



The Economics of Commercial Koa Culture in Hawaii

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INTRODUCTION

Koa (*Acacia koa*) is Hawaii's best known tree being important economically, ecologically and culturally. It is a dominant component of koa-ohia forest ecosystems providing wildlife habitat, watershed recharge areas and recreational opportunities. It has been central to culture in Hawaii from the time of the early Hawaiians to the present day. More importantly for purposes of this undertaking, koa is a source of high value wood used for furniture, cabinetry, interior work and woodcrafts. Total income (direct and indirect) attributable to Hawaii's koa industry was estimated at \$28.9 million in 1991 (Yanagida et al., 1993).

Native koa forests have been reduced to approximately 25 percent of their historical range. The remaining koa forests and trees are disappearing much faster than natural regeneration and current planting programs can replace them (Brewbaker et al., 1995). This will result in a simultaneous environmental loss due to the loss of native wildlife habitat, economic loss of a valuable commodity and possible species and/or species diversity loss due to genetic erosion. Hawaii can ill afford any such loss given its fragile and unique ecology and its need for economic diversity both of which would suffer from the demise of koa forests.

Various agencies, organizations and individuals have undertaken studies, workshops, seminars and other efforts ranging from basic research (e.g. koa genetics) to koa forest management plans. These efforts are necessary to ameliorate the current trend towards depletion. They provide necessary information and recommendations of practices for the effective management of remaining koa forests and successful reforestation of former koa forest areas. Lacking to date in these efforts, however, is a rigorous investigation of the costs of koa reforestation, and, more specifically to entrepreneurial private land owners, potential returns of commercial koa culture in Hawaii.

Commercial koa culture in Hawaii has the potential to relieve the pressure to harvest native koa stands for commercial purposes by providing an alternative source of koa wood to satisfy commercial demand. It also has the potential to sustain and greatly expand at some future point, the current level of direct and indirect economic activity in the commercial koa industry, and more immediately, provide a use for vacant agricultural (former forest) lands in Hawaii, business opportunities for Hawaii entrepreneurs, investment opportunities for Hawaii investors and employment opportunities for unemployed agricultural laborers and processors of value-added forest products.

PURPOSE AND OBJECTIVES

The purpose of this study is to investigate the economics of commercial koa culture in Hawaii. This requires fulfilling the following objectives.

1. Outline processes and systems required to establish, maintain, harvest and ultimately sell koa trees grown specifically for commercial timber.¹
2. Estimate costs for the respective processes and systems for commercial koa production.
3. Project expected revenues from koa sales at various harvest times. This entails projections of koa yields and price.
4. Based on the cost structure for commercial koa production and yield and price projections, determine: break-even production and price (*i.e.* cost per board foot of lumber produced), per acre revenues and profits and the net present value and internal rate of return on investment.

The various sections below correspond to the four objectives noted. The last section presents a summary of findings about the economics of commercial koa culture.

Approach

The study is organized such that the processes and systems described can provide guidelines to establish a commercial koa operation and its likely profit and rate of return. The contents of this study combined with appropriate island, region and site specific data, can collectively serve as a business plan for prospective koa growers.²

¹ A positive externality of commercial koa culture is the public benefit it provides. This public benefit is watershed and wildlife habitat enhancement. This benefit will be on-going for the life of the plantation.

² Computer files of study text and spreadsheets are available from the author and the Department of Research and Development of the County of Hawaii.



The size of operation modeled is 10 acres. This is the minimum size requirement to qualify as a State tree farm.³ Scale economies are not investigated.

KOA PRODUCTION PROCESSES AND SYSTEMS

This section delineates processes and systems required to establish, maintain, harvest and ultimately sell koa trees grown specifically for commercial timber. Table 1 presents a list of the various activities involved and their timing.

Table 1: Koa Production Processes

Activity	Performance Time
site selection	any time of year
seed gathering	September-December usually best
germination & seedling production	4-20 weeks pre-transplanting
site & soil preparation	1-2 months previous to planting
seedling transplanting	April-May ⁴
sapling care - years 1 & 2	likely weeding every 3 months
sapling care - years 3-5	as needed during year
tree care post year 5	as needed during year
harvest	any time of year

SITE SELECTION

Koa stands of commercial potential have generally been found (but not cultivated) at sites with the following characteristics (Whitesell, 1990):

1. higher rainfall areas with average annual rainfall ranging from 75 to more than 200 inches per year;⁵
2. elevation ranging from 2,000 to 6,000 feet with occasional frost (above 4,000 feet) and small temperature ranges;⁶
3. growing on soil types of all geologic ages and degrees of development, but growing best on moderately well to well-drained, acidic, silty clay to silty soils of the Hydrandepts and Dystrandepts of the soil order Inceptisol;⁷ and
4. generally found growing in closed forests with an associated forest cover of more than 80 trees, shrubs, vines, herbs, ferns, club mosses, grasses, and sedges.

These "commercial quality" koa stand characteristics provide some indication of the parameters required of a koa growing site. However, it is important to note that the exact replication of these parameters may not be required for successful commercial koa culture. Some industry sources contend that the best opportunity for short-rotation koa culture may lie within the 500-2000 feet elevation range assuming adequate rainfall or irrigation and select parent stock for such elevations.

³ Chapter 186, Hawaii Revised Statutes, authorizes the Board of Land and Natural Resources to classify private land as tree farms if it is suited for the sustained production of forest products in "quantity sufficient to establish a business." The program is administered by the Department of Land and Natural Resources, Division of Forestry and Wildlife (DOFAW).

⁴ This time period assures no frost at elevations where frost can occur (*i.e.* elevations greater than 4000 feet). Assuming adequate moisture, seedling transplanting can occur at lower elevations any time during the year.

⁵ Skolmen (1986) notes that the average annual rainfall where the tall dense koa forests exist is about 85 inches per year ranging from 65 to 125 inches per year with droughts rarely exceeding 2 months in any year.

⁶ Skolmen (1986) notes that the best koa growing areas have almost daily cloud cover for a portion of the day. This may solely be a function of the fact that koa stands currently only exist at higher elevation (above 4000 feet) where such conditions prevail.

⁷ These young soils are deficient in phosphorous, potassium and calcium but relatively high in organic matter (Hobdy et al., 1991). For more details on koa forest soil relationships see Conrad et al., (1986).



Study Site

The specific site used for study purposes is a parcel located in Wood Valley in the Ka'u district of the island of Hawaii at an elevation of approximately 2,200-3,000 feet. Soils are of the Inceptisol soil order (University of Hawaii Department of Geography, 1983). Annual rainfall is approximately 100 inches per year fairly uniformly distributed throughout the year. Solar insolation is generally high in the mornings but with convective cloud creation, low in the afternoon when Wood Valley is frequently shrouded in clouds and fog. These conditions are somewhat similar to the middle forest zone where remaining koa stands are concentrated. The existent ground cover is dominated by a mixture of sugar cane (*Saccharum officinarum*) and Spanish clover (*Desmodium uncatum*). Various grasses, including kikuyu (*Pennisetum clandestinum*), are also present. The planting site slope is moderate to steep.

SEED GATHERING

At the current stage of the development of a sustainable commercial koa industry, the only seed or seedling stock available is from the Division of Forestry and Wildlife (DOFAW). DOFAW's seed/seedling stock is only available in limited amounts and is of unknown lineage. This may change in time with the efforts of University and other personnel.⁸ But for now, most prospective koa growers will have to gather their own seed for seedling production.

Brewbaker (1995) suspects high self-fertility and line purity of koa. Thus, identification of "elite" trees for seed collection should occur. Selecting local "elite" koa trees insures producing trees acclimated to the growing area.⁹

Tree selection and seed collection proceed as follows.

1. Desirable characteristics of koa trees selected for seeds are as follows.¹⁰
 - a. trees are healthy and disease free;
 - b. trees possess tall, straight, robust trunks;
 - c. trees are curly;¹¹
2. Trees selected for seed are selected before the seed bearing season which generally occurs in late summer in the Wood Valley region.¹²
3. Attempts should be made to gather the seed pods soon after maturity before they dehisce as fallen seed pods provide lesser counts of viable seeds (Masaki et al. 1991).¹³
4. Seed pods are sun-dried on screen racks which allow the seed, when the pods split, to fall through to a tarpaulin placed below. This area must be rodent-free. Broken, small, bug-infested or moldy seeds are removed.¹⁴ Seeds should be stored in a cool, dry, bug-free environment.

⁸ Brewbaker (1995) supports the establishment of seed orchards from elite trees at the earliest opportunity to develop seed stock for reforestation. If such seed orchards are established, they could be the source of seeds for future commercial koa operations and insure genetic diversity of the koa stock through interplanting of trees produced from seed of various "elite" trees.

⁹ State seeds/trees have not done well in Wood Valley according to local koa growers. This may not be true for other growing areas but does support the notion of selecting local koa trees for seed collection. This is supported by Skolmen (1986) who noted that natural trees (i.e. trees from seeds obtained from koas in the region) had significantly less mortality than trees from seeds obtained from koas outside the region when both were planted within the region.

¹⁰ For maintenance of koa genetic diversity and research purposes, the location and characteristics of trees from which seeds are obtained should be recorded as part of the seed gathering process.

¹¹ Curl is a quality of koa wood that causes the wood grain to appear wavy and 3-dimensional. Such curl is termed fiddleback curl as opposed to compression curl. Fiddleback curl ideally occurs throughout the tree and heartwood only running out in the branches. It can, however, run out in the stump. Compression curl occurs only at compression points in the tree. If a koa tree has a visible scar or the bark has been peeled, whether a koa tree has curl can be directly observed. Barring either of these occurrences there allegedly are means to identify whether a koa tree has curl. These are not well-documented and thus not reported here.

¹² Whitesell (1990) indicates that koas generally flower from late winter to early summer (July) with lower provenances flowering earlier than high elevation provenances. Flowering can be dramatic but koa seed setting is sparse, often failing completely. When fruiting occurs, the fruit is a pod 6 inches by 1-1.5 inches in dimension containing about 12 dark brown to black seeds. The fruit matures at different times during the year depending on location and weather conditions.

¹³ Koa seeds are destroyed by the larvae of 4 different species of Tortricid moths. These moths can destroy a significant percentage of any given seed crop (Whitesell, 1964). Whitesell later reports (1990) that the koa haole seed weevil (up to 850 ft elevation), the branch seed weevil (up to 4900 ft elevation) and the koa seed worm (up to 6500 ft elevation) account for 96% of total damage caused to koa seeds. Whatever the cause of seed destruction, koa seeds are highly susceptible to damage and must be collected soon after maturity.

¹⁴ In three samples, the number of seeds per pound ranged from a low of 2,400 to a high of 7,400 (Whitesell, 1964, p. 4). There may be a



In the event that this is not feasible, other agroforestry options would likely be pursued. Among these are growth of mango, mahogany, pheasant wood or teak. Which of these options is selected in the event koa is not grown again after harvest will depend on the ability to culture the species in Wood Valley and market constraints. This would be true for non-tree species as well.

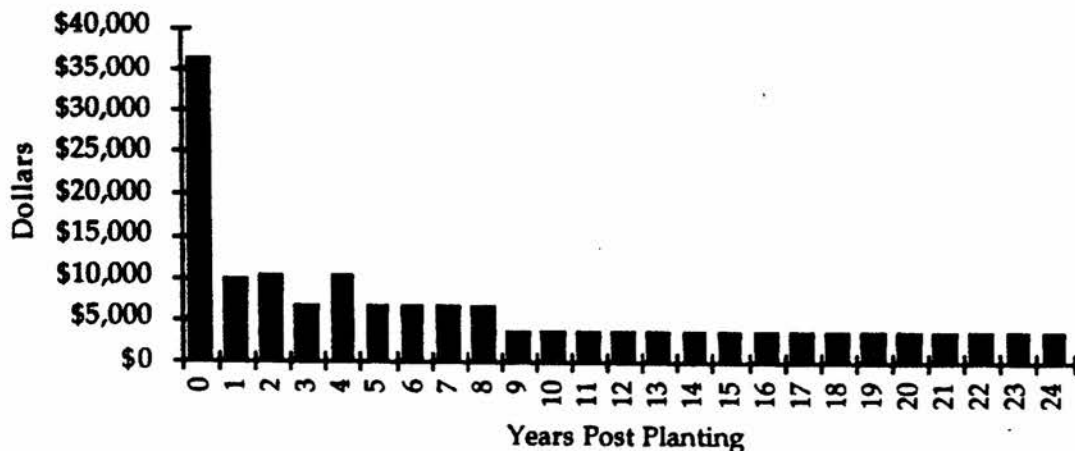
OTHER COSTS

Other costs include general and administrative, liability insurance, interest, taxes and miscellaneous annual expenses. General and administrative costs are estimated at 5 percent of total annual costs. Liability insurance costs are estimated at \$100 per acre per year. The only tax assumed to apply is the Hawaii State General Excise Tax estimated at 0.5 percent of koa gross sales. Miscellaneous annual expenses include annual costs to repair or replace tools used for koa production processes, possible disease or pest control costs and any other annual cost not explicitly covered previously that could be incurred. These costs are estimated at 2.5 percent of total annual costs.

COST SUMMARY

Total annual costs for a commercial koa operation as outlined in this study over a 25 year life derived from Tables 2 through 8 are summarized in Figure 1. It shows that costs are highest during the early years due to plantation establishment costs and sapling and tree care costs. The only costs after year nine are land lease and other costs. The total cost (1995 dollars) incurred over the life of the plantation equals \$159,000. Ninety-one percent of this cost is incurred previous to any koa harvest and subsequent revenues from the operation.

Figure 1: Koa Cost Summary for a 10 Acre Plantation Over 20 Year Expected Life (all costs expressed in constant 1995 dollar values)



Data Source: Tables 2-8

It is important to note that costs are site specific. Thus, total costs will vary dependent on site. Additionally, for the study site, it is assumed that some infrastructure such as for irrigation is in place. This may not be true for other sites. Finally, for purposes of the economic analysis, a 3 percent annual inflation rate is assumed on all costs.

EXPECTED KOA REVENUES

The stumpage fee (price per board foot paid to the grower) multiplied by the estimated total utilizable wood in a stand (quantity or board feet of wood) determines the total revenue for the trees sold. Each is separately discussed.



GERMINATION AND SEEDLING PRODUCTION (nursery practices)¹⁵

Germination and seedling production proceed as follows.

1. Seeds are scarified mechanically, briefly treated with sulfuric acid or soaked in hot water to soften the hard coat that retards germination. The water treatment is the most practical where the seeds are placed in water heated to 140° C and immediately removed from the heat source and allowed to stand 4 hours (Walters and Bartholomew, 1990). If the seeds fail to swell, the treatment can be repeated (Whitesell, 1990).
2. Tube-shaped grow bags¹⁶ (2" diameter x 12" length) are filled with soil or potting mix¹⁷ to 1" from the bag top. Two seeds are placed on the top of the soil and then covered with 1/4" to 1/2" of the mix. The seeds are watered and covered with black plastic for 1 day to create hot, moist conditions to facilitate germination. Germination should occur within 1 week (Whitesell, 1990).¹⁸
3. Young seedlings are grown in partial shade up to two weeks previous to transplanting after which they are transferred to full sun for "hardening" (Horiuchi et al., 1991). Moisture management is critical during the first month and care must be taken to not over water the emerging seedlings. Seedlings are thinned to 1 plant per bag leaving the most vigorous of the plants that have sprouted. Any weeds are also removed by clipping.
4. Seedlings must be transplanted before the seedling root system becomes bound or the seedling will be shocked and exhibit poor growth. This generally occurs in 4-20 weeks when the seedling reaches a height of approximately 8 inches (Whitesell, 1990).¹⁹ The seedlings should be planted at this time which means that the site must be ready to plant.

SITE AND SOIL PREPARATION

The planting area should be fenced to prevent entry of any grazing or browsing animals into the planting site.²⁰ Koa are vulnerable to grazing animals, particularly cattle (Scowcroft and Adey, 1991). Windbreaks can be planted to protect koa trees if strong winds occur at a planting site.²¹ Proper site preparation enhances stand survival and lowers stand maintenance costs. It proceeds as follows.

1. Management of existing and encroaching ground cover is of particular importance²² and depends on the ground cover. If the ground cover is cane or shrub-type plants two options exist.²³ The first is to clear the site of vegetation with a caterpillar type tractor wind-rowing the plant material within the site.²⁴ Alternatively, the cane

positive correlation between seed size and elevation.

¹⁵ Whitesell (1964, p. 5) has noted that direct seeding of koa on prepared seed spots has been moderately successful. Trees so planted (rather than transplanted) have greater viability and vigor early on. However, various koa growers have indicated that direct seeding requires more maintenance to prevent ground cover growth from covering the seeded area and preventing koa germination or from covering sprouted seedlings. Wood Valley koa growers have also reported that slugs have destroyed 90+% of seedlings when direct seeded. Given these considerations and the expense of seed collection, it seems advisable to grow seedlings for transplant as opposed to direct seeding.

¹⁶ Dibble tubes are another way of successfully germinating and producing transplantable seedlings.

¹⁷ A potting mix of ingredients that facilitates moisture retention while providing good drainage and aeration prevents "damping off" of the seedling at ground level. A seedling sprouting mix of 2 to 3 parts perlite to 1 part potting mix is an example of such a potting mix.

¹⁸ Precautions should be taken to insure that pests (e.g. slugs, pigs, cows, etc.) do not destroy the sprouting seedlings either by elevating the grow bags above the ground or using other appropriate methods (e.g. slug bait).

¹⁹ This range is based University practices (10-20 weeks seedling growth field pre-transplanting) and Wood Valley growers experience. Wood Valley growers use 3"x6" grow bags and transplant the seedling within 4 weeks of germination. The notion behind such early transplanting is to avoid any stress to the seedling due to the roots becoming bound in the grow bag.

²⁰ Pig eradication or expensive fencing may be required where large feral pig populations exist which can cause extensive damage to emerging and existent koa stands (Horiuchi et al., 1991).

²¹ Koa roots spread in all directions just below the surface of the ground. In spite of this characteristic, koa withstands heavy winds well. However, koa trees experiencing heavy winds do not attain the best trunk dimensions. In such situations, windbreaks are suggested.

²² Scowcroft and Adey (1991) reported for a site heavily infested with banana poka and kikuyu grass and planted in koa with no ground cover management, 82% of the trees were bent over or covered by banana poka vines and only 45% had acceptable to high vigor one year after planting. After 10 years at this site no koa survived. They further note that site preparation also affects the required frequency of weeding after planting.

²³ This is the type of ground cover at the study site. Other ground covers such as invasive trees including strawberry guava or Christmasberry, vines, bushes or other types of weeds will likely be managed differently. It is recommended that a County extension agent be advised as to the best method to eliminate any of these ground covers.

²⁴ Scowcroft and Stein (1986) noted that developing stands of koa saplings can easily be promoted by scarifying soil that contains viable seeds. Thus, clearing a site with a bull-dozer may establish a koa stand.



or shrub-type plants could be shredded with a brush hog or equivalent device. In either instance, sufficient time should transpire previous to transplanting the koa seedling to allow herbicide spraying to eliminate undesirable re-growth which could out-compete the koa seedlings for light and soil nutrients. The most undesirable re-growth is kikuyu or other grasses and/or banana poka.²⁵

2. Given planting site soil nutrient conditions,²⁶ the following soil amendments and per acre amounts are added to the soil.²⁷

Amendment	Per Acre Application
crushed coral	2,500 lbs
K-Mg	500 lbs
crushed phosphate rock	500 lbs

SEEDLING TRANSPLANT

Transplanting should occur when rainfall is commonly expected in the planting region. If irrigation water is available, transplanting could occur any time of the year. Seedling transplant proceeds as follows:

1. The soil in the grow bags should be made wet but not soaked prior to transplanting. This assists keeping the rootball in tact during transplanting.
2. Holes (8-12 inches diameter) are dug 3-6 feet apart within and between rows which gives approximately 1200-2700 trees/acre. This spacing has been used successfully by Wood Valley koa growers and University of Hawaii researchers growing koa (Brewbaker, 1995). Such a tight spacing is used to shade the ground to reduce evaporation and to control weeds. It also encourages erect growth (Brewbaker, 1995).
3. The best time to place seedlings in prepared holes is late in the day or on cloudy days to minimize sun exposure on the first day. Seedlings are carefully removed from grow bags to avoid damaging roots. The soil should be placed around the seedling in a manner to assure good soil contact with the seedling rootball without damaging any of the seedling roots. If possible, a mulch layer is placed around the seedling to reduce evaporation and weed growth.
4. (Optional) Flags can be placed at the site of each seedling (or seed location) as a locator in the event of aggressive ground cover re-growth.
5. (Optional) If enough (replacement) seedlings are available, poor performing or dead seedlings can be replaced.²⁸
6. In dry weather, seedlings should be watered every day for two weeks post-transplanting.²⁹

SAPLING CARE - YEARS 1 & 2 (post-planting maintenance practices early years)

Sapling care begins immediately after seedling transplant. It includes the following:

²⁵ Scalping is an ineffective ground cover management method for kikuyu grass because its deep rhizomes are not affected by scalping. It also only provides temporary control of banana poka vines. A possible herbicide application is 6.07 kg Round-Up™ active ingredient per hectare. This level of herbicide application provided the best site preparation in terms of tree survival and growth (Scowcroft and Stein, 1986).

²⁶ Study site soil pH is 5.5 with nutrient content characterized as good for phosphorous, low for potassium, medium for calcium and medium good for magnesium (8/10/94 University of Hawaii Soils Analysis).

²⁷ Scowcroft and Stein (1986) used a 10-30-10 formulation at a rate of 460 kg/ha plus MgSO₄ at a rate of 170 kg/ha for a site located on the flanks of Haleakala in the Makawao Forest Reserve at an elevation of 1050-1160 m. Brewbaker (1995) has reported koa growth is greatly suppressed on more acid (pH = 5.0) soils. This is consistent with observations of Wood Valley growers which is why the crushed coral recommendation for the study site is as high as it is. Additional research needs to be conducted to determine whether this is a recommendation applicable to all potential koa planting sites.

²⁸ Support for this step is provided by Brewbaker (1995) and DLNR (1984). Brewbaker reported that many koa trees can be described as "genetic junk." That is, they spread out like wild koa haole, or show high susceptibility to tip borers. DLNR (1984) notes that the only problem with koa as a plantation tree is that it has demonstrated very poor form when grown in plantation. The poor form results from insect attack to young trees stunting the trees and causing crooked stems. Young trees with good form are likely exhibiting insect resistance. This step can thus be considered a method of selection for insect resistance and/or a method to eliminate some of the "genetic junk" observed by Brewbaker (1995).

²⁹ Skolmen (1986) notes that as a young seedling during a drought, koa should have water every three or four days. Later it can survive 2 or 3 months without precipitation or irrigation if it has always grown in a uniformly wet area, and it can survive 6 months of drought if it originated in an area of frequent drought and adapted itself by growing a deeper root system.



1. If possible during the first year, saplings should be irrigated on an as needed basis to reduce stress during dry conditions.
2. Koa is intolerant of shade which means removal of growth that may shade or climb on the trees is desirable (Whitesell, 1990). Any such growth must be cut away or otherwise carefully removed from the saplings to avoid damaging the saplings.³⁰
3. Any saplings that have fallen over, are top heavy or are not growing straight are secured with strings in such a manner that the saplings stand upright for at least a couple of days. Experience of Wood Valley koa growers has shown that thereafter the saplings will remain upright.
4. Sickly, damaged, diseased and slow growth trees can be hand-culled once recognized. Stands will naturally thin as crowding occurs.³¹ However, some sources recommend hand thinning. If hand thinning is performed, spacing should not exceed 5-10 feet, dependent on tree growth, by the end of the second year. Thinning has a positive impact on the growth of the remaining trees (Scowcraft and Stein, 1986).³²
5. Pruning: Pruning of suckers or forks low on the trunk can occur during dry conditions to encourage the growth of long-straight boles. Pruning sap should be applied to the wound to prevent disease infestation.

TREE CARE POST YEAR 2 (post-planting maintenance practices later years)

Expected tree care and management post year 2 is considerably less than the first 2 years. This is primarily due to the fact that between the first and second year, the stand develops sufficient crown integrity to shade under growth reducing management needs. Tree culture after year 2 includes the following:

1. Given rainfall at the study site, trees will no longer require irrigation to survive. To attain optimal growth (*i.e.* merchantable trees within 20 years) and form³³ at particular sites, however, sprinkler or drip irrigation may be required. The level of irrigation will depend on water availability and the marginal profitability of irrigation.
2. Soil amendments or fertilizer can be applied as needed dependent on soil test results and recommendations.³⁴ Their application should be made only to potential crop trees by either broadcast or spot placement around the projected edge of the canopy.³⁵
3. Culling of sickly, damaged, diseased and slow growth trees should continue. Thinning may be practiced if the stand does not naturally thin in a manner consistent with desired tree production or the stand stagnates (*i.e.* no dominance is expressed when the canopy is closed or the health and productive value of the stand is compromised). Desired tree production ranges from bolts and half-logs to saw logs and canoe logs. Currently, all tree forms are salable. This includes trees with a main trunk of 6 feet below the first crotch if the tree is highly curled, and trees with arched stems which can produce a desirable compression curl. Production of trees of short length with highly colored heartwood versus tall-straight stemmed trees with clear boles can be encouraged with more drastic thinning accompanied by fertilization (Scowcraft & Snow, 1986).³⁶ Natural thinning will likely produce some combination of both tree types. Since ages for thinning have not been optimized by those recommending thinning (Horiuchi et al., 1991), the best time to thin is when trees to be thinned are large enough to have value.

³⁰ A Wood Valley koa grower has reported that encouraging Spanish clover ground cover has enhanced koa growth as long as it is prevented from climbing the trees. On Mauna Kea, gorse has been reported to enhance koa growth.

³¹ DLNR (1984) has noted that fertilization of natural seedlings up to 6 months of age caused them to become the dominant trees in the stand by overtopping and shading out their neighbors. Thus, assuming fertilization is a desirable koa cultural practice, it may be possible to use fertilization to control spacing without hand thinning. DLNR reported use of 25 grams of 10-30-10 in a hole 6 inches from the tree.

³² Scowcraft and Stein (1986) have noted that the magnitude of the growth response from thinning is determined by various physical and chemical factors including: amount and distribution of rainfall (this factor can be managed if irrigation water is available), temperature, composition and abundance of understory vegetation and age, vigor and genetic potential of the koa trees.

³³ The form of koa varies greatly and to some extent is genetically determined. In the rain forests on deep, rich soil, an occasional koa may reach 100 feet but few possess clean, straight boles. On drier sites, the form of koa is even poorer, and trees are often stunted and misshapen (Whitesell, 1964, p. 6). This suggests that to grow quality koa in marginal growing areas, irrigation may be a necessity.

³⁴ Scowcraft and Snow (1986) found that fertilization of thinned stands stimulated koa growth relative to un-fertilized stands. Information is unavailable, however, to determine if the marginal return from fertilization exceeds its marginal cost.

³⁵ Scowcraft and Snow (1986) indicated that, in general, fertilization is more likely to enhance tree growth prior to canopy closure or following thinning of a closed canopy stand.

³⁶ Rock (1911) noted that the tall forest-grown trees provided wood suitable for construction whereas the short boled open-grown trees provided attractively figured furniture lumber.



4. Pruning: Pruning is not generally recommended.³⁷
5. Companion planting after the last cull may occur. Whitesell (1964, p. 2) lists various trees associated with koa in native stands. On the property of the study planting area, coffee grows well with an established koa stand suggesting that it may be a suitable companion species. Species such as coffee could also provide a return to the land area well before obtaining any revenues from a commercial koa planting. Additional investigations related to symbiotic relationships between koa and any possible companion species and economic considerations will dictate whether a companion species is planted.
6. If the site is infested with banana poka vines, it may be necessary to periodically weed the site for 5-10 years to prevent banana poka vines from damaging the developing stands (Scowcraft and Adee, 1991).
7. Traffic through the groves should be minimized at all times to prevent root and tree damage.

DAMAGING AGENTS

Damaging agents that must be managed to the extent possible include the following.

1. Animals: Includes cattle, sheep, pigs, and goats which damage koa trees by trampling the seedlings, eating the seedlings or stripping bark off mature trees; the tree rat and the Hawaiian rat eat koa seeds and damage koa seedlings by stripping off bark. Damage by rats has been reported to be most severe by brush piles where rats nest (Whitesell, 1990).
2. Insects: 40 species of native insects are considered enemies of koa and 61 non-native insect species (Whitesell, 1990). The koa moth is one of the most destructive insects. It is a lepidopterus defoliator which can periodically occur in large numbers causing stunted growth and tree mortality (Whitesell, 1990). Other insects which can reduce and cause mortality are: the Fuller rose beetle, the acacia psyllid and the black twig borer (Whitesell, 1990). In Wood Valley, aphids have been reported to be a problem during drought conditions.
3. Diseases: Various pathogens causing disease include: shoot blight, crown rot, collar rot, and wilt caused by a fungus. Dieback is common in the crown of old trees and is associated with a root-rot fungus. Both seem associated with stands weakened by old age, extended droughts, and grazing. Sooty molds can cover leaves and restrict growth. Four rust fungi occur on koa causing witches' brooms and leaf blisters that deform branches and phyllodes. Hawaiian mistletoe can deform young koa. Heart rot is common in large, older (70 years at low elevation, 125 years at high elevations) koa (Whitesell, 1990).
4. Weeds: In certain areas weeds are a problem. Notable problem weeds include: banana poka (*Passiflora mollissima*), German ivy (Whitesell, 1990) and kikuyu grass (*Pennisetum clandestinum*). These plant species have been noted to limit reforestation success (Scowcraft and Adee, 1991).

Animal controls are effected by fencing and hunting. No measures have been taken to control koa insects and it is surmised that most are under natural control. Diseases are best controlled through proper site selection and preparation and by minimizing tree injury by animals and other site stress, such as waterlogging (Jones et al., 1991). Diseases may also be mitigated by planting of companion species. Weed control is effected during the site preparation phase and post-planting years as described.

HARVEST

Uniform growth of a koa stand will not likely occur. Thus, incremental harvest of a stand will be required. Trees are assumed ready for harvest when they attain a diameter breast height (dbh or 4.5 feet above ground) of 25³⁸ inches or greater. Such trees are assumed to have attained an average height of 50 feet with the first fork at an average height of 22.5 feet. Twenty percent of the trees in a stand are assumed to attain such a dbh in year 20.^{39, 40} The remaining trees in a stand are harvested at this rate such that harvest of the stand is completed in 5

³⁷ DLNR (1984) reported that pruning significantly improved clear stem length in thinned stands but not in unthinned stands. Scars from pruning healed rapidly and no post-pruning infection occurred. However, the diameter growth of thinned, unpruned trees was significantly larger than that of the pruned, thinned trees. For this reason and since thinning may be used as a koa cultural practice, pruning is not recommended during this management phase.

³⁸ It is important to note that smaller diameter trees are acceptable assuming that the wood has desirable quality characteristics.

³⁹ A koa growth rate wherein these tree size parameters have been attained by Wood Valley koa growers in 13 years ago. The growth rate on stands planted subsequent to this stand has been faster. Thus, a 20 years harvest would seem attainable. Koa growth curves have not been formulated, thus it is impossible to determine when optimal harvest would occur relative to economic and biological considerations. Given investment payback considerations, the earliest possible harvest time is used in lieu of any optimal formulation.

⁴⁰ Observations suggest that koa grows slower at high elevations versus lower elevations but lives longer. Thus, the growth rates reported



years or 25 years post-transplanting the koa seedlings. Thus, it is assumed that the trees remaining in a stand systematically attain harvest dimension according to the harvest schedule.

The number of trees harvested per acre will depend upon the final spacing dimension. Ideally, the final spacing is 24 ft x 24 ft with trees in evenly spaced rows. The actual spacing at harvest, assuming stand management similar to what is outlined in this study, will depend on the health and vigor of the stand. A healthy, vigorous stand would require less culling of diseased trees and/or thinning of slow growing "junk" trees and vice versa. Thus, when harvest commences, there would be more or less trees dependent on the health and vigor of the plantation. For purposes of this analysis, an average final tree spacing of 24 ft x 24 ft is assumed which implies 76 trees harvested over the harvest cycle per acre.

PRODUCTION COSTS

Cost categories correspond to the koa production process and harvest categories of the previous section. Cost estimates and a discussion of their derivation are presented. There are two basic cost categories, labor and material costs. Costs falling into either of these categories are considered operating costs incurred the year they occur. No capital costs are estimated. Given the size of operation modeled (*i.e.* 10 acres) and the production processes of commercial koa culture outlined, significant capital costs would not be required.⁴¹ Where they do occur (*e.g.* expenditures for minor tools and equipment such as backpack sprayers and wheelbarrows), they are expensed the year they occur. Irrigation infrastructure is assumed already on site.

The labor hour estimates for each activity are based on the experience of the author and others in Wood Valley for these activities. These estimates have been reviewed and refined by various forestry industry persons. Per hour labor costs for these activities are valued at the wage rate for an agricultural handy worker (Department of Labor and Industrial Relations, 1994) unless noted otherwise. Labor costs estimated in the study include wage and benefit (legally required payments including social security, unemployment and workers compensation, and medical benefits) costs. Benefit costs are estimated as a percentage of wage. This percentage is 20.6% (Chamber of Commerce, 1994).

No matching funding⁴² for the koa operation is assumed for this analysis. Any matching funding would improve the economic viability of a commercial koa plantation. Furthermore, since this document is designed to serve as a business plan and thereby facilitate planning and organizational efforts to establish, operate and manage a successful koa tree plantation, labor requirements for a business plan and related activities utilized in this study are minimized.⁴³

SITE SELECTION COSTS

Site selection costs include labor to search for and then investigate alternative sites suitable for koa production, legal and institutional costs incurred to meet any such requirements and annual land costs.

Site Assessment Labor

It is assumed that individuals interested in commercial koa production already have land and are considering viable crop or forestry alternatives to put such land to productive use. Thus, the only effort of such individuals related to site selection is the determination of whether the site is suitable for koa production. This would consist

in Wood Valley and assumed for this analysis may not be attainable at higher elevations.

⁴¹ This would not be true for a large agroforestry operation (*e.g.* 1,000 acres or more) specializing in commercial koa culture or a combination of agroforestry crops which would require specific capital expenditures (*e.g.* trucks, tractors, etc.) to support such a large size operation.

⁴² There are various sources of matching funding for reforestation and other business activities for which commercial koa culture qualifies. For example, the State of Hawaii through the Department of Land and Natural Resources (DLNR) operates a Forest Stewardship Program to financially assist land owners in managing, protecting, and restoring important natural resources and former forested lands. In addition to the State program, the U.S. Forest Stewardship Incentive Program (SIP) offers similar cost-share assistance to eligible landowners who actively pursue management of their forested lands. Requirements for application to these programs are available from DLNR.

⁴³ The author envisions use of this study by prospective koa farmers to create a draft business plan. It is anticipated that such a proposal would be reviewed by a professional resource manager for accuracy, relevance and specificity to the site and conditions of the proposed koa planting area to create a final business plan. Once reviewed by a professional resource manager, the resultant plan could also serve as a "forest stewardship management plan" which could be submitted to relevant agencies and entities for matching funding for the koa plantation.



of a comparative evaluation of the site relative to the parameters noted above (Site Selection section), related research to that end and soil testing. The work completed for the comparative evaluation would be incorporated into the business plan. The estimated value per hour for this labor activity is that for an agricultural research worker (Department of Labor and Industrial Relations, 1994).

Legal and Institutional Requirement Labor

There are no legal requirements that must be fulfilled to create a koa plantation. There are also no mandatory institutional requirements. Various optional institutional requirements are, however, assumed. This includes drafting a business plan, filing for tree farm designation with DOFAW,⁴⁴ applications to relevant programs for matching funding and application to support organizations such as the Hawaii Forest Industry Association. The labor requirements for these activities are assumed primarily provided by the plantation manager. The estimated value per hour for this labor activity is that for an agricultural resource specialist (Department of Labor and Industrial Relations, 1994). Twenty hours time of a professional resource manager who assists the plantation manager complete and finalize the business plan is assumed at a wage rate of \$75 per hour.

Land Lease Costs

For purposes of this analysis, whether the land used for a koa plantation is owned or leased, the estimated annual cost of using the land for koa production is assumed to be the estimated annual cost of leasing agricultural land. The cost of leasing agricultural land varies with leasing party and the nature of the lease agreement. A 55 year land lease in a Hawaii Department of Agriculture Park costs \$100/acre/yr., plus 1.5% of gross income. A Hawaii land holding company estate land lease typically costs \$200/acre/yr. plus 3.5% of gross income. Most estates and large corporations consider each venture separately, adjusting leases according to the company's experience and gross income or profit potential. A land lease cost of \$250/acre/year is used which presumes a 5% return on the per acre value of the land. It is further assumed that the annual lease payment covers annual property taxes. Table 2 summarizes site selection and site costs.

Table 2: Site Selection and Site Costs

Cost Item	Year(s) Incurred	Units	Unit Measure	Cost per Unit	Total Cost
<i>Labor Costs</i>					
Site Assessment	1	40	labor hrs	\$11.67	\$467
Inst. Requirements					
Draft Business Plan	1	80	labor hrs	\$21.23	\$1,699
Resource Specialist	1	20	labor hrs	\$75.00	\$1,500
TOTAL					\$3,665
<i>Other Costs</i>					
Land Lease Yrs 1-25	1-25	10	acre	\$250.00	\$2,500

SEED GATHERING COSTS

Seed gathering costs include labor time to select local "elite" koa trees for seed collection, seed gathering and seed pod drying and shucking to release seeds. It is assumed that there are no costs to enter into areas for seed gathering activities (e.g. right of entry) nor for the seeds collected. This assumption is consistent with current actual experience. Approximately 11 pounds of seed are required for planting a 10 acre parcel.⁴⁵ Table 3 summarizes seed gathering costs.

⁴⁴ An additional advantage of filing for and receiving tree farm status is the legal right to harvest guaranteed by the State.

⁴⁵ This amount is derived as follows: 2,500 seedlings per acre, 5,000 seeds per pound and 2 seeds per grow-bag and an additional pound of seeds for replacement seedlings in the event seedlings die after transplanting.



Table 3: Seed Gathering Costs

Item	Year(s) Incurred	Units	Unit Measure	Cost per Unit	Total Cost
<i>Capital Costs</i>					
Tree Selection	1	40	labor hrs	\$11.42	\$457
Seed Gathering	1	40	labor hrs	\$11.42	\$457
Seed Extraction	1	20	labor hrs	\$11.42	\$228
TOTAL					\$1,142

GERMINATION AND SEEDLING PRODUCTION COSTS

Germination and seedling production costs include labor time to prepare seeds for germination, preparation of grow bags for seed planting, seed planting, and seedling management including thinning, weeding and watering.

Materials for germination and seedling production include equipment and utensils required to prepare seeds for germination, soil, grow bags, a shade cloth structure, and water. A one-time cost of \$100 is assumed for use of equipment (e.g. gas or electric stove and pots) required to prepare seeds for germination. Soil is assumed obtained on site and thus of no cost. Thirty thousand grow bags are required to provide sufficient transplants for 10 acres of koa. Cost per grow bag used is typical for Hilo, Hawaii. The shade cloth structure must be 3,000 square feet to accommodate an assumed approximate 30,000 grow bags with seedlings.⁴⁶ The cost used is typical for Hilo, Hawaii. Costs to water the seedlings until transplanted are negligible so they are ignored. Table 4 summarizes germination and seedling production costs.

Table 4: Germination and Seedling Production Costs

Item	Year(s) Incurred	Units	Unit Measure	Cost per Unit	Total Cost
<i>Labor Costs</i>					
Seed Preparation	1	8	labor hrs	\$11.42	\$91
Grow Bag Preparation	1	83	labor hrs	\$11.42	\$951
Seed Planting	1	42	labor hrs	\$11.42	\$476
Seedling Management	1	98	labor hrs	\$11.42	\$1,119
SUB-TOTAL					\$2,637
<i>Material Costs</i>					
Seed Preparation	1				\$100
Grow Bags	1	30,000	bags	\$0.06	\$1,800
Shade Cloth Structure	1	3,000	sq. ft	\$0.13	\$385
SUB-TOTAL					\$2,285
TOTAL COST					\$4,923

SITE AND SOIL PREPARATION COSTS

A planting site may require fencing to prevent animal entry. If so, fencing cost is the first site preparation cost. The study site required fencing. The fencing cost used is based on actual experience for the study site. As noted, the study site existent ground cover is dominated by a mixture of sugar cane and Spanish clover with other

⁴⁶ Assumes grow bags are 3 inches in diameter, a grow bag row width of 5 feet, and 2 feet width walking rows between grow bag rows.



grasses, including kikuyu, also present. Thus, the second site preparation step is to shred the cane and other growth cover using a brush hog, the method chosen for the study site.⁴⁷ The per acre cost is based on the actual cost in Wood Valley for this service. Other site and soil preparation costs include labor time and materials costs.

Labor costs are for herbicide spraying and fertilizer or soil amendment application. Materials are herbicide spray (1.5 gals (RoundUp) @/acre) and fertilizer or soil amendments applied (1.5 t/acre crushed coral, 0.25 t/acre phosphate rock and K-Mag). The fertilizer application is study site specific. Costs are typical for the Hilo area. Fertilizer costs include an additional 10% of the purchase price for transportation costs to the planting site. Table 5 summarizes site and soil preparation costs.

Table 5: Site and Soil Preparation Costs

Item	Year(s) Incurred	Units	Unit Measure	Cost per Unit	Total Cost
<i>Labor/Contract Costs</i>					
Fencing	1	1,792	feet	\$1.59	\$2,852
Site Clearing	1	10	acres	\$140.00	\$1,400
Herbicide Spraying	1	40	labor hrs	\$11.42	\$457
Fertilizer Application	1	40	labor hrs	\$11.42	\$457
SUB-TOTAL					\$5,165
<i>Material Costs</i>					
Herbicide	1	15	gals	\$50	\$750
Crushed Coral (spread)	1	15	tons	\$39	\$578
Phosphate Rock	1	2.5	tons	\$441	\$1,103
Potassium (K-Mag)	1	2.5	tons	\$526	\$1,315
SUB-TOTAL					\$3,745
TOTAL COST					\$8,910

TRANSPLANTING COSTS

The primary cost to transplant the 25-30,000 seedlings for the 10 acre site is labor. Costs for use of any tools and equipment such as shovels, spades, wheelbarrows and a pick-up truck or tractor are subsumed under a single \$500 fee. Labor is required to prepare the seedlings for transplant (water, load/unload seedlings and transport to planting site) and to transplant the seedlings (dig hole, place seedling in hole, remove grow bag and firm soil around seedling root ball). Table 6 summarizes transplanting costs.

SAPLING CARE COSTS

Sapling care costs consist of irrigation water and labor costs. For the study site area, it is assumed that an acre inch of irrigation water must be applied on two occasions each year during the first two years after transplanting to prevent drought-related stress. Water cost is typical for Hawaii County water. Water distribution (e.g. hoses and sprinklers) costs are considered nominal and ignored.

Labor during the sapling care period is for irrigation, undergrowth control, sapling support and culling and thinning the saplings. Table 7 summarizes site and soil preparation costs.

⁴⁷ The reasons the site groundcover was cleared using a brush hog as opposed to using a bull-dozer was for ground cover management purposes. Evenly distributed, shredded ground cover material provides a mulch layer that retards ground cover regrowth that could compete with transplanted koa.

**Table 6: Transplanting Costs**

Item	Year(s) Incurred	Units	Unit Measure	Cost per Unit	Total Cost
<i>Labor Costs</i>					
Seedling Preparation	1	40	labor hrs	\$11.42	\$452
Transplanting	1	333	labor hrs	\$11.42	\$3,805
SUBTOTAL					\$4,257
<i>Material Costs</i>					
Tools & Equipment	1				\$500
SUBTOTAL					\$500
TOTAL COST					\$4,757

Table 7: Sapling Care Costs

Item	Year(s) Incurred	Units	Unit Measure	Cost per Unit	Total Cost
<i>Labor Costs</i>					
Irrigation	1-2	80	labor hrs	\$11.42	\$913
Undergrowth Control	1-2	240	labor hrs	\$11.42	\$2,740
Sapling Support	1	120	labor hrs	\$11.42	\$1,370
Culling and Thinning	1-2	240	labor hrs	\$11.42	\$2,740
SUBTOTAL					\$6,850
<i>Material Costs</i>					
Irrigation Water	1-2	543,086	gals	\$0.00069	\$375
SUBTOTAL					\$375
TOTAL COST					\$7,224

TREE CARE POST YEAR 2 COSTS

Irrigation is not considered necessary for optimal growth at the study site given rainfall levels and distribution. Thus, there is no irrigation water cost after year two. The soil amendment regime and costs (Table 4 Site and Soil Preparation Costs) is assumed repeated in years 2 and 4 corresponding to stand thinning and consequent canopy opening when fertilization is likely to be most effective (see note 34).

—Tree care labor is for fertilizer application as indicated in Table 4 (Site and Soil Preparation Costs) in years 2 and 4 and thinning (or culling) as indicated in Table 7 (Sapling Care Costs) through year 8 at which time the ultimate tree spacing is assumed attained and this activity is no longer required. Table 8 summarizes tree care post year 2 costs.

Costs for any companion planting are not relevant to the costs of koa production and thus are not included here. No labor is required for banana poka removal as it is not a problem at the study site.

HARVEST COSTS

All activities required for a koa grower to obtain revenues from the sale of koa are considered harvest activities. These activities include physical harvest of the trees, processing and marketing. The incremental costs of selling rough green lumber as opposed to stumpage includes costs associated with each of these activities. Incremental revenues result from the difference in the price of green lumber over raw stumpage. Thus, if the price



Table 8: Tree Care Post Year 2 Costs

Item	Year(s) Incurred	Units	Unit Measure	Cost per Unit	Total Cost
<i>Labor Costs</i>					
Fertilizer Application	2 & 4	40	labor hrs	\$11.42	\$457
Culling and Thinning	2-8	240	labor hrs	\$11.42	\$2,740
SUBTOTAL					\$3,197
<i>Material Costs</i>					
Crushed Coral (spread)	2 & 4	15	tons	\$39	\$578
Phosphate Rock	2 & 4	2.5	tons	\$441	\$1,103
Potassium (K-Mag)	2 & 4	2.5	tons	\$526	\$1,315
SUBTOTAL					\$2,995
TOTAL COST					\$6,191

for stumpage is very low in comparison to the price of green lumber, and the costs of harvesting, processing, and marketing are low, landowners would have an incentive to sell green lumber.

In Hawaii at the present time, the small (to non-existent) size of the market for koa makes it economically advantageous to have the wood processed on the mainland. Because of the small size of the market, local processors are not able to exploit economies of scale. If the koa supply situation changes and more wood becomes available, this situation would change quickly. In this instance, there would be room for a processing industry to develop in Hawaii. Currently, however, the best choice for the landowner is to sell the raw koa resource for stumpage rather than dealing with the problems of downstream processing and marketing. This will likely be the case in the long run.

A harvester performs harvesting, processing, and marketing activities and either pays the koa grower a stumpage fee⁴⁸ or sells the milled wood on consignment for the grower. The former practice is more common and is assumed for this analysis. Thus, there are no harvest costs estimated for this analysis. The only possible cost that would be incurred by a koa grower under this assumptions would be the labor time required to negotiate the highest stumpage fee among the various harvesters.⁴⁹ This is considered nominal and not estimated.

Post Harvest Land-Use Option

Various land use options exist post harvesting koa for wood. Another koa cycle could commence assuming there are no constraints to so doing and market conditions support such an action. If the koa harvested is high value, it may be possible to allow natural regeneration of the site from seeds produced by the stand just harvested. A tracked skidding vehicle could be used during the harvest process to ensure soil disturbance in the vicinity of the stumps. The soil disturbance would result from maneuvering the tractor for hookup and skidding of logs. If done properly, each stump would have a single skid trail with all trails leading to widely separated 'main haul' skid trails. Koa seeds would sprout in the disturbed ground thereby regenerating the stand (DLNR, 1984). If the harvested koa is not desirable stock, desirable seed stock can be procured as described in this study or perhaps from other sources. The process to establish a koa stand as outlined in this study can then be followed. The estimated site preparation costs in this instance would be for stump removal.

⁴⁸ The stumpage fee is the price per board foot paid to the koa grower by the harvester. It is not estimated on a per-grade basis but is rather a flat rate per estimated total board feet that will be harvested.

⁴⁹ A harvester offers a price per 1000 per board foot to the grower based on his or her well-winnowed judgment of the number of board feet which will be obtained from the harvest. Observations suggest that a tacitly agreed upon range for stumpage among koa harvesters likely exists. If so, all harvesters are working within similar stumpage fee ranges which vary based on individual harvester koa market perceptions. Given such a range in stumpage fees and the competitive nature of the market, it makes economic sense for koa growers to 'shop around' among the different harvesters for the highest bid for their resource.



STUMPAGE FEE

The stumpage fee a harvester can pay for plantation koa is determined by the market price for koa he/she can receive for the processed product. Koa market prices at harvest time are a function of the expected supply and demand for koa wood situations during the harvest period (*i.e.* in 20-25 years).

Koa Supply

There are two aspects of koa supply that are important for price determination. These are quantity and quality of the harvested resource.

Quantity of Koa Harvested: For the last 15 years, an average of approximately 1 million board feet of koa have been harvested annually.⁵⁰ Of this harvest amount, 20-30 percent is wastage⁵¹ leaving an annual koa market supply of 700-800 thousand board feet. This resource has been harvested from private lands only, as the State of Hawaii does not allow harvesting on State lands.⁵²

Operations harvesting koa are generally salvage operations harvesting old-age, senescent or diseased trees on private lands. Salvage koa is high in defect providing little usable wood which is costly to extract (Potter, 1994).

The total stock of koa on private lands is currently unknown. It is estimated to be at least 50 million board feet. Resource accessibility and economic considerations do not justify harvest of portions of this private stock and portions have been removed from the market for other reasons.⁵³ These factors reduce the total koa resource available for harvest or salvage.⁵⁴

The stock of koa on State forest lands which comprise over 50 percent of native forests with koa as a major species, are estimated to be in excess of several hundred million board feet (DLNR, 1984). It does not appear likely that the State will alter its forest management policy with respect to koa in the foreseeable future unless a realistic model of long range koa culture and management can be demonstrated. Thus, this stock of koa will not affect the quantity of koa moving to market. So long as some portion of private koa stock only, is harvested, it seems reasonable to assume that the annual quantity of native koa harvested will decrease over the time horizon of this study.⁵⁵ This decrease could be as much as 80 percent of the current harvest by the year 2010.

Koa Quality: Overall quality in koa is determined by 1) the presence of figure and curl in the wood grain where the curlier and more heavily figured the better, 2) texture, determined by density where the denser the better, 3) color, where the darker the better unless the wood is curly in which case any color is easy to sell, 4) length, where the longer the better, 5) width, where the wider the better and 6) lack of knots, in-grown bark, sap, pith stain and (wind or ring) shake.

Curl and figure in koa are highly valued. This is evidenced by the fact that the top three grades of koa (see below) are for the curly variety. The cause of curl is most often attributed to the genetic stock from which a tree came. The better textured or denser koa wood appears to come from trees that grow more slowly. Both young and old trees can have dense wood but the young trees have proportionately more "early wood" (center portion) which is soft and thus prone to shrinkage and collapse upon drying. Early wood is also generally lighter in color than the heartwood.

Koa color ranges from blond or white to dark red-purple. Color might be an artifact of the difference between high and low elevation seed stock as well as of age.⁵⁶ Generally speaking, the wood from trees grown at higher

⁵⁰ The peak harvest amount over this period was 1.2 million board feet and the harvest amount has been decreasing since 1993.

⁵¹ This wastage is sawdust and planks that may have 1-2 flat sides but are not usable.

⁵² The State currently follows an environmentally-conservative non-management of koa forests policy and does not allow the harvest of koa on State lands (Potter, 1994).

⁵³ In 1992, the largest private landowner, Kamehameha Schools/Bishop Estate (KS/BE), chose not to renegotiate logging leases with the two largest lumber producers in the state. This immediately gave rise to rumors of a koa harvest moratorium and scarcity (Potter, 1994).

⁵⁴ Even without cutting, the existing supply of koa on private as well as public lands is dwindling. This is due to the fact that there are no significant annual additions to this stock from regrowth or reforestation and due to the onslaught of old age, disease, grazing, and invasion of koa forests by destructive alien species (Potter, 1994).

⁵⁵ This supply may be supplemented by plantation koa that could be ready to harvest in 10 years. Availability of this resource is not expected to significantly alter this forecast over the study time horizon, however.

⁵⁶ There may also be a relationship between color and density. Generally, yellow-colored wood is lighter weight than dark-colored woods. Also, curly grained wood is denser than straight grain koa wood.



elevation are darker than those grown at lower elevations, and older trees are darker than younger trees.⁵⁷ Consistent with other tree species, koa sapwood is more prevalent in young trees but rarely over 2 inches in mature trees. Sapwood is creamy white or blond which sharply differentiates it from koa heartwood. Koa heartwood ranges in color from yellow to dark red-purple.

Long length and wide width are preferred because it is easier to match pieces and the wood goes farther. Even in the case of picture-frame molding, where one might assume that smaller pieces could be used, longer and wider is preferred due to production efficiencies.

The industry currently uses the grading system for black walnut with grades added for curly koa.⁵⁸ There are 7 grades with 1 being the best. Table 9 provides an estimate of the probability distribution range across the 7 grades from currently harvested koa. The percentages given are for the usable wood after waste has been eliminated from the total harvest. The best case estimates for the first 3 grades can flip-flop amongst themselves dependent on harvest site variability. The cumulative percent of these three grades for the best case, however, would be approximately 5%.

Table 9: Current Koa Grade Probability Distribution

Grade Number	Grade Name	Probability Distribution		
		Worst Case	Best Case	Median
1	premium full curl	0.0%	1.0%	0.5%
2	full curl	0.0%	2.0%	1.0%
3	select curl	0.0%	7.0%	3.5%
4	select and better	40.0%	60.0%	50.0%
5	#1 common	10.0%	10.0%	10.0%
6	select shorts	20.0%	10.0%	15.0%
7	#2 common	30.0%	10.0%	20.0%
TOTAL		100.0%	100.0%	100.0%

The overall quality of koa harvested over the past 15 years has been decreasing. As noted, lesser amounts of high quality material can be salvaged from areas open to harvest. This is due to use of an over-aged, senescent koa resource. The condition of the currently harvested koa resource is due to the lack of forest restoration planning and efforts in the historic range which could have allowed continuous harvest of a high quality, mixed-age, sustainable resource. Even with policy changes, it is unlikely that the decreasing quality trend can be reversed. This is due to the fact that much of the remaining koa resource that currently is not harvested is also old age, senescent or in otherwise poor condition.

Koa Demand

The principal market for Hawaii wood products and thus koa is the local (in-state) market. Mainland markets for koa are located primarily on the West Coast. Japan is the dominant foreign market (Yanagida et al., 1993).

In 1980, stumpage fees for koa ranged between \$100 and \$225 per 1000 board feet. By 1995 this range was between \$1000 and \$3000 per 1000 board feet. Ignoring the progression of price changes over the period, this translates into an average annual rate of price increase for the low end of the range of 16.6 percent, and for the high end of the range an annual average rate of increase of 18.8 percent. Inflation as measured by the Honolulu consumer price index for all urban consumers increased at an average annual rate of 4.9 percent over the same

⁵⁷ An important aside related to cultural practices and color is that generally, it is possible to grow high elevation seeds at a lower elevation, but not visa versa.

⁵⁸ The grading system was created by Ed Winkler.



period. Thus, koa price increases were well in excess of increases in the general level of inflation. Given a constant supply situation as discussed, this implies an increasing koa demand over the 1980 to 1995 period.⁵⁹

On average over the time horizon of this study, increases in koa demand are not expected to abate. In fact, it seems reasonable to conclude that the potential market for koa has barely been scratched. Koa is a unique wood differentiable from other woods. It is also currently grown only in its native Hawaii. With some coordinated effort similar to what has occurred with Hawaii's papaya and macadamia nut industries, one could envision a koa industry of equal dimension to other diversified agricultural products in Hawaii. That is, an industry with a much larger demand for its products than currently exists. Even without such efforts, if historic trends persist, koa demand will continue to increase.

Expected Future Stumpage Fee

The stumpage fee for plantation koa with expected harvest in 20-25 years will be determined by koa wood market prices and the substitutability of plantation koa for koa harvested from native stands.

Koa Wood Market Prices: Stumpage fee changes between now and the expected harvest of study site plantation koa will be determined by the koa wood demand and supply situations at expected harvest time. Based on the above discussion, one can expect koa wood price increases since the koa resource supply is shrinking while demand can be expected to at the least remain unchanged.

Substitution of Plantation Koa for Native Koa: The quality objective of plantation culture is to produce wood with curl, of dark color, dense texture, long length and wide width. If achieved, plantation koa could achieve a lumber grade distribution better than that shown in Table 9 which is primarily for salvage koa currently harvested.⁶⁰

Industry persons have reported the harvest of 20 year old koa trees not only of good color and density but also of exemplary curl and figure. Additionally, length and width of size sufficient for harvest within 20 years have been achieved for plantation koa in the study site region. These facts suggest that the quality objective of plantation culture is achievable if the suggested cultural practices are followed and seed stock having the potential to produce wood with curl, dark color and dense texture are used to establish the plantation.

It may also be possible to increase the likelihood of producing "quality" trees at the assumed study harvest time via management practices. For example, given that quality characteristics appear to be positively correlated with prime maturity, cultural practices may exist or be formulated that can force the tree into physiological responses consistent with prime maturity and the consequent production of desired wood quality. The addition of various soil amendments may also prove to be a factor increasing the likelihood of the production of desired wood quality. One industry person suggested the addition of iron to the soil to produce dark colored wood. Field investigations are required to verify the efficacy of such practices.

If dark color and dense texture are not consistently produced at the study harvest times (assuming adequate tree size), the substitutability of plantation koa for native koa will depend on the characteristics of the wood produced and market acceptance of the quality produced. As noted, younger trees generally have a higher percentage of sapwood which is less dense than heartwood and creamy white or blond in color.⁶¹ The market may accept such wood if more desired quality koa is unavailable and likely would due to the cultural significance of koa in Hawaii.⁶² One industry person suggested the possibility of staining lighter colored koa wood. The effect of such innovations or treatments and their market acceptance cannot be known until the wood is cut and processed.

In sum, there are issues related to plantation koa quality which cannot now be resolved from discussion or objective information. Plantation koa harvested within the assumed study time frame may have desirable quality

⁵⁹ Effectively, the koa demand schedule has increased along a perfectly inelastic supply schedule.

⁶⁰ In the long run, it seems reasonable to presume this will occur given expected improvements in stock for plantation culture and possible increases in the rotation age of plantation koa to achieve better quality than assumed.

⁶¹ An additional problem with sapwood in many tree species is that it cracks when dried. This does not appear to be a problem with koa sapwood, however.

⁶² The koa market has successfully adapted to changing supply conditions. For example, due to increasing prices, the market has increased utilization of waste, lower quality wood, shorter boards and veneers as opposed to solid boards. This has resulted in a higher percentage of log recovery and utilization. It also suggests that the market may successfully adapt to a different quality koa than is currently utilized. Nonetheless, plain lightweight koa will always be less valuable than figured material. Still, it will likely have sufficient value to merit its cultivation.



characteristics as currently dictated by the market. If not, it seems reasonable to conclude that there will be a market for plantation koa given the market's ability to adapt to different quality koa over time in the face of limited supplies. Thus, it is assumed for this analysis that koa harvested from plantations will prove to be a substitute for koa harvested from native stands and command comparable stumpage fees.

Stumpage Fee at Harvest: Given assumed substitutability of plantation koa for koa from native stands, stumpage fees for plantation koa will be determined from the projected demand/supply situation for koa wood. This demand/supply situation posits increasing prices as noted. Koa price increases mean increased stumpage fees.

The 1980-1995 average annual rate of koa stumpage fee increase noted above is 16.6 percent for the low end of the range and 18.8 percent for the high end of the range. Such high rates of stumpage fees increase likely occurred because the koa resource was undervalued at the beginning of this period. The fact that rates of stumpage fee increases have slowed, being only 5.9 percent from 1990-1995, supports this contention. Continued such stumpage fee increases seem unlikely given the current economic environment, but increases will yet occur. These increases are projected to be 4.5 percent per year. This rate of increase is the midpoint of the assumed production cost inflation rate and the 1990-95 stumpage fee rate of increase. A rate of stumpage fee increase greater than the assumed cost inflation rate seems justified in light of the projected demand/supply situation for koa wood.

A 4.5% rate of stumpage fee increase suggests a stumpage fee range of \$2.39 to \$7.81 per board foot in 20 years and \$2.97 to \$8.93 in 25 years. For the base case assumption set, the average of the low and high range is assumed. This implies an average stumpage fee over the harvest cycle of \$5.23 per board foot in 20 years.⁶³ The stumpage fee is changed for the sensitivity analyses conducted in the economic analysis section.

One other factor important in stumpage fee determination is the site location and related site specific costs of tree harvesting. For difficult to harvest sites, the stumpage fee can be discounted to cover high expected harvest costs. The study site does not qualify as a difficult site to harvest. Thus, the assumed stumpage fee is not discounted for this factor.

UTILIZABLE WOOD IN A STAND

Utilizable wood in a stand is determined by wood volume per tree (board feet), waste and the number of trees per acre.

Waste is primarily slash⁶⁴ and trees or wood from trees that are not removed from the site because they are dead, decayed, rotted or diseased. Salvage operations account for most if not all of the koa currently harvested. In such situations, waste varies between 40-50% of the total wood amount available for harvest because of the high number of trees or wood on a tree considered waste. In contrast to salvage operations, plantation koa trees will be harvested at relatively young ages before age-dependent conditions causing waste become evident or problematic. Additionally, assuming the management practices outlined in this study are followed, dead, rotting, decaying and diseased trees would be culled before harvest leaving healthy trees. This practice assures a stand containing trees with little or no age-dependent waste at harvest time. Based on these considerations, the estimated waste per tree for plantation koa is assumed to be 40 percent.

The wood volume per tree is estimated based on the parameter set outlined in the "Harvest" section above (dbh = 25 inches, height = 50 ft with first fork at 22.5 ft). The estimated number of trees harvested per acre is 76 (see "Harvest" section).⁶⁵ Multiplying estimated board feet per tree by the expected number of trees harvested per acre, suggests a total potential harvest per acre of 34,227 board feet of koa wood. For a 10 acre plantation, this

⁶³ In 1995 dollar terms, this stumpage fee is equivalent to \$2.73 per board foot.

⁶⁴ This is the branches and other residue left on a forest floor after the cutting of timber.

⁶⁵ No accounting is made of wood potentially recoverable above the first fork. If a tree is curly, branches of 4 inch diameter would have value. Thus, this may be an unduly restrictive assumption. It is, however, relaxed for sensitivity analyses.

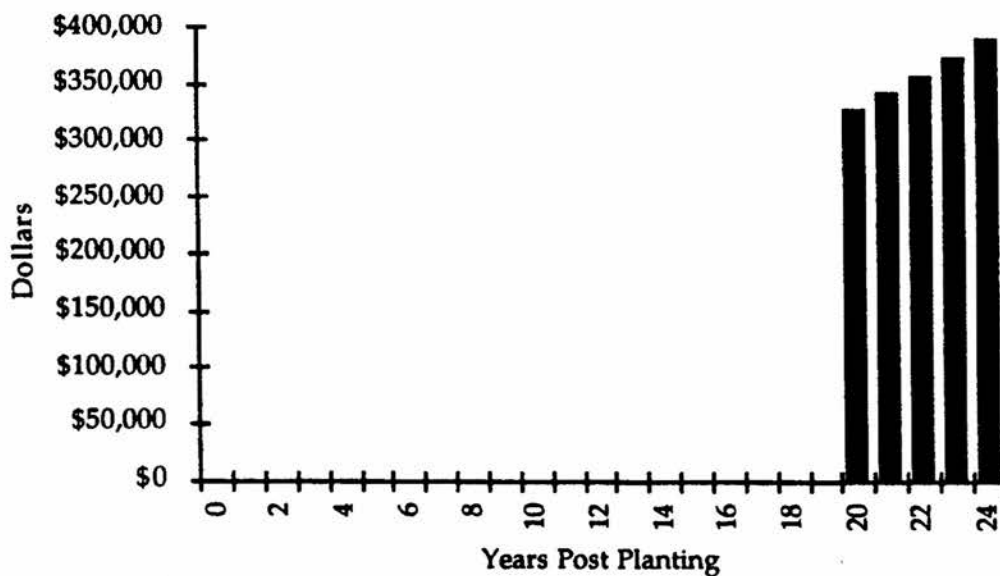


implies a total harvest of 342,266 or an annual harvest over the 5 year harvest cycle beginning in year 20 of 68,453 board feet.⁶⁶

TOTAL REVENUE

The total koa sales revenue based the estimated total koa wood production and stumpage fees at harvest estimated above is \$1.79 million current dollars.⁶⁷ Figure 2 shows the distribution of these revenues over the life of the plantation.

Figure 2: Distribution of Koa Revenues Over the Life of the Plantation



⁶⁶ The calculations underlying this amount are as follows:

Variable	Value
Assumed Tree Girth (ft)	6.6
Diameter at Breast Height (ft)	2.1
Area (ft-squared)	3.5
Harvest Height (ft)	17.5
Total Tree Volume to First Fork	62.5
Volume Wood per Board Foot	0.083
Wood Volume per Tree (board feet)	751
Percentage of Waste	40%
Board Feet per Tree	450
Number of Trees per Acre	76
Board Feet Harvested per Acre	34,227
Number of Acres	10.00
Total Harvest (board feet)	342,266
Harvest Rate Years 20-25	20.0%
Annual Harvest Amount (board feet)	68,453

The board feet per tree provided in Scribner's "Log Volume Tables" for a butt log of comparable dimension (*i.e.* length = 17 feet & diameter = 25 inches) is 490 board feet. This value compares favorably with that estimated in the table.

⁶⁷ This is equivalent to \$935 thousand 1995 dollars.



ECONOMIC ANALYSIS

The base case assumption set for the economic analysis is summarized below. All of these assumptions except that for income tax rates are based on the production process, cost and revenue discussions.

1. The koa production processes and systems outlined above are followed. If modified, they are appropriately modified for specific site characteristics or additional research suggest more effective processes or systems.
2. The harvest cycle begins in year 20 after field transplanting and ends 5 years hence with equal amounts of the plantation being harvested each year.
3. Production costs amounts and timing occur as outlined in the study. A 3 percent annual inflation rate is assumed for all costs.
4. The average koa stumpage fee over the harvest period (*i.e.* 20-24 years post-transplanting) is \$5.23 per board feet.
5. The per acre koa wood harvest is 34,227 board feet.

Economic results for the various economic parameters are estimated and presented. This is first done for the base case assumption set. Various of these assumptions are then relaxed for sensitivity analyses.

BASE CASE ECONOMIC RESULTS

Table 10 shows the economic performance of a 10 acre plantation koa operation using the base case assumption set. The break-even production⁶⁸ and break-even price⁶⁹ are less than half of expected yields and price. Thus, one would not expect to lose money from plantation koa culture. The internal rate of return on investment (IRR) is 15.0 percent. Thus, one should not expect a windfall return from plantation koa culture. This rate of return, however, is greater than the long term rate of return on interest bearing financial instruments⁷⁰ and the stock market.⁷¹

Table 10: Economic Results - Base Case Assumption Set

Item	Value
<i>Net Present Value</i>	
Interest Rate	10.0%
Per Acre Revenues	\$21,970
Per Acre Costs	\$10,564
Per Acre Profit	\$11,406
<i>Break-Even Analysis</i>	
Per Acre Production (board feet)	16,368
Stumpage Fee per Board Foot (average over harvest period)	\$2.49
<i>Internal Rate of Return</i>	15.0%

SENSITIVITY ANALYSIS ECONOMIC RESULTS

The various sensitivity scenarios are defined as follows.

1. Cost may be different than assumed for the base case scenario. Lower costs (Decrease) could occur if cost inflation is less than assumed (base case = 3%) or the koa grower obtains subsidies (see note 42) to help cover

⁶⁸ This is the level of production at which profit equals \$0.

⁶⁹ This is the average stumpage fee per board foot over the harvest period at which profit is \$0.

⁷⁰ The average annual rate of return on BAA bonds over the last 30 years is 10 percent.

⁷¹ Using the Dow Jones Industrial average, the average annual return on stocks over the past 30 years (assuming a 3% dividend rate) is approximately 9 percent.



costs. Costs could be higher than assumed if cost inflation is higher than assumed or koa growers incur costs not included in the analysis. A 25 percent decrease and increase of base case estimated costs is used to determine cost change impacts to koa plantation economic performance.

2. Harvest refers to the number of years from planting the koa are of sufficient size and quality for harvest. Early harvest presumes that the koa harvest cycle begins in year 15 as opposed to year 20 and is then completed in 5 years. As noted above, trees have attained the dimension assumed in 13 years in Wood Valley. Thus, harvest commencement in 15 years may ultimately prove possible. Late harvest presumes that the koa harvest cycle begins in year 25 as opposed to year 20 and is then completed in 5 years.

3. Wood Amount refers to the board feet of koa harvest per acre. It could increase (High) or decrease (Low) relative to the base case dependent on changes to the number of trees harvested per acre (base case 76), ⁷² tree size at harvest (base case see note 66) and the percent of wood harvested from a tree (base case 60%). Per acre wood harvest amount changes of plus and minus 25 percent are applied to the base case scenario to determine their economic impacts.

4. Stumpage Fee is the price per board foot obtained by the koa grower. A 25 percent increase (decrease) is applied to the estimated stumpage fee at harvest to determine the impact of these changes on the economic performance of a koa plantation. A stumpage fee greater (less) than that used for the base case scenario could occur if koa price inflation is higher (lower) than estimated or the plantation koa wood quality distribution is skewed to higher (lower) quality wood than assumed.

Table 11 presents the economic performance of a koa plantation for the various assumption sets noted.

Table 11: Sensitivity Analysis Results

Item	Costs		Harvest		Wood Amount		Stumpage Fee	
	Increase	Decrease	Late	Early	Low	High	Low	High
<i>Net Present Value</i>								
Interest Rate	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Per Acre Revenues	\$21,969	\$21,969	\$16,958	\$28,462	\$16,558	\$27,380	\$17,370	\$27,724
Per Acre Costs	\$13,160	\$7,940	\$10,813	\$10,161	\$10,523	\$10,577	\$10,527	\$10,579
Per Acre Profit								
Before Taxes	\$8,809	\$14,029	\$6,145	\$18,301	\$6,035	\$16,803	\$6,843	\$17,145
After Taxes	\$5,462	\$8,698	\$3,810	\$11,347	\$3,742	\$10,418	\$4,242	\$10,630
<i>Break-Even Analysis</i>								
Per Acre Production (board ft)	20,434	12,260	21,763	12,108	16,368	16,368	20,676	12,954
Stumpage Fee per board ft (average over harvest period)	\$3.11	\$1.86	\$4.13	\$1.47	\$2.49	\$2.49	\$2.49	\$2.48
<i>Internal Rate of Return</i>								
Value for Scenario	13.6%	16.9%	12.5%	19.4%	13.2%	16.4%	13.5%	16.5%
Difference from Base Case	-1.4%	1.9%	-2.5%	4.4%	-1.8%	1.4%	-1.5%	1.5%
Sensitivity to Change from Base Case	(0.48)		(1.10)		0.49		0.44	

Table 11 shows that the economic performance of a plantation koa operation has approximately the same sensitivity to cost, wood amount and stumpage fee changes. Specifically, over the range of differences from the base case (+/- 25%), a 1 percent change in any of these variables leads to a 0.44 to 0.49 percent percentage change in the IRR. In contrast, over the same range of differences from the base case, a 1 percent reduction (increase) in years to harvest leads to a 1.1 percent percentage increase (decrease) in the IRR. Thus, if harvest commences in year 15 and completes in 5 years (*i.e.* a 25% reduction in time to harvest) the IRR would increase to 19.4 percent.

⁷² For the base case it is assumed that there is no salvage value to trees culled or thinned. Such trees may have some salvage value and thus could also add to the amount of wood harvested per acre



This result is not surprising as the earlier one begins to receive a payback on investment, which is implied by an earlier than base case harvest, the better the return.

SUMMARY

The processes and systems required to establish, maintain, harvest and ultimately sell koa trees grown specifically for commercial timber include the following: site selection, seed gathering, germination & seedling production, site & soil preparation, seedling transplanting, sapling care - years 1 & 2, sapling care - years 3-5, tree care post year 5 and harvest. Trees are assumed ready for harvest when they attain a diameter breast height (dbh) of 25 inches or greater. Twenty percent of the trees in a stand are assumed to attain such a dbh in year 20 with the remaining trees in a stand harvested at this rate such that harvest of the stand is completed in 5 years.

The total cost (1995 dollars) of a 10 acre koa plantation to harvest completion equals \$159,000. Annual costs are highest during the early plantation years due to plantation establishment costs and sapling and tree care costs. The only costs after year nine are land lease and other costs which include general and administrative, liability insurance, interest, taxes and miscellaneous annual expenses.

The total koa sales revenue from a 10 acre koa plantation are estimated to be \$1.79 million current dollars. These revenues occur over the last 5 years of the plantation's life. They are estimated based on an annual koa stumpage fee inflation rate of 4.5 percent and an expected per acre harvest of 34,227 board feet. The rate of stumpage fee increase is greater than the assumed general level of inflation over the life of the plantation which is justified in light of the projected demand/supply situation for koa. Koa demand is projected to at least remain the same in the face of a shrinking annual koa supply. The per acre harvest is based on the estimated tree volume at harvest (751 board feet), waste (40%) and the number of trees harvested per acre (76).

The break-even production and break-even price are less than half of expected yields and price and the internal rate of return on investment (IRR) is 15.0 percent given the estimated costs and revenues of a 10 acre koa plantation. The IRR is most sensitive to changes in years to harvest and approximately equally sensitive to cost, wood amount and stumpage fee changes.

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