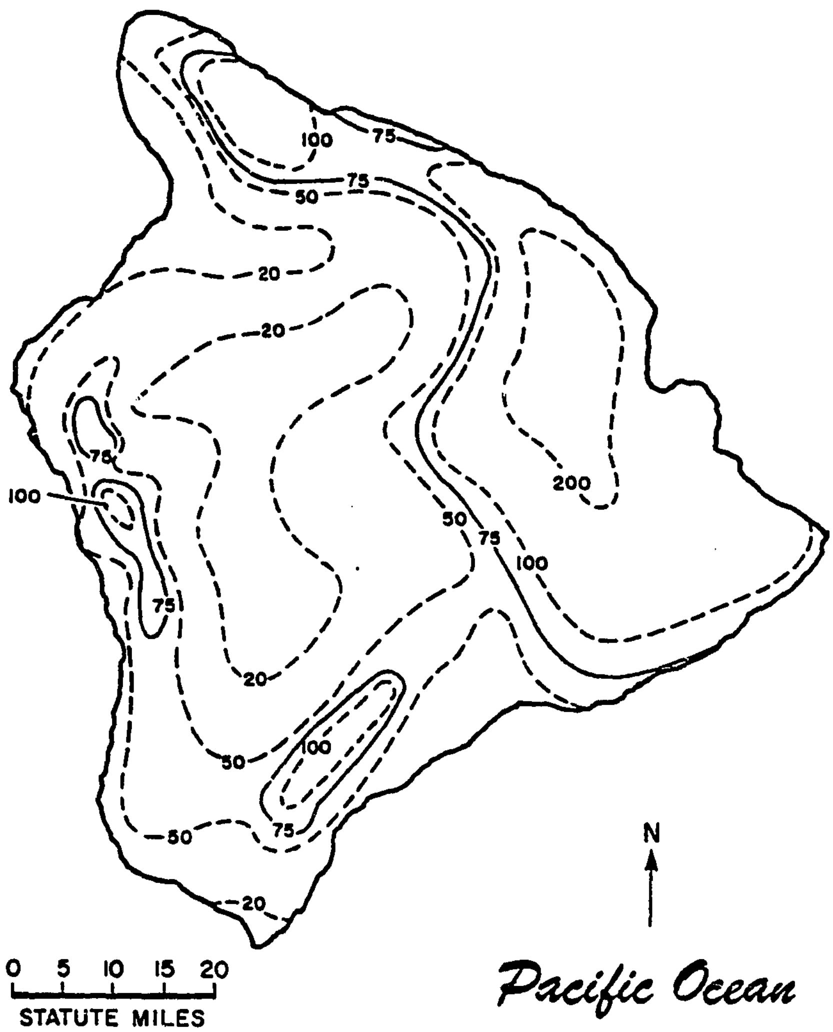



Figure 13. Rainfall Map, Island of Hawaii

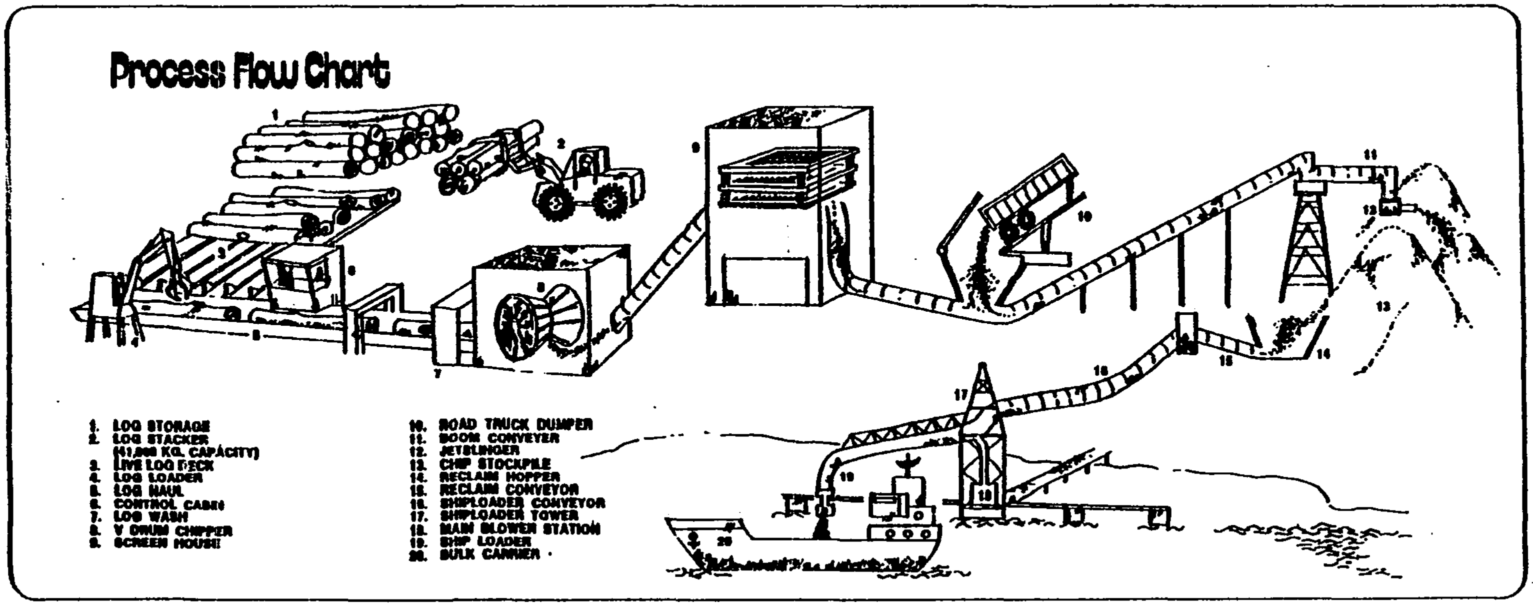
Mean annual precipitation in inches, based on period 1931-1955. Adapted from reference.

Isolines are drawn through points of approximately equal value. Caution should be used in interpolation, particularly in mountainous areas. Isoline at 75 in/yr drawn solid to indicate areas with rainfall considered sufficient for eucalyptus plantations.

Source: Christine Yang, et al. (Eds), Biomass Energy for Hawaii Volume IV Terrestrial and Marine Plantations, Institute for Energy Studies, Stanford University, Stanford, California, 1977, p. 6-31.

APPENDIX C

WOODCHIP PROCESSING FLOW CHART



# APPENDIX D

## TABLE 63 CAPITAL GAINS TAX

(In thousands of dollars)

| Year | Gross revenue | 66% of revenue* | Capitalized expenses | 5 Years Subtotal | Available depletion | Capital gains | 30% capital gain tax |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 634 | | | | |
| 2 | 0 | 0 | 465 | | | | |
| 3 | 0 | 0 | 543 | | | | |
| 4 | 0 | 0 | 621 | | | | |
| 5 | 0 | 0 | 699 | 2962 | | | |
| 6 | 7500 | 4950 | 480 | | 592 | 4358 | 1307 |
| 7 | 7500 | 4950 | 438 | | 592 | 4358 | 1307 |
| 8 | 7500 | 4950 | 438 | | 592 | 4358 | 1307 |
| 9 | 7500 | 4950 | 438 | | 592 | 4358 | 1307 |
| 10 | 7500 | 4950 | 438 | 2232 | 592 | 4358 | 1307 |
| 11 | 9000 | 5940 | 597 | | 446 | 5494 | 1648 |
| 12 | 9000 | 5940 | 470 | | 446 | 5494 | 1648 |
| 13 | 9000 | 5940 | 470 | | 446 | 5494 | 1648 |
| 14 | 9000 | 5940 | 470 | | 446 | 5494 | 1648 |
| 15 | 9000 | 5940 | 470 | 2478 | 446 | 5494 | 1648 |
| 16 | 6750 | 4455 | 480 | | 496 | 3959 | 1188 |
| 17 | 6750 | 4455 | 438 | | 496 | 3959 | 1188 |
| 18 | 6750 | 4455 | 438 | | 496 | 3959 | 1188 |
| 19 | 6750 | 4455 | 438 | | 496 | 3959 | 1188 |
| 20 | 6750 | 4455 | 438 | 2232 | 496 | 3959 | 1188 |
| 21 | 6000 | 3960 | 390 | | 836 | 3124 | 937 |
| 22 | 6000 | 3960 | 312 | | 758 | 3202 | 961 |
| 23 | 6000 | 3960 | 234 | | 680 | 3280 | 984 |
| 24 | 6000 | 3960 | 156 | | 602 | 3358 | 1007 |
| 25 | 6000 | 3960 | 78 | | 524 | 3436 | 1031 |

*66% of gross revenue is taxable as capital gains

TABLE 64

ORDINARY INCOME TAX

(In thousands of dollars)

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 150 | 0 | -150 | -77 |
| 2 | 0 | 0 | 150 | 0 | -150 | -77 |
| 3 | 0 | 0 | 150 | 0 | -150 | -77 |
| 4 | 0 | 0 | 150 | 0 | -150 | -77 |
| 5 | 0 | 0 | 150 | 0 | -150 | -77 |
| 6 | 7500 | 2550 | 2228 | 465 | -143 | -73 |
| 7 | 7500 | 2550 | 2288 | 465 | -203 | -104 |
| 8 | 7500 | 2550 | 2348 | 465 | -263 | -135 |
| 9 | 7500 | 2550 | 2408 | 465 | -232 | -166 |
| 10 | 7500 | 2550 | 2468 | 465 | -383 | -197 |
| 11 | 9000 | 3060 | 2566 | 465 | 29 | 15 |
| 12 | 9000 | 3060 | 2566 | 465 | 29 | 15 |
| 13 | 9000 | 3060 | 2566 | 465 | 29 | 15 |
| 14 | 9000 | 3060 | 2566 | 465 | 29 | 15 |
| 15 | 9000 | 3060 | 2566 | 465 | 29 | 15 |
| 16 | 6750 | 2295 | 2566 | 465 | -736 | -378 |
| 17 | 6750 | 2295 | 2566 | 465 | -736 | -378 |
| 18 | 6750 | 2295 | 2566 | 465 | -736 | -378 |
| 19 | 6750 | 2295 | 2566 | 465 | -736 | -378 |
| 20 | 6750 | 2295 | 2566 | 465 | -736 | -378 |
| 21 | 6000 | 2040 | 2566 | 465 | -991 | -509 |
| 22 | 6000 | 2040 | 2506 | 465 | -931 | -478 |
| 23 | 6000 | 2040 | 2446 | 465 | -871 | -447 |
| 24 | 6000 | 2040 | 2386 | 465 | -811 | -416 |
| 25 | 6000 | 2040 | 2326 | 465 | -751 | -386 |

*Ordinary income is 34% of gross revenue.

## APPENDIX E

## CONVERSION TABLE

| | | |
|---|---|---|
| 1 acre | = | 0.40469 hectare |
| 1 bone-dry ton(short) | = | 0.83 bone-dry unit |
| 1 bone-dry unit | = | 1.2 bone-dry tons (short) |
| 1 cubic foot | = | 0.02832 cubic meter |
| 1 cubic meter | = | 35.31073 cubic feet |
| 1 foot | = | 0.3048 meter |
| 1 hectare | = | 2.471 acres |
| 1 kilometer | = | 0.62137 mile |
| 1 long ton | = | 2240.0 pounds |
| 1 long ton | = | 1.016 metric tons (tonnes) |
| 1 long ton | = | 1.12 short tons |
| 1 metric ton (tonne) | = | 1000.0 kilograms |
| 1 metric ton (tonne) | = | 0.9842 long ton |
| 1 metric ton (tonne) | = | 1.1023 short ton |
| 1 mile | = | 1.6093 kilometers |
| 1 short ton | = | 2000.0 pounds |
| 1 short ton | = | 0.8929 long ton |
| 1 short ton | = | 0.9072 metric ton (tonne) |

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