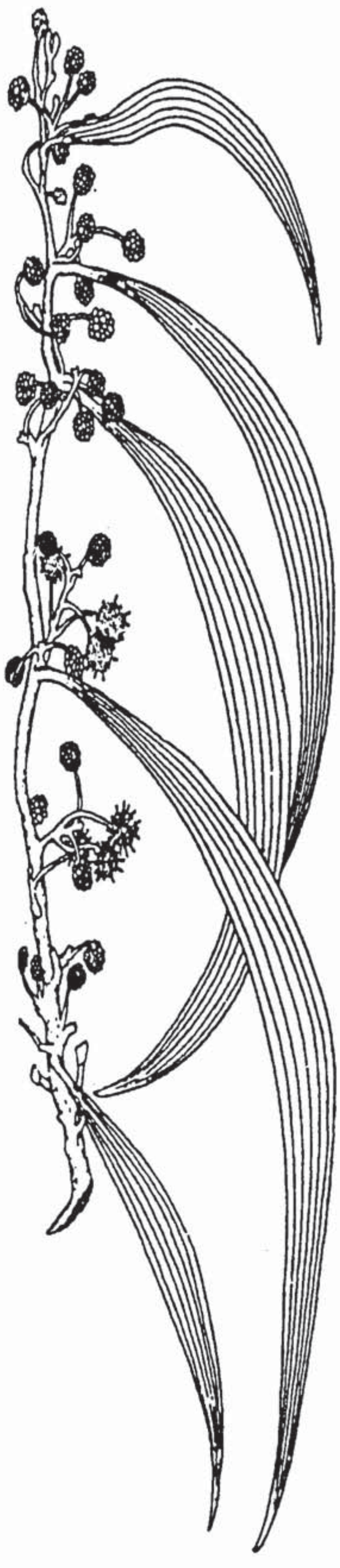

Koa: A Decade of Growth

Proceedings of the Symposium

Editors: Lisa Ferentinos and Dale O. Evans

Hawai`i Forest Industry Association 1996 Annual Symposium
November 18 and 19, 1996
Dole Ballrooms, Iwilei, Honolulu, Hawai`i

Cosponsored by:
Hawai`i Forest Industry Association
State of Hawai`i, Department of Land and Natural Resources,
Division of Forestry and Wildlife
U.S.D.A. Forest Service, Institute of Pacific Islands Forestry
University of Hawai`i, Renewable Resources Extension
College of Tropical Agriculture and Human Resources
Kamehameha Schools/Bishop Estate
Hawai`i Agriculture Research Center
Society of American Foresters

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DANIEL K. INOUYE
HAWAII

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Subcommittee on Surface Transportation
and Merchant Marine

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November 18, 1996

Hawaii Forest Industry Association
1996 Annual Symposium
Dole Ballrooms
Iwilei, Honolulu

Dear Friends:

Thank you for your gracious invitation to your 1996 symposium. I regret that I cannot be with you, but wish you success with this important event.

Though many of you have been involved in forestry for many years, you are on the brink of taking on a more important economic role in Hawaii than ever before. I do not need to tell you about the obvious and difficult changes over the last several years in Hawaii agriculture. In the past, there has been a lot of talk about diversifying Hawaii's agricultural base in preparation for inevitable reductions in sugar and pineapple production. For some of us, it was once difficult to imagine a time when sugar would no longer be king in Hawaii. For better or for worse, that time is upon us and I am heartened by the commitment of individuals and organizations like yourselves to take Hawaii into the future.

I would like to express my appreciation to all of the cosponsors of this symposium and all of you in the forest industry for your collaboration, your forward thinking approach and your critical contribution to making diversified and sustainable development an economically viable reality in the State of Hawaii. I was pleased to seek federal financial support for a forestry economic development initiative for Hawaii this year and will do my best to see that this support continues.

Aloha,

DANIEL K. INOUYE
United States Senator

DKI:mfw

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November 14, 1996

MESSAGE FROM U.S. SENATOR DANIEL K. AKAKA

It is with great pleasure that I extend my warmest aloha on this annual symposium of the Hawai'i Forest Industry Association, "Koa, a Decade of Growth."

Let me also express my mahalo to members of the Association for the work that has gone into arranging this symposium. The various presentations during two days of meetings ensure meaningful discussions that will be thought-provoking and educational as participants examine the current status of our efforts to protect, conserve and renew our forestry resources for an economically and environmentally sustainable forest products industry. I expect that with such a broad representation of knowledge in our presenters and attendees, the discussions over these next two days will also help further define the issues, goals and interests in an industry that has promising potential for high value wood products and proudly, products with a Hawaii label.

I also hope that this symposium will provide a better understanding and appreciation of both the science and economics of a viable forestry industry with examples of new ideas and tried solutions that can be applied by those in the field -- the front line where individual and collective successes add up to meaningful growth of this industry.

Let me also take this opportunity to express my appreciation to many of you here for your support of my efforts over the past several years. The National Tropical Forestry Recovery Act is a reality much because of your work to help me craft this legislation into law. Today, your work continues as you help in its implementation.

I look forward to working with all of you in pursuing our common goals.

Aloha pumehana,

Daniel K. Akaka

DANIEL K. AKAKA
U.S. Senator

Opening Remarks

Lloyd Jones, President, Hawai'i Forest Industry Association

On behalf of the association and our co-sponsors (the Division of Forestry and Wildlife, Hawai'i Department of Land and Natural Resources; the Institute of Pacific Islands Forestry, U.S. Forest Service; the Cooperative Extension Service, College of Tropical Agriculture and Human Resources, University of Hawai'i; Kamehameha Schools/Bishop Estate; the Hawai'i Agriculture Research Center; and the Hawai'i Chapter, Society of American Foresters) it is my privilege to welcome you to our annual symposium, this year titled "Koa: A Decade of Growth."

It is gratifying to see the wonderfully diverse community of interest in koa and our forests represented here today. Each person's attendance and participation enriches this symposium. I would like to particularly welcome our distinguished guests.

First, let me acknowledge the presence of one of the pioneers of koa forestry, Roger Skolmen. For many years he has been the definitive word on forestry in Hawai'i, has written the definitive work on forest trees of Hawai'i, and although he is enjoying a well-earned retirement, we know he will make a great contribution to this symposium.

We are honored to have with us the national president of the Society of American Foresters, Mr. Robert Bosworth. Mr. Boswoth will be more formally introduced later, but I want to welcome him and thank the Society of American Foresters for their support of this symposium.

A number of government leaders have shown their support for the forest industry and intended to be with us. Unfortunately, scheduling conflicts have prevented Senator Inouye, Senator Akaka, and Lorraine Akiba, the Director of the Hawai'i Department of Labor and Industrial Relations, from being here in person. However, we are pleased to welcome, in person, Mike Wilson, the Director of the Hawai'i Department of Land and Natural Resources. Mike has been a friend of HFIA and is an enthusiastic supporter of forestry. Thank you for joining us.

And I would like to acknowledge the hard-working committee that organized this meeting. Many people were involved and contributed to this meeting. In particular I will introduce some special people to be recognized for their extra efforts: Mike Robinson, chairman of the organizing committee, Wayne Ching, Nick Dudley, Bart Potter, Paul Scowcroft, and Peter Simmons.

Two people deserve special mention. They are Lisa Ferentinos and Andie Beck. The University of Hawai'i's Department of Agronomy and Soil Science, under Dr. Samir El-Swaify, has been most supportive of this symposium. Lisa Ferentinos has led their efforts in putting together all the documentation, including your booklets, and has put in countless hours. After the symposium, the Department of Agronomy and Soil Science (and Lisa) will produce the proceedings.

Andie Beck, the Executive Director of HFIA, is the person who has pulled all the details of this symposium together. She has worked extremely hard over the last few weeks, and we are all grateful over the next two days for her outstanding organizing skills.

I invite everyone, not only the speakers, to be an active participant in this symposium. You will find, as we have at previous symposiums, that some of the best benefits will come from informal discussions among the participants. The meetings are structured to permit time for discussion (never *enough* time, of course), and the informal reception this evening will provide further opportunity to enhance that dialog.

Koa: A Decade of Growth. Why that topic? Let me give you a quick overview of why HFIA considered this to be the most important topic to be discussed in this, our 5th, annual symposium.

Ten years ago the first of a series of koa symposiums was held in Hilo. At that time there was a recognition that koa as it had been known had come to the end of an era. For generations, koa had been plentiful. Koa forests were cleared to make way for other agricultural uses of the land. It was cheap—landowners received only loose change for their koa resources. But all that was changing. Ten years ago there was a recognition that nurturing and managing our koa forests needed to be accelerated and would have advantages for many sectors of society—economically, environmentally, and culturally. So a lot of efforts were initiated and some actions proposed.

This symposium is going to look at what efforts have been started in the ensuing ten years, what results we have seen, what we know now, and where we might be going in koa forestry in the context of Hawai'i's cultural and economic future.

In the years immediately prior to that 1986 conference, forestry was not a significant issue to Hawai'i economically or politically. Prior to that time, forestry was meaningful in terms of forest preservation or watershed management, but was a peripheral issue to most people. But in the last ten years we have seen increased recognition by society, expressed in legislation, that forestry is to be encouraged. Some examples of supportive governmental acts are:

1991 saw the creation of Forest Stewardship and Natural Area Partnership programs. These provided avenues by which one could apply forest management techniques, be it for commercial or preservation use.

1992 saw the revision of the Tree Farm Bill. This served as an important link in the effort to improve forest planning and management.

In 1992 the Governor's Agriculture Coordinating Committee funded a study to quantify the size of the existing forest industry in Hawai'i.

Senator Akaka's Tropical Forest Recovery Act passed in 1993. This was a strong expression of support for forestry in Hawai'i by the federal government.

In 1994 the Right to Harvest Bill was passed. This, in effect, states that a landowner has the right to harvest "new" trees grown after 1990.

In 1995 the State prepared a Forestry Investment Memorandum to encourage commercial-scale investment in forestry in Hawai'i.

In 1996 the County of Hawai'i revised their real property tax structure to encourage native forests.

This year an initiative has been started to recognize the contribution that forestry can make to recovery of economically impacted rural areas. This initiative has been funded by the federal government and is receiving strong state government support

So you can see that we have a decade of legislative direction to enhance forestry by the federal, state, and county governments.

The last decade also saw the formation and growth of the Hawai'i Forest Industry Association, a body of mostly private-sector interests dedicated to the nurturing of sustainable forestry in Hawai'i.

There has also been a decade of research. The scientific community has made great strides in applying genetic knowledge to koa. Also, we have had meaningful scientific work done in the areas of ecology, restoration, and the management of koa.

The last decade has seen an evolution in the public perception of the forest and man's relationship to it. We have seen new awareness of the many parties that have a stake in the forest. Also, we have seen an broadened understanding of the complexity of forest management. Unfortunately, we have also seen examples of the law of unintended consequences at work, where well-meaning inaction has been harmful to the health of the forests.

The private sector has been impacted in the last ten years by change in the price of koa. In the last decade the stumpage paid for koa has increased tenfold, and the retail price of koa wood has increased threefold. Yet this may be the savior of our koa forests. As sophisticated landowners learn that the growing of koa can be the highest return that they can have from their land, we may see the restoration of koa acreage happening.

Today, commercial forestry in Hawai'i is still a koa industry, and, despite the shortage of koa, the industry continues to grow. Now, approximately a thousand people owe their jobs to koa, people growing, harvesting, processing, crafting, selling, and advancing koa. This industry wants to know what the future holds. Public planners want to know what opportunities exist for jobs. And we all want to know what the prospects are for healthy native forests.

So HFIA has structured this symposium to try to shed some light on these issues. This symposium is designed to share knowledge that has been developed over the past decade, to assess where koa is today, and to look to future opportunities. We trust that you will find it an interesting and rewarding two days, and we will all have a better understanding of what the future holds for our koa forests.

Forestry—An Economically Viable Program for Hawai'i

Senator Daniel K. Akaka

Aloha! I am grateful to the Hawai'i Forest Industry Association for your continued support of this symposium. I want to thank Andrea Beck, Executive Director of the Hawai'i Forest Industry Association, for inviting me to speak to you today.

I believe the issues to be discussed at your symposium will have profound implications for future economic development in Hawai'i. Without question, the closing of our sugar plantations is an economic challenge facing Hawai'i today. We must seek long-term, productive altematives for idle cane acreage and other available agricultural acreage. As we search for new ventures to make productive use of these lands, we must identify opportunities capable of providing economic benefits over long periods, similar to what sugar provided for Hawai'i. The opportunities we choose must keep rural Hawai'i green and economically productive.

Forestry can provide us with some of the answers for sustained economic development and diversification. As a renewable resource, forestry opens exciting opportunities for new products and new markets for Hawai'i export. Using available lands in Hamakua, for example, we can create a stable forest products industry, based on high value tropical and uniquely Hawaiian species such as koa, sandalwood, kou, and kauila. The challenge is to develop a strategic mix of short-rotation tree crops with high value and longer-rotation hardwoods.

Koa is the monarch of the Hawaiian forest. It's the largest native tree and the second most common. Koa is widely distributed in both dry and rain forests, from 600 to 7000 feet in elevation, though most koa forests, which are important habitat for rare birds, have been disturbed by grazing and other human-induced influences. Associated with the power of Hawaiian Ali'i, used for powerful war canoes and house timbers, the tree has been revered over the ages. Valued today at $3.00 per board foot on the stump in the forest, and up to ten times that as boards ready for use, koa is the king of Hawaiian woods, the single most valuable species in trade within Hawai'i. Koa's current market value is a reflection of its relative scarcity as much as of its beauty and name. Like so many other gifts of nature, we have not valued it until trees of sufficient size for wood products have become scarce, and until undisturbed koa forests exist only in isolated, highly protected areas.

I have been actively working in Congress to help forestry in Hawai'i. In 1992, the Hawai'i Tropical Forest Recovery Act, legislation I authored, was signed into law. The thrust of this legislation, as you know, is to reverse the tragic decline of Hawai'i's ailing tropical forests and put them on the road to recovery. Among other things, it provides for a Hawai'i Tropical Forest Recovery Task Force charged with the responsibility of submitting an action plan to Congress.

Last year, Secretary of Agriculture Dan Glickman released the Tropical Forestry Plan, which identifies opportunities to rejuvenate Hawai'i's tropical forests and the potential for forest resource development. Hopefully, through the joint efforts of govemment and private industry, we will succeed in developing an economically viable forestry program in Hawai'i.

I also want to talk about a serious problem facing Hawai'i's forests. We all know that alien plants, animals, and pests are serious threats. Last year, on federal lands throughout the United States, we lost 4500 acres each day to noxious pests and weeds. That's a million-and-a-half acres a year, or an area three times the size of the State of Hawai'i. By comparison, forest fires, one of the most fearsome natural disasters, claimed only half as many federal acres as weeds and pests.

This problem affects all 50 states, but nowhere is it more serious than in Hawai'i. Because of our climate, Hawai'i is heaven-on-earth for pests and weeds. Gorse, ivy gourd, miconia, and banana poka are ravaging our forests, fields, and watersheds. This year, for the first time, foreign-introduced plants outnumber Hawai'i's rich heritage of native species.

Invasive foreign weeds and pests do more than just compete with Hawai'i's domestic species. They transform the landscape. They change the rules by which native plants and animals live. And, they undermine the economic and environmental health of our state.

We need to address this problem to be sure we have a forest of healthy trees and not a forest of miconia. Miconia can spread like wildfire. We want healthy forests in Hawai'i instead of healthy miconia, which has overwhelmed and destroyed some South Pacific islands. That's why I introduced legislation, "The Plant Protection Act," this year to revise and consolidate federal laws that control plant pests and noxious weeds. That is what brought Deputy Secretary Richard Rominger of the Department of Agriculture and other federal officials to Hawai'i last month. They saw for themselves what alien pests and weeds can do to Hawai'i. But legislation alone won't solve this problem. Without a sustained public and private strategy there is no hope of stemming the flow of alien species.

I wish all of you a very successful symposium and best wishes. You can count on my continued support for your efforts. Mahalo!

Hawai'i Forestry: A New Economy with a New Workforce

Lorraine H. Akiba, Hawai'i Department of Labor and Industrial Relations

Introduction

Good morning! I am disappointed that I could not be there with you in person today. This symposium is a significant prelude to the upcoming Governor's Forestry Conference scheduled for January 1997, and I would like to extend greetings from Governor Cayetano for a successful and productive symposium. Additionally, I would like to thank the Media Lab at Leeward Community College for assisting me in greeting you today.

Although your program agenda today is directed toward koa and native forest stewardship, I would like to address the concept of sustainable forestry and the Department of Labor's perspective on the role that sustainable forestry can play in Hawai'i's economic development and how our educational and workforce development efforts will be integrated to assist in the growth of this new industry.

Mike Wilson will also be talking to you about forestry and trees as an economic initiative.

Sustainable forestry does not mean the old clear-cut, "rape and pillage" timber industry. It is instead based on ecologically sound principles of ecosystem management. It is also founded upon community-based rural economic development, which leverages public and private resources to maximize support for value-added forestry industry products and high-skilled, high-paying jobs. The goal of sustainable forestry, like sustainable agriculture, is to increase economic development, enhance environmental stewardship, and improve the quality of life in rural communities.

I was very fortunate to have recently been part of a team from Hawai'i to accompany a site review team that visited the timber communities in Oregon, Washington, and California which have been part of President Clinton's Northwest Plan. For those of you that are unaware of it, the Northwest Plan was a community economic revitalization effort which was initiated to assist the transition of declining "old growth" timber communities to new economic opportunities and community development based on ecosystem management -based forestry and value-added forest industries.

Economic and Workforce Development

Hawai'i's economic future and investment in new economic initiatives are directly linked to an investment in our social and human capital. Our highest priority must be to provide Hawai'i's workforce with the skills to be employable and successful in a future that will be increasingly competitive in a global marketplace.

Without workforce development there can be no economic development. They are integrally linked to each other. The Department of Labor is working with other state agencies to reform both education and job training to produce improved higher skills for our workforce. This effort is integrated with the State's economic development efforts to develop the high-skill and high-wage jobs for new workforce entrants to fill. Workforce development improvements will not automatically lead to high-skill, high-wage jobs. We need to strengthen the demand side of the labor market as well as reform the workforce supply side. New growth industries will come to Hawai'i because of the quality of life and skilled human resources we can offer them. That is what the forestry initiative is all about.

Natural Resource Development

In Hawai'i, we have seen prime agricultural lands planted in sugarcane decline from 1 million to 300,000 acres in the past five years and a loss of 5300 high wage agricultural and manufacturing jobs in the sugar industry in that same period. These former sugar lands provide an economically and environmentally sound opportunity to create jobs, strengthen the *'aina,* and promote rural social and economic development in areas of our islands that desperately need attention, such as East Hawai'i and the island of Kaua'i. With 25 to 30 percent of available lands in public ownership, State government policies are being geared towards positive leverage for the conservation and restoration of natural forest ecosystems. Stimulating a value-added forest industry would be one of the highest and best uses of our scarce natural Hawaiian resources.

An aesthetically and environmentally sound forestry industry can be developed in Hawai'i by taking great care in planning and policy-setting. We are all very sensitive about preserving the special qualities that make Hawai'i such a unique physical and cultural environment to live in.

Hawai'i's businesses and workers increasingly are facing a new reality of global competitiveness. Not only do we see this in the current reality of our main economic base industries like tourism and retail sales, but we see its effects radiating into all business operations in Hawai'i.

Value-added forestry will be more than just commercial operations that focus only on resource extraction. Value-added forestry opportunities will create high-skilled and well-paid jobs locally. It also will create second-tier jobs through the processing of and marketing of secondary forest products. What are value-added forestry products? These include herbs, crafts, weavers, and ecotourism services as well as ecosystem management technicians and forestry technical expertise in scientific areas like agronomy, siviculture, etc. If well planned and guided, new sustainable forests can add value to the recreational and aesthetic opportunities for our local communities and visitors alike.

Currently, many traditional work skill expectations are changing. For example, in the tourism/hospitality industry, hotel workers are no longer expected to do just one limited job. Quality management and high productivity expectations are changing the way work and business is done in the tourism industry and everywhere else in Hawai'i's new economy.

Emerging growth industries will require new ways of doing business and new life skills for workplaces. Businesses will thrive if they can be world class and tap into the global network. In the workplace desired attributes will be teamwork, collaboration, and the flexibility to meet changing needs of the business. The new workplace in the 21st century will require many salaried or wage earning workers to acquire entrepreneurial and business skills.

What will the emerging forestry industry look like and what will it require to contribute in a positive way to Hawai'i's economic development? Sustainable value-added forestry industries with multiple levels of processing and varied outputs and products are preferable because they create the greater variety and number of high-skilled/high-paying jobs and can make a more significant contribution to long-term rural community development. This longer view is the more difficult road, however. It places a greater burden on financing, on building industry support and capacity, organizational energy (such as in the formation of viable rural community organizations and cooperatives), and especially in developing and training the local workforce. But this is the high road we must take.

We must develop a common vision based on public/private partnerships to move down this road. We must bring together the landowners, forest related businesses, workers, environmentalists, scientists, and public policy makers. Only through a disciplined and strategic approach to economic, workforce, and environmental development can we realize this vision so that Hawai'i will benefit overall.

The upcoming Governor's Forestry Conference will provide us with this opportunity. It will allow us to form and strengthen partnerships among all key stakeholders. We will collaborate on protecting native ecosystems while promoting sustainable forest industries on former sugar lands and degraded forest areas. We will develop action plans for the next steps to best pursue sustainable forestry based on input from working groups that represent all interest groups.

I encourage your participation in this effort and undertaking and look forward to seeing all of you in person at the Governor's Forestry Conference in January 1997.

Managing the Largest Tropical Forest in the United States with Urban Decision-Makers

Michael Wilson, Hawai'i Department of Land and Natural Resources

I am really excited to be here. I've had some great opportunities as head of the Department of Land and Natural Resources. It's probably the most wonderful job in the entire world, and one of the reasons is because we take care of the largest tropical forest in the United States, and we take care of the eleventh largest state forest, with over 100,000 acres (actually close to 700,000 acres) of land owned by the State of Hawai'i that's managed for forest reserves and forest lands.

We have thousands of acres—depending on how you calculate it. On the Big Island, we may have 100,000 acres that can contribute to a forest industry. So here we stand, from the point of view of trying to take care of this incredible resource. And the title of my speech, which alluded to trying to manage the largest tropical forest in the United States with urban decision-makers, is one that I try to share with you because I don't necessarily equate you with the concept of urban decision-makers. In the State of Hawai'i, among the other states, we're about forty-eighth in fish and wildlife funding. We have the eleventh largest state forest, as I mentioned. We have the fourth largest coastline in the United States. We have a budget though, that if you closed your eyes and got the information and didn't know what state you talking about, you might think that we were talking about Rhode Island or Pennsylvania or maybe even Utah, but actually if you thought we were talking about Wyoming, you'd be wrong, because Wyoming has a $7 million budget to take care of its aquatic resources. I'm sure you're all aware that Wyoming doesn't even have a coastline. In the State of Hawai'i, compared to the $7 million that Wyoming has, we have a $2.9 million budget for our aquatics program.

We are in an era where it's very important for those who care about and understand natural-resource issues to have some kind of impact at the legislature, and I think that many of you can, are I hope you are going to be at the legislature this next session to talk about the importance of this new forestry initiative. The Hawai'i Tropical Forest Recovery Act has been pursued by our congressional delegation, Senators Akaka and Inouye and our Representatives Neil Abercrombie and Patsy Mink. They've all worked very hard so that we will be getting half-a-million dollars a year for an as yet undetermined period of time from our United States Department of Agriculture under the U.S. Forestry budget.

If you imagine the kind of value added-forest industry where we're not just extracting and growing eucalyptus but we have a significant koa forest industry with associated value industry such as carpentry, and additional skills that we would like to see develop, what you're imagining is a concept that isn't here. It's not in the legislature—where it needs to be—and we're going to need help to get it there. The governor has made a commitment seeking $500,000 from the legislature for matching funds through the Tropical Forest Recovery Act, but this is not an issue that I think is a familiar one to our legislature.

But let me go the ultimate issue, and that has to do with What does it mean to Hawai'i?, What does it mean to our forest and this magnificent resource that we have? As we are supposed to at the Department of Land and Natural Resources, I think of that in terms that aren't just present-oriented, but future-oriented. I think what's preceded us in terms of the history of the forest movement, the history of forestry and all that's gone into it, the human imaginings behind it, is in many ways a very satisfying concept, particularly given the most recent developments. But, the history that has proceeded us is one in which the Forest Service was defined as not taking care of our natural resources. We had a tremendous dislocation in the northwest that attracted the President of the United States. $200 million was invested in five years in an effort to take care of the forest economy, in the sense of it being dislocated because of what happened with the spotted owl.

The Forest Service made magnificent efforts through a process that I think was initiated through the President's forest recovery efforts and Lorraine and I, at the invitation of U.S. Forest Service, went to see what has been the result of decades, you might even say ever since the time that the country has been settled, what has been the result of the forestry movement in the United States, and that is a recognition that we don't want to just invite big industries in to extract the forest without paying attention to the community. We don't want to ignore local talent, we don't want to ignore indigenous people, and, hopefully, we want to recognize the concept of sustainability, which is the ultimate management scheme for our department and hopefully the management scheme for the world, so that we don't continue an era of depletion without thinking of sustaining the resources.

After we went to the Forestry Initiative, we decided we wanted to make sure that Hawai'i takes the benefit of all those years and almost a century of learning about what happened when we cut down most of the forests in the United States and entered into an era of extraction that ultimately resulted in a revolt in the Pacific Northwest and economic dislocation of enormous magnitude that got the personal attention of the President of the United States. I guess we don't have to go through all that economic dislocation here, and hopefully we can move forward well to do something about it.

In that regard, just to get an idea of where we are in our view in terms of Hawai'i's history, let me speak a bit about Hawai'i as it exists today.

If we look at Hawai'i from space, it's the most remote land mass on earth. It, as I mentioned to you, has a wonderful resource, and that resource in terms of forest is the eleventh-largest state forest in the U.S. A lot of people forget that this island chain has that magnificent resource. For us to take care of it, we do need to recognize that we are the most remote land mass on earth. We can't borrow resources from other parts of the country like many other states can, and we truly should think of ourselves as a community here to take care of this miracle that's probably one of the best resources on earth.

We have a provision of the state constitution that pertains to our Department of Land and Natural Resources, and it's got some wonderful concepts in it. It is Article 11, Section 1, and it says, "For the benefit of present and future generations, the State and its political subdivisions shall conserve and protect Hawai'i's natural beauty." It's an interesting concept for a constitution, and it's not in many constitutions around the country, this idea that you elevate to the most important, powerful, legal level the concept of natural beauty. So, for present and future generations, we're supposed to conserve and protect, not just natural beauty, but the natural resources including land, water, air, minerals, and energy sources, and we shall promote the development and utilization of these resources in a manner consistent with their conservation.

Well, now we are hopefully at the point in Hawai'i's history where we can give some meaning to that, instead of just moving headlong into exploitation and extraction. Our department is not the Department of Business and Economic Development, our department is here to protect and conserve these resources and, more appropriately, develop them. So an industry—even one that has the word forestry attached to it—that's not focused on conservation to a certain extent is not one that we can support. In furtherance of the self-sufficiency of the state, this is where we adopt the concept of sustainability as our management philosophy, that says all public natural resources are held in trust by the state for the benefit of the people. The public natural resources, the state lands, including forests and pasture lands, are to be managed for the benefit of all the people. Not just for the benefit of the individual leasees who take over the land.

Many of you have been helpful in prodding us to pay attention to pasture leases, and now we are in the process of divising those areas that we want to return to forests, with the help of you folks and also the governor. Hopefully, we'll be able to move culturally to a point where harvesting koa is not considered to be an intrusion on the culture and in fact can contribute to the culture and contribute to a stable economy in a sustainable forestry effort.

"Hawai'i: Earth's Best." We remind ourselves at the Department of Land and Natural Resources that we take care of the best resources on earth; that's our job. Unfortunately, if you're forty-eighth in the United States in fish and wildlife funding, given the size of our resource, it doesn't reflect that our urban decision-makers in the legislature are acquainted with what the size of our resource is and the challenges we face, because we don't have a program in the Department of Land and Natural Resources that is "Earth's Best."

This is an exciting symposium for us because people are being brought together. I know I'm speaking to the converted, that are willing to go to the legislature and say, "You know, Hawai'i does have a meaningful forestry industry; we can make it even better, and we can make it one of the models for the country in terms of being a sustainable industry where we're not just again bringing in large industries, extracting trees, and forgetting about the local folks that live here."

"Sustainability" is a word that can cause feelings of inspiration, and it can also be overused. But it is a word that helps us get focused, because with our small amount of resources, we need to have a teamwork strategy, so we that can beat the odds and actually take care of this incredible resource and this amazing state.

One of the things that we have to consider is that we, as a group, have to be aware and have to let the legislature know that we are concerned about exotic species, alien species coming to our forestland. Awareness of miconia has increased in Hawai'i. In Tahiti, this green cancer has covered 70 percent of their forest area, producing a forest monoculture. The root system of the miconia is much more shallow than most of our native forest trees. It holds less water, so it compromises the water system and it contributes to landslides, and it would be a national emergency of epic proportions were it to get here.

When we think of the forest industry, again I think we need to think of ourselves as part of the culture that's advocating for forests in general. And when we talk about the need to harvest koa when we're talking about it in the next or maybe a prior breath, we're not talking just about the idea of harvesting koa, but taking care of that forest and paying attention to things like alien species and making sure we have budget to take care of things like miconia, it makes a point that we're a community that's looking at this forest, not just in a single-minded way. I don't say this because I'm suggesting this isn't a perspective of the forest industry, because I know it is, but it's just something we need to remind ourselves about when we present a balanced view about our forestry program.

I want to conclude by citing a very interesting passage in a book by David Brower, an often-quoted reference to the changes here on earth during the time people have been here an in a way that helps us get a perspective that is interesting and historical.

This proposition starts from the assumtion that the earth was created in six days, into which period we can put all the geologic, biological, and cultural changes that have occurred. If you start on Sunday at midnight, when the earth is created, there's no life until Tuesday. Millions upon millions of species come during the week and millions of species go during that week. By Saturday morning at 7:00, there has been enough chlorophyll manufactured by plants, and the fossil fuels to begin to form. Around 4:00 in the afternoon, the great reptiles appear. They hang around for a long time, as species go, until 9:30, a five-hour run. The Grand Canyon begins taking shape 18 minutes before midnight, and nothing like us shows up for another 15 minutes—this is of course at the end of the week. No *Homo sapiens* until thirty seconds ago. A second-and-a-half back, we threw the habits of hunting and gathering to the winds and learned to change the environment to suit our appetites. We get rid of everything we can't eat as fast as we can, and that's the beginning of agriculture. A third-of-a-second before midnight (again this is on the last day) Buddha arrives, a-quarter-of-a-second, Jesus Christ, a-fortieth-of-a-second, the Industrial Revolution, an-eightieth-of-a-second, we discover oil, a-two-hundredth-of-a-second, we discover how to split atoms, and that brings us just about to where we are, and—maybe—we've got four million years left.

Well, Hawai'i is above the surface of the ocean and we're at a watershed point right now because we are looking at an industry that will define us as to whether we continue to move headlong without learning from the past and move into an extraction industry that forgets sustainability or whether we really take advantage of what efforts have gotten the attention of the President of the United States and—now—that have gotten the attention of the Governor. I'm really excited about it. I look forward to the Forestry Summit, and I thank all of you for taking the time to come here. It really means a lot to Hawai'i. Every one of you makes a difference. The leadership in Hawai'i is what takes the theory and turns it into something. We have incredible potential in leadership in this state, and the Forest Service is willing to help us and bring in additional talent. I'm really excited about where we're going to go from here, and I look forward to working with all of you. Let's hope that our urban decision-makers in the legislature will make the right decisions and help us with our forestry initiative, with all of you there testifying. Mahalo.

Koa Stewardship —North and South Kona

Sally Rice, Agro Resources, Inc.

For those of you who have suffered through the torrential rainstorms of the last couple of weeks, all of us on the islands from Moloka'i to Hawai'i extend to you our aloha and wishes for a speedy recovery from the devastation. However, that ill wind did blow us some good by bringing rain to our drought stricken areas on Hawai'i.

North and South Kona, which is the area about which I am reporting this morning, has had several years of excruciating drought, which finally broke about July this summer. The rains have continued into what is normally (although I don't think there is a normal anymore) dry fall season. The impact of the prolonged dry weather prior to the last few months on the forests of Kona has not been good. At the very least, growth and regrowth has been fairly static. Add the vog that has saturated Kona since 1983, creating acid rain and acid fog in the upper elevations, and you find that our forest areas are suffering from natural causes.

That is the bad news. The good news is that the stewards of land in Kona are very slowly moving in a more positive direction toward appreciation of our forests as an asset and as areas that can and do generate economic value. It is still a hodge-podge out there, without any hard numbers, but I want to share with you some of activities our Kona landowners and lessees are doing. Several large mauka areas encompassing tens of thousands of acres have been sealed off from cattle, sheep, and goats with the express intent of encouraging reforestation.

Both passive management and active replanting of koa are proceeding in these areas. Logging of koa is sporadic and in all cases selective. No one is clearcutting. After logging, various methods are used to reforest. In some cases the scarified areas are left to natural koa seed germination. Where it is anticipated that cattle will graze the area, one logger piles the slash, which acts as an impenetrable barrier to the livestock until the koa seedlings are too big for the cattle to eat. By that time the log piles are rotted. In these piles tree ferns, mamaki, and other native plants also grow. Another West Hawai'i landowner is planning to put tree corridors between his pastures, a practice he observed in Scotland. The tree corridors provide windbreaks and songbird and gamebird refuge. Selective logging can be done as the trees mature to ensure maintenance of the tree corridors.

On the Kona Coast there are five logging activities, and only one of these could be considered a substantial logging operation. Other activities within the forest areas are just starting. Ecotourism is one of them, where the operator takes small groups into specific forest sites to show visitors and in some cases local folks our birds, plants, and insects. Along with the visual enjoyment, the tour leader usually provides his customers with a wonderful dose of history and lore—and Kona coffee. Pig hunting as a sport, for food for local families, and as a management effort is prevalent from one end of the Coast to the other. There is limited hiking and horseback riding for pay. Landowners are looking at other activities, like mountain-biking and picnicking.

In summarizing the situation in North and South Kona, I would say that koa stewardship is in slow-motion forward. By forward I mean more area is being considered for foresting and managed forest preservation with ancillary activities. One large landowner expressed his feeling this way: "My goal is to develop sustainable economic activity that does not interfere with the quiet enjoyment by my family of this property, nor does it damage the integrity of it." The native forest property tax incentive recently passed by Hawai'i County now gives the landowner or lessee a viable option for maintaining native forest (65 percent endemic species with at least 25 percent tree canopy) or for developing a transition plan to change from pasture to native forest. The property tax rate of native forest is now the same as the lowest agricultural rate in the county, i.e., livestock grazing. This is probably the single most important factor for the future of koa forests on Hawai'i.

Koa Stewardship —Hamakua, Hilo, and Ka'u

Mike Robinson, Resource Management

Koa is alive and well in the Big Island districts of Hamakua, North and South Hilo, Puna, and Ka'u—but barely. We often expect to find koa in a pristine native forest setting, but frequently it can also be found invading fields or in mixed stands with other trees, including non-natives. For this presentation, one federal, three state, and seven private land managers and/or owners were interviewed about their koa management strategies. Interviews were limited to those with 10 or more acres. Not all landowners could be contacted; therefore the following information is conservative in its estimations.

There are at least 250,000 acres identified in the East and South Hawai'i koa belt, defined as elevations from 1200 ft to 7000 ft and where koa is or has been known to occur. To date only about 4000 of these acres are being managed for the commercial production of koa. An additional 4000 acres is currently planned for commercial koa management in the next 20 years. When combined, the total of 8000 acres equals about 3 percent of the identified koa land. Although no one has clearly determined the acreage needed to supply the existing koa industry, extrapolations can be made using estimates.

At the 1986 koa conference, Roger Skolmen, a since-retired U.S. Forest Service researcher, estimated a per-acre volume in a managed koa stand at 40,000 board feet per acre. Tom Loudat, in his economic analysis of koa released earlier this year, suggests volumes of 35,000 board feet per acre. These estimates may be high, at least for the first rotation or until genetics and silvicultural research catches up with management goals. Natural stand production can provide more conservative projections which, when combined with unproven yet well thought out estimates, result in a range of koa productivity on a volume per acre basis. In one stand on Mauna Kea, for example, volumes were measured at an average of 2900 board feet per acre. Discussions with loggers have resulted in a similar range of about 3500 to 5000 board feet per acre in natural stands. These are stands that have been logged before or in which mortality is high.

Under managed conditions, however, we should hope to produce at least 20,000 board feet per acre. At this level of stocking, 8000 acres of managed koa would yield the equivalent of 260 million board feet. On a 50-year rotation, this could produce a sustained yield of over 3 million board feet per year, or about six times the estimated annual cut of 1991. Even at 10,000 board feet per acre, substantial income can be generated by value-adding to koa at current levels. As a $29,000,000 a year industry, Hawaii's furniture makers and craftsmen turn a small amount of resource into significant revenues.

The 8000 acres planned for commercial koa management is all located on private lands, with the exception of 30 acres planned for public research and 130 acres proposed for management by the Department of Hawaiian Home Lands. Reforestation, for a variety of land uses, is currently under way on about 16,500 acres. Planting koa seedlings is the most prevalent form of active koa reforestation today, although we know soil scarification in the presence of a seed source works very well. As a fast growing species, koa can reach heights of 12 feet in just a few years. Spacing varies, but most managers are using closer spacing as a means for producing straight stems. Whether applying high-tech research techniques or backyard gardening methods, the results are usually the same: good. Other methods include fencing to remove ungulates, which allow natural seedlings and root suckers to reestablish themselves. Once ungulate pressure is removed, koa naturally invades, even in heavy grasslands.

Other land uses within the koa belt vary. Hunting, as the most popular use, was allowed on most surveyed state lands and on all private lands. The second most prominent land use was cattle grazing. Of the 46,250 identified koa acres used for cattle, 86 percent, or just over 40,000 acres, are on state lands. However, this data does not include the extensive Parker Ranch holdings on the Big Island. Those ranching operations occupy large amounts of koa belt lands in this regional reporting area. Other significant land uses include watershed, hiking, and quiet/aesthetic use. Less prevalent uses of the koa belt range from research and cultural gatherings to aquaculture and movie sets.

All public and private land owners and managers interviewed stated their desire to manage for koa. The most common incentive was that it is the "right thing to do." All private land owners desired an economic return from their koa land, as compared to only one state agency. Only half of the private land owners sought a real property tax break for managing koa. In Hawai'i County this is most likely because low tax rates are already enjoyed for those grazing cattle, and many landowners graze cattle.

Management constraints included inadequate knowledge of silvicultural requirements and uncertain economies. Government managers had limited budgets and/or manpower while private entities were unsure of the long term returns, the maintenance costs, and the availability of niche markets.

Government agencies at the federal and state levels expressed concern over the lack of public support for their efforts and desired higher funding levels. Private landowners sought answers to the constraining lack of detailed information about koa management and marketing.

There are individuals, organizations, businesses, and agencies committed to the perpetuation of koa in Hawai'i. Whether the effort is a few acres in size, or an attempt to reforest thousands of acres of former pasture, all efforts will pay dividends in the future. We now know that in as little as ten years koa can contribute heavily to the re-establishment of diverse forests. As we practice the art and science of planting, growing, harvesting, and utilizing koa, our knowledge base will broaden. Most importantly, the benefits of koa will continue for generations to come.

Koa Stewardship—Maui and O'ahu

Bart Potter, C. Barton Potter Co.

I have interpreted my task as being to deliver useful information on the past, present, and projected future of koa on the Hawaiian islands of O'ahu and Maui. I'm sure that the presentation may be both limited and colored by my own personal research, experiences, and hopes, and I welcome anyone with information that may add to or correct that which I present, to please feel free to fill me in. I want to thank the people who contributed information and assisted in this effort. The Nature Conservancy generously made Shannon McElvaney, GIS technical whiz for TNC's Heritage Program, available to provide me with maps, and the Hawai'i Agricultural Research Center provided the assistance of their librarian, Anne Marsteller, who, along with Bob Osgood, steered me in the direction of materials that might be useful to this talk. Credit also goes to various authors but particularly to Roger Skolmen for his work summarizing the plantings on the forest reserves between 1910 and 1960. Landowners and resource managers on both Maui and O'ahu were enthusiastic about the report and happy to talk about their koa, or lack of it.

I had the good fortune to be born and raised on O'ahu. My parents bought land on Tantalus in 1950. I have come to realize that the koa trees on their particular property were most probably planted as much as 50 years prior, along with almost all the other trees I took for granted as being natural to the mountain during the time I was growing up. I have come to realize the speed with which koa grows, while I wonder at the ironies that inhibit its replenishment.

In a nutshell, koa has historically been, is now, and will likely continue to be a significant component of forests on both Maui and O'ahu. What is little recognized is the degree to which the pre-human koa population and range may have changed subsequent to human arrival, what man has done both to decimate and to perpetuate the species, and what measures we may take—as soon as right now—to drastically increase the population of this commercially, culturally, and ecologically important tree.

A revelation and a discovery to me, which ran contrary to my childhood perceptions that the forest had always been as I knew it, was the discovery of the phenomenal human resources put into efforts at forestation in the period from the '20s through the early '40s. Whatever else one may think of it, the sugar industry is largely to thank for precipitating interest in and action on the establishment of forest reserves and the planting of forests as a means to ensure sufficient water to support its agricultural needs. Now we are at a point in history where an industry that has occupied hundreds of thousands of acres of fertile lands for over 100 years (most of which suported forest of one form or another prior to cultivation in cane) is disappearing silently and almost without a whimper. There is concurrently opportunity to create a forest resource of multiple benefit to environment and economy, and koa, being a fast-growing, high-value native tree, can play a key role.

In 1856 in a lengthy and eloquent address to the Royal Hawaiian Agricultural Society (principally on the topic of the importance of forests as watersheds), Dr. William Hillebrand specifically recognized koa as an endemic asset (worthy of propagation alongside other valuable trees) in saying, "If we go on to fell these [koa] trees without proportioning the increase to the consumption, this source of wealth is likewise doomed to extinction."

Hillebrand was one of the many impassioned and knowledgable individuals to have had a dramatic influence on charting the course of Hawai'i's forests. At any given time (including the present), dedicated giants in their fields have locked horns over what constituted proper forest management in Hawaii and what trees and plants should make up a forest. All, however, seem to acknowledge as irrefutable the fact put forth in an often-quoted old Hawaiian adage: *"Hahai no ka ua i ka ulu la'au"*—Rains always follow the forest. An updated restatement of that adage might include that forests assimilate the rain to our benefit better than any other covering on the earth.

Superceding the agendas of passing governments, the need of humans for water rises in proportion to the numbers of the populace, and forests provide the best known way of entrapping precipitation and occasioning it to percolate beneficailly into our aquifers rather than to run off into the ocean, carrying our soils. Given the dramatic rise in population Hawai'i has experienced and is expected to continue to experience, as well as the genuine and continuing concern over lack of sufficient water, it seems imperative that we seize the present opportunity to build forests on lands recently vacated by the sugar trade to ensure that in the long term we catch and hold the maximum amount of precipitation that passes over the islands. It is also worth mentioning the relative ease with which these lands could be managed compared to the more precipitous or inaccessible interior regions.

Figure 1. Areas currently supporting koa (////) and proven potential to support koa (within dark lines) on O'ahu.

Of course, we also need lands to live on and lands to grow food on, and these need to be planned for as well, but long-term prosperity begins with healthy forests.

We also know today, after witnessing over 1500 years of experimentation with different species, that the wealth provided by Hawaiian forests need not be limited to the waters they secure or the other ecological benefits they may provide. Our young and miniature forest industry, which generates $28 million a year from small amounts of a single species of a nonmanaged tree, gives a clue to the economic potential of our forests.

Koa, being the second most common native tree, is a significant component of some native forests and often survives handsomely with as little rainfall as 40 inches and as much as 200 from elevations ranging from 500 ft to around 7000 ft. I thought maps representing pre-human native forest would present a good indication of where koa may have grown in the past and where there might be opportunities to consider incorporating it in forests of the future.

Figure 2. Areas currently supporting koa (////) and proven potential to support koa (within dark lines) on Maui.

Although it might seem unthinkable today to "mess with" intact native ecosystems, such was not always the case: it bears mentioning here that planting on the areas I'm identifying could be conducted completely outside of existing intact native ecosystems and even perform the function of expanding cover conducive to increasing at least significant elements of native ecosystems.

When we look at the pre-human map of O'ahu and infer rainfall patterns from forest type, we see that koa could have been widespread on the land. Experience has proven that just because a species is thought not to have occurred in an area is no reason to believe that it can't: In Figure 1, the crosshatching approximately represents significant concentrations of koa existing today; the dotted line surrounds areas that would be conducive to silviculture that included koa (based on rainfall and elevation zones where koa has done well). Except for areas currently in agricultural production or recently out of sugar production (not specified on the map), many of these lands may already support introduced trees and some may support planted koa. Clearly, significant opportunities to cultivate koa fall outside existing intact native ecosystems.

A look at the Maui map (Figure 2) may give us occasion to dream: the collar around the top of Haleakala is known to have supported a huge and dense forest that included koa. There is also known to have been a regularly occurring cloud that extended in a plume to the west of Haleakala and caused precipitation to fall on Kahoolawe. This cloud has in current times apparently withdrawn and now seldom occurs, resulting in very little moisture condensing on Kaho'olawe. Ulupalakua Ranch reports that the rainfall on their portion of Haleakala has remained relatively constant over the last 100 years, but given that forest cover has been proven to be a more effective captor and percolator of airborne moisture in clouds than the current cover of grasses (USDAIUSFS study in 1970 by Hulten Wood, referred by personal communication of Bob Hobdy, DLNR Maui), a reforestation of the "collar" would unquestionably result in more water percolating into watersheds from the clouds that almost daily cloak the west-facing slope of Haleakala. Downslope communities would benefit from this increase, and maybe the Kaho'olawe cloud would even return.

We can again see that on Maui as well as O'ahu there is major opportunity to establish forests that include koa without having a negative impact on the remaining ecosystems. The topic of management of the remaining native ecosystems is fruit for another symposium.

The forest histories of Maui and O'ahu are similar in that both experienced post-Polynesian impacts from plant and animal introductions, agricultural activities, and cultural practices of a growing populace. Both also experienced the transformation of major forest zones in the years following Western contact and the introduction and establishment of cattle, goats, and other ungulates. After this, increases in the human population and the needs of visiting ships resulted in forest clearing for fuelwood in the proximity of the major ports. Lands on both islands were increasingly cleared to accomodate large agriculture. It was recognized that reforestation and afforestation were essential to reverse the despoliation caused by cattle and to secure the water supply so essential to the future of Hawai'i.

Around 1900, in the view down Tantalus, over Punchbowl and out to Honolulu harbor where the tall masts of sailing ships could be seen in silhouette, one could see rows of planted trees on the slopes above Makiki Valley and a fairly well established band of trees that was probably the impressive eucalyptus forest that we know today, which was planted in the mid-1800s. Other photographs taken in this area illustrates the dearth of large trees at the time.

Today at this spot we can see a dramatic increase of vegetation resulting from plantings that took place from the 1880s on through the early 1940s. This area has been host to a fine koa population over the last 80 years or so and may, indeed, have supported it in previous times as well, although many trees are at the end of their lives and, in spite of the viability of their seeds, competition from other trees, shrubs, and groundcovers often limits their ability to naturalize themselves.

In 1933, in Manoa Valley and on Wa'ahila Ridge, although there was notable nakedness of the hills and valleys that now support substantial verdure, one could see rows of newly planted trees on Wa'ahila (some of which are recorded to have been planted in 1932), many of which we now experience as the Norfolk pine-filled park at the top of St. Louis Heights. About 5660 koa were also planted on Wa'ahila between 1932 and 1935. If the koa which one sees on the ridge hike today are the result of those plantings, they provide a good example of how well koa can do—some of the trees farther up the ridge are fine specimens, but since the ridge gets little rain until it nears the back of Palolo and Manoa, the koa on the ridge above the park is quite scrubby. Much of it is dying off, but more about that later.

In Palolo Valley in 1933, the top of St. Louis Heights was as yet devoid of the homes to come. Forest could be seen at the very back of the valley, a relatively small area of which was then and is today koa. Though I could find no records specifically listing planting of koa in Palolo, much koa is on the town side of significant plantings of brushbox, kauri, Norfolk pine, ficus, and mindanao gum. I have gathered that crop cultivation extended into the valley farther than any of those plantings, so it can be assumed that in addition to the naturally occurring koa, koa was planted in areas where it can be seen now.

Other old views of Palolo, both of Pukele and Wai'oma'o, the two portions of the back of the valley divided by a ridge, illustrate not only what are probably both planted and natural populations of koa but a die-back of koa. Also to be seen were koa in the proximity of brushbox, kauri, and Norfolk pine. Such plantings were to be found all over the islands. Between 1915 and 1941, 58,321 koa were recorded to have been planted on various locations on Tantalus alone, with 387,998 planted on O'ahu during that period.

O'ahu's forester during much of that time was the late, great C.S. Judd, who had a fondness for the native plants and saw to it that they were included, however marginally, in plantings. Stuff of legend is his ongoing debate with Harold Lyon, who was a great proponent of (among other noxious weed tree species and many excellent trees) various *Ficus* species for reforestation. All the mistakes, surprises, successes, and disappointments that resulted from those years of plantings make fertile ground for discussions not to be held today, though they should be revisited before any serious forest planting is undertaken.

Latter-day plantings have been ongoing on state forest lands since the 1960s, though the DOFAW baseyard reports that in the severely eroded areas targeted nowadays, lack of funding and manpower preclude the site preparation alleged to be necessary for the success of koa on hardpan (either digging or blasting holes, then mulching them), and therefore species like slash and loblolly pine are being planted to break up the earth and prepare it over the long term for future planting with more desirable species.

Large landowners on O'ahu have not undertaken much koa planting to date, although resource managers for the state, The Nature Conservancy, and the Army are all working to improve their forests. Their efforts center not around creating a koa resource but around stopping erosion and getting a grip on alien species invading remnants of natural ecosystems.

Small private landowners (small ranches and houselots) are generally very interested in seeing their koa regenerate when the old ones die, and it is ironically those smaller resource owners who have been more proactive in generating small but significant amounts of new koa.

Also worthy of mentioning is the significant amount of healthy koa regrowth to be found along the H-3 corridor in mauka Halawa Valley. These trees are no older than four years and are doing exceedingly well.

If I can make one recommendation regarding the koa of O'ahu, it would be to seize the opportunity to collect seed from trees that are still bearing while they can be identified for desirable characteristics (good form, good health, and possibly curly grain wood). The chances are that if they have just or may later later succumb to the dieback, they will rot away in the woods, leaving a seedbank in the ground but no record of their attributes. The next step would be to establish seed orchards from these desirable trees, allowing them to hybridize to produce a varied but higher quality complement of trees than has yet been accomplished. I would be honored to lend what little I know about selecting desirable koa to such an effort. The question of whether it may be better to avoid trees that have died from the blight though they might have good form is one I am inclined to bypass in favor of "just doing it."

On the island of Maui, historically speaking, 458,820 koa are reported to have been planted in the period between 1928 and 1941. I have seen one five-acre plantation of very respectable 60-year-old koa in the area mauka of Ka'anapali that is encouraging in terms of its growth in comparison to nearby exotics planted roughly concurrently.

Current Maui landowners and land managers universally like the idea of planting koa if it can be an affordable pursuit with the downstream guarantee of being able to selectively harvest that which they have planted. All are pursuing planting in a very minimal fashion right now. Haleakala Ranch and Ulupalakua Ranch have done some recent planting of koa, though costs of fencing and planting cause planting to take a low priority to the usual business of running a ranch. Those disincentives should be alleviated, and at the same time a right-to-harvest and a property tax structure for tree farms that is no higher than what they now pay for pasture should be instituted. Maui Land and Pine reports enthusiasm for the planting of koa for economic and environmental purposes if the return can be shown to be there.

Regarding other landowners, the Department of Hawaiian Home Lands is doing a very interesting, community-based project that will involve forest restoration—including koa—on the lands of Kahikinui on the southern slope of Haleakala. This has the potential of rebuilding a critical portion of the circlet of historic koa mentioned earlier around the top of Haleakala. An East Maui landowner reports that he has spent $50,000 on management plans and efforts to control invasive species on his 1200 acres that allow him to selectively harvest koa by helicopter. He is experiencing good regeneration by the little bit of scarification that accompanies harvest, and he is managing that regeneration for future resource. Another small landowner who is in the business of raising high-value hardwoods for sale reports that business isn't what it could be but that he manages to break even selling several thousand koa per year along with starts of other species. He reports that most of his sales are to other small landowners who can afford to plant for long-term returns and who are philosophically attached to the notion that they are doing the right thing.

The nature of a 20-minute talk on such a meaty topic is that much great material gets left out. I apologise for the inevitable omissions. Mahalo a nui for your attention. May you go forth, propagate, and prosper!

Koa Stewardship —Kaua'i

Bill Cowern, Kua Orchards

When I was asked to look into what kind of koa was being managed on Kaua'i, I must admit that initially I just drew a blank. There are a number of reasons why there have not been significant plantings of koa in the recent past. As I started to think about it, I thought that the most important thing that I could perhaps mention were the reasons why I and other people have chosen in fact not to plant koa. And, perhaps, we can deal with those problems or those opportunities and increase the potential for planting this fabulous tree.

There were significant plantings of koa in the Koke'e area of Kaua'i in the 1930s. I'm not even certain when all these plantings occurred, but I know much of the it occurred in the '30s. And much of it was from Hawai'i Island seedstock. Some of those trees have grown into very nice form, especially some of the trees that are at the forestry cabin, up in Koke'e; most have not. Most have become rather straggly or have lesser-quality form. There seems to be a similar amount of curliness to material that comes down every once in a while.

I had to ask myself, Why is it that I am not deciding to plant koa? And why is it that so few people on Kaua'i have planted koa in the recent past? We could only find maybe a couple of people who have planted a hundred trees here or there. And I had to go back and look from my own standpoint and say, These are the reasons I made this decision. I can't say that these were the reasons that someone else in my position that is looking at a commercial activity would make these decisions, but these are the reasons that I made the decision.

First of all, most of the lands on Kaua'i that are available to someone like myself, who wants to start a "forest industry" that is a commercial forest industry on the island, planting and harvesting trees and hopefully taking that into secondary and tertiary products. Most of that land is between about 400 and 1200 feet in elevation. For the most part, koa doesn't grow well in those elevations and as such, it's precluded right off the bat. But after thinking a great deal about that, here obviously is an opportunity. The lack of availability of seed sources for low elevation that have been proven to produce a quality tree is an impediment. There is really no knowledge of the chance of having a successful product at the end of your growth period, either due to the quality of the logs, the quality of the wood itself or even due to the recent die-back problems which are even to some extent not fully understood.

So, therefore, we lack available land. We have a lack of available seed sources, and we have one other issue which at least was partially was in my mind when I looked at what I was going to grow, and that was the fear of not being able to cut it down once I've grown it. While that has certainly been lessened by the passage of the Right to Harvest Bill here in Hawai'i, it still is an issue that comes right the forefront, because anytime you start dealing with native species that support endangered species you begin to think about, "Gee. What happens if I get an endangered bird that takes up residence in my koa forest?" When I came in today, I must admit the fact that I was going to mention that was heightened a little bit by the flyer out there that said: "Stop Cutting Down the Koa Forests". I'm not, by any means, intimating that we should cut down all the koa forests.

But that is an issue, and it's an issue that needs to addressed. We need to work from a commercial and from an environmental standpoint to understand what are the limitations that we're going to work under here and how can we work with each other. If people are scared to plant, that is obviously not going to help expand the koa forests on the islands of Hawai'i.

To summarize, the factors that led me away from planting koa were the lack of available seed sources (and therefore the ability to guarantee that you could get a good quality crop) and the lack of available land (especially public land). I have attempted to look at leases on public land and have been told no, there just are no leases available. The only lands where you could begin to expand koa forests on Kaua'i are public lands, for the most part which are high enough in rainfall to achieve that kind of success. The final factor is the fears about regulatory interventions, which are in some cases real and in some cases perceived, but nonetheless, whether they're either, they have an impact on people making decisions.

Questions to the Panel

Q: [to Sally Rice] I'm interested in the tax incentive on the Big Island. A little over a year ago we were in Hilo, and one of the biggest problems that the landowners were facing was the inequity in the tax system. Can you tell a little bit about how the changes in taxes were brought about and what's happening on the other islands for local tax breaks?

Sally Rice: On the Big Island, it was brought about by many people. The councilwoman from Ka'u, Keiko Bonk, was one of the instigators of the original bill, along with councilman Al Smith from Puna. The HFIA was very supportive, and has been pushing for something like this for many years, and decided to concentrate on those islands where we had the best shot of having something passed. The politicians and the people on the Big Island seemed to be going down the same road. It took us awhile and a lot of hard work on everyone's part to get it honed to a satisfactory bill in terms of the economics. The bill is in place, and later if you want to get specific about it, you can speak with someone here from the real property tax office. It gives you the real property tax value as livestock grazing, but there's certain restrictions, and the land must be inspected. I think it's pretty practical and well set up. The HFIA tax committee is looking at helping the other islands. Kaua'i has gotten fairly far along; they have a tree farm bill that was recently passed. For Maui, we need to do some research there, then we're going to see what we can do.

Bill Cowern: I want to expand on what happened on Kaua'i, because it's a significant bill. The tree farm bill basically states that if a management plan is presented to the real property tax division and accepted as a reasonable management plan for planting timber, that land is exempt from planting taxes completely until harvest. If you were in fact, for instance, planting 1000 acres, 100 acres per year, in your plan that entire 1000 would be exempt from taxes until harvest. That is an exemption, not a deferment; there is no other condition. It just reverts back to a normal agricultural tax at the time harvest takes place.

Q: [to Robinson] On your slide, you had one that pertained to yield per acre, and you had 10,000 board feet per acre. Over what time frame are you talking about? Per 40 years?

Mike Robinson: That was on a 50-year rotation. That's basically on a sustainable basis, if you had 50 acres and you cut one acre per year. You get 10,000 board feet per acre regardless of how many acres you sold, but a 50-year rotation.

Q: [to Robinson] Have there been any plantings or research done on planting koa amongst gorse?

Mike Robinson: Gene Conrad and also Paul Scowcroft have done a lot of work up in that country. They did some studies and actually found out it worked its way up through the gorse and survived and did well. I think you still have that little exclosure there that you can see from the road where the trees are 20–25 feet tall in the midst of the gorse. I don't think you can get to it anymore because of the gorse around it. But it worked. We've got 60,000 acres of gorse and we know that gorse can't handle shade. If we establish some tree cover in that land, it could probably take care of the gorse.

Q: [to Cowern] What happens after harvest in terms of the property tax? Does it go back to an exemption for second rotation and then third rotation?

Bill Cowern: The first problem that was attacked on Kaua'i was to get forestry listed as an agricultural activity. That was done in 1991 as an administrative change. That put it into the general agricultural rate, which means that the land would be assessed at $1000 per acre per year. The exemption then happened this year, passed on July 31, and will actually become effective next year [1997]. At the end of the harvest period, one year after harvest actually, the land reverts back to the standard agricultural rate and would remain that. It is an incentive to start the industry only, not to continue it.

Q: [to Robinson] You said the industry currently uses about 600 acres. Do you have any idea of the age of koa that's being used for that kind of quality?

Mike Robinson: That's using natural forest situations, something like 3000–5000 board feet to the acre. It was something like 500 board feet per tree and 7 trees per acre. Again, this was talking with loggers that are out there cutting these stands. As far as the age, what, 150-year-old koa probably? Really unknown.

Q: [to Cowern] What you are growing, what did you decide to grow instead of koa?

Bill Cowern: Let me preface it by saying there is a long-range plan here. The first stage of this plan is to produce a crop that will give you enough income to control the land and proceed to your next step. For that purpose, we're planting *Eucalyptus deglupta* and *Eucalyptus microcorys*, chosen for a number of reasons, but primarily for the speed at which you can get a return. When you're spending . . . I'm probably spending $150,000 this year . . . whether you get a return in 15 years or whether you get a return in 25 years is a big issue. It's important to make the thing economically viable. Beyond that, you can then change your mix. You can get into more native species. The problem with doing it initially is that it probably wouldn't be economically viable. You either can do it or you can't. But I'm open to suggestions.

Q: Maybe from each of the panel, what could be done now to remove what you perceive as disincentives or to augment existing incentives?

Bill Cowern: I think we've already gone through the disincentives. Clearly, better seed sourcing is the biggest issue that I see, if we can find a good, stable source of seed that would produce a quality product. I think Dr. Brewbaker's been working on this for some time. That would be the biggest issue, in my mind, that would allow us to proceed with a better koa plantation.

Bart Potter: Having spoken to some landowners on Maui, they were principally worried about property tax and the ability to harvest. On Maui, they haven't seen any property tax activity yet. I think the seed source or a source of viable propagules is important. Either one could be developed.

Mike Robinson: Anytime there's a disincentive it's attributed to risk. People don't want to take a risk with their money unless they can realize something back, although there are people taking risks even though it may cost them in the long run. If we really want to get some scale to this industry, or to the growing of koa, I think we need to remove as much risk as possible. There are too many unknowns right now about koa. There are people that think it takes 200 years to grow a decent tree, and we've got people who think it takes 20 years. Plugging into decision-making formulas, like how long will it take me to pay off my fertilizer debt, nobody has pinned that down. It's still at the proprietary level, and maybe not even at that level. The faster we can get a government entity that doesn't have vested interest in their returns on their research to take a hard look and answer some of those questions and remove that risk for people, the faster people can make informed decisions about getting into koa. Those are the kinds of disincentives we need to remove to make it happen. I've laid things out based on my own knowledge and sense, but I don't think that's enough for some people, and that's why it's not happening at the scale we need it to happen at.

Sally Rice: I agree with Mike to a large extent. One of the things that we don't know is what we've got. We haven't a clue, as I found out in doing my survey of the Kona area. How much board feet of koa exists? Nobody knows. It's very hard to base an industry on speculation. We need hard numbers. We need business plans. We need some extension help on what we can do in a business way on the small lots and in large areas. We need a change of perception. That will come with time. Cattle grazing has been the choice for most of the large landowners on all the islands except for O'ahu. There are some of them here today that are looking at other alternatives. The change in perception has to be worked on by everyone.

Jay Warner: My own perspective on things comes predominantly from being a furniture-maker. A lot of the wood-workers, who are moderately represented here today, have very different ideas about what they see going on with the state of the forest, with the state of the lumber-cutting industry itself, and the distribution of lumber once it's sawn and dried. If there was a better way of distributing information about what's going on overall, statewide, to all of the wood-workers that are using this product, once it's all said and done, that'll help a lot to spread information to the general public, who are the people who are buying things from us furniture-makers and wood-workers. That will help be a good incentive to give koa a good reputation as being a sustainable and usable thing, not something we need to lock up and hide and protect behind large gates that no one can ever go up and use. I hope that more of that happens in the future. With this symposium and people talking here and sharing knowledge back and forth, we'll be able to do a lot for that.

Bart Potter: Even thought the focus of this conference is koa, the industry has the potential to be more than koa. It's tremendously important, but the koa industry could be part of a bigger industry that uses many of the other woods that have been planted here over the years.

Q: It's my understanding that a lot of the trees planted over the years [by the state] were for commercial harvest. There doesn't seem to be a process of harvesting this wood now on state forest land on a larger scale than a tree here or there.
Mike Robinson: HFIA's board has discussed that recently because of some issues that happened on one island concerning permits. I know the board has decided to make this as high a priority as possible, considering the resources we have, to investigate how that permitting process works on state land, see if it's fair, if people have access in some equitable way. So HFIA is looking into it. We'd be glad to have some volunteers help us with that.

Q: It seems like one of the biggest impediments to making a koa tree farm is starting with a blank slate and then waiting for the first harvest. It seems if you went into a property that has a koa resource available for salvage or harvest, and start at that point and then put in your trees and take care of them, that you'd be much further ahead in the game. Are there any areas of state or private lands that are available to do that?
Sally Rice: I'm not the expert on this, but I've been selected to answer the question. The private land resources are at this point fairly limited because the young trees are not old enough and the older trees are being logged by contract loggers or the landowners themselves. The state land is where there is a resource and hopefully, in the future, based on Mike Wilson's talk this morning, there will be a window of opportunity there where a private person can develop a management plan with the state and do selective harvesting. Unfortunately, at this point, that's all we know.

Q: Is that concept that a private company, or whatever, would be able to get a lease and be able to operate that as a koa plantation, more or less?
Sally Rice: Those are details that have not been worked out and, relative to state land, your best bet is to have a talk with Mike Buck.
Mike Buck: Concerning harvesting existing plantations or wood resource, the state has planted over the years about 46,000 acres of plantations. A lot of them are more for erosion control; they're really non-commercial species. You had some harvesting in the past for wood chips. We've had some harvesting that's been blocked by lawsuits. We had a eucalyptus harvest on Maui that was blocked by a lawsuit. We had a Moloka'i harvest that was blocked by a lawsuit over access. A lot of these areas that were planted had communities grow up around them, and some people don't like the concept of having the trees cut, native or non-native. We are currently, as part of the initiative you heard about, planning an inventory of all our existing, available, non-native plantations we know we won't have any problems in harvesting. Part of the initiative is going to the community and asking what's the best strategic use of that resource. It includes a whole mix of non-native species. That's an issue that we need help from the community and the industry about, how best to use the existing resource we have now to prime the pump while new resources are coming on-line. The issue of harvesting native trees from at least forest reserves has been very controversial. There hasn't been any in the last five years, at least legally. We had a koa management area set aside on the Big Island and we had a threatened lawsuit on the environmental assessment. We had a community group involved in some sort of demonstration. Then we had some native Hawaiian gathering and that overlay of issues came up. This is in the Kapapala area, a 1200-acre piece that was zoned ag that was pulled out of a pasture lease for a demonstration koa management project. That's an ongoing issue that's kind of stalled right now. On the issue of pasture leases and availability, there's lots of land right now that's in pasture leases. You just can't go to someone that's a current leasee and say, "I'm sorry, we're going to change your land use." I think the dialogue needs to be over some cost-benfit analysis. What is the public land? How is it being used? Then negotiations with the current lessees to change the land use or doing some other administrative type issue to make that land available. Next, there is currently 5000 acres of ex-sugar land that is out for lease for commercial forestry. We were one of the first people off the block. When we released our forest investment memorandum, we put some land on the table as well. We found out that 5000 acres is too big for small people and too small for big people. We were negotiating with Fletcher Challenge from New Zealand, and that didn't work out. We are currently at the end of a long negotiation with the new Oji Paper Co. We're not sure that's going to work out. Subsequently, the issue we're dealing with is what is the appropriate role for public lands and public assets? For some of the shorter-rotation forestry, the economics have been validated on adjacent private lands. We'll

be going to you during the forestry conference and asking how to utilize some of the federal and state funds. Forestry co-ops? Leases in smaller pieces? Even potentially joint-venturing with the private sector on some commercial use of our existing plantations that are already zoned for commercial forestry? That may be a better way of dealing with it than having the government manage the lands. In the late 60s, this was before I came, we bulldozed about 20,000 acres in the Waiakea area and planted non-native timber plantations. Many of those areas may not have been appropriate. I'm not commenting on it. We don't do any more bulldozing of native forest. Of that 20,000 acres, there's about 4000 or 5000 acres of trees that are stocked. That'll be part of the inventory. There's probably another 4000 to 5000 acres of land that is planted with a tree species that shouldn't have been there that could be available in the future. Some of that land should never have been cleared at all, but it's a valuable resource for the industry to look at. We've done that damage historically; that was done in a different context. How do we best restore that land and use that for some economical land use? It's a very appropriate issue for some environmental groups to say, "Look, you already bulldozed 20,000 acres, what do you have on the land right now?" Maybe there's ways we can work with the private sector, because there sure isn't funds in the public sector for us to do anything proactive about that.

Q: . . . Wood Valley area and our proposal was turned down because we didn't offer them the money they want. They want $50 per acre per year and the longest lease they'll do is a 15-year lease. To grow trees, I think we should pay the same amount of money as they're leasing to the cattle ranchers. We're trying to compete with cattle ranches yet we have to pay four times the price that they pay to lease land. We're coming from Maui and we're looking for land on all these different islands and so far we've come up with nothing. We grow 20,000 trees per year. Right now we have enough trees to grow 50 acres, and we're doing it on six acres. So our problem is finding land that we can afford to lease and study the whole thing.

Mike Robinson: There's a lot of landowners in this room, large and small. Maybe in the next few days, match up with some of these people. Looking to the private sector is probably a good idea given the political situation around public lands. In my area, I interviewed three state agencies, and only one was interested in an economic return. Hawaiian Home Lands is pursuing economic development of its lands, however there's a lot of politics with that one, too. Any time you write a plan for public land, you find out what the state's up against. I'm not saying the state doesn't want to do it. It's nearly impossible. These days with limited funds and limited resources, it's better to look at the private sector in the near future.

Evolution of Ecosystem Management as a Modern Forestry Tool

Robert Bosworth, Society of American Foresters

Thank you for the opportunity to talk a little with you here in Hawai'i. This is my second visit to Hawai'i. In 1965 I was on a troop ship with about 900 others coming back from Korea. We docked in Honolulu and were allowed off the boat at ten in the morning and required to be back on the boat at ten at night. We'd not been paid for about 45 days, and not drawing a lot of pay at that time we had very little spending money, and we left very little impact on the economy of Honolulu while we were here.

It is of special interest to be speaking at a koa conference. I won't be talking about your subject directly, but I dabble a little in wood carving and cabinetry, and my particular thrill is trying to draw out the grain that is in a piece of wood to help accentuate whatever I'm working on. Today is the first time I've ever seen koa wood, and it is indeed a beautiful wood. I'd love to work with some of it. The title that I was asked to talk about today is a a bit daunting. The field of ecosystem management is something I think is an evolving subject. What I will try to do today is give you a field practioner's view of what ecosystem management might mean and what it means on the ground, based on about 25 years of experience.

Some have argued that ecosystems can't be managed, and the example that I've heard is that the entire Mississippi River drainage is an ecosystem, and it is certainly not within our power or capability to manage that entire ecosystem. But I think it had been pointed out that there are valuable elements within that river systems that need to be taken care of, and that we can use sound ecological concepts and theories to take care of those parts of the river to maintain a healthy river ecosystem.

I was in Albequerque, New Mexico, last week and the chief of the U.S. Forest Service, Jack Ward Thomas, was there. There are many who claim that ecosystem management is poorly defined, and Jack's response to that is that ecosystem management is really a concept, and concepts aren't usually defined in black and white like other parts of our vocabulary. He challenged folks to think that the term "multiple-use management" was a concept that was never well-defined, yet a lot of people subscribe to multiple-use management, so ecosystem management is a move further along the scale of our knowledge.

It's a fact that I compete in lumberjack contests. One of the reasons that I still compete in those events is that I've come to realize that people who work in the woods by hand are very skilled individuals and are truly an important part of our heritage. If we don't hold on to parts of our heritage, we're doomed to a dismal life, I think. Where it kind of came to me was when one of the speakers today used the term "rape and pillage of the past" relating to clear-cut forestry. You know, if we cast dispersions on previous generations, we're doomed to that in old age ourselves. Those old lumberjacks that were working out in the woods by hand and that built a fantastic lifestyle and standard of living that you and I now enjoy weren't rapists and pillagers, they were simply intent on trying to make a living for themselves and provide society with a lot of things that society really wants. Many of them would have done their practices differently if the economy of the times would have allowed them. We all work within the context of the economic times and social atmosphere; we need to remember that.

Another speaker showed a slide earlier that said "Sustainable, Sustainable, Sustainable," and I've come to think that sustainability is really a bit more of a social thing than a scientific thing. For example, we could go to Iowa where they grow grain crops, and we could make a social decision that it's important to the human population that it's important to grow grain crops on that land, and I think that we probably can sustain that for a very long period of time. We can make an alternative decision and decide that we should return that land to the native prairie. And we *could* do that, and those lands would sustain native prairie for a long, long, long time. And yet, there is a third option: on some of those lands there where people are growing black walnut for a very, very long time. So, the question of sustainabilty in that situation is really, "What does society want from that land," not "What is our scientific ability to do certain practices?"

I'm going to show you a little bit about Northern Idaho, which is where I've worked since 1962. I'll show you a little about my thoughts about ecosystem management, where we started some 35 years ago, and maybe where we are today.

The change factor in forests in Northern Idaho is forest fires. The Sun Dance burn occurred in 1967, a wild fire that whipped across about 55,000 acres. Just up the ridge line about twenty miles, another fire was started by the same lightning storm, the Trapper Peak Burn, which burned about 16,000 acres, and I've spent a good share of my time in Idaho working on both of these fire locations and reforestation and other management.

Some of the early thinking in forestry was that it will mimic natural forests. We felt that when we clear-cut ,slashed, and burned, we were in essence mimicking nature. Well, as we move along in our knowledge base, up the scale of knowledge, we come to find that there were some elements in the ecosystem that weren't particularly well addressed when we clear-cut slashed and burned, particularly with a burn that got as hot as fires often do. One of the early practices that the Forest Service began to apply was when had big elk herds in Idaho and the elk would browse back the brush to the point that there was no feed available for the elk to survive on. We used some ecological knowledge that if you run fire through brush fields that are old and decadent, you stimulate resprouting from the crowns and roots of the plants, and you can produce copious volumes of food for the animals on the site. That was probably one of our earlier applications of ecosystem management, returning fire into these brush fields so that we could maintain elk herds that the hunters so enjoy in Idaho.

About 25 years ago I began to move away form the clear-cut prescription and move into the seed-tree and shelter-wood systems, for a couple of reasons. One, we were really getting hammered on the looks of clear-cuts, and I thought maybe the seed-tree and shelter-wood systems would provide a viewscape to the public that would be a bit more acceptable.

Western larch is a very valuable species in our forest, but it is terribly expensive to collect seeds for the western larch, or at least it was in those days. And there was evidence around that if you left seed trees on an area and did a good job of under-burning, you could get larch to regenerate underneath itself as a natural seedling. So, we began to do this, essentially a partial cutting and then running fire through the understories of these trees.

We began to have a lot of experience with seed-tree shelter-wood cutting, having done it on several thousand acres. People in the northwest had talked about leaving "legacy" trees, and this was related primarily to the spotted-owl issue. We began to look at some of these shelter-wood cuts and say, Gee, this really looks a lot like summer wildfires. Some of those 1000-, 2000-, 5000-acre wildfires cross our landscape on a pretty routine basis and leave scattered individual trees that would survive the fire and be the monarchs that would re-establish forest on the area. At the same time, they were providing some elements of ecosystem that we hadn't been providing in our clear-cut, slash and burn. They're providing some vertical diversity in the canopy that was appealing and important to many species of wildlife.

Early on in the clear-cut logging days we were focusing on deer and elk habitat, and now our national laws indicate we need to be concerned about spotted owls, certain woodpeckers, and so on. Our objective was to establish good, healthy forest regeneration. Initially, I had started into the stands with an intention to leave the seed trees long enough to get their reproduction and then pull the seed trees off. We are now leaving portions of these seed trees on stands for long periods of time, perhaps more than one rotation, as legacy trees.

If you work near fire ecosystems, you find that nearly every one of us is a pyrotechnic at heart. It's not hard to find people to go out on these crews and lay strips of fire across the stand and do this underburning. We can produce well-controlled burns that exactly meet the prescription that was designed for the site. As we moved along our scale of knowledge, our foresters went from almost nearly pure conifer stands, to stands that have pockets of aspen, which probably occured more frequently in the past when there was more fire on the landscape, because aspen is an early pioneer species. So when we moved along, we began to leave these clumps out of the burns for their wildlife habitat. Aspen is also a tree that you can kill the tops by fires and the roots will send up sucker sprouts, and you can re-establish an aspen stand pretty quickly with fire.

I think it's imperative on the national forest lands that we use something called ecosystem management. I talked earlier about the Trapper Peak Burns, burned in 1967. We didn't realize at the time we began re-foresting this area that it was core habitat grizzly bear, a threatened species on the endangered species list, and it's also a core area for the woodland caribou, an endangered species on the list. Well, if you're a grizzly bear, you're going to get along real well in such a burn. Grizzly bears feed on the plants that come in after a fire, so a grizzly bear is going to get along pretty well on a burn like the Trapper Peak Burn, at least until well into its re-vegetation phases. However, if you're a caribou and you require different type of timber stand, you are going to have a long wait before you've got a home to go to on the Trapper Peak Burn.

And so I think, in my vision of things, if we're going to keep grizzly bear and caribou in these districts in Idaho, we absolutely have to manage our timber stands, or one or the other of the species could go extinct in that area, because without management, we are not going to have the proper proportions of the landscape that both of these species need. They, I think, define the need for ecosystem management very well, because they work at opposite ends of the ecological spectrum. Man has moved in, and we farm in the valleys and build roads and run power lines around the countryside, but grizzly bear and caribou don't have the luxury of moving long distances—like they did prior to human habitation—to find the kinds of habitats that they need. So, we'll have to do some deliberate things on the landscape to help them find what they need to live.

In the re-forestation of the 16,000-acre burn, we did a lot of tree planting in the 1970s. The plan was designed to move us to desired proportions of caribou and grizzly bear habitat in the shortest period of time. We established some targets, and we can look at what the present acreges are and see how we're moving toward our target. In the early plan we allocated certain lands for caribou habitat, but research on the caribou and their needs has moved along as well and we now find that caribou needs some land for early winter. They have a summer-range need, a spring-range need, a late-winter need, and a late-summer need. And each of the types of timber stands in each one of those categories is somewhat different.

And at the same time, we had the grizzly forage that was laid out keeping stands in more condition to feature grizzly bear. This gives us at least a plan to work to, and we can compare parent-stocking levels, and we can look at the current stocking levels to compare them and track progress toward the kinds of habitat that are most suited. And we can do deliberate things in those stands, with sending thinners in or doing other cultural activities in the stands to help speed those stands toward desired habitat conditions. We can take our targeted stocking levels and compare to the plan and move to another situation.

In the western United States, ponderosa pine or savannah types of timber stands don't exist at near the proportions they did at the turn of the century. The reason for that is that we excluded fire from them. So one way to maintain those savannah types of timber stands is by allowing fire to re-enter on a recurring basis. We also feel that under that savannah type that our forest will be healthier than if allowed to naturally overpopulate the stand, because there won't be so much competition for water and nutrients.

More and more, particularly across the Western United States, we find that nice homesites are built out in the wildland-urban interface. When fires start, these houses often don't survive. For ecosystem management right now, this wildland-urban interface is going to be a real challenge to foresters and fire fighters across the country. I appreciate the opportunity to give you my field view of where ecosystem management started and where we are today. I am happy to have been here.

Genetic Improvement, a *Sine Qua Non* for the Future of Koa

James L. Brewbaker, Department of Horticulture, University of Hawai'i at Manoa

Introduction

I have come to preface essentially all of my forestry talks with a reminder about the logarithmic curves of tropical deforestation and human population growth, one down and one up. By this century's end, forests will disappear at around 15 million hectares annually (15 times the size of Hawai'i), and people will appear annually around 100 million (100 times our population). No look at trees to be harvested twenty or fifty years from now can afford to ignore these damning statistics.

It is safe to state that no significant plant competes long in today's world market without significant plant breeding. Essentially no breeding has been done with *Acacia koa*, the subject of this conference. To be sure, koa has the charisma of Kona coffee, and its immediate future looks bright with no major improvements at all. How long can this last?

The studies of our team, to be reviewed by Dr. Sun, indicate a basis for optimism for impressive improvement by genetic selection in this native tree. However, these studies can as well be interpreted to indicate that most koas are very bad, indeed, thus improvement is easy. That such improvement is a *sine qua non* to koa's future is the theme of this talk.

At a recent conference on sustainable tropical forestry (Brewbaker and Sun 1996), over 200 authors from the tropics concurred in the view that genetic improvement was a *sine qua non* to every species being considered. Nature does not automatically select the best germplasm for man! It is only very rarely that the major commercial species in one location evolved there. Monterey pines are commercial in New Zealand, not in California; Caribbean pines are commercial in Australia, not the Caribbean; Australia's eucalypts are commercial in Brazil, Zaire, and soon in Hawai'i, not in Australia. No agriculturist would think of breeding any crop based solely on germplasm from his state, let alone in one county or on one island in it.

Koa evolved in Hawai'i, probably from a very limited germplasm base. It evolved in the absence of goats and pigs, that ruin it today in most of Hawai'i's ecosystems. It evolved in the absence of the hundreds of insects and pathogens worldwide that thrive on its genus, *Acacia*. We are very naive to think that koa is perfect just the way "God made it" and will thrive commercially without improvement. Genetic improvement requires dedicated, long-term support of public and private agencies to appropriate research, and at present such support is negligible in the state of Hawai'i.

Koa's evolution -- a fragile germplasm base?

Acacia koa Gray is a member of a large genus of legumes with about 1200 species, of which 800 are Australasian. It is in the section Heterophylla of the genus together with about 20 other species, trees found in the South Pacific and in the Mascarene Islands off Africa. Koa is a polyploid species, with 2n = 52 chromosomes, probably the result of species hybridization and doubling. About one forth of the acacias studied are similarly polyploid. Like koa, most of these polyploids are able to reproduce by self-fertilization, in contrast to their diploid relatives, which are self-sterile. Such polyploid species are usually isolated genetically from their diploid ancestors, forming seedless hybrids. We are exploiting similar seedless interspecific hybrids in leucaena ("koa haole") as a high-value hardwood in Hawai'i (Sorensson and Brewbaker 1995). If harvestable in six to eight years, such fast-grown hardwoods may have a more exciting future than koa. I returned yesterday from a conference on tree production in the newly thriving country of Venezuela, where *Leucaena* spp. play a major role.

It is probable that koa arrived in Hawai'i as a few seeds dropped by birds, producing trees that fortunately could reproduce by self-fertility. Even for a polyploid, this creates a narrow gene base that can ultimately cripple any species for evolution or breeding in the modern context. This context includes six million tourists a year coming to Hawai'i, many carrying fungi on their shoes or insects in their luggage. This context also includes the fact that many of these fungi and insects will have cohabited with the 1200 acacias of the Americas (200 species), Africa (200 species), or Australasia (800 species). In our careful assessment of challenges for improvement of koa (Brewbaker et al. 1991), it was stressed that 101 insects and 94 pathogens have already been identified on koa, most of them as probable pests. To these, one must add new pathogenic strains and insect races that arrive regularly in Hawai'i, despite best quarantine efforts.

The islands of Hawai'i abound with examples of species built on a fragile germplasm base, often easily disrupted. The examples are more easily and effectively dramatized for animals than they are for plants. A typical example from our research would be koa's relative, koa haole (*Leucaena leucocephala*). Hawai'i's koa haole is derived from a single self-fertilized plant, probably near Acapulco about 1580, and came through the Philippines to Hawai'i around 1850 (Brewbaker 1995). There is no genetic variation at all in Hawaii's "native" koa haole (Sun 1996), and it succumbed badly to the introduced leucaena psyllid in 1984. Another example is Hawai'i's "native" keawe (*Prosopis pallida*), that evidently traces back to two cross-fertilizing trees, ultimately from Peru (*idem*). This germplasm could never serve as a solid base for genetic improvement.

The fragility of an inbred genetic base is more easily seen in the Hawaiian crow or perhaps the nene, two species that will attract vastly more research money than koa ever will in my lifetime. These species will need continual coddling, particularly if ecologists will allow no thought be given to introducing some vigor and pest tolerance from related birds (as I would).

Genetic diversity of koa

In the 1960s we initiated germplasm collections of *Acacia koa* throughout the islands, and concluded from field morphology and isozymic observations that they were genetically variable. When CTAHR's Hamakua Research Station (2200 ft elevation) reopened in the late 1980s, we initiated a set of annual performance trials. These normally contain families derived from individual trees, in two reps of 10 trees each. A valuable added trial location was provided by HSPA-HARC at Maunawili, O'ahu (600 ft elevation) in 1993. We have not been able to add important additional high-elevation sites to this study from Kamehameha Schools Bishop Estate, State of Hawai'i Division of Forestry, and other agencies, despite their help in seed collections.

Evaluation of koa's genetic diversity by Sun (this conference) reveals impressive genetic variability, to be sure. Among about 200 families studied, genetic variations have been observed in form, vigor, limbiness, fluting, rate of phyllody, tolerance of rust, and several other traits. In general, about 10 percent of our families can be ranked of sufficient quality to encourage progeny studies, and possible interim use as parents. Put another way, 90 percent should be discarded. Among the most disappointing provenances have been those provided commercially in Hawai'i. High uniformity characterizes many families, suggesting a high degree of self-fertilization in this species. Differences among the islands do occur, but variation within each island is much greater than that between.

Koa is a fast-growing tree under these experimental conditions, with careful attention to weed management, exclusion of animals, and provision of enhanced soil fertility during the first year of growth. Canopy closure can be achieved in six months, and weed suppression is good after the first year. Without this care, koa is a very weak competitor with aggressive grasses like kikuyu. Genetic differences in growth rate are clearly evident in one year, and juvenile-mature regression coefficients in height and diameter are very high. Outstanding genotypes reach tree heights of 30 ft in four years and can be found with straight boles and low limbiness or fluting. Most koas can be pollinated within five years, when thinned to allow good solar interception. High wood figure ("fiddleback") characterizes a small fraction of koa trees, attracting top prices in the market, and has proven to be heritable in other trees. Thus this is a species that appears to lend itself well to genetic advance through selection.

Genetic constraints of koa

Koa can hardly be considered at present to be "domesticated," relative to trees like teak, blackwood, mahogany, rosewood, or even koa haole (Brewbaker and Sorensson 1994). In nature, it grows under an increasingly debilitating environment of exotic pests: pigs, goats, cattle, lianas like banana poka, and aggressive woody pests like strawberry guava. These exotic pests probably have much to do with koa's "sudden-death" syndrome, for most koas in the state are growing under atrocious conditions from a forest-plantation viewpoint.

This conference could be important in dramatizing how much needs to be known of koa's biology, its genetic variation, its nutritional requirements, its response to biotic and abiotic stresses, or its growth response to the simplest of agricultural loving care. Few at the conference would even agree on the rotation age for koa grown in well-managed plantations, nor the quality of wood from such plantations. My guess is that harvest can be under 20 years, given the best genotypes under the best management. And if we consider relevant the studies of *Acacia mangium* and related tropical species, now grown commercially on over a million acres in Southeast Asia, wood from these "fast-grown" trees (5-7 years) will be of fully acceptable hardwood quality.

What might be the genetic constraints of koa? It is clear that koa suffers badly from some or all of the following factors:

Poor form, limbiness, and fluting
Poor wood color, rotting of heartwood
Response to sustained waterlogging of soils
Response to sustained drought
Susceptibility to black twig borers, koa moths, psyllids
Susceptibility to leaf fungi such as fusiform rust
Susceptibility to root diseases such as *Fusarium oxysporum*
Intolerance of inadequate phosphate in soil
Inability to clone by vegetative propagation, micropropagation, or grafting

Many of these issues will be considered in detail at this conference. Some can be addressed through control measures, assuming costs are manageable. For many of these constraints, genetic improvement based on intraspecific variation may be remote. Even more remote may be the funds to permit modern genetic approaches involving intra- and inter-specific gene transformations such as those common today for coffee, papaya, corn, and tomatoes.

There is evidence, however, that genetic variation may presently occur in koa for all of the conditions listed above. The geneticist's attitude must be that any long-range selection and breeding program will achieve major improvements.

A proposed genetic improvement program for koa

1. Extensive evaluation of >1000 families at four sites
2. Selection of superior families on basis of clonability, exploiting root-sprout technology
3. Extensive intraspecific hybridization to expand site adaptability range
4. Introduction and hybridization with all species in Section Heterophylla
5. Use of juvenile-mature correlations to identify superior progenies
6. Research based at the University of Hawai'i and the Hawaii Agricultural Research Center
7. Long-term, low-input support (e.g., two graduate students)
8. Determination of heritability for tolerance of *Fusarium oxysporum*, tolerance of rust(*Endoraecium acaciae*), and "fiddleback" (overlapping spiral grain)
9. Major survey of genetic variability between islands, based on molecular markers
10. Major survey of chromosome number variation, based on flow cytometry
11. Short-range breeding: Multiple breeding populations evaluation for breeding value, with progenies combined as seed orchards
12. Long-range breeding: Evaluate clones for G*E, planting high-quality, high-figure clones

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Isozyme Studies of Genetic Variability

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Abstract

Little is known about genetic variation and geographic patterns of diversity of *Acacia koa*. We analyzed diversity using laboratory studies of enzymes. Wide samples of koa possess significant variation in six enzyme genes; several genes have alleles in intermediate frequencies. The variable genes have average expected heterozygosity of 0.41; this indicates that koa has significant levels of genetic diversity to adapt to varied natural environments, and it provides evidence that tree improvement can operate on a rich genetic base.

Samples from trees on Kaua'i, O'ahu, and Maui appear closely related; all share about the same profiles for the variable enzyme genes. It is noteworthy that two populations on the Island of Hawai'i, one above Kailua and the other in Hawai'i Volcanoes National Park, have enzyme profiles that are similar to one another, but both differ substantially from the profiles of populations on Kaua'i, O'ahu, and Maui. This island-to-island differentiation indicates that it is important for foresters to plant with seedlings from local seed sources until more is known about the adaptations and growth of koa geographic races.

The introduced and naturalized *Passiflora* vine (banana poka) has potential to over-top and smother forests; it is adapted to elevations and conditions characteristic of native koa forests. Banana poka seed samples from Kaua'i, O'ahu, Maui, and the Kailua and Hawai'i Volcanoes National Park areas on Hawai'i all were found to lack genetic variation: enzyme patterns were identical throughout Hawai'i, there was no evidence of allelic variation for 14 genes, there was no evidence of genetic diversity, and the observed heterozygosity was zero.

The Hawaiian banana poka enzyme gene profile exactly matches the profile of *Passiflora tripartita* var. *tripartita* from Ecuador, Colombia, and Venezuela. The latter species, a common domesticated juice plant of the high Andes, is also genetically uniform and homozygous, with a single allele type at each enzymegene. The other Andean candidate progenitor species, *Passiflora tripartita* var. *mollissima*, has distinctly different enzyme profiles. Researchers can collect *Passiflora* biological control organisms in South America for tests on *Passiflora tripartita* var. *tripartita* with knowledge that significant genetic differences exist between the two Andean species, and with knowledge that var. *tripartita* and banana poka have identical and homozygous genetic constitutions.

Isozyme studies of koa genetic variability

Little is known about the relative amounts of genetic variation of the geographic patterns of genetic diversity of *Acacia koa*, Hawai'i's signature wood and major forest tree species. While some workers collected seeds, planted common garden trials, and evaluated growth adaptations, we analyzed genes using laboratory studies of enzymes. Enzyme genes disclose levels of diverstiy and help to reveal geographic races.

Fresh seeds were collected from the Waimea Canyon, Koke'e, Alaka'i forest of Kaua'i (60 trees in the sample); Wai'anae Range (24), and also northern [Pupukea (44)], and southern Honolulu (32) forests of the Ko'olau Range, O'ahu; forest near the Hosmer Grove, Haleakala, East Maui (6); and forests on the island of Hawai'i: Hualalei above Kailua-Kona (18), and Mauna Loa Strip Road, Hawai'i Volcanoes National Park (28).

Our laboratory analyzed enzyme genes from the embryos of germinating seeds. Koa is a tetraploid, 4N plant that presents numerous isozyme band patterns. Initial analyses of seeds from individual pods, each being a full-sib family, helped to characterize the gel band patterns from six polymorphic genes (6PG2, IDH, MDH2, PGI2, GOT3, GDH). Our species analysis used one seed per tree to avoid seed parent bias and to provide wide evaluation of diversity within the respective forests. Koa population samples possess relatively large numbers of alleles per gene, from three alleles for IDH, up to seven for MDH2. Several of the genes have alleles in intermediate frequencies. Overall, the variable genes have average expected heterozygosity of 0.41.

This is a high value compared with many other organisms. It suggests that koa has significant levels of genetic diversity to adapt to varied environments. It provides evidence that tree improvement can operate on a rich genetic base.

Samples from Kaua'i, O'ahu, and Maui appear closely related; all share about the same allele frequency profiles. Figure 1 presents a diagram of genetic distances showing the relationships among populations. It is noteworthy that the two sample populations from the island of Hawai'i are similar to one another, but both differ substantially from the genetic profiles of koa from Kaua'i, O'ahu, and Maui. Big Island populations have intermediate frequencies for two alleles of 6PG2 and one allele of IDH that are absent from Kaua'i, O'ahu, and Maui samples. One allele of 6PG2 and one of IDH are present in samples from Kaua'i, O'ahu, and Maui, but absent from Hawai'i. Island-to-island differentiation indicates that it is important for foresters to plant with seedlings from local seed sources until more is known about the adaptations and growth of koa geographic races.

Isozyme studies of banana poka genetic variability

The introduced and naturalized *Passiflora* vine, banana poka, has potential to over-top and smother forests; it is adapted to elevations and conditions of native koa forests. To develop opportunities for biological control of banana poke, we assessed its genetic diversity and compared its gene profile to profiles of the most likely progenitor species.

Field collections of banana poka were made in four major outbreaks in Hawai'i by harvesting individual mature pods from numerous, separate vines. Isozyme analyses of 15 enzyme genes in seed samples from Kaua'i, Maui, and the Kailua and Hawai'i Volcanoes National Park areas of Hawai'i lacked genetic variation; enzyme patterns of all samples were identical throughout Hawai'i; each gene had one allele type; there was no evidence of genetic diversity; the observed heterozygosity was zero.

Finding genetic uniformity within Hawai'i is highly significant, because it predicts that banana poka has very little opportunity to evolve. It lacks the capacity to modify gene frequencies as a means to adapt to new challenges. The plant's environmental tolerances are set the basic adaptations of its monotypic genotype. Although it possesses poisons that effectively protect it from many predators, any organisms that overcome its defenses will have access to a uniform host. Biological control researchers consider this an ideal situation, because their control agents can be tailored for target-specific success against a unique genotype.

It is possible that insects and diseases in Hawaiian forests may eventually adapt to banana poka. But researchers can hasten control of exotic weeds by importing their native associates to weaken them, feed on them, and reduce their reproductive capacity. What then is the parent progenitor of Hawai'i's banana poka?

While there are approximately 400 species of *Passiflora*, Hawaiian banana poka only resembles a few South American varieties, those cultivated for juice and grown extensively in gardens of small villages through the Northern Andes. Entomologist Rex Friesen, when conducting biological control research at Hilo and Volcano, determined from first-hand experience in Ecuador, Colombia, and Venezuela that two varieties closely match the morphological features of banana poka. Dr. Friesen, with assistance from South American colleagues, made extensive seed collections from the primary, candidate progenitor species: *Passiflora tripartita* var. *tripartita*, and *P. tripartita* var *mollissima*. The collections were in villages at elevations from 2075 meters (6800 feet) up to 3100 m (10,200 feet). "Fuzzy, felt-like" describes the underside of leaves of variety *mollisima*; it is the main characteristic distinguishing it from smooth leaves of variety *tripartita* and banana poka. We hasten to note that the taxonomic nomenclature of these varieties is unsettled; various species and varietal names are in local use.

Seeds from South America were analyzed in starch gels alongside seeds from banana poka to compare enzyme gene profiles. The Hawaiian banana poka enzyme gene profiles exactly match the profiles of *Passiflora tripartita* var. *tripartita* from Ecuador, Colombia, and Venezuela. Surprisingly, our isozyme analyses of 15 genes, based on extensive collections and numerous vine samples, indicate that variety *tripartita* is also genetically uniform and homozygous and, with only a few rare excepetions, consists of a single allele type at each enzyme gene. It is now clear that banana poka's homozygosity traces to a cultivated variety that is homozygous. The other Andean candidate progenitor species, *P. tripartita* var. *mollissima*, has distinctly different enzyme profiles: it is highly variable with allelic variation (5 alleles were present in GOT2) in 12 of a total of 15 enzyme genes; observed heterozygosity reaches a high of 0.15 for Venezuelan samples (expected heterozygosities are substantially higher—0.35—indicating a breeding system with substantial inbreeding).

Genetic similarity relationships among banana poka and the two Andean varieties are shown in Figure 2. The two Andean species differ significantly with alternate alleles at 7 of the 15 loci.

Researchers collecting *Passiflora* biological control organisms in South America for tests on Hawaiian banana poka should concentrate their efforts on *Passiflora tripartita* var. *tripartita*. This can be done with knowledge that significant genetic differences exist between the two Andean species and with the knowledge that variety *tripartita* and banana poka have identical and homozygous genetic constitutions.

Acknowledgments

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Figure 1. Pair-group clusters of Hawai'i populations of koa.

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              Genetic Distance
 .30  .25  .20  .15  .10  .05  0.0
 -+----+----+----+----+----+----|
                     +----------*   Kauai
                    +|
              +-----|+----------*   Waianae Range, Oahu
              |      +-----------*  Pupukea, Koolau Range, Oahu
    +---------|   +--------------*  Honolulu, Koolau Range, Oahu
    |         +--|
    |            +--------------*   East Maui
    |       +-------------------*   Hualalai, Hawaii
    +-------|
            +-------------------*   Volcano, Hawaii
 -+----+----+----+----+----+----|
 .30  .25  .20  .15  .10  .05  0.0   (0.0 means identical)
```

Figure 2. Pair-group clusters of *Passiflora tripartita* var. *mollisima*, Hawaiian banana poka, and *P. tripartita* var. *tripartita*.

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                 Genetic Similarity
 .60  .65  .70  .75  .80  .85  .90  .95  1.0
 -+----+----+----+----+----+----+----+----|
                                         +-*   v. mollissima, Ecuador
                                   +------|
      +---------------------------|      +-*   v. mollissima, Colombia
      |                            +--------*  v. mollissima, Venezuela
      |
      |                                    *   Hawaiian banana poka
      |                                   +*   v. tripartita, Venezuela
      +----------------------------------|*   v. tripartita, Colombia
                                          |
                                         +*   v. tripartita, Ecuador
 -+----+----+----+----+----+----+----+----|
 .60  .65  .70  .75  .80  .85  .90  .95  1.0  (1.0 means identical)
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Clonal Propagation of *Acacia koa*

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Introduction

Koa (*Acacia koa*) is currently the most important commercialized hardwood in Hawai'i's forests. A sustainable supply of koa will depend on reforestation with the best adapted seed sources and perhaps with vegetatively propagated cultivars having unique traits. At present, koa forests are in a serious state of decline, and improvement appears warranted if sustainable supply is to be achieved.

Vegetative (clonal) propagation provides large numbers of genetically identical plants. Conventional methods include cutting and grafting, while in vitro micropropagation is a more recent approach. These methods would be useful to propagate koa trees selected for superior growth and stem form, disease and insect tolerance, and desirable wood characteristics such as curly or fiddleback grain. Clonal propagation could provide opportunities for commercial-scale production of koa. Furthermore, clonal koa trees would be useful for breeders in testing for adaptability and developing elite seed sources.

Conventional vegetative propagation of *A. koa* is not presently viable on an operational scale. In vitro propagation (micropropagation), on the other hand, has been used successfully to obtain large numbers of identical trees in various tree species including the genus *Acacia*. In *Acacia*, micropropagation through shoot multiplication and somatic embryogenesis (induction of seed- like structures in cultures of somatic cells) has been reported in the past 10 years in *A. melanoxylon* (Jones and Smith 1989), *A. nilotica* (Garg et al. 1996), *A. auriculiformis* (Mittal et al. 1989), *A. mangium* (Galiana et al. 1991), *A. saligna* (Barakat et al. 1992). In Hawai'i, Skolmen (1977), of the Institute of Pacific Island Forestry, studied clonal propagation of *A. koa* using both in vitro and conventional methods. Plants were produced through callus culture (Fig. 1), air-layering, and mist rooting from young shoots of juvenile trees. However, development of a successful large-scale clonal propagation method is still needed.

We studied micropropagation, building upon the earlier work of Roger Skolmen. Objectives of our study were: (a) to develop a method for koa micropropagation through shoot multiplication (Fig. 1), (b) to optimize the method for higher efficiency in multiplication, and (c) to induce roots in multiplied shoots.

Collection of plant materials

Various tissues of koa including young shoots, phylloid tips, root suckers, and seedlings from the Island of O'ahu were used to initiate tissue culture (Table 1). Plant materials from mature trees were collected from healthy branches with new growth.

Initiation of culture

Shoot tips and young phyllodes were washed with commercial detergent and left under running water for 3–5 hours before use. Plant materials, including shoot tip areas, were cut to 3–5 cm in length, and leaves were removed. They were surface-sterilized with 30% Clorox (sodium hypochrolite 1.5%) and a drop of 0.2% Triton X-100, followed by rinsing in sterile water. Shoots tips were placed on modified MS medium with various amount of cytokinin (kinetin). Lateral shoot growth was observed in culture 3–8 weeks after initiation from young shoots as explants in kinetin media, while no response was found in the culture from a mature tree (Table 1). In a recent experiment (data not shown), in vitro shoots were obtained from a 2.5-year-old tree grown at Maunawili from seed of a selected tree on Maui. Various combinations of auxin (2,4-D and NAA) and cytokinen were also used to follow Skolmen's results for callus induction (Skolmen and Mapes 1976, Skolmen 1977). Various types of callus were derived from explants such as young shoots and phyllodes, but no plants were regenerated from these calluses. Effect of kinetin in culture medium on culture establishment was studied in the phyllode explants from Waimanalo. Green shoots were observed from over 30% of explants cultured on the K8 medium (kinetin 8 mg/L), while only 10% were obtained on E1 medium which contained

Figure 1. Scheme of Acacia koa micropropagation.

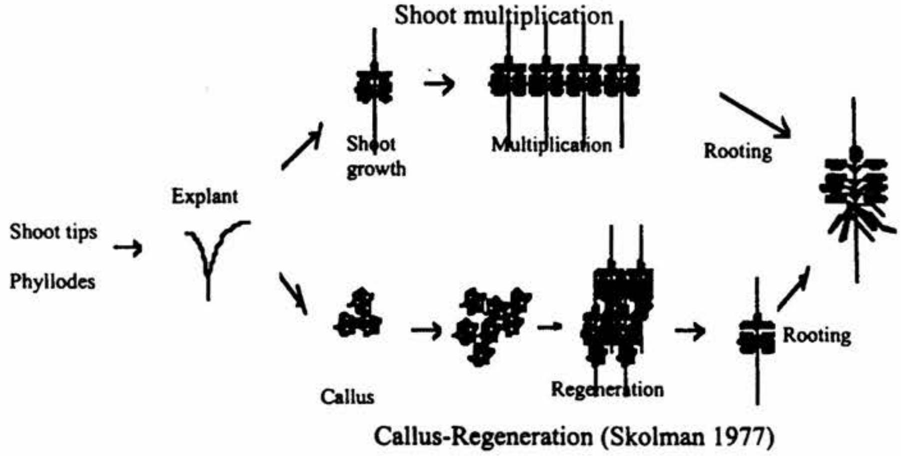

Table 1. Explanting and culture initiation of *Acacia koa*.

Date	Source	Tissue	Age	No. initiated	No. callus	No. multiplied
2/16/94	Waimanalo	phyllode	3 yr	40	6	0
3/3/94	Kunia	young shoots	2 mo	317	25	21 (6.6%)
5/12/94	Kunia	young shoots	2 mo	252	114	35 (13.9%)
6/1/94	Tantalus	phyllode	20 yr	73	-	0
8/30/94	Palolo Valley	phyllode	10 yr	58	-	0
		true leaves		25	-	0
11/24/94	Waimanalo	shoot	3 yr	186	-	7 (3.8%)
to		phyllode		206	-	15 (7.3%)
1/10/95		sucker		60	-	6 (10%)

combination of kinetin and BAP 0.7 mg/L for eucalyptus culture at HARC.

Multiplication

Shoots were further multiplied from the initial shoots in the MS medium with kinetin at 4–6 mg/L. Multiplied shoots were transferred to fresh medium every six weeks. Multiplication rate was low at the rate of multiplication x 1.5 per 6 weeks in the most vigorously growing culture. Callus formation at the base of multiplied shoots was observed in approximately 20% of the cultures on kinetin media. In these cultures, shoots stopped growing, and multiplied shoots were dead in 2–4 weeks after callus formation. This result indicated that prevention of callus growth was important for active shoot multiplication of koa.

Rooting

Roots were induced from multiplied shoots in culture media with auxin, IBA. Several rooted seedlings were transferred to vermiculite medium. They will be transplanted in the greenhouse at HARC's Maunawili Breeding Station.

Future study

We were encouraged by these initial results, and will continue our study of methods to increase the efficiency of shoot multiplication and rooting and to initiate cultures from mature trees with combinations of growth regulators and pre-treatment of explanting materials.

Summary

Tissue culture of A. koa was initiated from shoots and phyllodes of young trees. Shoot culture was most successful in a medium with high kinetin (8 mg/L). Shoots were multiplied in MS medium with kinetin at 4-5 mg/L. Roots were induced on culture medium with IBA.

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Genetic Variations of *Acacia koa* Seed, Seedling, and Early Growth Traits

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Introduction

Koa (*Acacia koa* Gray) is a native Hawaiian legume tree with 2n=52 chromosomes (Atchison 1948). It is endemic throughout Hawai'i's main islands from sea level to 2300 m elevation. Koa is prized for its beautiful wood and is used for variety of wood products (Whitesell 1990). Koa provides a sustainable economic resource for Hawai'i's forest industries and an ecosystem for many endanger'ed Hawaiian species. Koa forests have diminished significantly owing to the establishment of ranches and sugarcane plantations in the last two centuries (Metcalf et al. 1978).

Previous studies suggest koa has a diverse genetic base. Morphological differences including phyllode size, tree form, seed size, and flower characteristics are found among natural koa stands throughout the Hawaiian islands. These differences have led to the classification of three species within Hawaiian *Acacia*, namely, those of *A. koa* Gray, *A. koaia* and *A. kauaiensis* (Hillebrand 1888, Rock 1920, Lamoureux 1971, St. John 1979). Brewbaker (1977) reported isozyme polymorphism and variation of phyllode size and shape among koa populations from the islands. Attempts of koa reforestation have also shown variable growth performance (Judd 1919, Whitesell and Isherwood 1971, Ching 1981, Scowcroft and Adee 1991). Conrad et al. (1995) reported differences for plant growth among eight koa provenances from four Hawaiian islands. Genetic variation of koa wood quality and other traits have also been observed. Simmons et al. (1991) reported variation in wood color, grain, and specific gravity. Skolmen (1990) observed differences in koa response to volcanic fumes. Plants from regions distant to an area of volcanic activity were more prone to fume damage than plants proximal to volcanic activity. Further evidence of the genetic variation in koa is suggested by its highly diverse ecological range.

The objectives of this study were to quantify seed sources for reforestation and to select superior koa as the basis for long-term genetic improvement.

Materials and methods

Acacia koa germplasm was collected from 1991 to 1996 from diverse ecosystems around the state. Most accessions were collected as families from single trees. Accession seed sources were documented and seeds were stored at the University of Hawai'i Foundation Seed Facility at 15°C. Average seed weight (based on a random sample size of 100 seeds), width, and length (based on a random sample of 10 seeds) were measured in the laboratory. Seedlings were raised in the greenhouse, and growth rates were measured until transplanting at the CTAHR Waimanalo Research Station, O'ahu.

Three-and-one-half-month-old seedlings were planted at the CTAHR Hamakua Research Station, Hawai'i (650 m. a.s.l.) on May 25, 1991. The station's annual rainfall averages 2500 mm and annual mean temperature 19°C. The soil series is the Maile silty clay loam with a pH of about 5.0. An augmented design of the randomized complete block (RCB) with two replications was used to test 48 accessions. Each plot consisted of 10 trees in two rows. Plant spacing was 1 x 1.5 m, or 6667 trees ha^{-1}.

Individual tree height and DBH (diameter at breast height) were measured at five- and seven-month intervals. Phyllode development rate based on the percentage of phyllode coverage in the tree was scored one year after transplanting. Survival percentage of each plot was also recorded yearly. Analysis of variance was done on these data using a Quattro Pro spreadsheet (Brewbaker 1993) and PROC GLM of SAS (SAS 1990). Individual tree and family heritability estimates for the tree growth rates were according to Zobel and Talbert (1984) with modification. Individual-tree narrow-sense heritability is calculated as $h^2=3*\sigma^2_F/(\sigma^2_W+\sigma^2_{RF}+\sigma^2_F)$; family heritability is calculated as $h^2_F= \sigma^2_F/(\sigma^2_W/TR+\sigma^2_{RF}/T+\sigma^2_F)$. σ^2_W, σ^2_{RF}, and σ^2_F are the within-plot, replication X family, and family variance components, respectively. T and R refer to trees per family-replication plot and replications. Predicted family genetic gain is calculated as $G=S*h^2_F$, where S is the selection differential between mean of the selected families and mean of all families.

Figure 1. ***Acacia koa*** **seeds collected from the Hawaiian Islands.** 1M2-1: Makiki, Oahu; 1N2-1: Nuuanu, Oahu; 2PH1-2: Puu Hinahina, Kauai; 2PK1-2: Puu Ka Pele, Kauai; 2W2-2: Waimea Canyon Drive, Kauai; 5KO1-1: Kokomo Rd., Maui; 5MA1-2: Hamana Rd., Maui; 6KMC2C: Kilauea Military Camp., Hawaii; 6MLR1-1 and 6MLR7-1: Mauna loa Rd., Hawaii.

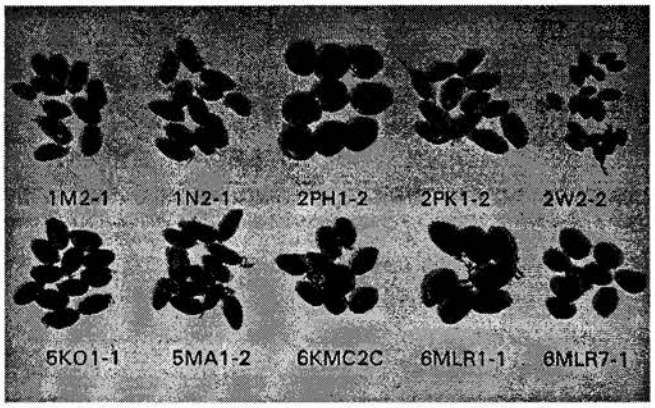


Table 1. Traits observed in two distinct *Acacia* populations from Kaua'i.

Trait	*A. koa*	*A. kauaiensis*
Seed shape	Oblong	Round
Seed width (W)	4.8 mm	7.5 mm
Seed length (L)	10.0 mm	9.8 mm
L/W ratio	2.1	1.3
Seedling color	purple	green-yellow
Seedling height		
3 mo	35 cm	16 cm
12 mo	250 cm	110 cm
Phyllode size	Narrow to medium	Variable
Flowering seasons	winter	summer
Location	Along highways	Widely distributed

Results and discussion

To date, a total of about 400 koa accessions has been collected and documented. This collection includes 116 accessions collected by Brewbaker during the 1970s and 44 accessions contributed by the USDA Forest Service in Hilo. These collections were mainly from Kaua'i, O'ahu, Maui, and Hawai'i. A wide range of ecological conditions are represented in these collections, with elevation ranging from 100 to 2300 meters above sea level and mean annual precipitation from 600 to 5000 mm.

Variation in seed weight, size, and morphology from different koa collections was observed (Fig. 1). Seed weight of *Acacia koa* from 294 accession averaged 8.5 g per 100 seeds and ranged from 1.7 g (about 58,800 seeds/kg) to 17.7 g (about 5650 seeds/kg). Seeds from Kaua'i and Hawai'i were significantly ($P<0.05$) heavier than those from O'ahu, Lana'i, and Maui. Koa seed width from 95 accessions averaged 6.4 mm and ranged from 3.4 to 9.3 mm, while seed length averaged 10.2 mm and ranged from 6.7 to 13.4 mm. Two distinct seed types, round and oblong seeds, were found among 49 Kaua'i collections. The round seeds averaged 7.5 mm in width, and were significantly ($P<0.05$) wider than the oblong seeds. However, no difference was found for seed length between these two seed types.

Distribution of trees with oblong seeds on west Kaua'i are limited to certain areas compared to trees with round seeds. Trees with round seeds are widely distributed in west Kaua'i. Trees with oblong seeds could only be found along Waimea Canyon Drive, Koke'e Road, Ka'aweiki Ridge, and Kumuwela Trail, and are presumed to trace to reforestation in the 1930s.

Significant ($P<0.05$) differences for seedling height two weeks after sowing were found among 80 accessions from Kaua'i, O'ahu, Maui, and Hawai'i. Average seedling growth rates from the different islands are presented in Figure 2. Accessions with the round seeds from Kaua'i grew significantly ($P<0.01$) slower than those from Kaua'i with the oblong seeds from O'ahu, Maui, and Hawai'i. The result is in agreement with a similar study using different koa seed sources (Sun et al. 1996).

Three groups of seedlings were observed among these collections based on the different color of the seedling stem, the leaf rib, and the leaflets. Group I is from Kaua'i and has round seeds; green stems, leaf rib, and leaflets; and slow growth. Group II is distributed on O'ahu, Maui, and some areas of Kaua'i and has oblong seeds, purple stems and leaf ribs, dark green leaflets, and normal seedling growth. Group III is from Hawai'i and has both round and oblong seeds, green leaflets, reddish stems, and normal growth. Two koa groups

Table 2. Estimated variance, heritability, and predicted family selection gain for tree height and DBH at various growth stages.

	Height (m) in month				DBH (mm) in montth			
	6	14	26	31	26	37	48	60
Mean	1.7	3.0	5.0	5.9	57.0	85.0	99.0	109.0
Variance								
Between family(s^2_F)	5.10	0.13	0.17	39.60	100.10	2.64	3.59	3.63
Rep/family(s^2_{RF})	2.90	0.05	0.15	10.30	0.00	0.41	0.35	0.15
Within family(s^2_W)	22.60	0.60	1.11	70.00	620.00	10.50	12.90	18.01
†Heritability								
Individual tree(h^2)	0.50	0.50	0.36	0.99	0.42	0.58	0.64	0.50
family(h^2_F)	0.69	0.74	0.50	0.80	0.79	0.74	0.75	0.68
‡Predicted family selection gain	0.5	0.7	0.8	1.3	26.1	25.8	30.1	34.8
Gain%	28.6	24.6	15.0	21.8	45.8	30.4	31.2	31.9

†Individual-tree narrow-sense heritability is $3*s^2_F/(s^2_W+s^2_{RF}+s^2_F)$; family heritability is $s^2_F/(s^2_W/TR+s^2_{RF}/T+s^2_F)$.
‡Predicted family genetic gain is $S*h^2_F$ where S is selection differential from the selected best performance family.

found on Kaua'i can be easily distingished and should be treated as separate species (Table 1). Trees with round seeds from Kaua'i were previously described as *A. kauaiensis* (Lamoureux 1971). Koa groupings suggested in this study seem to have some geographic partitionings in addition to morphological similarities. This suggests there may be some evolutionary significance to the groups. For this reason, it may be expected that other traits such as wood characteristics, disease resistance, and even molecular markers may also tend to be classified according to these groups.

Overall koa seedling survival at two months was 95.5 percent and declined to 84 percent two years after planting. The lowest survival rate was from accessions of 6-1288C (Hawai'i), 2DT2-1, 2MA2-1, 2MA3-1, and 2OV1-1 (Kaua'i), with 30, 0, 20, 60, and 60 percent survival, respectively. After three years, all four Kaua'i accessions were dead. All these accessions were the round-seed phenotypes.

Significant ($P<0.05$) difference for phyllode development was found among the 22 replicated accessions. One year after planting, phyllode coverage averaged 64 percent and ranged from 0 percent for 2DT2-1 to 100 percent for 1M7-1, 1SL3-1, 5K1-1, and NFTA891C. Accessions from Hawai'i showed earlier ($P<0.01$) phyllode development than those from the other islands.

Differences ($P<0.05$) in height and DBH were found among these accessions. Overall, average tree height attained 3 m in the first year and continued to add two meter every year thereafter. After two-and-one-half years, heights of these accessions averaged 5.9 m and ranged from 2.0 to 7.6 m. After five years, DBH averaged 109 mm and ranged from 55 to 166 mm. Significant differences for DBH among accessions from the same area were also observed after five years. DBH of 1M6-1 and 1M8-4 from Makiki, O'ahu, was significantly different after two and half years. This was not the cause for height. Similar results were observed for 2PH1-1 and 2PH2-1 families from Kaua'i and 5K1-2 and 5K1-6 families from Maui.

Estimated variance, heritability, and expected family selection gain for tree height and DBH at early growth stages are presented in Table 2. Family heritablity estimates for height and DBH were about 0.7. Predicted genetic gain for one cycle of family selection was about 1.3 m for height at two and a half years and 35 mm for DBH at five years.

Various disease symptoms of koa rust and sooty black mold were observed in this trial. Variation of disease symptoms among families was noticed. Overall, the progenies from Hawai'i were more susceptible to rust compared with the progenies from the other islands.

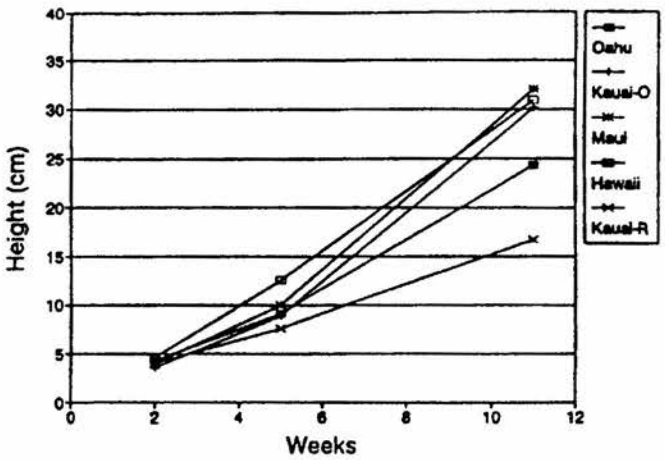
After five years, the fastest growing families in terms of DBH (>140 mm) were 1M6-1 and 1N2-5 from O'ahu, 2PH1-1 and 2PK3-1 from Kaua'i, and 5K1-2 from Maui. Some of these families flowered and set seed in year four, and seeds were collected from these outstanding families. Testing of these advanced progenies will be carried out to study the potential genetic gain from selection.

It is evident that *Acacia koa* is a fast growing tree in the juvenile stage. This finding is in contrast with the general assumption that koa is a slow growing tropical leguminous tree (NAS 1979). This conclusion may have derived from the observation of koa trees growing in degraded forest lands. The slow growing trees may also be due to poor seed source. However, an early study did record that koa was a fast growing tree in juvenile stages, in which it reached 9 m in 5 years (Judd 1919). Skolmen (1990) observed that one progeny grew straight and tall while the other was defoliated and died shortly thereafter at Volcano, Hawai'i. Conrad et al., (1995) reported koa provenances from Kaua'i and O'ahu grew faster than koa from Maui and Hawai'i when grown at Wahiawa, O'ahu. Progenies with round seeds from Kaua'i always grew slower than progenies with oblong seeds (Sun 1996).

There appears to be genetic differences for early plant growth, survival rate, and development among the koa collections from the different islands. Consistent and significant differences for these traits over five years were largely due to seed source. The presence of genetic variability in tree growth is very important and can be used immediately for rapid genetic advance at relatively low cost through individual tree or family selection. The results of estimated individual tree and family heritability for height and DBH clearly suggest that there is potential for genetic improvement of koa, especially, the fast growing koa populations from some areas of Kaua'i, O'ahu, and Maui.

Skolmen (1990) reported that only the Big Island koa with wide phyllodes would make long, branch-free logs for timber production. However, most of the fast growing koa progenies with a single main stem identified from this trial were from Kaua'i, O'ahu, and Maui. These koa populations with unique seedling characteristics, described as Group II koa, are different from koa with round seed character on Kaua'i and koa on the Island of Hawai'i. The present findings suggest that more attention should be paid to selection and silviculture of these koa populations for the state reforestation programs.

Figure 2. Average seedling growth rate of *Acacia koa* collections from the Hawaiian Islands. Kaua'i-O is from Kaua'i with the oblong seed; Kaua'i-R is from Kaua'i with the round seed.



Acknowledgements

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Questions to the Panel

Q: You put up a measure related to the seeds; I assume it was weight, size, etc. You had the unit of measure as mm, which I take as millimeter.
A: That should be grams.

Q: For example, I noted that the weight for Big Island was 6.4, that should be 6.4 grams. What is the quality seed source that you identified, is it the Maui seed?
A: We identified some from Kaua'i, some from Maui, some from this island, Oahu.

Steve Smith: [to J. Brewbaker] In your abstract, which you didn't really talk about, you made a comment that "there are superb tropical hardwoods such as *Acacia melanoxylon*, that will simply wipe out koa in the future, unless koa is genetically improved." Is this because they've done a lot of work already on the melanoxylon, or because we haven't seen a lot of good stuff here in Hawai'i?
Jim Brewbaker: Well, they don't have exactly the 80-year head start that Bill was talking about, but melanoxylon ranges in Australia all the way from central Queensland down to Tasmania. There's tremendous genetic diversity through that range. They have cloned it quite easily using root-sprout cloning. Otherwise, they're not a heck of a long way into commericialization of blackwood, but it is a beautiful wood, and it does have curly wood, and so forth. Our foresters have grown it here through the years and there is a very good reason to keep it in the arsenal of species that could be researched in Hawai'i. After all, there are 1200 other acacia species out there, and many of them are quite striking. One that has both extensive recent research and is a good hardwood is *Acacia mangium*, and also its related species like *auriculiformis*. Of course, there's the historic work on *Acacia mearnsii*, and now in South Africa

extensive breeding for hardwood rather than gum.

Q: [to Conkle] The research from Dr. Sun concentrated on half of the equation, which was the quantity side and how fast can we grow them. I know Dr. Brewbaker and I have talked about the quality side, and we have to make sure we select seed that gives us both fast growing seeds but that are worth something when it comes time to harvest them. Dr. Conkle, you showed a dendrogram that showed some sort of relationship between trees from different islands. It seemed like Maui and Kaua'i were more closely associated than O'ahu and Kaua'i. I was curious if that was significant, if it was an anomaly; why do trees in those two islands, which are further apart, have more closely related genetics?
Tom Conkle: I think those are tempting dendrograms. My collection from Maui was more limited than from Kaua'i and O'ahu, and I have less confidence in the Maui genotypes and characteristics of that geographic location. I would enjoy having more seed, and I'm really working on techinques using those phyllodes as the source of enzymes to do genetic trials. It would put these numbers up into the thousands of trees that we look at, rather than the hundreds that we looked at in this collection. The answer is that the Maui collection was rather small and I wouldn't put a lot of confidence in the exact location of those three. My take-home message is that the three island populations are relatively similar in comparison to the Hawai'i collections.
Jim Brewbaker: May I add a point to this? Wei Guo did show a PDR, phyllode development rate. Big Island material develops phyllodes . . . you might comment on that.
Wei Guo Sun: On Kaua'i, it's very interesting, if you work along the highway in Waimea Canyon, you will see two kinds of koa trees. One has zigzag pods and this one flowers in the summer. Another one has a straight pod and flowers in the wintertime. When you go into the ridges and hike, you will only see the zigzag pod with round seeds, none of the oblong-seed koa. We assume that along the highway and a couple of ridges, including Koke'e, the seed is from another island. The round seed occurs all over the rest of west Kaua'i.

Q: I'm curious to see if any of the panelists knows anything about the genetic variance with the Maui koa, why it is this particular color, why it's always darker, and more of a red leaf, especially when they're young.
Wei Guo Sun: Through evolution the Maui situation perhaps [evolved] through some difficiency.
Jim Brewbaker: Is there no exception to that? Are all the Maui red?
Wei Guo Sun: To a certain degree. Some are much darker, some are almost the same as O'ahu.

Q: It seemed that there are two ways that you could improve the trees that we have in the field. One was a vegetative approach that Chifumi Nagai talked about. The other was sexual reproduction, cross pollination. What are the relative advantages and disadvanteages? When would you use one as opposed to the other?
Jim Brewbaker: From the evidence that we have, one would argue on the basis of the heritability values you've just seen that an initial step, replicating what's been done with every other important tree species, using sexually derived material from elite trees, would make a substantial improvement in form, in growth rate. Something on the order of the estimates that have been given here, we could go into the 1991 planting, which is starting to seed, and rogue it down to what we would consider elite parental trees, and derive seed from that. One of the biggest questions in my mind, still unanswered, is to what extent that seed will be derived by hybridization within the population and to what extent it will be selfed seed. If, in my view, there is a high degree of self-fertilization occurring, then we can ask the question, why not take selfed seed from individual superior trees. Then you have several options. You certainly don't want to plant entire plantations from progenies from a single tree. It' s difficult to show pictures that illustrate this, but many of the single-family progenies are like peas in a pod. They are extraordinarily uniform. Wei Guo did show a picture, for example, from Maunawili of such a family. All ten trees were lovely in form. I'll let Chifumi address the question of clonal propagation, but anyone with the experience of Bill Libby would certainly say that's the direction we'll head in ultimately if we want to capitalize on the genetic opportunities in a cross-pollinated polyploid, in particular to improve quality, color, fiddleback, and so forth.
Chifumi Nagai: I want to add that for clonal propagation you can speed up, as a supplement to the sexual cycle of selection and breeding, when you must wait years to get the results. For example, if the method works to clonally propagate a certain seedling, we can propagate hundreds of each one. Meanwhile, if longer-term selection is going on and breeders decide here is the elite tree, there's already propagules available.

Interactions Between Site and Koa Seed Source

C. Eugene Conrad, Institute of Pacific Islands Forestry

Introduction

Interaction between plants and their habitats is not simple. Sometimes, however, this complex of interactive process is treated as though two parts can be separated from all others. The approach might assume that when one process is modified, the other has a straightforward concomitant reaction to the change. In real life, changing one part of a process changes the entire process, it may change the way other processes function, and it may feed back to readjust responses to the intentional changes. Species having been once common in a particular habitat is not an assurance that they will return, even with careful nurturing. In particular, for example, the genetic material of even the most common species could be mismatched with the habitat after the biological and physical processes have changed.

Previous reports

This paper is an initial look at information from a Maui elevation-transect study showing some influences that site (location) has on how koa (*Acacia koa*) responds to environmental differences. In another paper, Ikawa and I (Conrad and Ikawa 1995) compared nutrient concentrations in young koa with the concentrations in young pines (*Pinus* spp.) grown in the same sites. As expected, because koa is a nitrogen fixing legume its tissues contained more nitrogen. Other differences were less expected. The needles of two pine species contained 5 and 10 times greater aluminum concentration than found in koa phyllodes. The concentration of aluminum was more than 3 times greater in pine twigs than in koa twigs.

Conrad et al. (1995) showed that koa seedlings from different native environments reflect the relative disparity of the environments by their survival and growth. This seed source study was at the Waiawa Correctional Facility on O'ahu. Survival of seedlings from several locations on Hawai'i Island was only 52–64 percent, and growth was 9–21 cm/yr. Waiawa receives about half as much rain as the native habitats of some seedlings from Hawai'i Island. Average temperature in their native habitat is 3.0–5.6°C (6-10°F) cooler. Seedlings from other islands did better. Survival was 79–98 percent and growth was 49–73 cm/yr for seedlings whose provenances were Kuiaha (Maui), koa-ridge on O'ahu, and Kamalomaloo (Kaua'i). Compared with Waiawa, temperatures in these habitats were within 1°C (1.8°F). Rainfall at Waiawa was about the same as nearby koa-ridge and 635 mm (25 in) less than at Kuiaha.

In an *Acacia* growth potential study, Cole et al. (1996) showed that intensive site preparation and fertilizing can overcome environmental deficiencies. They ran a growth potential study for 19 months. The F_0 treatment included deep plowing, rototilling, and a single fertilizer application at planting. This treatment resulted in 90 cm/yr Kaumana koa height growth. The F_1 treatment included the F_0 applications plus liming and more fertilizer; the resulting height growth of Kaumana was 220 cm/yr. The Kaumana provenance was also used in the seed source study (Conrad et al. 1995) and in the study discussed here. In the seed source study, Kaumana koa growth was 21 cm/yr with minimal site preparation and only two applications of NPK slow-release fertilizer (Conrad et al. 1995).

The Maui elevation transect

Three of the objectives of the Maui study were to (1) determine the influence of climate and soil on establishment and growth of the test species or varieties, (2) determine effects of site variability on tree performance, and (3) correlate site variability and understory herbaceous competition with tree performance. We chose to base the research on an elevation transect on Haleakala's north slope, where rainfall would remain roughly the same with increasing elevation but temperature would decline as a function of increasing elevation. Study units were established at three locations on an elevation transect (Table 1).

A low-elevation unit was located off West Kuiaha road about 2 km (1.25 mi) south of Kuiaha village. The middle elevation unit was about 3 km (2 mi) south of Makawao town at the University of Hawai'i's Haleakala

Table 1. Environmental features of the Maui study units.

Study unit	Elevation meters (feet)	Temperature °C (°F)	Rainfall mm (in)	Soil order
Kuiaha	305 (1000)	22 (71)	2184 (86)	Ultisol
Makawao	640 (2100)	20 (67.5)	2159 (85)	Ultisol
Olinda	1067 (3500)	16 (61)	1549 (61)	Andisol

Table 2. Environmental features of the koa provenances.

Provenance	Elevation meters (feet)	Temperature °C (°F)	Rainfall mm (in)	Soil order
Kaumana	670 (2200)	19 (66)	3556 (140)	Andisol
Kukaiau	1158 (3800)	16 (61)	3048 (120)	Andisol

Research Station on Pi'iholo road. A high-elevation unit was at the Olinda bird-rearing facility, 7.4 km (4.6 mi) south of Makawao on Olinda road. For many years, the Kuiaha location was used for pasture and the Makawao and Olinda locations were used for agricultural crop research.

Seedlings from Kaumana and Kukaiau koa provenances (Table 2) were planted in each study unit in March and April 1986. The Kaumana provenance was near Hilo, Hawai'i, and the Kukaiau provenance was on Kukaiau Ranch on Mauna Kea. The study also included Caribbean pine (*P. caribaea*) seedlings plus seedlings and tissue culture clones from two families of loblolly pine (*Pinus taeda*) provided by Weyerhaeuser Co. research from stock at an Arkansas facility. At each study unit, the seven test varieties were planted in 36-tree plots in a randomized block design with six replications. Planting was in a staggered-row pattern with trees in adjacent rows offset by one-half the distance between row trees. The minimum distance between trees was 1.8 m (6 ft) in the rows and the maximum was 2 m (6.6 ft) on the diagonal between rows.

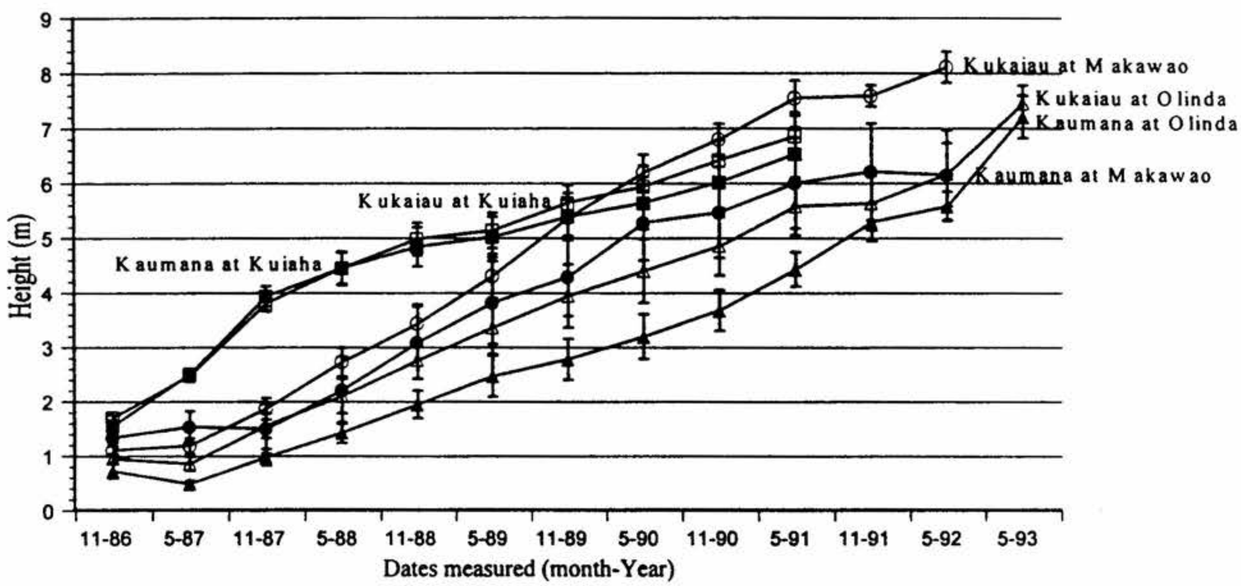
The seedlings were sown on greenhouse flats in a potting soil mixture. They were transplanted into 15 cm (6 in) dibble tubes after the cotyledons were fully developed. Planting in the field plots was done in March and April 1986 when the seedlings were at least 40 cm (15.5 in) tall. Before planting, each site was disk plowed several times to control immediate, severe herbaceous weed competition. After planting, an 0.8 m^2 (0.9 yd^2) area around each tree was hand-weeded once or twice a month for about 18 months or until the tree was above the competition for light. At planting time, each tree was given about 57 g (2 oz) of slow-release fertilizer (14-14-14 N-P-K) in dibble holes next to the seedlings. Nine to ten months after planting, another application at the same rate as at planting was broadcast and stirred into the soil in a 30-cm radius around the trees.

Temperature at Makawao was close to the temperature at Kaumana. Olinda and Kukaiau temperatures were also similar. Kuiaha was 3.0–6.0°C (5–10°F) warmer than the provenances (Tables 1 and 2). Rainfall at the three Maui sites was less than at either of the two provenances on Hawaii island. The extreme difference was 2007 mm (79 in) between Kaumana and Olinda and the least difference was 864 mm (34 in) between Kuiaha and Kukaiau. Even though rainfall and temperature varied considerably between the provenances and the study units, both temperature and moisture were within requirements of koa.

Field visits were done every two to four weeks during the first seven months after planting to monitor survival, control herbaceous weed competition, and to replant seedlings as needed. When replanting was required, we tried to use seedling stock grown from the same provenance. Unfortunately, we were not able to grow sufficient Kaumana seedlings to maintain full replacement at either Makawao or Olinda. Replanting seed-source treatment trees to use for analysis was stopped after May 1987. Replanting non-treatment trees was continued for about six months to maintain competition in plots.

We began regular tree measurements in November 1986 and continued every six months until sample trees were harvested. Harvesting began at Kuiaha in 1991 and followed in 1992 at Makawao and in 1993 at Olinda. Routine biannual measurements were done on the

Figure 1. Koa height over time. Solid symbols are Kaumana seedlings; open symbols are Kukaiau seedlings. Squares, circles, and diamonds indicate Kuiaha, Makawao, and Olinda study units. Error bar lengths are one standard error above and below the mean.



middle 16 trees of the 36-tree plots. Observations included measuring the height and stem diameter of each tree. Breast-height diameter (DBH) was measured when the seedlings exceeded 1.4 meters (4.5 ft). Before seedlings were tall enough to measure DBH, stem diameter was measured 2.5 cm (1.0 in) above the soil at the base of the seedling. At each measurement, we also observed and recorded several characteristics about each tree. These included seedling condition, leaf color, form, and growing tip quality. Tree form was classified for straightness and major branching below the crown.

Height growth

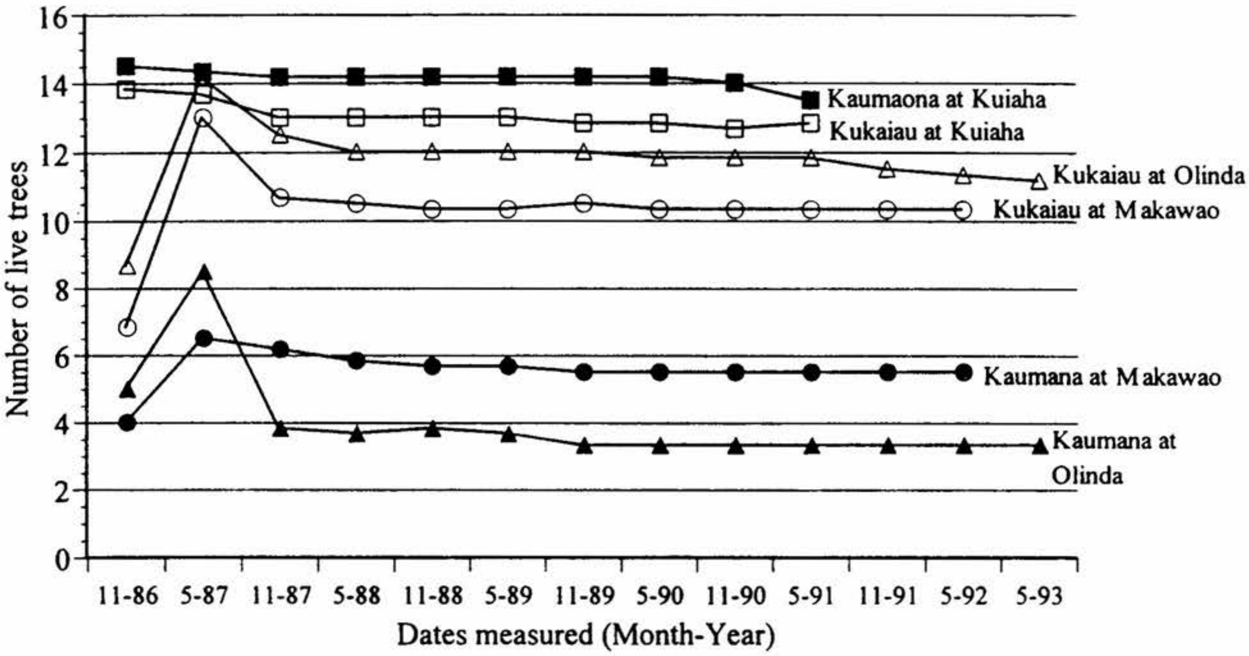
Tree height is presented here as an indicator of growth (Figure 1). Kaumana and Kukaiau koa growth was nearly identical at Kuiaha. At Makawao the data show 1.3 m/yr (4.26 ft/yr) average Kukaiau growth and 1.0 m/yr (3.28 ft/yr) Kaumana growth. By the end of the experiment, the difference was almost 2 m (6.4 ft). At Olinda, some significant differences in heights occured, but by the end of the experiment these differences were gone. Figure 1 also shows rapid growth at Kuiaha between November 1986 and November 1987, but then growth slows to less than at the other sites.

Live trees

Figure 2 shows the number of live treatment trees per 16 measure trees. At the end of the experiment, live trees numbered from an average of less than four Kaumana koa trees at Olinda to almost 14 at Kuiaha. Kaumana survival was greater than Kukaiau only at Kuiaha. Replanting between November 1986 and May 1987 was done at Makawao and Olinda because poor survival threatened to end the experiment. Replanting Kukaiau at Makawao and Olinda resulted in rebound from the initial 1986 survival. Kaumana replanting did little to improve the number of measurable Kaumana at Makawao and was of no benefit at Olinda. Non-treatment seedlings were planted as replacements when replanted Kaumana koa failed to survive. These trees were measured but not counted in the analysis.

Clearly, survival was best at Kuiaha. Poor survival at Makawao and Olinda was due partly to our inability to control competition. Herbaceous weeds and vines

Figure 2. Number of live treatment koa trees per 16 measure trees.



were the most serious competitors at both Makawao and Olinda. Grass competition at Kuiaha was not a threat to the seedlings.

Tree health

After the initial crash in survival, the tree health data did not indicate significant differences between the seed sources but did show differences between elevation transect units. The curves in Figure 3 were determined by dividing the number of healthy trees from both provenances by the number of all live measure trees. For this exercise, health was based on condition codes only. Trees in poor health sometimes continued to survive and remain in poor health. Rarely, seedlings that appeared dead recovered by resprouting from the base or lower stem. The ratio shows that health declined to about 90 percent at Kuiaha and was mostly near 98 percent at Makawao and Olinda.

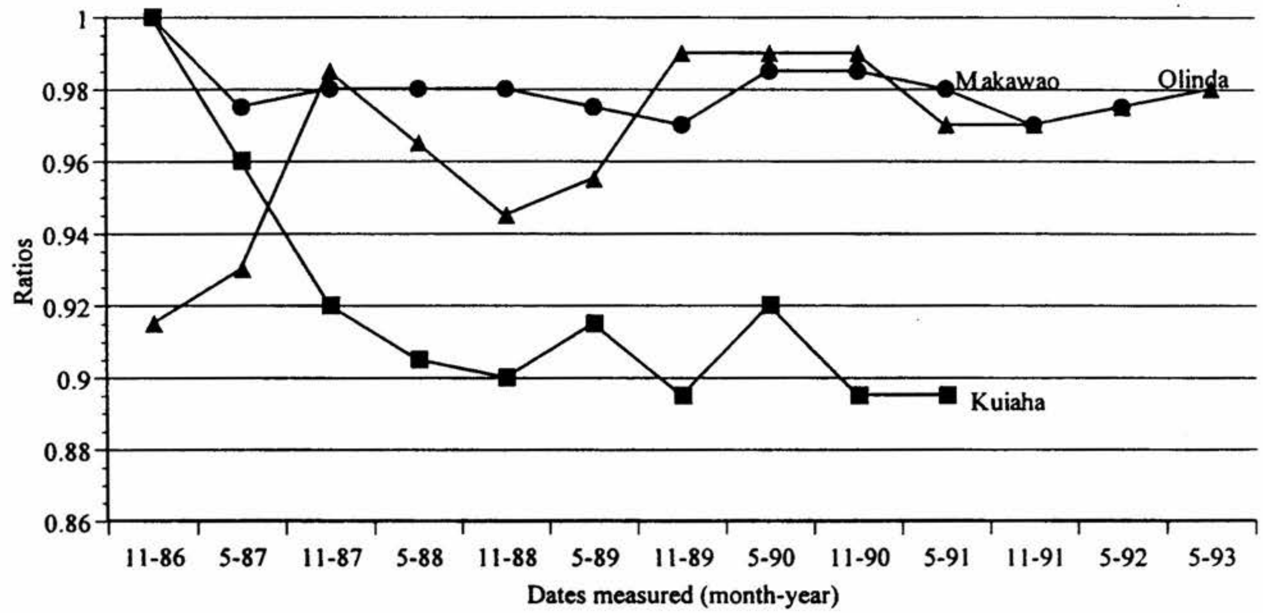
One major insect attack occurred at Kuiaha due to an outbreak of black twig borer in 1987 and 1990. The attack is reflected in the reduced health ratio shown in Figure 3. Various chewing insects attacked the trees at all three units but did not effect health enough to warrant assigning poor health codes.

Conclusions

Some of the reduced growth rate at Kuiaha might be due to the insect attack that occurred during the period of slow growth. The major difference among the study units was in the number of viable measure tree numbers. Clearly Kaumana koa survival was poorer at both Makawao and Olinda. The error bars for tree height were longer as a result. Kaumana koa heights did not reflect growth advantage from reduced within plot competition because we planted non-treatment koa into some of the gaps to maintain competition.

The data strongly suggest that new koa seedlings are most vulnerable to competition. In the first 19 months following planting, koa at Kuiaha grew at a rate of 2.27 m/yr. During the same period, average growth of both seed sources at Makawao and Olinda was only 0.69 m/yr. These estimates are based on healthy trees only and assume an average of 40 cm per seedling at planting time. A difference in the subsequent response was that the Kukaiau seed source recovered from the lack of early growth rate but Kaumana was less successful. Even though both seed sources showed good health after they became established, the Kaumana koa did not grow as rapidly as the Kukaiau. Further analysis is needed to

Figure 3. Ratios of healthy to live koa measure trees. Data are combined for both Kaumana and Kukaiau koa.



determine if these differences are likely to be real.

The number of live koa trees (Figure 2) continued to show some decline after the initial poor survival. This decline may not be significant, pending further analysis, but there is suggestion that the number of Kaumana koa at Kuiaha was declining because of latent effects of the twig borer attack. Several seedlings that were below the crowns of surrounding trees died during this period of decline. Kukaiau koa at Kuiaha did not appear to decline like Kaumana, but this may be artificial. Several trees in each plot from both provenances were not in the dominant layer of trees and probably would eventually have been lost. We did not observe any tree that was able to recover dominance after it was lost from any cause.

Acknowledgments

Thanks are especially due my co-workers at the Institute of Pacific Islands Forestry and at the University of Hawaii, Department of Agronomy and Soil Science, who provided expertise and land for the experiment. I particulary thank my research partner Dr. H. Ikawa for his cooperation and patience. The Hawaii Department of Land and Natural Resources provided land for the Olinda unit, personnel when we needed help, and transportation several times. Partial funding was provided from the Governor's Agricultural Coordinating Committee, GACC Contract No. 91-04.

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Questions

Conrad: All of these sites are on Maui, on the north slope of Haleakala. If you remember the maps shown earlier today [Potter], we were just outside of that koa growing area at Kuiaha.

Q: Gene, can you say something about the need for weed control on your plots versus the plots that Tom and Russel Yost were fertilizing more heavily.
Conrad: They did a good job of weed control. I believe they used Roundup; is that right Tom? [Tom: A sickle, too.] We used a sickle also, but that wasn't adequate. We had a safety problem with sickles. Once we got into it I really didn't want to do a major job with weed control because that was not fair because we could only do it on a few plots, so we left them uniform, grass and vines. Kuiaha was almost entirely grass. We had a lot of leguminous vines at Makawao and vetch up at Olinda, which I was familiar with as a kid in Oregon.

Development of Silvicultural Practices to Promote Growth and Quality of *Acacia koa*

N. S. Dudley, Hawai'i Agricultural Research Center

Acacia koa is the premier timber species of the Hawaiian forest. The range of *Acacia koa* has been greatly reduced due to logging, land clearing for agricultural production, and cattle grazing. Presently, the demand for *Acacia koa* lumber exceeds the sustainable supply. This has resulted in shortages and a significant increase in price. Landowners are considering reforestation with *A. koa* as a viable land-use alternative.

As these *A. koa* plantings expand, what combination of genetic potential and forest management will enhance the value of these regenerated koa forests? The first steps towards answering this question are the development of a forest management system for *A. koa* and the development of genetically improved seedlings for future planting.

Forest management options can range from no silvicultural interventions to a series of treatments over the life of the stand to promote quality and growth. Little is known about the effects of silvicultural treatments on stands of *A. koa*. However, related research indicates that faster rates of growth, an increase in the quality of timber in the stand, and a significant increase in value over unmanaged stands may be expected (Daniel et al. 1979).

Silvicultural management is most effective when combined with tree improvement. This ensures that the tree with the best possible genetic make-up is utilized to produce the most valuable forest product as rapidly and as efficiently as possible. The objective of a tree improvement program is to produce trees that exhibit superior growth rates, high quality wood, and resistance to pests. Several rate-of-return analyses on tree improvement programs indicate wood volume improvement as low as 6.3 percent will yield 8 percent return on rotation ages up to 50 years (Zobel 1984).

With the above introduction, I would like to share my experience managing *A. koa* tree improvement trials at Maunawili, O'ahu. This site is on former sugarcane land at 350 ft elevation. The soil series is Kaneohe silty clay loam. The historical average rainfall is 83 inches per year. The historical average temperature is 77°F. At this site, a series of *Acacia koa* family trials were established in cooperation with the University of Hawai'i in 1994, 1995, and 1996. There are over 150 different *A. koa* families, representing a state-wide collection.

Site preparation

When establishing a koa stand on former agricultural or range land where a seed bank of *A. koa* does not exist, sampling the soil of the planting area is very important to understand the nutrient status of the site. The planting site can then be amended as indicated by soil test results. In site preparation, the degree of tillage and depth are important considerations. Disking and ripping (subsoiling) operations need only occur along the planting lines as the site is prepared. Koa seedlings are highly sensitive to the quality of soil preparation. Better growth and survival of koa seedlings can be expected on sites that have been well prepared.

Planting stock

Only well-grown *A. koa* seedlings should be planted. Visually inspect the seedlings for vigor and check the root plug for rhizobium nodules. Here is the formula for tree improvement and characteristics of ideal *A. koa* seedlings: Plant *A. koa* seedling with best genetic potential + management at right time and amount = tree improvement. The ideal type of koa has highly figured wood, good stem form (straight and erect), good branch angles (and self pruning), resistance to insects and disease, and a moderate to fast growth rate.

Vegetation management

Weed competition will limit growth and survival of young koa seedlings. Control can be easily and economically accomplished with the selective use of herbicides or mechanical methods. Reduced competition of weeds for nutrients and soil moisture will enhance tree growth. Mechanical vegetation management methods include mowing, mulching, and crushing. Pre-plant herbicides should control a broad spectrum of weeds, and selective herbicides are used to control specific types of weeds post-planting. The post-planting control can then be further divided between preemergence applications and postemergent applications. To quickly establish the *A. koa* seedling, each of the chemical control methods were utilized.

Pests

Although the pests of koa are well known (Whitesell 1990), at the Maunawili site significant damage was caused by the black twig borer (*Xylosandrus compactus*). A qualitative index of insect damage was developed with a range of 0 to 4. A tree with no insect damage was given a rating of zero and the higher the amount of infestation the higher the score, with complete mortality scoring a 4. The scoring was based on 10 trees per plot. The following ranking was assigned: families scoring 20 or less were ranked as tolerant; families scoring between 20 and 30 were ranked as moderately susceptible; families with scores of 30 were ranked as being highly susceptible. There were 12 families of 35 (34.3%) that ranked as tolerant. An additional 20 families of 35 (57.2%), were ranked as moderately susceptible. Finally, 3 families of 35 (8.6%), were ranked as highly susceptible.

Maintaining growth and quality

At 30 months, the 1994 *A. koa* family trial was thinned by half per family. After identifying the dominant and codominant trees in the stand, a selective thinning treatment was applied. The thinning is expected to increase stand vigor by removing less vigorous trees and reducing competition for light and nutrients. This will also increase volume in the remaining trees.

The objective of pruning is to improve stem form and remove lateral branches at an early age to promote development of a single, dominant stem with defect-free, high-value wood. This is a two-step process. First, corrective pruning removes forks or multiple leaders from selected trees. Then, lateral branches are removed. Generally, this is done periodically until at least 9 ft of the tree is clear, because veneer logs are normally 8 ft long. This initial pruning treatment will be limited to 25 percent of the canopy leaf area of any one tree. Pruning wounds should be monitored for rates of closure and insect infestation.

Summary

This is an intensive approach that a land manager could use in managing *A. koa*. After three years of experience, we have gained some insight into how to establish a koa stand on former sugarcane land. The forest management techniques outlined above should be viewed as tools that can be adopted where appropriate. Finally, the issues of wood quality will take some time to answer. It is not known whether the offspring of a curly koa mother will retain the same character in the wood and if regenerated koa will retain similar wood properties to wild-grown koa.

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Questions

Q: Do you think pruning might increase susceptibility to the twig borer?

A: I don't know. My gut feeling is, no. I think the twig borer attacks a tree based on stress and maybe some physiological or chemical signals it gets. The more likely scenario might be a fungal or bacterial attack in the wound. I think the other thing that's important is the size of the pruned branch. It's important to get to the branches at a fairly small diameter so the wounds close fast.

Q: You showed crushing the sugarcane down and planting directly in it. Did the sugarcane become real competition? **A:** It's dead.

Q: Your sprayed it before you crushed it? **A:** Yes.

Q: My question has to do with wood quality versus the silviculture. You say you don't have the answer to get those high-quality woods.

A: My point is that you have to apply silviculture to get high-quality wood. On the other hand, I don't know. I haven't taken it to harvest. The path along the way may be full of obstacles.

Q: Do you have any suggestions on what path research could take to try and develop that relationship?

A: I suggest the questions generated by this study. You can break down each component. You can do more weed control studies. You can do more pruning studies. You can do more fertilizer studies. I feel that probably the two things to enhance stand quality would be looking at pruning and thinning in a critical way. A relatively condensed 24- or 36-month study might be appropriate.

Koa Stand Development and Grazing Impacts

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Introduction

People have a lot of questions about koa. "How long does it take for a full-statured stand to grow?" "How long do I have to wait before I get trees of commercial size?" "To maximize the profitability of a plantation, how long do I have to wait, and how many trees of what sizes will I get?" "If I want to thin, how many trees should I remove, and how long until the stand is again fully stocked?" "Can we graze cattle under and amongst koa trees, and what will this do to the koa stand?" Questions like these are quantitative, meaning that instead of "yes" or "no" answers, they ask "how much" or "how long," and the answers to them have to be based on measurements. Questions like these are also long-term, and would take longer than most professional careers (and certainly longer than funded research projects) to answer by "trying and seeing." Finally, the answers to these questions are affected tremendously by all the soil, weather, insect, disease, economic, and management factors and fluctuations that affect tree growth, vigor, and value.

Our research tackles these questions. Everything presented here is the result of measurements on koa trees in field environments, mainly upland areas of the island of Hawai'i. To make reasonable predictions about long-term events, we have analyzed records from permanent inventory plots, some of which are nearly 50 years old, and we brought together these patterns of koa recruitment, growth, and death into a quantitative prediction tool (a computer model) and added to this results of short-term, intensive studies of cattle impacts, light absorption by koa canopies, and grass growth. Finally, we have taken into account some of the ways that koa stands grow differently on sites ranging from "good" to "poor," the seemingly random fluctuations in sapling density and risks of tree death, and some reasonable estimates of timber quality and of effects of financial interest rates on economic outcomes of management choices.

It is my hope that this summary of our research will give land owners, managers, and advisors the information they need to sort out some of the choices confronting them. Naturally, we don't guarantee anybody that if they follow one of our graphs, they can become wealthy in a certain number of years, or that biodiversity of native flora and fauna will be perpetuated. For one thing, we don't claim to predict what catastrophes the future might hold. Also, the details, mathematical derivations, and assumptions of this work would take too much space (and have too much jargon) for this presentation, although they have been spelled out in a thesis (Grace 1995) and are soon to be reported in technical journals. What I hope to do here is to give enough detail and substance that people can put the results to work for them, and to provide just enough background that they understand how these came to be our best quantitative estimates of koa growth and effects of management.

Field studies

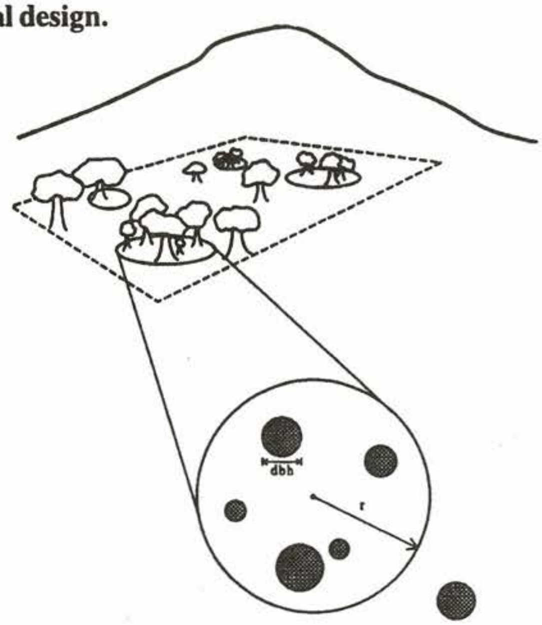
Three kinds of field studies have gone into this synthesis: long-term growth monitoring, grazing, and pasture shading (Table 1). Long-term monitoring plots were established by Hawai'i DLNR Division of Forestry and Wildlife foresters 5 to 12 years after clearing. Each tree was measured and its position recorded in 0.04 ha circular plots. Each plot was remeasured approximately every 5 years, until most recently in 1994. These results were analyzed to learn about and quantify the controls of growth, dominance, and death of koa trees. At each measurement, each tree had its growth rate calculated as the change in stem diameter since the last measurement. The rate of growth of each tree was compared with the relative ranking of the tree among the others in the stand. For each tree alive at a measurement, the probability of its dying before the next measurement was analyzed as a function of its current growth rate and relative dominance in the stand. Three plots (12, 23, and 24) were analyzed and used to estimate the coefficients of the computer model; plot 41 data was reserved as an independent test of the model.

A key concept in understanding the dynamics of koa forest development is stand basal area (Fig. 1). Stand basal area is the cross-sectional area of tree stems per

Table 1. Koa field studies.

Site location, Plots	Start date	Elev. (m)	Annual Rainfall (mm)
1. Long-term growth plots			
Waiakea Forest Reserve,			
Plot 12	1949	1250	3800
Plot 23	1963	1500	2500
Plot 24	1963	550	5000
Hilo Forest Reserve			
Plot 41	1974	1450	3800
2. Grazing study			
Pu'u Wa'a Wa'a Wildlife Refuge, Hualalai			
31 plots	1992	1400	1200
3. Shading and pasture			
Keauhou Ranch			
16 plots	1993	1500	1500

Figure 1. Stand basal area illustrated as the cross-sectional area of tree stems within a circular plot of radius r. Several other conceivable plots are illustrated to show that assessment of a tract of land requires a sampling strategy incorporating proper statistical design.

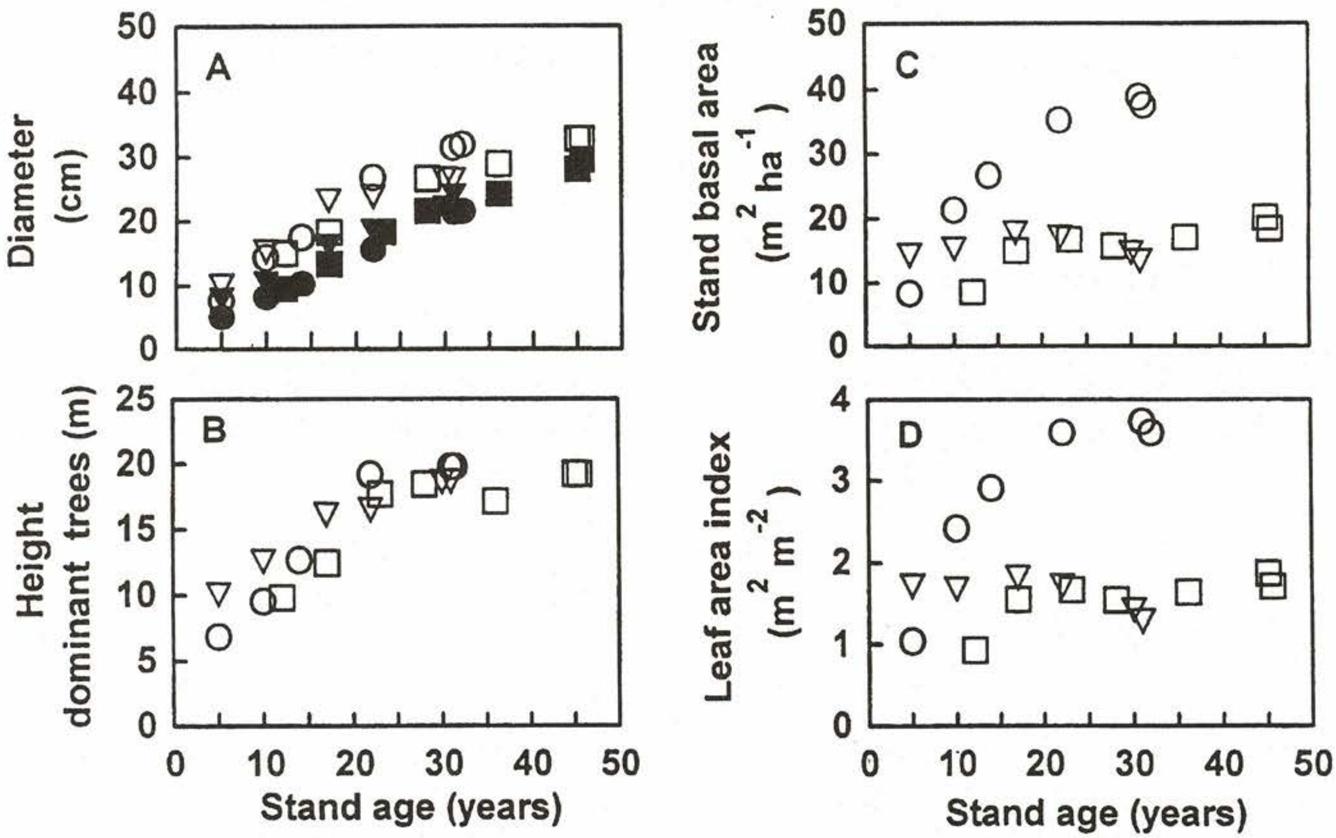


unit of land area. This index combines the effects of number and sizes of trees into one number that reflects the relative occupation of the site by forest. The biological basis for its use is the rough proportionality between sapwood, which conducts water through the stem, and the area of leaves exposed to the sun and drying air. Stand basal area can be measured by measuring tree trunk diameter at 1.4 m height (DBH) of each tree in a plot. These diameters are squared, added up, and multiplied by p/4, then divided by the land area. Typical ranges of basal area for fully developed koa stands would be 20 m^2 / ha for a "poor" site to 40 m^2 / ha for a "good" site. What soil, plant, and climate factors result in high or low maximum basal area for koa is only partly known: on Kaua'i we showed that it was related to rainfall and relative water stress (Harrington et al. 1995), and the question is being studied now on a variety of soil types in the Honaunau Forest by Adrián Ares.

The grazing study consisted of two experiments performed from 1992 to 1994 at the Pu'u Wa'a Wa'a Wildlife Refuge in Hualalai, Island of Hawai'i. One was a replicated trial using large paddocks, where high and low intensities of cattle grazing were compared with an ungrazed control treatment. Tree growth, survival, degree of defoliation, and indices of water status were measured. The initial tree population density and size class distributions from these plots were also taken to give a statistical picture of the variability of koa regeneration in former pasture land. The second experiment treated replicate single-tree plots with every combination of four possible grazing impacts: defoliation, soil trampling, grass removal, and manure deposition. This information, compared with the results of the large grazing trial, allowed us to establish which of these factors was most important in causing the observed effects on koa.

The pasture shading experiment was performed in 1993 and 1994 at the koa reforestation area of Keauhou Ranch. Sixteen 0.03 ha plots were established in areas of varying canopy density of koa. Light absorption by the koa canopy was measured with a group of sensors and a datalogger and averaged for a two week period. Permanent quadrats centered on each light sensor were harvested by clipping, to measure grass biomass, species composition, and forage quality. Rates of grass production (regrowth) were measured by clipping again at 0.5, 1, and 2 months.

Figure 2. Results of long-term monitoring of koa growth plots 12 (□), 23 (○), and 24 (▽), showing (A) average diameter of all trees (filled symbols) and of dominant trees (open symbols), (B) average height of dominant trees, (C) stand basal area, and (D) leaf area index (leaf area per unit ground area).



Results of field studies

The three growth plots had fairly similar trends of average stem diameter and dominant tree height over time but differed considerably in stand basal area (Fig. 2). Plot 23 in particular had nearly twice the basal area (Fig. 2C), and correspondingly greater wood volume, compared to the other plots. This result means that "site index" (height of dominant trees at a reference age), as used in some temperate forest management, would not be a useful indication of site potential for koa forest management. Instead, we propose that the maximum stand basal area that stands approach over time (Fig. 2) is more nearly related to a site's ability to support koa forest. In using this index at another site, the question arises, "How do we know whether a stand is at its maximum or not?" The only sure way is to measure it over time, but the present-day stand basal area could be used if, based on the experience and judgement of the land manager, the stand has not been disturbed for 10 or more years or if it seems to be as fully stocked as any nearby stands ever get under similar soil and climate conditions.

The approach of stands to a maximum basal area suggests that either tree growth slows down as the maximum capacity to support koa forest is reached, or that some trees die as fast as the remaining ones grow (or some combination of these two effects). The answer is found by analyzing the diameter growth rates of dominant trees: they slow down to nearly one third of their initial growth rates as the stand as a whole approaches its maximum basal area (Fig. 3). Why the dominant trees slow down as the stand as a whole reaches its maximum is a complicated question that is under study in several related projects. The answer may have to do with the size and proportions of leaves versus respiratory tissue in individual trees, or with depletion of resources (e.g., water or nutrients) by all the trees in the stand. Never-

Figure 3. Average growth of dominants in each plot and growth interval, versus stand basal area relative to the maximum basal area.

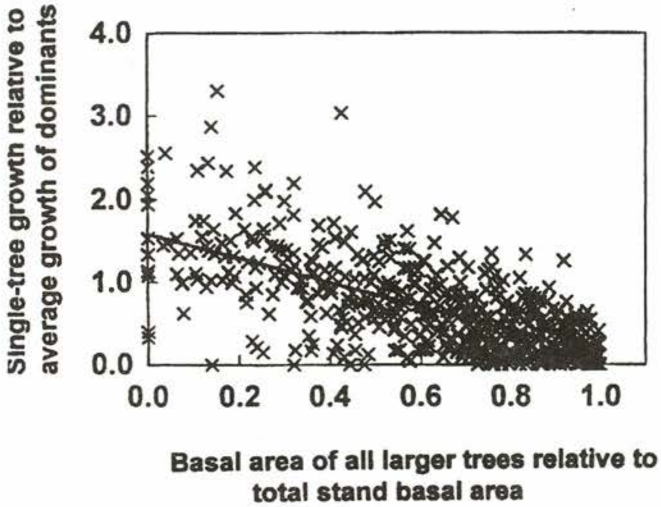
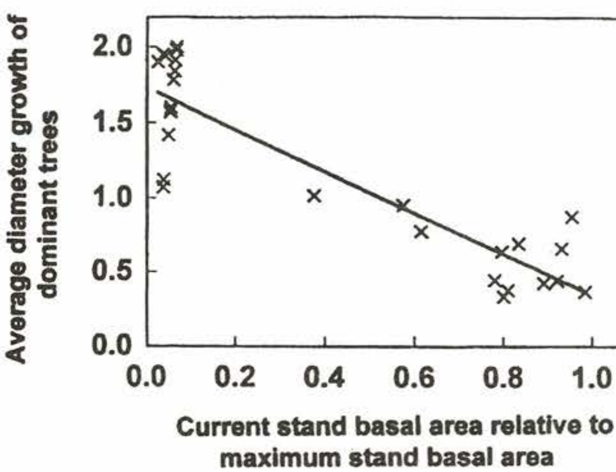


Figure 4. Growth of individual trees relative to the growth of dominants, versus an index to suppression within the stand (fraction of stand basal area in trees larger than the subject tree).



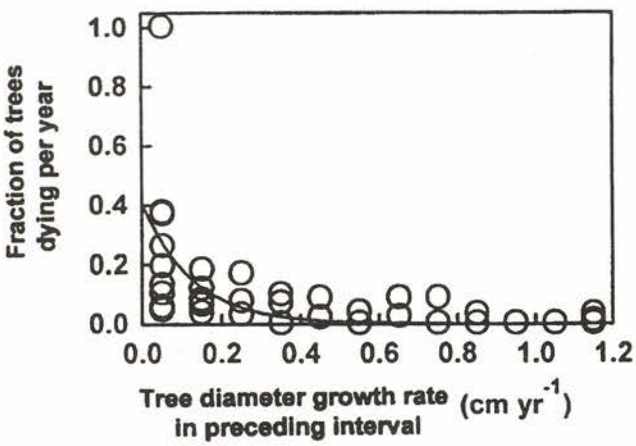
theless, the finding that dominant trees slow down is important in projecting how fast stands grow and develop. Whether the subdominant trees are suppressed by the dominants is the next question we took up.

One of the new findings of our work is the clear demonstration of a competitive hierarchy within koa stands. Because growth rates vary tree by tree, year by year, and also with site quality and stand age, it is difficult to see this pattern in the raw data. However, when diameter growth of each tree is expressed relative to the dominant trees in the plot, and suppression is expressed as the basal area of all the larger trees in the plot, relative to the total stand basal area, a strong trend can be discerned (Fig. 4). The more severely suppressed it is, the slower a tree grows compared to the dominants of the stand. Although there is a lot of scatter around the relationship, it should be noted that these data are for individual trees from all three plots across all the measurement intervals.

It is often assumed in predictions of temperate forest dynamics that trees growing below some threshold rate have a greater chance of dying. The idea is that trees with barely enough energy to keep growing are less likely to survive the insults of drought, disease, insects, and storms. We did not want to assume that the same relationship applied to koa forest without good evidence. For each plot, in each measurement interval, we grouped trees together according to their growth rates, and then calculated what fraction of each group did not survive until the next measurement. The results were striking—trees growing in the range of 0 to 0.1 cm / yr had on average three times the risk of dying as trees growing from 0.2 to 0.3 cm / yr (Fig. 5). It is somewhat hard to see in the scale shown, but even vigorous trees also had some chance of mortality, and the smooth fit to the data never quite reaches zero chance of dying. Although these stands did not suffer catastrophic disease, insect outbreaks, or direct hurricane impact, it should be noted that this sample includes more than 100 plot-years of data, during conditions when nearly 80 percent of the trees initally present had died before the last measurement. Taken together with the previous results, we can then predict that there is a strong tendency for smaller trees in a stand to be suppressed, and that these are more likely to die. This finding has important implications for management practices such as thinning or grazing.

In our second group of studies, on the effects of cattle grazing, we found that there was a strong relationship between the removal of leaf area by browsing and the reduction in tree growth (Fig. 6). For trees greater than 3 cm DBH, there was almost no mortality. In our second experiment, we attempted to understand what factors produced this result. We obtained clear proof that trampling the soil decreased tree growth rates (Fig. 7).

Figure 5. Probability of mortality versus diameter growth class.



In both experiments, koa shoot water status (xylem pressure potential) was decreased, suggesting that root damage interfered with water uptake. Interestingly, clipping the kikuyu grass from around the trees increased growth, showing competition from below the tree crowns (Fig. 7). We found a slight indication that this competition was for water, but further studies need to be done to really prove it. Manure had no significant effect on tree growth, because the nutrient content, averaged over the land area, was insignificant as a source of fertilizer. The approximate sizes of the negative trampling effect and the positive effect of release from competition with grass were about the same (Fig. 7), suggesting that the effects of grazing could be predicted well enough from simply the degree of defoliation from browsing. Interestingly, when the growth rate decrease from browsing was entered into the mortality function from the growth plots (Fig. 5), the calculated chances of a tree dying were very close to the observed mortality in the grazing trial. This check on the consistency of results from different studies suggests it is reasonable to integrate them for the purposes of long-term prediction of management outcomes.

In the third group of studies, we found that the koa canopies decreased kikuyu grass production in proportion to the density of shade cast. Interestingly, there seemed to be a competitive shift in the grass community from kikuyu to pu'u lehua grass as the shade increased. In kikuyu grass, there was a tendency for higher protein content under shade in both the standing and regrowth forage. The effects of these shifts in species

Figure 6. The relationship between stem diameter growth during the 12 months after grazing treaments versus the fraction of leaf are remaining after the treatment in light (◇) and heavy (▽) grazing treatments. "Heavy" grazing was putting enough cows into the experimental paddock to deplete all available forage in 3 days, while "light" was the same stocking for only 1 day.

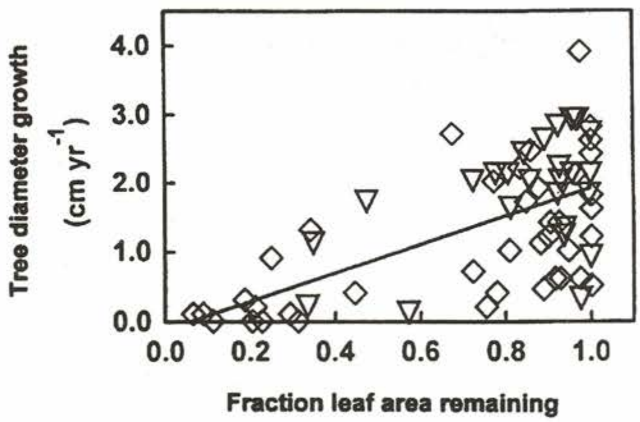


Figure 7. Mean diameter (A) and diameter growth rate (B) of trees trampled (circles) versus untrampled (squares) with grass clipped (open) versus unclipped (closed).

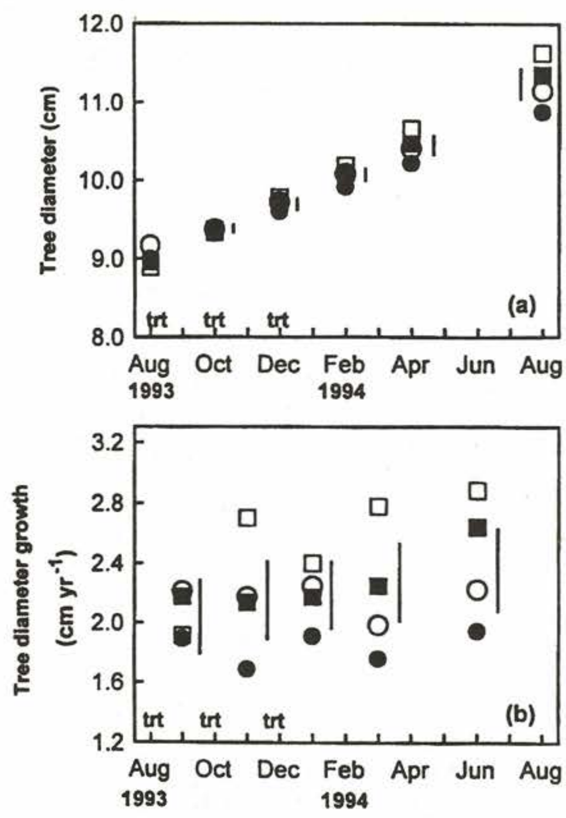
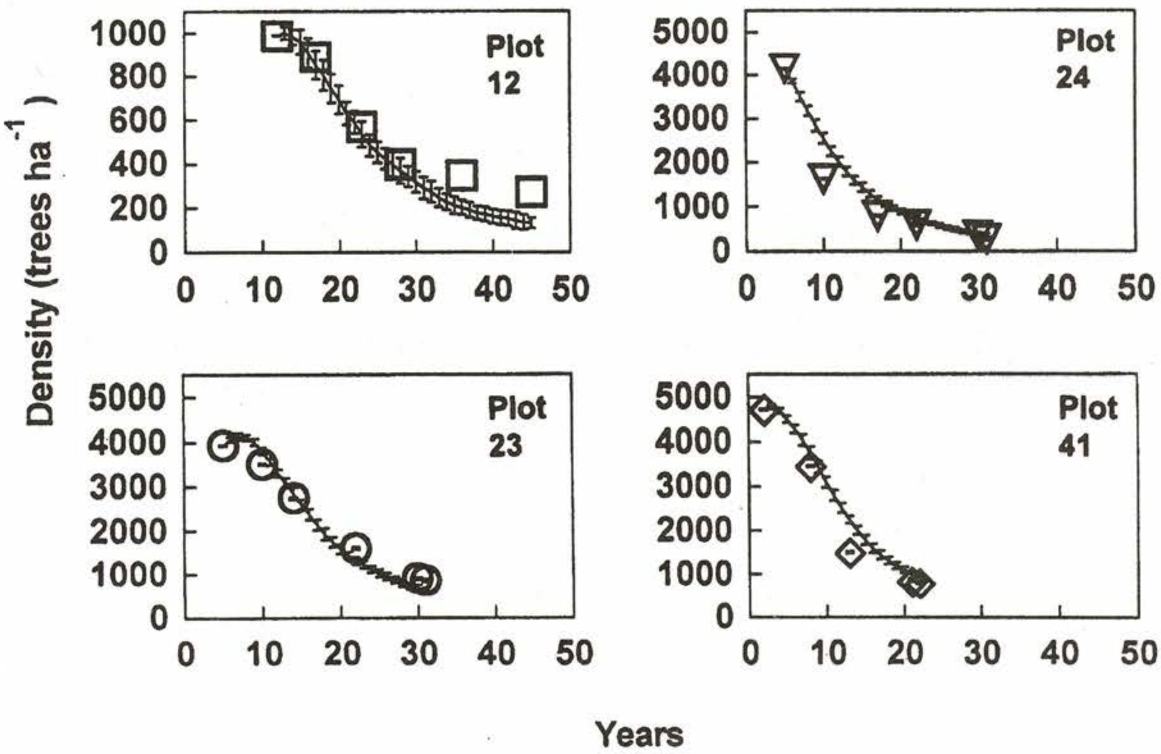


Figure 8. Measured (symbols) versus simulated (mean plus or minus 1 standard deviation) koa tree density over time, beginning with the initial conditions of the long-term growth plots.



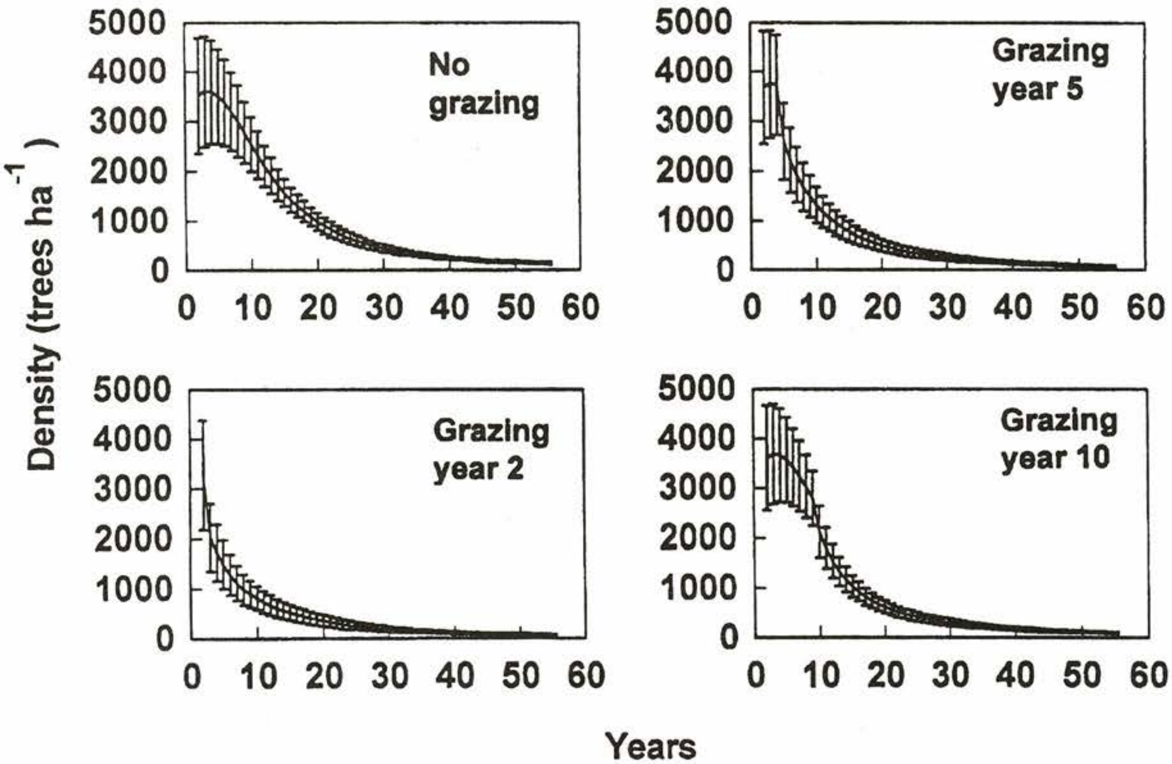
and forage quality were relatively small compared to the decrease in pasture productivity. We conclude that the basic decrease in grass growth under shade is the primary effect on pasture to be considered in a silvopastoral system of grazing under koa trees.

Predictions from synthesis of field studies

The goal of our synthesis is to pull all of these different studies together and come up with some answers to the questions posed by land managers. Naturally, the assumption has to be made that what was observed, perhaps in one place in certain years, applies to other places. But if we are unwilling to make this assumption, everything that has been learned about koa remains piecemeal, and thus unable to provide even provisional answers. I also want to reemphasize that in creating a computer model of koa growth and management, we did not take a model of some other forest and "tweak" it to resemble koa, nor did we invent functions with no basis in reality. Our first objective was to link these studies together by seeing their effects on the population processes (recruitment, growth, death) of koa. The results of the field studies, as summarized above, were statistically fitted by equations, and these equations were linked together to predict the outcomes of management choices.

In addition to synthesis, another objective of our approach is to deal directly with variability. It is obvious from the results that trees, groups of trees, sites, management impacts, and years fluctuate considerably despite our attempts to discern "average" trends. Nowhere is variability more important than in initial stand establishment in old pasture and in mortality of trees. Furthermore, some decisions may be based more on consideration of risk ("What are my chances of going bust?") rather than average or typical returns. For these reasons, we used the number-crunching power of the computer to simulate a collection of plots, which might be viewed as a sample of plots from a larger landscape, and drew random numbers (distributed according to measured averages, probabilities, and variances) to determine the number of saplings starting a plot and, annually, whether each tree dies. An interesting result of

Figure 9. Simulated effects of cattle grazing on reforested old pasture based on cattle being intoduced in various years since stand establishment.



this approach is that the computer predictions are not exact, but cover a range similar to the range observed in field studies.

In addition to variability, the clear effect of tree size on damage by cattle and the development of suppression and its effects on growth and mortality required that we adopt a size-structured approach. In simpler words, the assumption that a koa population acts like collection of "average" individuals is simply no good. This approach is again dependent on the processing powers of the computer, but it has the advantage of bringing together the size-dependent and seemingly random features of forest growth.

Initial conditions specified at the beginning of each scenario are equations describing the relative proportions of leaf area and woody biomass as a function of tree size, the maximum basal area for the simulated site and the land area of the simulated plot, and the parameters for the equations describing koa recruitment, growth, death, shading, and pasture growth. There are two ways of creating initial populations. The first is to read in a list of measured tree diameters. This approach was useful in the testing of the model versus field data from growth plots. The second approach is to draw a random number of saplings (with a random average size) based on the plots set up in young koa forest growing on old pasture. This approach was useful for simulating various potential management strategies for silvopastoral systems.

In each simulated "plot" we keep track of the size of each individual tree, and each year we estimate its growth rate based on site, stand basal area, position in the size hierarchy, and leaf area removal by grazing (if any); chances of mortality are calculated from growth rate. If the draw of a computer-based random number falls within the range of mortality, then that tree "dies" and is removed from the list of living trees. Then the next tree is considered, until the plot is finished and a new year begins. An estimate of merchantable wood volume of the stand is made from measurements of the size of the clear bole in field-grown koa trees, then reduced 50% to roughly account for defects in the wood.

Each run of the same initial conditions was repeated 50 times to give a reasonable picture of the outcomes of the specified conditions.

Beginning with the initial measurements of the growth plots, the model predicted well the changes in tree density due to mortality over time (Fig. 8). Plot 41, which was not used in the calibration of the model, also was well predicted by the model. The large drop in number of living trees means that deliberate thinning to increase the value of the koa stand is a good idea. Because so many of the trees are ultimately doomed to die, in particular the suppressed ones, forest managers may want to choose healthy or promising trees to be among the few that survive. For example, given roughly 50 percent natural mortality between years 10 and 20, a fairly radical 50 percent thin at age 10 would seem justifiable. At present, we cannot predict some of the characteristics that most affect the economic value of a stand (e.g., wood color and figure), so the decision of how much and what to thin out must also be made based on the experience and judgement of the manager.

Another interesting feature of the model results is the relatively small spread among the replicate runs (Fig. 8). The competitive hierarchy was already established early in the life of the stands, and despite all of the random-number drawing in the program, the predictions converged on a relatively tight trajectory around the averages. By comparison, the simulation of reforestation of old pasture showed much wider variability as a result of the patchiness of koa sprouting and early growth (Fig. 9). This variability was then "funnelled down" into a much tighter pattern, again as the result of competition and its effects on growth rate and mortality in stands. Although simulation of grazing beginning at years 2, 5, or 10 had fairly large effects on the number of trees (Fig. 9), there was relatively less effect on simulated merchantable volume (Fig. 10). This surprising result is caused by the fact that the largest trees have the bulk of the merchantable volume and are dominant in the stand, and suffer the least damage from cattle browsing. Even the most radical treatment of bringing in the cattle at year 2 only reduced volume by one-third or so at age 50. The appearance of trees of merchantable volume around year 15 was highly variable, due to the decision that any stem less than 30 cm was "not" merchantable. As the accumulation rate of merchantable volume tapers off around 40 years, the discount rate would become greater than the relative rate of increase in volume or value; for this reason one might conclude that 35 to 40 years is the time required until peak profitability of a koa timber harvest. Obviously many other factors are weighed in the decision whether or not to harvest all or parts of a stand.

Conclusions

To answer some of the questions posed at the beginning, although trees of commercial size (30 cm) begin to be obtained around 15 years, it would be inadvisable to harvest them at that point, because they are just starting to accumulate value. Our estimates, which include the effects of discount rates and many other detailed factors, suggest that the time until maximum profitability of a koa rotation would be about 35 to 40 years. After that time, the stand continues to accumulate in value, but at a slower relative rate than the discount rate. A basic problem facing a land manager is determining the ultimate potential of a given site to support koa.

A central concept emerging from this work is that stand basal area is able to capture much of the variation in stand dynamics we see among sites and over time at a given site. Fortunately, it is something that consulting foresters and land managers can measure rapidly without computers or other fancy gear. Henceforth, it should be part of every forest description and management plan, along with a description of what sampling or cruising strategy was used to determine it. Furthermore, if the results summarize here hold up elsewhere in Hawai'i, the traditional concept of site index (height of dominants at a reference age) does not seem useful for koa.

The question of how many trees of what size survive until some point in the future, and the related question of how much to thin a stand, are both based on how important population processes are to koa forests. For one thing, most koa trees die by natural processes before the stand reaches what could be considered its economic point of harvest at 40 to 50 years. Growth rates and chances of dying are inextricably linked together with the whole stands' approach to the maximum capacity of the site and with each tree's relative ranking within the stand. We are only beginning to understand what controls the site capacity for koa, but that doesn't mean we shouldn't be managing forests now. A manager seeking to increase the economic value of a stand may wish to preempt the 50% mortality seen naturally from 10 to 20 years, and perhaps again from 20 to 30 years, in favor of removing the 50% of least promising individuals from the stand. By the same token, the large variability in young regenerating stands may not be a "problem" in the sense that stand densities eventually even out due to self-thinning of the higher-density areas. Finally, although our data spans many years and many conditions, it is fair to admit that none of the growth plots were directly devastated by hurricane or pests, and we cannot yet estimate the risks of factors like these.

About the question of whether cattle can be grazed under koa, and what effects will that have, our results confirm the observations that cattle damage trees, and yet in the long run, the loss of volume may be relatively small compared to other benefits of grazing, such as grass and weed control, cash flow, and (possibly) taxes. A silvopastoral agroforestry system of koa and cattle appears promising on these grounds. A caveat on this conclusion is that our grazing experiments were not chronic and the cattle were very carefully managed, having adequate forage and water at all times. It may be that continued root damage could open the way for diseases and foster decline of koa stands.

A final conclusion to this work is to reiterate the need for synthesis and for performing studies that can be linked into synthetic schemes. Individual experiments, field observations, and unreplicated demonstrations may all have their appeal today, but unless they fit into a larger context their conclusions will forever remain piecemeal. We have a long way to go in pulling together what is already known about koa, but these results suggest a promising future for koa forestry and agroforestry.

Acknowledgements

This work was supported in part by the McIntire-Stennis forestry research program and in part by cooperative agreement with the USDA Forest Service. Thanks for help and access in the field go to the Pu'u Wa'a Wa'a Ranch, the Hawai'i DLNR, and Kamehameha Schools/Bishop Estate. Particular thanks are due to the DLNR's Division of Forestry and Wildlife and USFS staff, who generously shared data from growth plots and ongoing koa biomass and leaf area work.

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Questions

Q: How many animals for grazing?

A: This was a short-term, intensive grazing management. We had five animals in each experimental paddock, which was a small area, but they were only in there for one day. We had a more intensive treatment where they were in there for three days. This was based on their ability to completely browse down all the green fodder on the ground. So this was not like letting your cows go and coming back in two months and saying "Okay, how many head were there on your acreage?" This was very intensive grazing management, but the three-day grazing treatment did remove all the green fodder.

Acacia koa: A Review of its Diseases and Associated Fungi

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Abstract

Acacia koa (koa), among the most prominent overstory species of native Hawaiian forests, is affected by a number of diseases, including those caused by rust fungi, wood-rotting fungi, root-infecting fungi, and diseases categorized as seedling blights, foliar infections, and vascular wilts. A number of fungi occurring saprophytically on koa substrates are also known. Symptoms of other apparent diseases and disorders of unknown origin, or whose cause has not been clearly demonstrated, are often manifest as leaf spots or other foliar abnormalities. Endemic pathogens which have evolved with their host may be responsible for many of the heretofore observed disease conditions, and as such usually do not threaten koa populations. However, a condition tentatively referred to as "koa decline" may represent an exception. This condition is characterized by slow to rapid wilt and death of apparently healthy, vigorous trees of all ages, occurring in more or less well defined disease centers. This phenomenon is particularly prominent in upper-elevation koa forests on the slopes of Mauna Loa on the island of Hawai'i. Other apparent decline problems on O'ahu and elsewhere in the Islands have been reported, some associated with insects. The relationship of these observations to the koa decline on the Big Island has yet to be determined, and the question as to whether "koa decline" represents a complex of disease conditions or can be more closely attributed to a single, specific cause requires further study.

Koa (*Acacia koa* Gray), endemic to the Hawaiian Islands, is the second most abundant overstory species in upper-elevation forests. It forms nearly pure stands in montane forests such as those on the slopes of Mauna Loa between approximately 4000 and 7000 ft (1230 and 2150 m) (Whitesell 1990). Koa is distinctive in the formation of crescent-shaped phyllodes which, in older trees, assume the function of the pinnately compound true leaves produced in juvenile stages of development.

As an endemic tree, koa is of critical ecological importance, forming habitat for numerous native birds, insects, and other flora and fauna. As a nitrogen-fixing leguminous species, koa is thought to account significantly for the nitrogen content of otherwise nitrogen-poor volcanic forest soils (Whitesell 1990). Koa is also prominently represented in early Hawaiian legends and culture, and economically is considered the most valuable of the common native timber species. Koa wood, sometimes referred to as "Hawaiian mahogany," can be highly polished to emphasize its deep reddish coloration and wavy grain, and is used for furniture, paneling, and such woodworking crafts as bowls and ukuleles.

St. John (1979) recognized three distinct species as representing the genus *Acacia* in Hawai'i: *A. koa* Gray, *A. koaia* Hbd., and *A. kauaiensis* Hbd. Furthermore, within *A. koa* three varieties were recognized: *A. koa* var. *koa*, found on all major Hawaiian islands; *A. koa* var. *latifolia* (Benth.) St. John (= *A. koa* var. *hawaiiensis* Rock); and *A. koa* var. *waianaiensis* St. John; the latter two restricted to the islands of Hawai'i and O'ahu, respectively. Although the current treatment of *A. koa* (Wagner et al. 1990) combines all of these forms within *A. koa*, the distinction among them is still apparently sufficient to delimit the host ranges of host-specific pathogens, such as the rust fungi. Reference to St. John's classification is therefore useful to this discussion.

Several observations of diseases and pathogenic fungi occurring on koa have been individually reported in the literature as they have been observed over the years (Raabe et al. 1981), or have not been formally published. It was of interest to assemble such published information, together with as yet unpublished observations of fungi and disease conditions of koa, to provide the basis for a discussion of the pathology of this pivotal species.

Diseases caused by rust fungi

Rust fungi, members of the order Uredinales, are so called because of the often brownish to orange appearance of the spore masses. These fungi produce perhaps the most widespread and prominent diseases of koa, collectively referred to as koa rust. Stevens (1925), originally described a single fungus, *Uromyces koae* Arth., as the cause of the disease, but five species of rust fungi, four of which are considered endemic and one indigenous, are currently recognized on koa (Hodges and Gardner 1984, Gardner 1991), each with distinctive symptoms. These include three species now placed in the genus *Atelocauda*, *A. koae* (Arth.) Cumm. & Y. Hiratsuka, *A. digitata* (Wint.) Cumm. & Y. Hiratsuka, and *A. angustiphylloda* Gardner, and two species of *Endoraecium*, *E. acaciae* Hodges & Gardner and *E. hawaiiense* Hodges & Gardner. *Atelocauda koae* occurs commonly on *Acacia koa* var. *latifolia* on Hawai'i. and on *A. koa* var. *koa* on Kaua'i, O'ahu, and Maui. It has not been reported on Moloka'i, nor has it been found on *A. koaia* anywhere. *Atelocauda koae* is confined to young tissue, occurring most frequently on newly developing true leaves, phyllodes, and shoots of saplings, but also found on new shoots of older trees. It is evident as raised, powdery, brown leaf spots, 1–10 mm diameter, occurring singly or in groups, on both leaf surfaces. Heavy infection, in which spots coalesce to form large, irregular powdery blotches, can cause severe distortion of leaves, shoots, and small branches, leading to stem deformation (Hodges and Gardner 1984, Chen et al. 1996).

Atelocauda digitata is known from all major islands except Lanai, although its presence on this island in upland forests would not be surprising. On *Acacia koa* var. *latifolia*, the conspicuous stages of this fungus cause "witches'-brooms" up to approximately 15 cm tall, comprised of clustered, misshapen, abnormally thickened shoots developing from infected branches. The diseased tissue may be covered by powdery, brown spore masses that are easily rubbed off. Removal of witches' brooms is ineffective in controlling the disease, because the fungus invades branch tissues systemically. From one to many brooms may occur in a tree. Less conspicuous stages of *A. digitata* occur as small, brown, raised sporulating pustules up to approximately 1 mm diameter on the surface of otherwise normal phyllodes. Occasionally such spots are surrounded by larger chlorotic spots, causing them to be more conspicuous. *Atelocauda digitata* kills branch portions distal to the broom, but entire trees are typically not killed by this fungus alone. On *Acacia koa* var. *koa* on Maui and O'ahu *A. digitata* produces hypertrophy of flower and shoot tissue, resulting in malformation, but it does not produce witches' brooms typical of those on *Acacia koa* var. *latifolia* (Hodges and Gardner 1984).

Atelocauda angustiphylloda is confined to *Acacia koa* var. *latifolia* and is limited in distribution on the island of Hawai'i, but visible in large koa trees on the upper Saddle Road. This rust forms large (up to 1 m tall) witches' brooms comprised of hypertrophied but abnormally reduced, much narrowed phyllodes almost circular in cross section, giving a "shoe-string" appearance (Gardner, in press). As with *A. digitata*, brooms are covered with powdery, brown spore masses. Although limited in distribution, large numbers of brooms (100+) may occur in certain mature, presumably susceptible trees. Host trees appear to tolerate infection by *A. angustiphylloda*, but loss of vigor and local tissue death may occur.

Endoraecium acaciae, the most common of koa rusts, has been found on *A. koa* var. *koa* on Maui, Kaua'i, and Hawai'i, and on *A. koaia* on Hawai'i, Kaua'i, and Moloka'i. It has not been found on *A. koa* var. *latifolia*. This fungus produces conspicuous, profusely branched brooms up to 30 cm long comprised of much-reduced, flattened phyllodes covered with spore masses. In apparent contrast to other koa rusts, *E. acaciae* may cause severe damage to the host, and heavy infections producing multiple brooms may kill the entire tree. Brooms of *E. hawaiiense* are similar to those of *E. acaciae* but are smaller, being seldom taller than 12 cm, and relatively inconspicuous. This fungus appears to be limited in distribution, having been found only at certain sites on O'ahu on *A. koa* var. *waianaiensis* and *A. koa* var. *koa*. An insufficient number of trees heavily infected with this fungus has been found to assess its potential for host damage. The two species of *Endoraecium* are further separated from one another by differences in spore morphology.

Wind-distributed spores of the koa rust fungi are thought to be the principal means of long- and short-distance dispersal, although Leeper and Beardsley (1973) noted the possibility that the koa psyllid *Acizzia uncatoides* (Ferris & Klyver) [= *Psylla uncatoides* (Ferris & Klyver)] may at least in part account for short-distance dispersal where populations of these insects are high. Wherever koa rust diseases are observed, evidence can be found of variability in susceptibility to infection among neighboring individual trees. Koa breeding programs directed at selecting such resistance may be the most effective control approach for rust diseases.

Wood-rotting fungi

A number of diseases of koa caused by wood rotting, "higher" fungi (i.e., basidiomycetes) have been described. These fungi are characterized by external production of fleshy or woody fruiting bodies which are often conspicuous and indicate the presence of already well-established internal infection. Bega (1979) reported *Phaeolus schweinitzii* (Fr.) Pat., *Laetiporus sulphureus* (Bull. ex Fr.) Bond. & Sing. (= *Polyporus sulphureus* Bull. ex Fr.), and *Pleurotus ostreatus* (Jacq. ex Fr.) Kumm. for the first time in Hawai'i. These species, together with *Armillaria mellea* (Vahl ex Fr.) Quél. and *Ganoderma* sp., were associated with deteriorating old-growth stands of koa on several thousand acres of range land in the Keanakolu, Halepiula, Spring Water Camp areas of Hawai'i Island at an elevation of 5000 to 6000 ft. (1540 to 1840 m).

Wood-rotting fungi produce characteristic types of infection, such as brown cubical rot of heartwood produced by *Phaeolus schweinitzii* and *Polyporus sulphureus*, but positive field identification is usually possible only if the fruiting body is present. An exception, however, is *A. mellea*, which causes a stringy white root and butt rot of a wide range of woody hosts in Hawai'i and elsewhere, including koa (Laemmlen and Bega 1974, Raabe and Trujillo 1963), produces distinctive "shoe-string" rhizomorphs and mycelial fans under infected bark by which it may be identified. Bega (1979) reported that the honey-colored fruiting bodies (mushrooms) of this species were not known in Hawai'i; but fruiting bodies of a fungus agreeing with *A. mellea* in its previously described broad concept have now been found to be common in certain sites (G. Wong, personal communication).

A new species of *Phellinus*, described as *P. kawakamii* Larsen, Lombard, & Hodges, recently was found on *Acacia koa* var. *koa* and *A. koaia* on Kaua'i (Larsen et al. 1985). The same species was also found on *Casuarina equisetifolia* L. on Hawai'i and O'ahu. This heartwood-decaying fungus produces white pocket-rot in its hosts and is characterized by a large fruiting body (to 70 cm wide, 20 cm thick) which is produced near ground level and may be obscured by leaf litter and thus easily overlooked. No fruiting bodies were found on koa during casual observations made in old-growth stands on O'ahu, Maui, and Hawai'i. However, internal decay typical of that produced by *P. kawakamii* was found in a substantial number of stumps of *A. koa* var. *koa* trees salvaged following the 1982 hurricane, indicating that presence of fruiting bodies may not indicate the true incidence of disease in a stand (Larsen et al. 1985). Rather than killing their hosts directly, pathogenic heart and root-rotting fungi destroy timber usefulness and predispose trees to wind-throw and branch or stem breakage. Nelson and Wheeler (1963) reported that more than half of the large koa trees reported in the 1959-1961 forest survey were considered unmerchantable because of excessive wood rot.

Other higher fungi associated with koa, either as saprophytes on dead material or as weak parasites, were reported earlier by Burt (1923). These include *Schizophyllum commune* Fr., a common wood-inhabiting fungus of wide host range and world-wide distribution, where it occurs on dead parts of living trees and on hardwood slash. As an exception to its normal saprophytic activity, *S. commune* was reported to cause wilting of planted three-year-old *Acacia* saplings in South Africa (Ledeboer 1946), but similar virulence on koa has not been documented. *Fomes fasciculatus* Burt was described as a new species on dead koa on Kaua'i, and *F. hawaiensis* Forbes in Lloyd was found on koa on Hawai'i, Kaua'i, Lana'i, and Moloka'i, but its pathogenic ability was not mentioned. Burt (1923) also reported the wood-rotting fungi *F. australis* Fr. on Kaua'i and *F. fullageri* (Berk.) Cke. (location not given) on koa. Although not classified among the higher fungi, wood-inhabiting fungi of the family Xylariaceae: *Hypoxylon annulatum* (Schw.) Mont., *Nummularia guarantica* Speg., and *Xylaria rhopaliodes* Mont. have been reported on koa (Stevens 1925). These genera produce dark, usually conspicuous stromata (fruiting bodies) visible on the bark of infected tissue. The above genera are distinguished by the general morphology of their stromata: flat or cushion-like in *Hypoxylon*, cup-shaped in *Nummularia*, elongate or club-shaped and borne on stalks in *Xylaria*. Most members of the Xylariaceae are saprophytic or weakly parasitic, which is probably true of the species occurring on koa.

Root infections

The ubiquitous "water mold," *Phytophthora cinnamomi* Rands, a root-infecting fungus favored by the oxygen-deficient conditions of waterlogged soil, is known to attack a wide range of plant species. This pathogen was isolated from roots of koa, among those of a number of other forest species, in studies directed at determining its role in the decline syndrome of 'ohi'a (*Metrosideros polymorpha* Gaud.) in Hawai'i

(Kliejunas and Ko 1976). Koa was categorized with species considered "moderately tolerant" to the fungus (Kliejunas 1979), suggesting that *Phytophthora* root rot, while present under conducive soil conditions, usually was not a significant disease of koa. Other ubiquitous root-invading pathogens with wide host ranges, including the fungus *Rhizoctonia* sp. (Raabe et al. 1981) and the root-knot nematode *Meloidogyne incognita* (Kofoid & White) Chitwood (Raabe 1966), have also been found on koa, but the extent of any damage from these agents was not reported and is presumed to be minimal.

Seedling blights

Two species of the fungus *Calonectria* have been reported as causes of koa diseases. *Calonectria crotolariae* (Loos) Bell & Sobers, the pathogen causing collar rot of papaya (*Carica payaya* L.) seedlings, also caused a severe collar rot among a dense cover of koa seedlings reforesting a burned area in Kipapa Gulch in the Ko'olau Mountains of O'ahu (Aragaki et al. 1972). The disease caused a quick decline and collapse associated with signs of fungal growth and production of orange-red fruiting bodies near the soil line. Death occurred two days following onset of symptoms. A slower decline also was observed among some seedlings, in which lower leaves became chlorotic and a progressive wilt led to seedling death in seven days. *Acacia melanoxylon* R. Br. ex Ait. seedlings also were found to be susceptible when inoculated with the fungus from culture. Whereas the incidence of collar rot on koa seedlings was severe, it appears to have been a single event resulting from the coincident occurrence of several predisposing factors. Shoot blights caused by *C. theae* Loos were reported on koa and 'ohi'a on O'ahu (Nishijima and Aragaki 1975). The disease, which also is known to occur on other species of *Acacia*, causes small dark spots on leaves and green twigs. Whereas artificial inoculation of koa seedlings resulted in considerable leaf drop, natural infection has been found only infrequently in Hawaiian forests and was not found to cause significant damage in these environments.

Gardner (1980) reported a severe wilt disease of seedlings of *Acacia koa* var. *hawaiiensis* Rock (= *A. koa* var. *latifolia*) caused by a specific form of the vascular wilt fungus *Fusarium oxysporum* (Schlecht.) Snyd. & Hans., designated *F. oxysporum* f. sp. *koae* Gardner. The disease appeared spontaneously among seedlings grown from seed collected in Hawai'i Volcanoes National Park, and the fungus was shown to be seedborne. Experimentally inoculated seedlings of *A. koaia, A. confusa* Merr. (Formosan koa), and *A. simplicifolia* Druce, the latter two being introduced species, were also wilted by the fungus. *Fusarium* wilt diseases have been reported in a wide variety of agricultural and horticultural crops on a world-wide basis, where historically they have been of major economic importance.

Foliar infections

Sutton and Hodges (1983) described a new leaf-spotting fungus, *Gloeocoryneum hawaiiense* Sutton & Hodges, on *A. koa* var. *koa* at Makaha Ridge on Kaua'i. Although *G. hawaiiense* originally was found on only two trees, both trees were heavily infected. Leaves infected with this fungus have since been found on Maui (Gardner, unpublished). The fungus appears as small, dark, spore-producing leaf spots (conidiomata), often arranged in short, more or less linear rows 30–120 mm long. Following maturity of the conidiomata, the immediately surrounding area becomes necrotic. Notwithstanding the severe leaf infection, the disease was reported to cause little apparent damage to the host itself. A leaf spot disease in which numerous (i.e., > 30 per cm^2) dark, circular to oblong spots, 0.8–1.5 mm in diameter, on both phyllode surfaces was observed among koa trees planted in plots near Kahului, Maui (J. Tavares and D. Ogata, unpublished). The spots, which sometimes coalesced to produce larger blotches, were associated with *Alternaria alternata* (Fr. ex Fr.) Keissl., although the role of this fungus as the primary cause of the disease is questionable and remains to be experimentally demonstrated. This fungus most often occurs as a saprophyte or a weak parasite on a broad range of plant hosts. The dry conditions of the koa plots outside of their natural elevational range may have placed the trees under unnatural stress, predisposing them to infection. *Alternaria alternata* also was reported on koa leaves in Hawai'i Volcanoes National Park, but a description of symptoms of infection was not included (P.H. Dunn and G. Baker, unpublished). Stevens (1925) reported *Lophodermium intermissum* Starb. on presumably live koa at Wahiawa, O'ahu, and Pogue's Ditch Trail on Maui. Species of *Lophodermium* may occur either saprophytically or parasitically, causing leaf spots containing dark, erumpent fruiting bodies.

The Meliolales, or "dark mildews," are found primarily in tropical regions and are well represented in

Hawai'i, occurring on a wide range of native species. The members of this well-defined group are closely allied with one another and have other characteristics in common with the powdery mildews (order Erysiphales) and the rust fungi. Like the rusts, they are highly specialized, usually host-specific, obligate parasites (that is, they cannot be cultured on artificial medium but require living host tissue for survival). Most of the species of dark mildews occurring in Hawaii are known only from endemic host species, and are themselves considered endemic (Stevens 1925, Goos and Anderson 1972). The dark mildews are conspicuous as black, more or less circular spots or blotches on leaf surfaces. The fungal colony, which may appear somewhat thick and velvety in texture, may occur as an isolated spot, or several colonies may coalesce to cover much of the photosynthetic area. The dark mildews are sometimes confused with another group of black fungi, the sooty molds, which occur superficially on plant or other surfaces and are not considered parasites. *Meliola koae* Stev. is recognized as the species occurring on koa (Stevens 1925, Goos and Anderson 1972). A second species, *M. bidentata* Cke., also was reported on koa by Raabe et al. (1981) based on previously unpublished data from the files of the Department of Plant Pathology, University of Hawai'i at Manoa. The identity of this fungus appears questionable and should be confirmed through further collection.

Petrak (1953), in his "Contributions to the Fungal Flora of Hawai'i," listed a number of fungi associated with native plants, including the leaf-spotting fungus *Mycosphaerella koae* Petr., which he found on dry seed pods of koa at Kona (Hawai'i Island) and described as a new species. Although the original collection was associated with dead tissue, members of the genus *Mycosphaerella* are often parasitic and are known to cause serious leaf diseases of other hosts (Hanlin 1990). Other than the initial report by Petrak, no information apparently is available concerning occurrence of *M. koae* on koa, however.

A number of apparent phyllode infections occur, some commonly, for which a cause has not been found. Although leaf-spotting fungi in such cases are usually suspected, sporulation or fruiting, which is necessary to identify such agents, has not been observed. Of particular note among these symptoms is a prominent chlorotic (yellow) speckling which is frequently observed on *A. koa* var. *latifolia*. Until fungal agents of known pathogenicity are isolated as the probable causes, the possibility that such symptoms may also result from abiotic factors, such as physiological stresses or imbalances, must also be considered.

Vascular wilt diseases

As was indicated by the seedling disease caused by *Fusarium oxysporum* discussed above, pathogenicity and host range of the suspected causal agents of these diseases is most easily demonstrated experimentally on seedlings. However, vascular wilt diseases are typically virulent on all developmental stages of the host, where they cause rapid, irreversible wilting and decline. On older plants, the fungus systemically invades the vascular system and is contained within internal tissues during most stages of disease progression and is therefore not directly visible. In agricultural systems, development of resistant varieties has been relied on as the only practical control approach to a number of economically important vascular wilt diseases of crops caused by *Fusarium* and *Verticillium*. Genetic resistance is probably present in population of forest species as well, including koa, but has not yet been as well investigated or exploited.

Centers of decline among koa stands in the Mauna Loa Strip region of Hawai'i Volcanoes National Park have been observed for a number of years (Gardner, unpublished). Some such centers are apparently no longer active or are progressing slowly within mature stands in which a number of older trees have died. On the other hand, well-defined centers of decline are obviously active among otherwise vigorous stands of koa in the Mauna Loa Strip, in which pre-senescent trees of all ages, including saplings, are rapidly dying. Symptoms of the decline point to *Fusarium* wilt as a possible cause (Gardner 1980). *Fusarium* agreeing with the description of *F. oxysporum* f. sp. *koae* has been isolated from diseased trees at these sites, cultured and shown to be virulent to inoculated healthy seedlings (Gardner 1980; unpublished). However, lack of consistent recovery from older trees to date suggests the need for more thorough investigation before definite conclusions can be drawn. In 1994 a *Fusarium* isolate associated with wood discoloration was recovered from branch sections of a mature, dying koa tree, marked by progressive thinning of the crown, at a homestead on Mt. Tantalus, O'ahu. Pathogenicity of the isolate was subsequently demonstrated in inoculation tests of koa seedlings

(Gardner and E. Yoshino, unpublished data). Because decline caused by vascular wilt organisms may be rather nondescript, without overt evidence of the causal agent, death of isolated, individual trees such as this possibly occurs more commonly than is currently recognized.

Koa decline

Addressing the subject of koa decline, Laemmlen and Bega (1972) reported that according to aerial surveys in 1954, 67,000 acres of koa and ohia forests occupying approximately 600,000 acres on the island of Hawaii were in slight (<20% dead trees) to severe (60% dead trees or more) decline. In 1965, the affected areas had increased by 10,000 acres, and the severely affected portions had increased from 5000 acres in 1954 to 14,000 acres, with more recent ground surveys indicating a steadily deteriorating situation. The decline was characterized as a rapid wilt and death of trees and/or a slow progressive decline causing a thinning of foliage with many dead twigs, followed eventually by complete defoliation and death. The most severely affected forest was on the slopes of Mauna Kea at an elevation of 750–1700 m. Laemmlen and Bega (1972) mentioned several possible causal or contributing biotic agents, including the fungi *Armillaria mellea, Phytophthora cinnamomi*, and *Diatrype princeps* Penz. & Sacc.; the insects *Xylosandrus compactus* Eichoff (black twig borer) and *Plagithmysus bilineatus* Sh., a native wood-boring beetle; together with the activities of wild pigs and other mammals (presumably rats). Damage to young koa by stripping of bark from limbs and trunks has been documented as an apparently common phenomenon, with up to 54 percent of trees sampled in four- to six-year-old stands in the Laupahoehoe and Waiakea areas on the island of Hawaii affected (Scowcroft and Sakai 1984). Whereas in this study complete girdling by such bark removal was rare, injury has been observed in the Mauna Loa Strip region of Hawai'i Volcanoes National Park in which girdling, presumably caused by rats, resulted in the death of branches of older trees. Such effects result in conspicuous browning and wilting of foliage and may be confused with disease symptoms, such as those generally attributed to koa dieback (Gardner, unpublished). Abiotic factors such as changes in soil drainage were also suggested as possible contributing factors. Although Laemmlen and Bega (1972) indicated that quantitative and qualitative studies of the decline were to be initiated, the original scope of the work became separately focused on the prominent ohia decline phenomenon (c.f. Hodges et al. 1986), with little emphasis on koa. The extent to which a vascular wilt disease may be operative in the forest decline syndrome described by Laemmlen and Bega is not known, but the high degree of host-specificity characteristic of the wilt *Fusaria* suggests that such a disease would not fully account for a general decline of forests including both koa and 'ohi'a and possibly other species.

Nonpathogenic fungi associated with koa

In addition to the diseases and disease conditions of koa described above, and to the fungi that under favorable conditions may cause or contribute to koa disease, a number of fungi have been reported associated with koa tissue as saprophytes. Petrak (1952) described as new species two stromatic fungi found on dead koa branches on Mt. Tantalus: *Diaporthe sheariana* Petr. and *Thyridaria koae* Petr.

Fungi also have been found existing on leaf surfaces but causing no apparent harm to the plant. Members of the genus *Pestalotia* are frequently isolated from diseased tissue, but their role as pathogens is questionable. *Humicola brevis* (Gilman & Abbott) Gilm. and species of *Pestalotia*, including *P. angusiana* M.B. Ellis, *P. breviseta* Sacc., and *P. stevensonii* Peck have been found on apparently healthy koa phyllodes in Hawaii Volcanoes National Park (G. Baker, unpubl.). A number of other more or less common fungi, including *Cylindrocephalum* (= *Chalara*) sp., *Cylindrocarpon* sp., *Cylindrosporium* sp., *Epicoccum purpurascens* Ehrenberg, *Papulospora* sp., *Sporotrichum laxum* Nees, *Stachybotrys atra* Corda, and *Triscelophorus monosporus* Ingold also have been reported on koa leaves (phyllodes) or leaf litter (Goos 1978; G. Baker and P.H. Dunn, unpublished records in the University of Hawai'i Department of Botany). Whereas some saprophytic or epiphytic species are more or less generalists, capable of subsistence on a wide variety of substrates, others show some degree of specificity. In a study to determine the association of fungi with leaf surfaces of three endemic trees, koa, 'ohi'a, and olapa (*Cheirodendron trigynum* (Gaud.) Heller.), Baker et al. (1979) found a large number of fungi on leaves of 'ohi'a but significantly fewer on koa phyllodes and leaves of 'olapa, which were not as widely sampled. They concluded that the smooth phyllode surfaces of koa retained spores poorly. Stoner et al. (1975), listed a large number of fungal species in surveys of soil of root zones of native vegetation types, including *A. koa* var. *hawaiiensis*, of the Mauna Loa region of Hawai'i Volcanoes National Park.

Conclusions

Whereas a considerable number of fungi and other possible disease agents (i.e., nematodes) are associated with koa, relatively few of these currently cause diseases of significance to the general well being of native *Acacia* in Hawai'i. Outbreaks such as the above-described seedling collar rot caused by *Calonectria crotolariae* are locally devastating but, because they depend on a coincidental occurrence of several conditions favorable to disease development, are observed only rarely. Many wood-rotting fungi, while probably more prevalent than published reports indicate, are most prevalent in older, senescent or presenescent trees, often hastening but not causing their decline. Among the exceptional diseases which may impact otherwise vigorous, actively growing trees are those caused by rust fungi and agents responsible for the koa dieback observed in the Mauna Loa Strip area of Hawai'i Volcanoes National Park. The rust fungi attacking koa are relatively well understood and all are thought to be native species, closely related to one another, having evolved in close association with their hosts (Hodges and Gardner 1984). While infection causes branch flagging, with heavy infection by *Endoraecium acaciae* resulting in some apparent death of koa, and timber quality may be affected by distortion of the terminal development of young trees infected with *Atelocauda koae*, rust diseases are not considered threatening to koa populations.

Perhaps the most ominous threat to koa, from the standpoint of disease, is the koa decline syndrome, currently prevalent and well defined in the Mauna Loa Strip region of Hawaii Volcanoes National Park. As stated above, although the presence of *Fusarium oxysporum* f. sp. *koae* has implications, the extent to which this fungus contributes to the decline is not known. Likewise, the relation of decline in this location to other, more incidental death of koa trees elsewhere throughout the islands, is not known. Perceived increases in frequency of such deaths may be a result either of increased awareness of koa itself or reflect an actual disease situation. Research directed at elucidating these problems is anticipated.

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Growth Response of Koa to Phosphorus Applications at Planting on Two Tropical Soils

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Abstract

A field experiment with 5 rates of P (0, 150, 300, 600, and 1400 kg ha^{-1}) applied at planting was conducted with two provenances of *Acacia koa* on a Rhodic Eutrustox (Oxisol), Wahiawa soil series, and a Typic Kanhaplohumult (Ultisol), Leilehua soil series, to determine the effects of phosphorus applications on the growth and nutrient response of koa. Both provenances increased in height, basal diameter, and diameter at breast height with increasing rates of phosphorus in the first two years of growth. Growth of the low elevation provenance was better on the Oxisol than on the Ultisol. The lower water-holding capacity of the Ultisol probably contributed to the poorer growth on the Ultisol. Height of the lowland provenance increased from about 0.4 m at transplanting to 2.6 m at two years with 1400 kg P ha^{-1} compared to the unfertilized plants which increased in height from 0.4 m to 1.5 m in the same period. In contrast, the high elevation provenance increased from 0.4 m at transplanting to 1.6 m at two years with 1400 kg P ha^{-1} while the unfertilized plants increased from 0.4 m to 0.86 m in two years. Application of phosphorus at planting to phosphorus-deficient soil increased the growth rate of transplanted koa.

Introduction

There is considerable interest in reforestation with *Acacia koa* in areas where native forests have been cleared for pasture, crops, and other uses. Many of these areas have high rainfall and the soils are usually acid with high amounts of soluble iron and aluminum. These soils have low phosphorus content and can readily fix applied phosphorus making it unavailable to plants. Young koa trees transplanted in these soils with existing vegetation must compete for light, nutrients, and water. The lack of phosphorus severely limits the growth of many young plants and it is believed that the establishment of transplanted koa in these soils is hindered by the lack of adequate phosphorus. Therefore, we decided to evaluate the effects of phosphorus fertilizer applied at planting on koa seedling growth. Our objective was to determine the growth response of koa from two seed sources to phosphorus applications on two soils, an Ultisol (Leilehua series) and an Oxisol (Wahiawa series).

Materials and Methods

Location. The experiment was conducted at the Waiawa Correctional Facility located in Central O'ahu on the leeward side of the Ko'olau moutain range. It is at 250 m elevation and recieves about 1270 mm rainfall annually. Annual air temperatures average 22°C. Soils in the area belong to the Oxisol and Ultisol orders.

Treatments. The treatments consisted of five rates of phosphorus, two sources of koa seed, and two soil series. Seedlings from the Pacific Palisades seed source were planted in both the Leilehua and Wahiawa series while those from the Kukaiau seed source were planted only in the Wahiawa Series because the seed supply was limited. A comparison of seed sources was carried out in the Wahiawa series while the comparison of soils was carried out with the Pacific Palisades seed source. The treatments were installed in each soil series as a randomized complete block design with four blocks. Spacing of trees was 2m x 2m and there were 16 trees per plot. Measurements were made on the interior four data trees in each plot.

Seed sources (provenances). Seed was collected from the Pacific Palisades (PP) area on the island of O'ahu at an elevation of 275 m, with an annual rainfall of 1500 mm and an annual temperature of 22°C and from the Kukaiau (KK) area on the island of Hawai'i at an elevation of 1100 m, with an annual rainfall of 2000 mm and an annual temperature of 18°C. The seed was germinated in dibble tubes by the U.S. Forest Service on the Island of Hawai'i and the seedlings were shipped to Oahu for transplanting in the experiment.

Soils. The experiments were planted on soils of two soil orders. The Leilehua series is a Typic Kanhaplohumult (Ultisol) and the Wahiawa series is a

Table 1. Analysis of soils. (0-30 cm depth)

Characteristics	Leilehua	Wahiawa
Avail. water (pct)	8.0	16.0
pH (water)	4.8	5.0
Organic C (g kg^{-1})	26.1	29.5
Total N (g kg^{-1})	2.3	2.5
Ca (cmol kg^{-1})	0.4	1.8
Mg (cmol kg^{-1})	0.4	1.7
K (cmol kg^{-1})	0.2	1.2
Extractable Al (cmol kg^{-1})	3.10	0.45
Al Saturation (%)	74.0	5.7
P-Mod. Truog Ext. (mg kg-1)	6.7	10.0

Rhodic Eutrustox (Oxisol). The chemical characteristics of the soils are given in Table 1.

Phosphorus treatments. The five rates of phosphorus applied were 0, 150, 300, 600, and 1400 kg P ha^{-1}. The seedlings were transplanted on April 14-16, 1992 in the following manner. About half of the phosphorus, as triple superphosphate, was applied in the bottom of the planting hole, mixed with soil, then covered with a layer of soil. The seedling was positioned in the hole and about 3/4 of the hole filled with soil. The remaining phosphorus fertilizer was applied to the outer edge of the hole and the hole was filled with soil. No additional phosphorus or other fertilizer was applied to the trees.

Data collection. Plant height and stem diameter at 10 cm above the ground were made monthly for the first 12 months after transplanting and then every four months for the second year. Diameter at breast height (1.4 m) was recorded as the trees grew.

Results and discussion

Both provenances exhibited a response to phosphorus at 24 months in the Wahiawa series (Fig. 1a); however, PP was significantly taller than KK. The response to P application was essentially linear at 24 months. The PP provenance grew more slowly on the Leilehua series than on the Wahiawa series. Similar response patterns were evident in the diameter at breast height (DBH) measurements (Fig. 1b). The high Al saturation (74%), generally lower fertility, and lower water holding capacity probably contributed to the slower growth of the PP provenance on the Leilehua series.

The rate of growth of the PP provenance on the Wahiawa series over the 24-month period reflected the phosphorus treatments (Fig. 2a). The unfertilized trees grew 110 cm in this period while the trees that received 1400 kg P ha^{-1} grew 220 cm. The differences between the higher P rates became more apparent as the trees grew for 20 months or more. The growth trends were more evident in DBH and the trees that received 1400 kg P ha^{-1} at planting were growing at a very rapid rate in the last 8 months (Fig. 2b). It appears that at least 300 kg P ha^{-1} is required for reasonable growth of koa and growth is even better with higher P rates. It is interesting to reflect on the fact that the phosphorus fertilizer was applied 24 months earlier in the planting hole. At that time, the tree roots were concentrated in the soil volume of the planting hole, but as the trees grew, their roots extended far beyond the planting hole and extracted nutrients from a much larger soil volume. Apparently the applied phosphorus stimulated growth of the entire plant, including the roots, and made them more effective in extracting nutrients from the soil due to increased root length, root number, root volume, etc. The readily available supply of P in the P-deficient soil gave the trees a boost that kept them growing at an increasingly faster rate than those that received no P or smaller amounts of P at planting. Trees that received the higher amounts of P fertiilizer would have a better chance to survive in a forest than those given little or no P. This assumes competing plants would not have access to the P.

The growth rate of the KK provenance on the Wahiawa series (Fig. 2c) was much slower than that of the PP provenance. The unfertilized trees grew 40 cm in the 24-month period while the trees that received 1400 kg P ha^{-1} grew 120 cm in the same period. This is in marked contrast to the growth of the PP provenance mentioned above. The response to P application was minimal in the first year with the 150 and 300 kg P rates producing similar growth and the 600 and 1400 kg P ha^{-1} treatments having similar growth, but it was higher than that with the 150 and 300 P treatments. After the first year, the effects of the P rates became more evident, although they were not very large. The reduced growth rate of the KK provenance is strikingly evident in the DBH measurements that never exceed 1 cm (Fig. 2d). The decrease in DBH after 12 months is due to the death of the main stem and the growth of secondary stems that were smaller. In many plants the apical buds

Figure 1. The effect of five rates of phosphorus fertilization applied at time of planting on height and stem diameter at breast height of two provenances of 24-month-old *Acacia koa* planted in an Oxisol (Wahiawa soil series) and an Ultisol (Leilehua soil series).

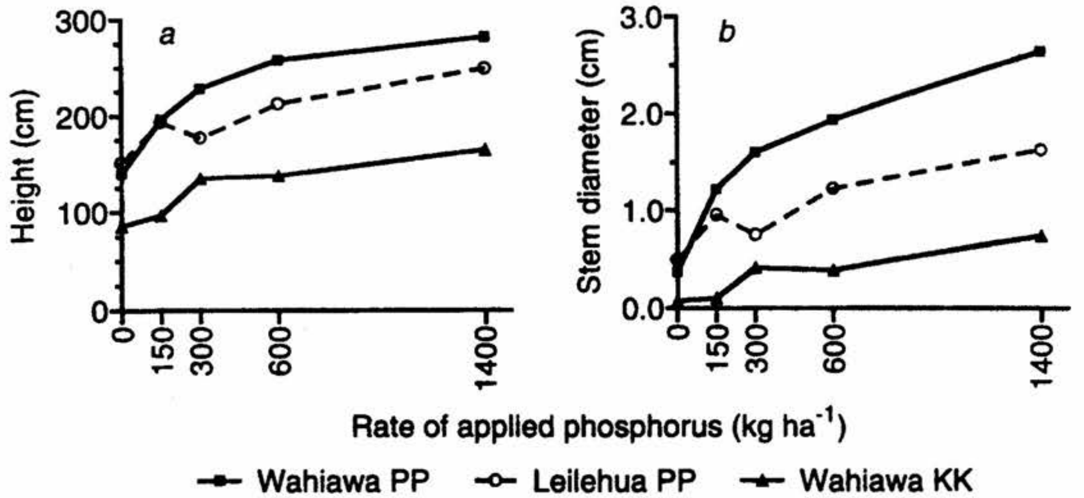
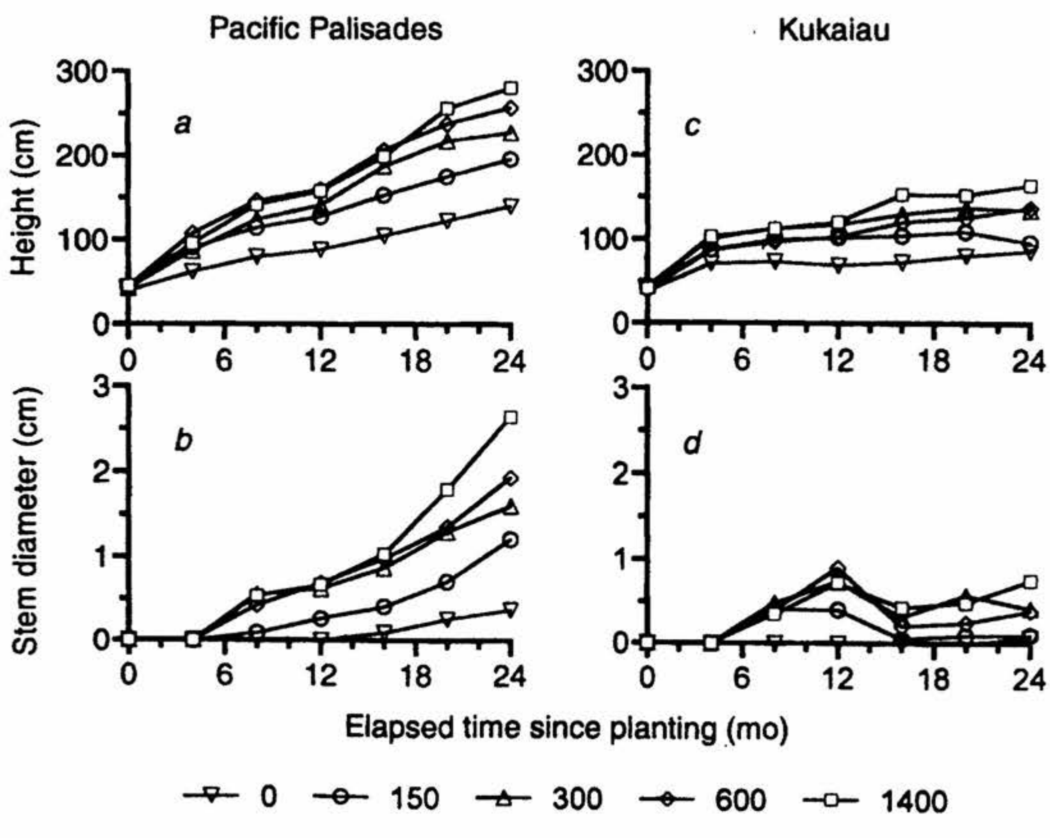


Figure 2.Mean height and stem diameter at breast height growth of *Acacia koa* trees during the 24-month period following planting in an Oxisol (Wahiawa soil series) as a function of seed source and the rate of phosphorus applied at time of planting.



remained dormant or the tip of the stem died. Obviously the KK provenance was not adapted to the environment at the site and did not grow well. This emphasizes the importance of selecting a koa provenance from a site with similar environmental conditions as the site in which it is going to be planted.

Conclusions

The following conclusions may be drawn from this study.

1. Both koa provenances benefitted from application of phosphorus at planting and the effects were still evident at 24 months after planting.

2. For the Pacific Palisades provenance, maximum growth at 24 months was obtained with 1400 kg P ha^{-1} on both soil series. For the Kukaiau provenance, maximum growth was also achieved with 1400 kg P ha^{-1}, but the increase over 300 and 600 kg P ha^{-1} was small.

3. The Pacific Palisades provenance was better adapted to the environment of the Wahiawa series than was the Kukaiau provenance.

4. Growth of the Pacific Palisades provenance was better on the Wahiawa series than on the Leilehua series.

Acknowledgements

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Questions

Q: You mentioned that you were using treble super phosphate as your phosphate source. Isn't that highly soluble? At the end of the 24 months how much of the original application will still be there for use by the plant?

A: Probably not a great deal, but phosphorus, although it's very soluble when you first add it, does get tied up as iron phosphate in soils with low pH. Therefore, although it's not immediately available, it can be released over time, gradually. So there would still be some slow release of some of the phosphorus that's there. I remind you it's in a very small area or volume of the soil. When we applied the phosphorus, we put some of it in the bottom of the hole before planting, mixed it up with a layer of soil, then put the seedling in. As we covered it up, we had about 2/3 of the hole filled, we applied the rest of the phosphorus in a ring on the outside of the 8-inch holes, and that's all they had. It was very close. When the roots first came out they had a very good supply of phosphorus, but then as they grew out they got into the soil itself. Koa does have mycorrhizal associations and therefore, with the mycorrhizae and that large root volume that they eventually had with the high phosphorus, they were able to pick up phosphorus in the soil.

Q: Did you test and see if there were any mycorrhizal associations with all of the different provenances at the different sites?

A: We didn't actually measure that, but we should have. Generally, forest koa does have. There is koa in the vicinity, so my guess is that it is mycorrhizal.

Impacts of Hurricane Iniki on Koa Forests

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Abstract

On 11 September 1992, Hurricane Iniki struck koa forests we had studied along an elevation gradient (500 to 1300 m) on western Kaua'i. The hurricane decreased canopy leaf area by 29 to 80 percent, and damage was proportional to pre-hurricane leaf area and canopy height. At some sites, phyllodes were stripped from intact branches, leaving the canopy otherwise intact. At other sites, many large branches and a few entire trees were broken off, thereby removing most of the overstory canopy. The canopy damage resulted in a large pulse of litter, ranging from 4 to 19 t ha^{-1} across our study sites. In the first six months following the hurricane, tree growth rates decreased in proportion to leaf area lost. Thereafter, growth rates increased, generally following the pattern of leaf area recovery. Survival of severely damaged koa trees (losing more than 75 percent of their crowns) ranged from zero to 80 percent, and was higher at wetter sites. Koa seedling densities were highest at mid-elevation sites as a result of both high emergence and high survival. Seedling densities were lower at sites with greater amounts of hurricane-induced litter. The alien species guava (*Psidium guajava*) generally had higher survival than the native 'a'ali'i (*Dodonea viscosa*), both as adults and as seedlings, but there was relatively little invasion of alien species following the hurricane. At these sites, there was no drastic change in species composition following hurricane disturbance, and forest structure and productivity had recovered to a great degree within two years.

Introduction

Hurricanes are a major force affecting the structure and function of tropical forests. The passage of Hurricane Iniki (11 September 1992) over the island of Kaua'i provided an opportunity to assess mechanisms controlling the patterns of damage and recovery of Hawaiian forests. Prior to the hurricane, we had found that canopy leaf area, canopy height, and woody biomass increment of koa (*Acacia koa* Gray) stands increased along a gradient of increasing elevation and rainfall (Harrington et al. 1995). Taller stands or those with greater amounts of leaf area may be more susceptible to wind damage than would shorter or sparser canopies, and it is reasonable to expect that more severely damaged stands would recover more slowly and show greater reduction in growth and survival. Differences in patterns of damage and recovery across species may have important implications for conservation of native forest if alien species survive better than natives. Also, recruitment of aliens into damaged native forest may cause changes in forest community dynamics and species composition. Our overall objectives were (1) to assess if hurricane-induced damage was related to pre-hurricane stand characteristics along a naturally occurring gradient of stand height, canopy leaf area, and productivity, and (2) to assess how species differed in their responses to damage, both as adults and as seedlings, because of the implications for long-term changes in species composition and the impact of alien species on native Hawaiian forest. A more detailed account of this study is presented by Harrington et al. (1997).

Severity of hurricane damage has been related to stand characteristics in other studies. Within a site, taller or larger diameter trees are more damaged than smaller trees (Basnet et al. 1992, Foster 1988, Gresham et al. 1991, Reilly 1991, Walker 1991). An analysis of the distribution of damage from the 1938 hurricane in New England indicates that the proportion of damaged trees increased with increasing stand height (Foster and Boose 1992). Therefore, we hypothesized that hurricane damage would be proportional to koa stand stature and canopy leaf area across the elevational gradient, and that within a stand the largest trees would be the most damaged.

An important impact of hurricanes on forest ecosystems is the large flux of biomass from the canopy to the forest floor. In Puerto Rico, Hurricane Hugo resulted in a loss of 6.0 t ha^{-1} leaves and 13.5 t ha^{-1} branches and boles from aboveground biomass in floodplain forest (Frangi and Lugo 1991) and approximately 10 t ha^{-1} of fine litterfall in subtropical wet and lower montane sites

(Lodge et al. 1991). Leaf litterfall induced by Hurricane Allen ranged from 6.1 to 13.7 t ha^{-1} in lower montane Jamaican forest (Thompson 1983).

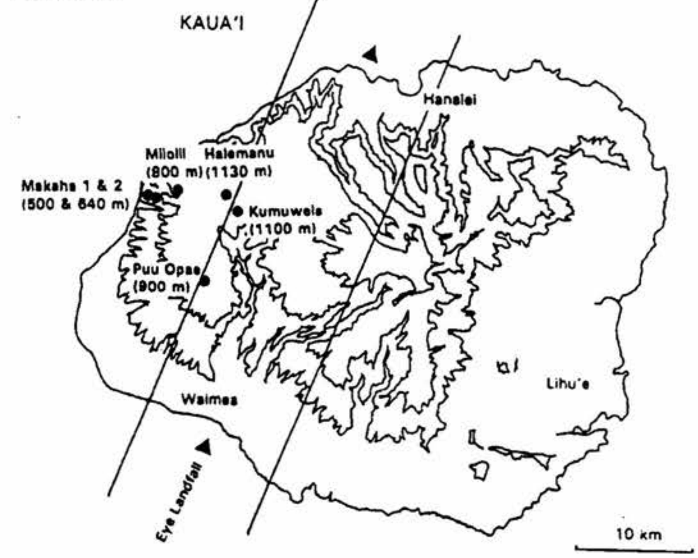
The presence and amount of litter has implications for establishment and survival of seedlings. A large pulse of litter, such as that induced by a hurricane, could bury seeds and seedlings, thus reducing germination and survival. You and Petty (1991) observed that 60 percent of the seedling population in *Manilkara bidentata* forests in Puerto Rico died after being burried by litter following Hurricane Hugo. However, although a large pulse of litter may have a negative impact on seedling establishment, loss of canopy leaf area results in increased light availability at the forest floor (Brown 1993, Fernandez and Fetcher 1991), and thus accelerated seedling growth rates for the seedlings present (Burton and Mueller-Dombois 1984, Osunkoya et al. 1993, You and Petty 1991). Therefore, it is difficult to predict the potential effects of canopy disturbance on the demography of seedling populations. Another goal of this study was to assess how seedling recruitment, survival, and growth rates of native and alien species were related to light availability and hurricane-induced litterfall in koa forests following Hurricane Iniki.

Differences among species in susceptibility to and recovery from hurricane damage may alter forest species composition. Our study sites were originally chosen for their dominance of koa in the overstory canopy and minimal presence of alien species in the understory (Harrington et al. 1995). However, the exotic species lantana (*Lantana camara*), guava (*Psidium guajava*), and blackberry (*Rubus argutus*), which are believed to threaten the persistence of native Hawaiian forest (Smith 1989, Wagner et al. 1990), were present at some of the sites. Their presence allowed us to assess if alien species exhibited higher rates of recruitment, growth, or survival than native species following disturbance, which could potentially lead to increasing density of these alien plants in native Hawaiian forest.

Methods

Study sites. Our study was conducted in koa forests on the northwestern slope of the island of Kaua'i (Figure 1). Sites were located along an elevational gradient ranging from 500 m to 1130 m, with rainfall ranging from 850 to 1800 mm from low to high elevation (Giambelluca et al. 1986). Six study sites, in the Pu'u Ka Pele Forest Reserve, Na Pali Kona Forest Reserve,

Figure 1. Path of Hurricane Iniki relative to the location of study sites (•) in *Acacia koa* forests along an elevation/precipitation gradient on west Kaua'i, Hawai'i.



and Koke'e State Park, were established in 1992 to study the effects of rainfall on forest productivity (Harrington et al. 1995). Plots were circular, 20 m in diameter, except for Makaha 1 (500 m asl) and Miloli'i (800 m asl), where 12 m diameter plots was used to allow sufficient gap-free border. Prior to Hurricane Iniki (Table 1), koa stands along the gradient had basal area ranging from 8 to 42 m^2 ha^{-1}, canopy leaf area per unit ground area ranging from 1.5 to 5.4, canopy height ranging from 2.6 to 11.3 m, and annual wood production ranging from 0.7 to 7.1 t ha^{-1} y^{-1}, all generally increasing with elevation and rainfall (Harrington et al. 1995).

The major canopy species at all sites was koa, with some individuals of 'ohi'a (*Metrosideros polymorpha*) present in the canopy and sub-canopy at most sites. The indigenous species, 'a'ali'i (*Dodonaea viscosa*) occurred in the sub-canopy at Makaha 2 (640 m asl), Miloli'i, Pu'u 'Opae (900 m asl), and Halemanu (1130 m asl). Some exotic species were also present at most sites. Lantana was present in the understory at Makaha 1 and Makaha 2; guava was in the sub-canopy at Makaha 2, Puu Opae, and Kumuwela (1100 m asl); and blackberry was present in the understory at the two high-elevation sites, Kumuwela and Halemanu.

Table 1. Site and pre-Hurricane Iniki stand characteristics of six koa (*Acacia koa*) forests growing along an elevation-precipitation gradient on northwestern Kaua'i, Hawai'i.

Site	Elevation (m)	Precipitation (mm y^{-1})	Slope (°)	Aspect (°)	Stem density (ha^{-1})	Mean DBH (cm)	Leaf area (m^2/m^2)
Makaha 1	500	850	10	265	4686	4.0	1.4
Makaha 2	640	1000	25	310	1210	10.8	3.5
Miloli'i	800	1165	12	280	6012	3.7	1.7
Pu'u 'Opae	900	1270	10	20	1878	9.4	2.5
Kumuwela	1100	1750	17	210	2992	10.0	5.4
Halemanu	1130	1800	10	170	8244	5.0	4.1

Hurricane Iniki moved over the island of Kaua'i in a roughly NNE direction, with steady winds of over 230 km hr^{-1} and gusts over 280 km hr^{-1} (National Weather Service 1992). The estimated track of the eye passed closest to Puu Opae and Kumuwela and within a few kilometers of the other sites (Figure 1).

Damage assessment and growth response. Background data collected prior to the storm included stem diameter at 1.3 m (DBH) for all trees (>2.0 cm) in our measurement plots in spring 1992 at all sites except Miloli'i. We measured DBH at all six sites during the four days just before Hurricane Iniki struck. We assessed initial damage to our field sites from 10 to 18 d following Hurricane Iniki. Damage classes, ranging from 1 to 4, were based on visual estimates of percent of canopy removed: (1) <25 percent canopy removed, (2) 25–50 percent canopy removed, (3) 50–75 percent canopy removed, and (4) >75 percent canopy removed. After the hurricane, survival and DBH were measured at six-month intervals for two years.

Canopy leaf area. Pre- and post-hurricane canopy leaf area were estimated at each site using an LAI-2000 plant canopy analyzer (LI-COR Inc., Lincoln, NE). Post-hurricane leaf area was compared with pre-hurricane values to determine leaf area removal. Recovery of leaf area was monitored monthly for the first year and every three months during the second year following Hurricane Iniki.

Light availability. For a given time interval, light availability beneath the forest canopy (Q_t, moles m^{-2}) was estimated as a function of the average canopy leaf area (L) over the interval with the following equation: $Q_t = Q_0 e^{-kL}$, where Q_0 (moles m^{-2}) is the total incident photosynthetically active radiation (PAR) over the time interval and k is the radiation extinction coefficient. PAR (moles m^{-2}) was measured using LI190SB quantum sensors located in clearings at 500, 800, and 1100 m elevation along the gradient (Figure 1). A k value of 0.45 was used in this study (Meinzer et al. 1996).

Litterfall. Litterfall induced by the hurricane was estimated from nine litter traps (each 0.19 m^2) per site which had been put in place from one to four days before Hurricane Iniki. Litter traps were not installed at Makaha 2 and Pu'u 'Opae before the hurricane. Hurricane-induced litter was collected 10–18 days after the hurricane. The collections from each site were composited in the field and subsequently separated into leaf, twig (<1 cm diameter), and wood (>1 cm diameter) components, and dried at 70°C.

Seedling recruitment and survival. In July 1993 (ten months following Hurricane Iniki), four permanent quadrats were established at each of the six study sites. No other major disturbances occurred following the hurricance prior to the set up of the quadrats. The quadrats ran out from the center of the pre-existing plots in north, south, east and west directions. Quadrat size was 1 x 8m for a total of 32 m^2 sampling area at all sites except Makaha 1 (500 m) and Miloli'i (800 m). At Makaha 1 and Miloli'i, quadrat size was 1 x 5m for a total of 20 m^2 sampling area, to accommodate the smaller size of the pre-existing measurement plots (see *Study sites* above). In July 1993 all seedlings within these quadrats were tagged and identified by species. In February 1994 and July 1994 new seedlings were identified, tagged, and recorded as recruitment, and growth and mortality of old seedlings were calculated. We defined a recruit as a seedling which was not present at the previous inventory but had since germinated and had survived until the following inventory. Our inventory method did not account for seedlings which became established and subsequently died between two measurement times.

Results

Stand level damage. Types of damage differed across sites along the gradient. Makaha 1 experienced mostly loss of senesced phyllodes and dead twigs, although a few individuals lost major structural branches. At Makaha 2 large gaps were formed in the canopy primarily due to removal of both large and small branches, rather than the stripping of senesced phyllodes from intact branches; one dominant koa tree partly tipped over. At Miloli'i the damage observed was primarily the removal of senesced phyllodes, leaving the canopy otherwise intact. Pu'u 'Opae was the most severely damaged site, with many large branches and a few entire trees broken off, thereby removing most of the overstory canopy. Damage observed at Kumuwela included the breakage of major structural branches, many of which remained suspended in the canopy. Although Halemanu was located close to Kumuwela, damage was limited primarily to the stripping of green foliage from twigs in the canopy, so although much leaf area was removed, the major canopy branch structure remained intact, as with Miloli'i.

Immediate losses in canopy leaf area ranged from 18 to 58 percent, but became greater over time ranging from 29 to 80 percent (Figure 2) because of structural damage to major branches (e.g., Kumuwela and Pu'u 'Opae). Total loss of leaf area was positively correlated with pre-hurricane leaf area and canopy height, as hypothesized (Figure 3a, b).

Removal of foliage and twigs from the canopy resulted in a large flux of biomass to the forest floor. The flux at the high-elevation sites, Kumuwela and Halemanu, was greater than at low-(Makaha 1) and middle-elevations (Miloli'i; Table 2). Total litterfall mass ranged from 3.9 t ha^{-1} at Miloli'i to 18.6 t ha^{-1} at Kumuwela, and fine (leaf and twig) litterfall mass ranged from 3.3 t ha^{-1} at Miloli'i to 14.2 t ha^{-1} at Kumuwela. The proportion of litter composed of wood and twig debris was relatively constant, ranging from 71 percent at Halemanu to 80 percent at Kumuwela.

Table 2. Dry weights of leaf, twig (<1 cm diameter), and wood (>1 cm diameter) litter blown down by Hurricane Iniki and collected eight to ten days after the storm at four study sites along an elevation/ precipitation gradient on northwestern Kaua'i, Hawai'i.

Site	Component	Litter (t ha^{-1})
Makaha 1	Leaf	1.3
	Twig	3.6
	Wood	1.2
Miloli'i	Leaf	0.9
	Twig	2.4
	Wood	0.6
Kumuwela	Leaf	3.6
	Twig	10.6
	Wood	4.4
Halemanu	Leaf	3.1
	Twig	6.3
	Wood	1.3

Recovery. Recovery from canopy damage varied over the six sites. Leaf area had returned to pre-hurricane values within one year at Miloli'i and Halemanu (Figure 2). The immediate increase and subsequent slight decline in leaf area at Makaha 1 was the result of flushing and dieback of the alien lantana, which exceeded 2 m in height at the site. Canopy recovery at Pu'u 'Opae took two years, while the canopies at Makaha 2 and Kumuwela still had not fully recovered by that time (Figure 2) due to extensive structural damage.

Tree growth rate generally paralleled the decrease and subsequent recovery of leaf area over time at each site. The percent increase in basal area over the first year following the hurricane was negatively correlated with canopy loss (Figure 4). During the two years following Hurricane Iniki, tree growth rates were positively correlated with leaf area in all sites except Makaha 1 (Figure 5). Diameter increment had recovered to pre-hurricane values at five of the six sites within two years after the hurricane, and exceeded pre-hurricane values at Pu'u 'Opae and Kumuwela.

The two main sub-canopy species, aalii and guava, were both severely damaged in the hurricane, but their

Figure 2. Canopy leaf area at six koa (*Acacia koa*) forest stands on west Kaua'i from spring 1992 (pre-hurricane (m)) to September 1994. Error bars denote standard errors (n=9).

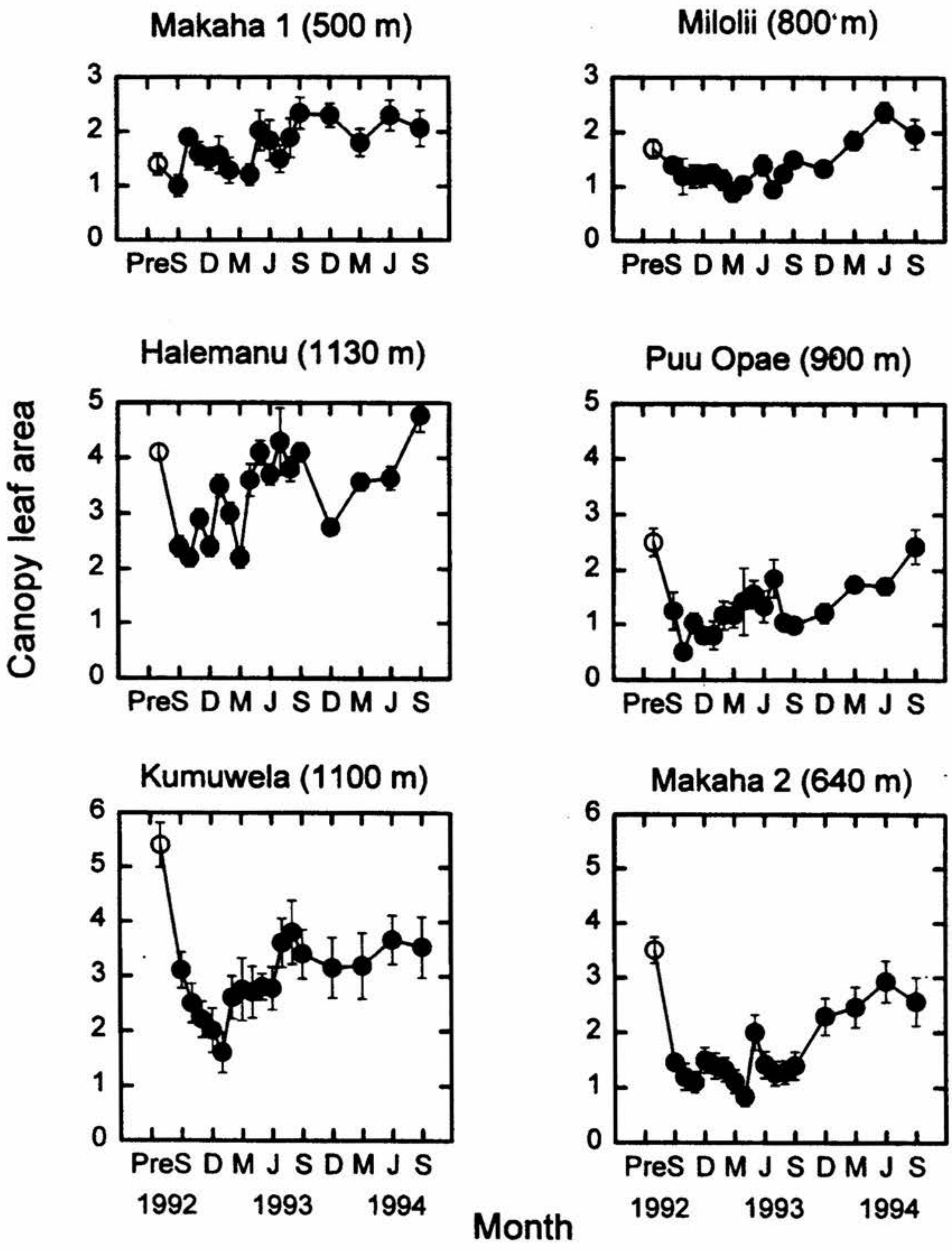


Figure 3. The relationship between amount of canopy leaf area removed and (a)pre-hurricane canopy leaf area, and (b) canopy height in koa (*Acacia koa*) forest stands on western Kaua'i. The six study sites were Makaha 1 at 500 m (●), Makaha 2 at 640 m (○), Miloli'i at 800 m (■), Pu'u 'Opae at 900 m (□), Kumuwela at 1100 m (▲), Halemanu at 1130 m (△).

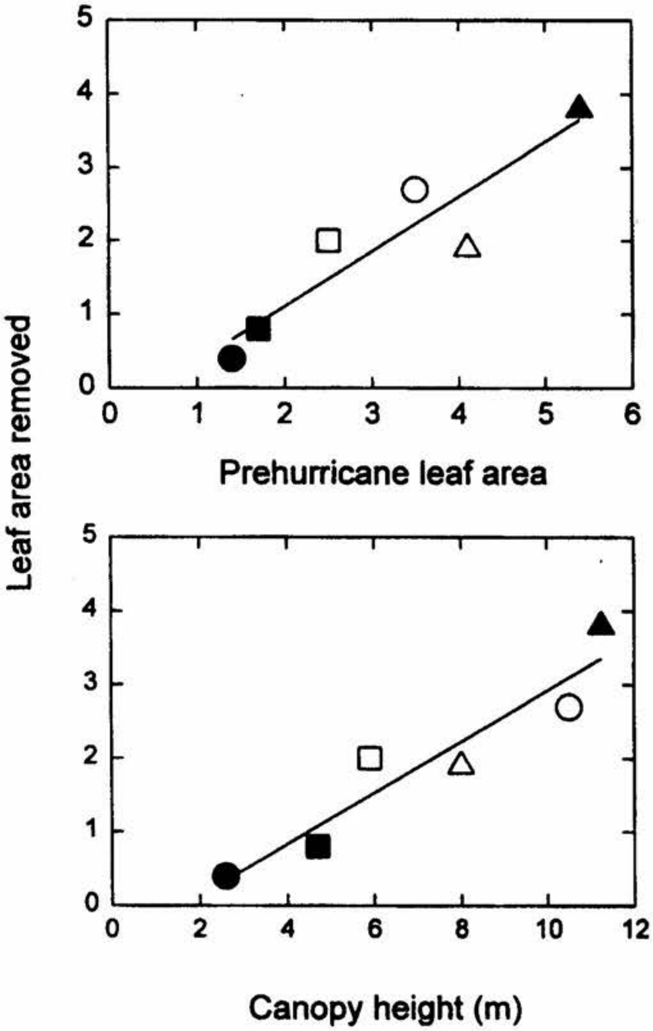
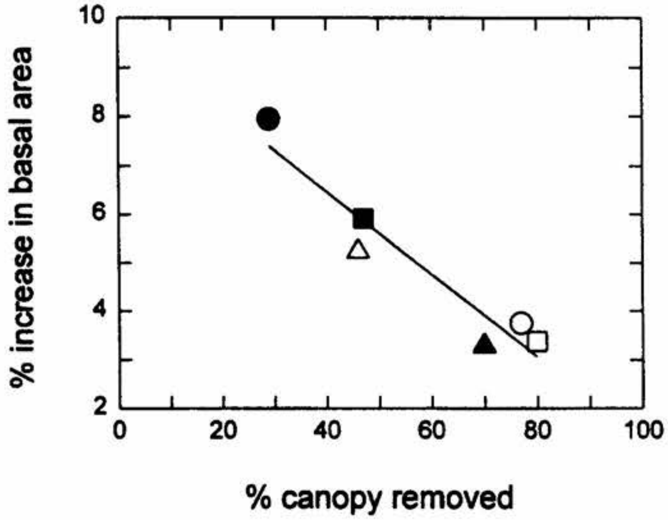


Figure 4. The relationship between the percentage increase in stand basal area one year after the hurricane and the percentage of the pre-hurricane canopy leaf area that was removed by the hurricane.



recovery from severe damage was quite different. At one of the two sites where it occurred, all severely damaged guava trees survived, and on the other site, two thirds of the severely damaged trees survived (Table 3). In contrast, the native 'a'ali'i generally had less capacity to recover: none of severely damaged trees survived at one of the three study sites where it occurred, and 50 and 86 percent of severely damaged individuals survived at the other two sites (Table 3).

Seedling density, recruitment, and survival. Total seedling densities varied by an order of magnitude across sites, and generally increased with increasing light availability at the forest floor (Figure 6), but were not correlated with hurricane induced litterfall. Koa had the highest density and annual recruitment of seedlings at the intermediate sites (Miloli'i (800m) and Pu'u 'Opae (900m)) along the rainfall gradient (Table 4). 'A'ali'i, however, experienced the highest seedling density and recruitment at the driest, low elevation site, Makaha 1 (500 m). Densities and recruitment of guava seedlings and blackberry shoots were relatively low at the sites where they were found, even though blackberry was the predominant understory species at the two wet sites, Kumuwela (1100m) and Halemanu (1130m). Seedling growth and survival were not correlated with light, precipitation, or litterfall for any of the four species. However, the ratio of annual mortality/emergence of koa increased linearly with amount of hurricane-induced litterfall (Figure 7), resulting in lower seedling densities at sites with higher amounts of hurricane litterfall.

Figure 5. The relationship between tree diameter increment and stand canopy leaf area in koa (*Acacia koa*) forest stands on western Kaua'i for the first two years following the hurricane. Each point represents a single six-month interval.

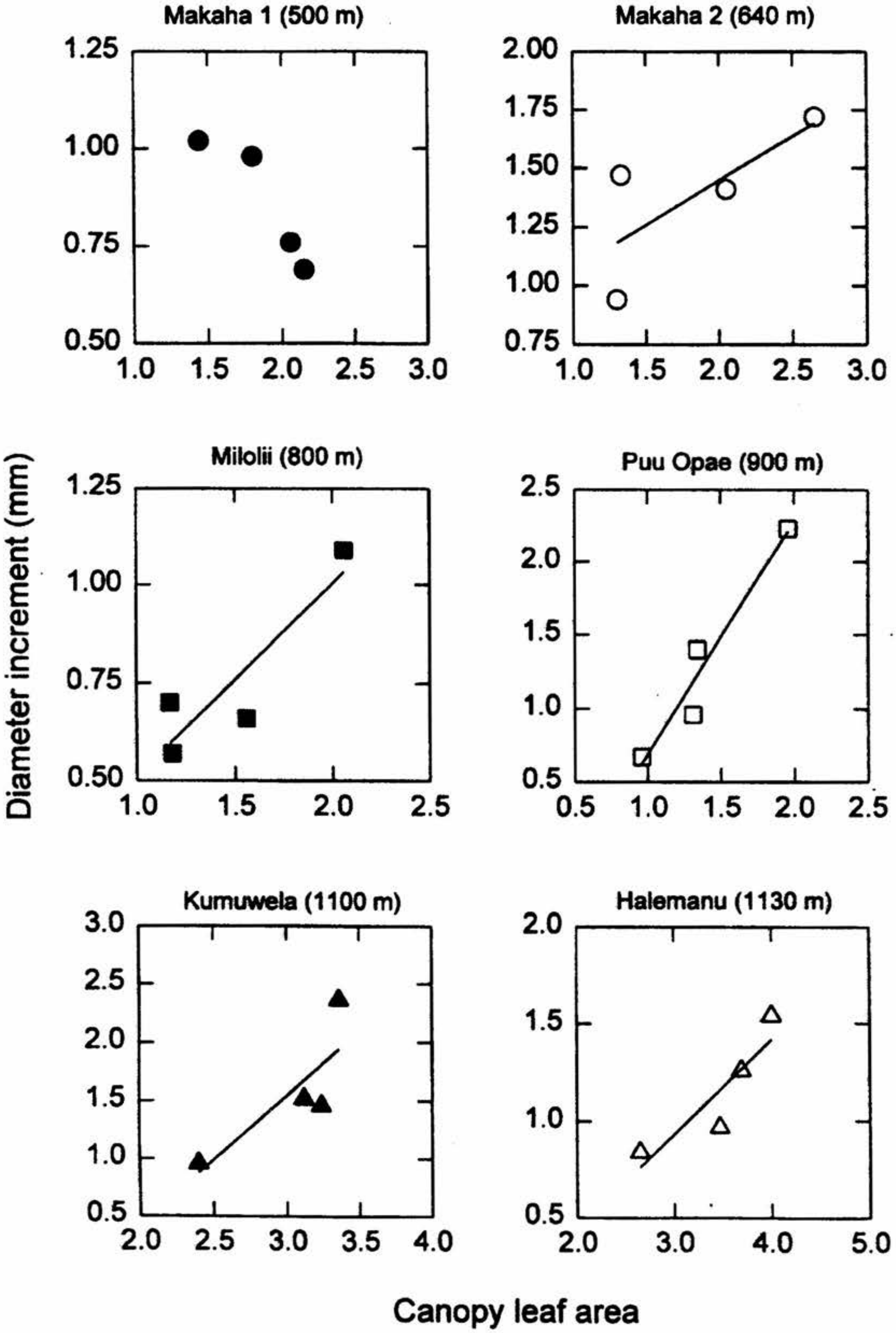


Table 3. The total number of individuals (N) of koa (*Acacia koa*), aalii (*Dodonaea viscosa*), ohia (*Metrosideros polymorpha*), and guava (*Psidium guajava*) at six study sites on northwestern Kauai; with the percentage of the individuals in each damage class immediately following Hurricane Iniki and the percent survival of individuals in damage class 4, six months after the Hurricane. Damage classes are defined in terms of percentage of the canopy removed were: (1)0–25 percent, (2) 25–50 percent, (3) 51–75 percent, and (4) >75 percent.

Site	Species	N	Damage class 1	2	3	4	% survival of class 4
Makaha 1	*A. koa*	53	51	22	12	15	50
Makaha 2	*A. koa*	36	47	33	5	14	80
	M. polymorpha	37	30	32	0	38	79
Miloli'i	*A. koa*	68	91	5	2	2	0
	D. viscosa	21	38	10	19	33	86
Pu'u 'Opae	*A. koa*	66	27	23	24	26	53
	D. viscosa	9	0	0	0	100	0
	M. polymorpha	16	6	44	25	25	25
	P. guajava	6	0	0	0	100	67
Kumuwela	*A. koa*	87	18	23	24	35	80
Halemanu	*A. koa*	252	44	23	12	21	69
	D. viscosa	96	25	43	3	29	50
	M. polymorpha	39	90	5	0	5	100

Discussion

Damage. The strongest pattern of damage among sites was the correlation of leaf area loss with pre-hurricane leaf area and canopy height. Our results agree with data from nearby 'ohi'a forest, where differences in pre-hurricane canopy leaf area among plots had been created by fertilization in a randomized block design (Herbert and Fownes 1995). In these plots, leaf area loss was also correlated with pre-hurricane leaf area (Herbert 1995). However, very severe localized damage, greater than that observed in our studies, occurred in other forests on Kaua'i. This severe damage was often associated with violent microbursts which appear to be more or less random in occurrence because they are not related to either topography or stand characteristics (National Weather Service 1992).

The magnitude of hurricane-induced litterfall observed across our sites was within the range of hurricane-induced litterfall observed in other tropical forests (Frangi and Lugo 1991, Lodge et al. 1991, Thompson 1983). We have no measurement of pre-hurricane litterfall at our sites for direct comparison, but litterfall in mature koa forests on the island of Hawai'i ranged from 6.3 to 12.2 t ha^{-1} y^{-1}, with foliar litter comprising approximately 70 percent of the total fine litterfall (Scowcroft 1986). Therefore, the flux of litter we observed as a result of the hurricane was equal to or greater than total annual litterfall observed in other koa forests, although the wood-to-leaf ratios were approximately reversed.

Recovery. The six sites varied in their response to canopy damage, and the differences observed were attributable to the amount and type of damage incurred. The slow recovery of Pu'u 'Opae, Makaha 2, and Kumuwela was caused by the loss of major structural branches, resulting in large gaps in the canopy and loss of 69 to 80 percent of total leaf area. This interpretation is supported by the large masses of woody litter at these sites (Table 2). The parallel trends in leaf area recovery and diameter increment agree with our pre-hurricane

Figure 6. The relationship between total seedling density and light availability in koa (*Acacia koa*) forest stands on western Kaua'i following Hurricane Iniki.

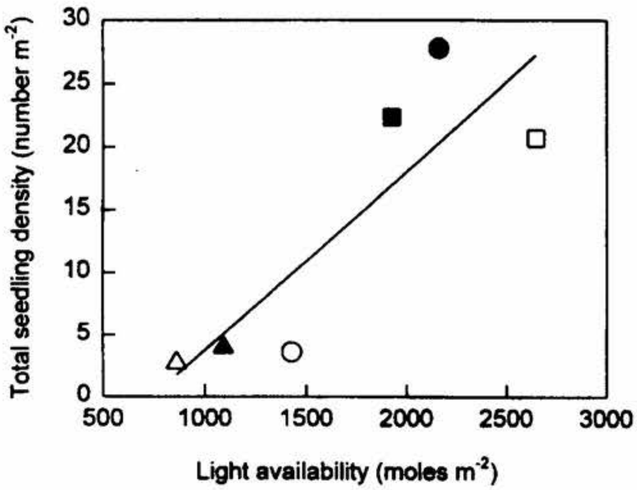


Figure 7. The ratio of seedling mortality to seedling emergence for koa (*Acacia koa*) as a function of the amount of Hurricane-induced litterfall.

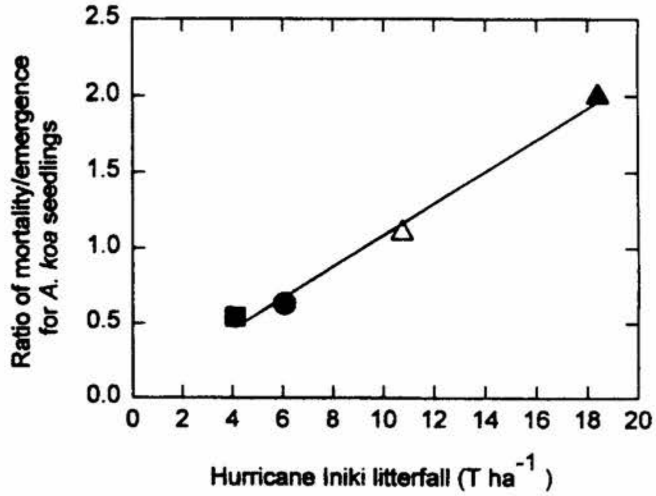


Table 4. Seedling density in July 1993 and July 1994, and annual (July 1993 - July 1994) seedling mortality and emergence, and percent survival, for koa (*Acacia koa*), 'a'ali'i (*Dodonea viscosa*), guava (*Psidium guajava*), and blackberry (*Rubus argutus*) on sites damaged by Hurricane Iniki on western Kaua'i.

Species	Site	Density (m^{-2}) July 1993	Density (m^{-2}) July 1994	Mortality (m^{-2} y^{-1})	Recruitment (m^{-2} y^{-1})	Survival (%)
A. koa	Makaha 1	0.1	0.4	0.6	0.9	50
	Makaha 2	1.4	3.0	0.8	2.3	61
	Miloli'i	12.6	18.8	7.0	12.9	57
	Pu'u 'Opae	21.3	19.4	7.4	5.7	36
	Kumuwela	1.5	1.0	0.9	0.5	47
	Halemanu	0.4	0.4	0.3	0.3	57
D. viscosa	Makaha 1	2.6	22.1	3.4	22.7	53
	Makaha 2	<0.1	0.5	<0.1	0.5	100
	Milolii	2.5	3.5	1.3	2.1	38
	Pu'u 'Opae	0.5	0.3	0.2	0.1	40
	Halemanu	<0.1	0.1	<0.1	0.1	67
P. guajava	Makaha 1	0.9	1.6	0.2	0.6	67
	Makaha 2	0	<0.1	0.0	<0.1	
	Pu'u 'Opae	1.9	2.3	0.8	0.6	48
R. argutus	Kumuwela	2.5	2.4	1.7	1.6	35
	Halemanu	2.4	2.0	2.7	2.2	9

observation that diameter increment was correlated with canopy leaf area (Harrington et al. 1995).

The differences among species in recovery from damage has implications for future species composition. The comparatively low survival of both adults and seedlings of the native 'a'ali'i suggests that the more resilient alien guava will increase its importance in the understory. At Makaha 1, the rapid flushing of lantana leaf area may suppress future recruitment of koa. However, there was little entry of new seedlings of alien species in these sites, suggesting that changes would be incremental rather than drastic. Based on our study sites, the impact of Hurricane Iniki on native koa forest was in general not catastrophic and, to a great degree, forest structure and productivity had recovered within two years.

Acknowledgments

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Questions

Q: Your last point seemed fairly important. If the native species don't do as well as the alien species, we're going to have to go back in there again and get more of the guava out. Is that really your conclusion, that in the long run the guava will survive a lot better?

A: My data are only from a single disturbance event. The data showed that guava had much higher survival than the other subcanopy species on the site, the *Dodonea*. So I can't say how guava is going to do versus other native species on other sites with different species compositions. Although we didn't have a big recruitment, with other aliens coming in, I'm saying this is something to watch out for. They have an ability to have some resilience after a disturbance like that.

Q: I went to the island after the hurricane and saw the native plants looking a lot more disturbed than the eucalyptus and stuff.

A: There are two things going on. You've got resistane to disturbance, and also there's an ability to recover from it. A couple of the slides showed the eucalyptus hammered, but it had the ability to come back. It's just a characteristic of that family; they can sprout back after being cut, after being totally defoliated. Guava is the same family as eucalyptus. 'Ohi'a is too. Jim Fownes had a graduate student looking at 'ohi'a in the forest at Koke'e after the hurricane, and he found out that they came back.

Symbiotic Nitrogen Fixation by *Acacia koa* at the Keauhou Ranch Reforestation Area

Holly L. Pearson, Department of Biological Sciences, Stanford University

Introduction

The rate at which *Acacia koa* (koa) stands develop has important implications for koa plantation forestry and the use of koa in ecosystem restoration. How quickly individual trees grow, how growth rate changes over time, and how stands self-thin is not well understood.

Development of koa stands may differ from that of other trees because koa is a nitrogen-fixing species. Like most legumes, koa is able to convert atmospheric nitrogen to a plant-usable form. In many Hawaiian forests, nitrogen is the nutrient that limits plant production, so koa may play an important role in ecosystem processes. The questions that I'll address include What is the rate of biomass and nitrogen accumulation in koa stands of different ages?, and How does nitrogen fixation by koa change as stands age?

Site description

Keauhou Ranch is the site of the largest and most complete age sequence of koa stands in Hawai'i. The Ranch, which is owned by Kamehameha Schools/ Bernice Pauahi Bishop Estate (KSBE), is located on the slope of Mauna Loa above Kilauea Caldera on the Big Island. Of the Ranch's 11,000 ha (27,180 acres), 3723 ha (9200 acres) have been withdrawn from cattle lease, and over 486 ha (1200 acres) are part of the koa reforestation project (Peter Simmons, pers. comm.).

Beginning in 1977, KSBE began to reforest land that had previously supported logging and grazing. The approach is to fence an area of 20–40 ha (50–100 acres) and to scarify the soil by bulldozing. Many seedlings sprout from the seed bank, and bare spots are planted with seedlings by KSBE students and staff. Over the years, intensity of scarification has decreased, and more seed trees and pockets of native forest have been left (Peter Simmons, pers. comm.). Stands are heavily dominated by koa; the ground cover is largely exotic grasses.

The completeness of this stand-age sequence presents a unique opportunity to look at koa stand development. In December 1995 I established four plots each in the 1977, 1984, 1988, and 1991 stands in relatively homogeneous areas of koa; plots are circular and 10 m in diameter. Although the reforestation area lies on a mixture of different-aged lava flows, my plots are all on 2000–3000 year old a'a. Mean annual precipitation in the area is 1900 mm (75 inches) (Giambelluca et al. 1986) and elevation is 1800 m (5900 ft).

What is the rate of koa biomass accumulation?

To estimate how quickly koa biomass accumulates over time, I measured diameter at breast height (DBH, 1.4 m) of all koa trees in the study plots and used allometric equations to calculate aboveground koa biomass. Allometric equations were developed by the USDA Forest Service based on harvests at Keauhou. In summer 1994 the Forest Service harvested 54 trees in the 1977–1979 stands; DBHs ranged from 8 to 30 cm. In November 1995 the Forest Service and I harvested an additional 25 trees in younger stands (1987 and 1991) to provide accurate data for trees from 1.5 to 8 cm DBH. Whole trees divided into stem, branches, twigs, and leaves were weighed in the field. Tissue subsamples were dried in the lab. Tree DBH is related to aboveground dry weight as shown in Figure 1.

Estimates of aboveground koa biomass in stands ranging from 5 to 19 years in age show that biomass accumulates relatively quickly for the first 12 years but slows substantially between 12 and 19 years (Figure 2).

What is the rate of koa nitrogen accumulation?

To estimate aboveground nitrogen accumulation in koa leaves, branches, and stemwood over time, I used allometric equations to calculate biomass of these pools and multiplied by tissue percent nitrogen. Nitrogen analyses (Kjeldahl digestion) were done at Stanford University.

Stem and branch wood nitrogen accumulates relatively rapidly during the first 12 years of tree growth and more slowly for the next seven years (Figure 3). Total mass of leaf nitrogen, on the other hand, increases for the first eight years of stand development and then declines. On a per-hectare basis, leaf biomass is similar

Figure 1. The relationship between aboveground biomass and DBH for 79 sample trees in Keauhou Ranch Reforestation Area. $f(x) = -0.109x + 0.233x^2 + 0.002x^3$; R2 = 0.969.

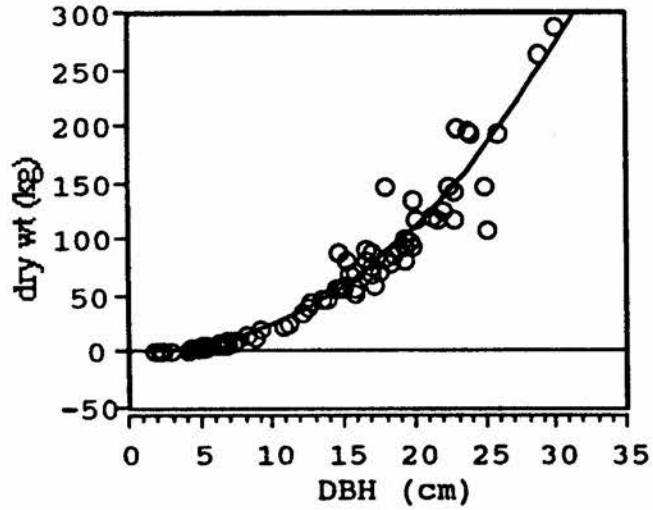


Figure 3. Accumulation of aboveground koa nitrogen in an age sequence of stands at Keauhou Ranch Reforestation Area.

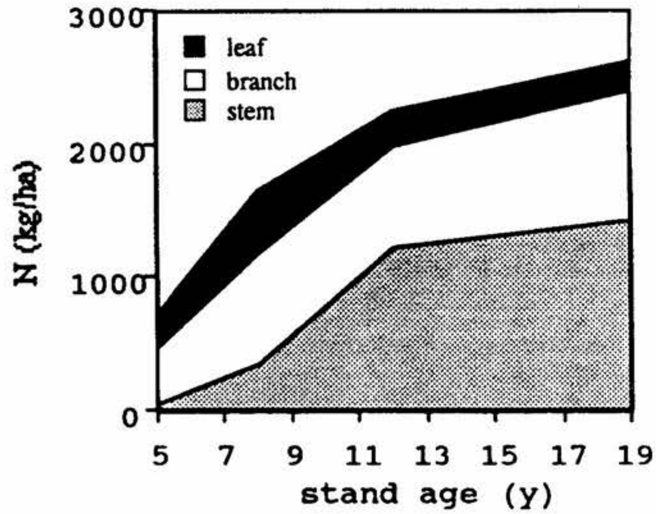


Figure 2. Accumulation of aboveground koa biomass in an age sequence of koa stands at Keauhou Ranch Reforestation Area (mean ± standard error).

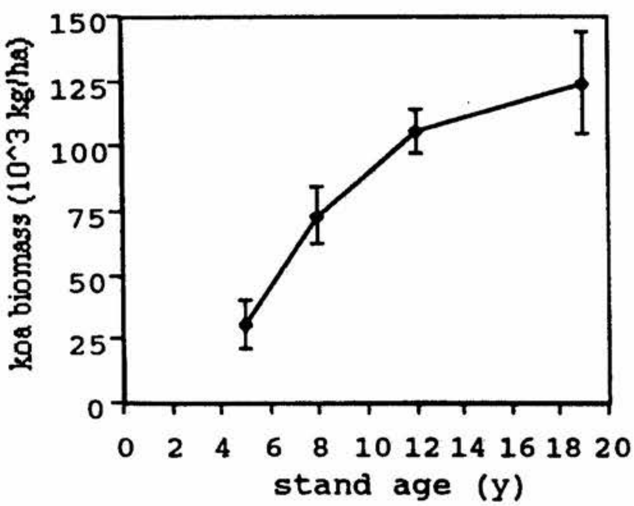
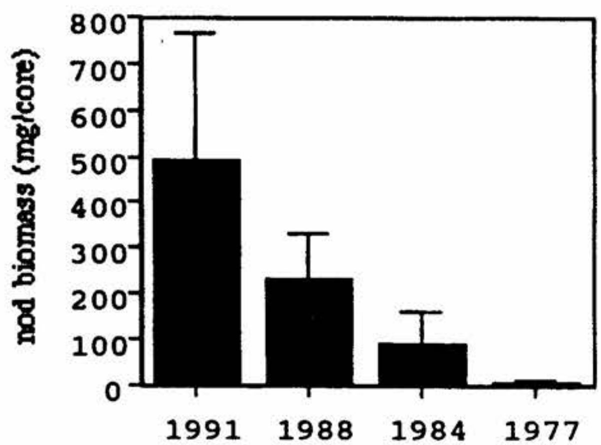


Figure 4. Nodule biomass per unit area of soil in an age sequence of koa stands at Keauhou Ranch Reforestation Area, Feb. 1996 (mean ± standard error). Cores were 0.05 m², 30 cm deep; n = 8 per stand age.



in the 5-year-old and the 19-year-old stands, which may have important implications for stand development.

How does nitrogen fixation by koa change as stands age?

There are three major sources of the nitrogen that become incorporated into koa biomass: the soil, atmospheric deposition (i.e., dry deposition and precipitation), and symbiotic nitrogen fixation. I estimated the amount of nitrogen that koa fixes in stands of different ages.

Nitrogen is fixed by bacteria (*Bradyrhizobium* spp.) that live in nodules on the tree roots. Nitrogen input to the ecosystem depends on both the rate of the enzymatic reaction in nodules and the abundance of nodules. Using an enzymatic assay (acetylene reduction), I found that reaction rate did not vary significantly between nodules in old and young stands. Thus, the important variable to consider is nodule abundance.

To measure abundance of nodules in the field, I dug soil cores in study plots. Nodules were sorted from the soil, dried, and weighed.

I found a striking pattern in nodule abundance: while young trees are heavily nodulated, nodule biomass declines quickly, and by 19 years of age trees have essentially no nodules (Figure 4). Thus, nitrogen input to the ecosystem via fixation is important only in the early years of stand development.

Discussion

Why these declines in tree growth rate and nitrogen fixation occur is not obvious. In natural mixed-species forests, koa trees of greater size and age than those in the oldest stand here continue to fix nitrogen (pers. observation), so some feature of these stands or this site must be responsible for the decline that we observed.

I think that the explanation involves energy. Tree growth and nitrogen fixation are both dependent on energy supply—carbon is fixed by photosynthesis in the leaves and transported to other parts of the plant, including nodules. Leaf biomass decreases relative to wood biomass as stands age (Figure 3). With a decline in rate of carbon accumulation relative to tissue respiratory costs, trees may not be able to spare carbon to support growth and nitrogen fixation.

The idea of a photosynthesis-respiration imbalance has been used to explain the general phenomenon of a decline in aboveground net primary production with stand age. This hypothesis has recently been called into question because sapwood respiration comprises a small part of stand carbon budgets and increases little after canopy closure (Gower et al. 1996, Ryan and Waring 1992). Other proposed mechanisms of decreasing nutrient (especially nitrogen) availability and photosynthetic rate over time seem to be relatively more important (Gower et al. 1996). However, the importance of sapwood respiration increases with temperature and if sapwood biomass continues to increase over time (Gower et al. 1996, Ryan et al. 1995). Thus, in the case of these koa stands, a limitation of growth and nitrogen fixation by carbon supply seems plausible: sapwood volume is increasing substantially over this short age sequence; temperatures are relatively warm year-round; and nitrogen availability increases, rather than decreases, over time (H.L. Pearson, unpublished data), presumably because koa is a nitrogen-fixer.

I am currently testing this explanation in a thinning experiment at Keauhou. The experiment will tell me whether trees sustain higher growth and nitrogen-fixation rates for a longer period of time if they are widely spaced.

I have worked in only one site so I cannot make generalizations for all the places in which koa grows. I expect, however, that these patterns will be found in other dense koa stands, but that rates of tree growth and the decline in nitrogen fixation will differ. Climate, soil fertility, and other ecosystem characteristics would be expected to influence stand development.

The results of this study are interesting from both scientific and land-management perspectives. Effective use of koa in plantation forestry and ecosystem restoration requires an understanding of how koa stands develop and why they develop that way.

Conclusions

The patterns of koa stand development that I found at Keauhou Ranch are as follows:

1. Rates of koa biomass and nitrogen accumulation decline substantially after the first decade of tree growth.

2. Nitrogen fixation by koa also declines as stands age, so that input of nitrogen via fixation is negligible in stands older than 12 years.

Acknowledgements

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Questions

Q: Your data indicate there's stagnation occurring in the stand, and what is your proposed thinning percentage?
A: I should point out that in the stagnation, the decline in koa biomass accumulation rate, there can be two things going on: one is density changes, and one is growth-rate changes. What I'm finding is that tree density changes, falls off dramatically over time, but that growth rate of dbh increases, continues to increase. Most of that biomass pattern can be explained by decline in density over time. What I've done in the thinning experiment is to reduce basal area by about 50 percent. I did that by removing trees that were smaller and that were mis-shapen, and I tried to pick out ones that I thought a forester would leave. But the density that I have left is probabaly much higher than we'll see in, say, a 40-year-old stand.

Q: Could you describe the soils in that area and their productivity? How do they compare with other soils throughout the islands?
A: Yes, I didn't present any of the soils data at all. It's a two-to three-thousand-year-old a'a flow that's been bulldozed. It's a jumble of rocks, a very rocky substrate. I think available phosphorus as quite low at that site. I expect that will increase, but not in the time scales we're looking at. Available N . . . I can't compare that off the top of my head to other sites, but one interesting thing I've found is that as the stands get older, nitrogen availability increases. Which is the pattern we'd expect to see with a nitrogen-fixer.

Q: What was the original plant spacing on those sites?
A: After the scarification, a lot of seedlings came up out of the seed bank, and then bare spots were filled in with seedlings. I know the original density of seedlings put in was tremendous, about 80,000 seedlings per acre in the first allotments. Then in later years, in the eighties and nineties, that density was down. Still, thousands of seedlings per acre.

Forest Stewardship and Forest Legacy Programs

Karl Dalla Rosa, Division of Forestry and Wildlife, Hawai'i Department of Land and Natural Resources

The Hawai'i State Forest Stewardship and Federal Stewardship Incentive Programs provide technical and financial assistance to owners of nonindustrial private forest land committed to the stewardship, enhancement, and conservation of their forest resources. The information and assistance provided to landowners under these programs is intended to help them understand and implement management practices to enhance and protect the timber productivity, wildlife habitat, water quality, recreational values, and/or aesthetics of their forest properties.

The state Forest Stewardship Program was adopted through Act 327, as enacted by the 1991 Legislature, and provides state funds to assist private forest landowners financially. The Department of Land and Natural Resources Division of Forestry and Wildlife administers this program under advisement from the state Forest Stewardship Coordinating Committee. This committee is made up of resource professionals and private landowners. It is mandated by the program's authorizing acts to review applications to the federal Stewardship Incentive and state Forest Stewardship programs and to recommend to the State Forester the selection of qualified projects for funding.

The federal Stewardship Incentive Program was established by the Forest Stewardship Act of 1990. The program is administered by the USDA Forest Service at the national level, and by the Division of Forestry and Wildlife and the USDA Farm Service Agency at the state and county levels. The Forest Stewardship Program has expanded rapidly since its establishment. As of this year, 16 landowners had enrolled and more than 1600 acres are now being restored or managed under the program. Both small and large landowners are participating in the program, and their objectives are varied. Many landowners are reforesting former sugar plantations or degraded pastures with high-value hardwood species, while others are improving the health of their forest resources by removing undesirable non-native vegetation and promoting the regeneration of native species.

As part of the 1990 Farm Bill, Congress created the Forest Legacy program to identify and protect environmentally important private forest lands threatened with conversion to nonforest uses—such as subdivision for residential or commercial development. Forest Legacy was set up to authorize the USDA Forest Service to acquire permanent conservation easements on private forest lands that are at risk of being converted to non-forest uses. Easements are purchased only from willing landowners at fair market value.

Hawai'i became eligible to enter the Forest Legacy program in 1994, when its Assessment of Need for the program was approved by the U.S. Secretary of Agriculture. However, federal funding limitations have prevented the establishment of an active Forest Legacy Program here.

Questions

Q: Can you use that money to lease or purchase land?

A: No, the landowner has to already own at least five acres. Lease land can be assisted under the program, but there has to be at least a ten-year lease. I've also been coordinating the Forest Legacy Program. I forgot to mention it because we haven't really gotten the program off the ground here in Hawai'i. We spent quite a bit of time developing an assessment of need for the state of Hawai'i for this program. The Forest Legacy Program is set up to acquire conservation easements to properties, primarily intact forest areas, that are considered to be threatened by conversion to non-forest uses such as development for hotels, perhaps clearing for agriculture, something like that. The government will purchase a certain number of land-use rights that are transferred from the landowner to the government in perpetuity, and the government pays fair market value for those use rights. The idea being that the landowner retains title to the land, maintains most of the rights to the land except for those uses that are considered to be threatening to the forest. In this way it ensures that this forest area will be productive and useful but also conserved for future generations. We developed an assessment of need, we

were approved, and officially we're part of the National Forest Legacy Program. Because of recent years of congressional cutbacks in budgets for these things, there's been such limited funding that we really haven't been able to seriously consider starting a forest legacy program here in Hawai'i yet. Perhaps the status of the federal funding will change, but we're ready to go if and when we do get more support for that program.
Nelson Ayers: There is a Forest Legacy Program, but due to a lack of funding most of the monies go the East, like Connecticut, Rhode Island, Maine. In the West, California and Hawai'i have completed our assessment of need, but because of lack of funding to purchase, most of the monies went to the East Coast. So there is a Forest Legacy Program, but in the West we don't have monies to purchase.

Q: Under the Forest Stewardship Program, you're not allowed to cut any trees down while you're in the program? Is that correct?
A: No, that's not correct. Usually, it's a ten year committed program, so you wouldn't be harvesting during the time you are officially enrolled in the program. We assist landowners with the establishment of forest resources. We encourage wise stewardship, but we have no requirements that limit the landowner in how to use that forest in 20 or 30 years. They perhaps require the landowner follow best management practices that the Division's currently establishing, something like this. I think that might be a good idea. The public is very concerned that some of the public money might be spent to establish forests that might be harvested unwisely in the future, so there may be some attempt to do that in the near future. I can say right now that most of the landowners that have enrolled in the program, and if you see the way the program's set up and what they have to go through, most are people that are very environmentally minded and I doubt very much that anyone would go in and just clearcut or do something in the future that was detrimental to the forest. I think most people are concerned with the health of the forest.

Q: But there's no assurance that that could happen?
A: Not right now, there's no assurance.

Q: In this program, if you sign up, are you relegated to doing forestry only, or can you do companion planting with, for example, a koa-coffee mix? Would you qualify for the Forest Stewardship Program?
A: You would. However, the Forest Stewardship Program would only fund the koa establishment portion of that project. The program does not assist with the establishment of orchards or what are considered under the program to be orchards. The forestry portion would be funded.

Q: You mentioned the Division has management practices. Have you established management practices?
A: Yes. Those are in this handbook. We have nine categories of management practices that are eligible for funding under the program, and under each one of those there's particular practices that are eligible for funding, and under those we've established hold-down or maximum cost-share rates that are allowable to be funded.

Tree Farm, Forestry Incentive, and Conservation Reserve Programs

Nelson L. Ayers, Division of Forestry and Wildlife, Hawai'i Department of Land and Natural Resources

The Department of Land and Natural Resources (DLNR) Division of Forestry and Wildlife supports environmentally responsible forest resource management on private lands. The state Tree Farm Program and the federal Forestry Incentive and Conservation Reserve Programs provide a mixture of resource management options for private landowners in Hawaii.

The state Tree Farm Program helps private landowners to grow and harvest new trees for commercial use according to a tree farm management plan that is approved by the Department. Landowners receive no program funding and it is strictly voluntary. Under this program, a condition was recently added to allow approved landowners the right to harvest new trees grown for commercial timber. Additionally, landowners can petition their county to receive a real property tax rate for their tree farm dedication similar to what is being offered for pasture use.

The federal Forestry Incentive Program (FIP) is a federal and state partnership designed to increase the nation's supply of timber products by sustaining the management of non-industrial private forest lands, implementing cost-effective forest improvement practices, and enhancing other forest resources. The USDA Natural Resources and Conservation Service (NRCS) has recently been assigned to administer the FIP program nationwide. The Division of Forestry and Wildlife will help landowners complete a FIP management plan requirement with NRCS to qualify for program funding. In Hawai'i, NRCS plans to restart this program in October 1997.

The federal Conservation Reserve Program (CRP) helps landowners of highly erodible cropland conserve and improve the soil and water resources on their farm or ranches. This program is administered by the USDA Farm Service Agency. The Division of Forestry and Wildlife assists landowners interested in growing trees under CRP to complete a conservation plan for their property. But historically there has been no interest in this program. With the program's low cost-share rate per acre coupled with Hawai'i's high land values, it is difficult to convince landowners that it makes sense to convert their revenue-producing cropland into permanent vegetative cover for a minimum of ten years.

Questions

Q: Concerning FIP, one of the reasons you may not have had any takers, when I went in and asked for information on the program, they told me they not only didn't have any information, but they didn't have any money. That may be why you're not getting any people applying. The question I had is, if you go through the FIP program and you get an approval of your management program, does that automatically make you a tree farm, or do you need to apply as well?

A: You need to apply as well. I think the components of planting trees in the reforestation effort would apply to your tree farm management plan. I would say that perhaps components of your FIP, the tree component, would apply to tree farming. Let me just say that the tree farm program is a state program. Counties control how they run their real property taxes concerning tree farming, so it's not a very good mix sometimes. Not all counties are like that, but I heard one county wants ownership. Maybe that's the reason for the little interest, even though we've added the right to harvest in the law.

Q: We're at a stage now in the history of Hawaii when we're looking at partnerships and getting away from the "us" and "them" approaches we've taken in the past. I was wondering if you saw an opportunity for maybe having information on these kinds of things available in quantities at the county extension offices so they can encourge the forest stewardship and tree farm programs?

A: Hawai'i County is here; I can send them or give you a whole bunch.

Response: I think they're the first line of exposure to a lot land managers and landowners, so it would be great if they could do some of this missionary work.

Natural Area Partnership Program

Peter Schuyler, Division of Forestry and Wildlife, Hawai'i Department of Land and Natural Resources

Introduction

Hawai'i is known for its endemic flora and fauna and its unique native ecosystems. Hawai'i is also known for the high number of endangered species found within its borders. With only 0.2 percent of the land mass in the United States, the state has close to 40 percent of both the listed plants and birds on the U.S. endangered species list (263 plant taxa, 31 bird taxa), as well as nearly 75 percent of the historically documented extinctions in the nation (Hawai'i Department of Land and Natural Resources et al. 1991). Although there are a number of state programs directed toward the protection of natural resources on state lands, at least 15 percent of Hawaii's approximately 180 natural communities are not found on any state lands and another 73 percent are found on both state and non-state lands (Hawai'i Heritage Program, 1987). Clearly, if natural resource protection efforts are to succeed in Hawai'i, private landowner conservation efforts must be encouraged.

To help provide conservation incentives to private landowners, the Natural Area Partnership program (NAP) was established in the Department of Land and Natural Resources (DLNR) by the Hawai'i Legislature in 1991 through Act 326 (Hawai'i Revised Statutes 1995). This innovative program, the first of its kind in the nation, provides state matching funds on a 2:1 basis with private funds for the management of natural resources on private lands that are permanently dedicated to conservation. This program complements the existing state natural area reserve system by providing long term protection and management of unique natural resources on private lands. It also complements the state Forest Stewardship program (FS), which provides 1:1 state matching funds for approved forest management programs on private lands that do not qualify for the NAP program (Hawai'i Revised Statutes 1995). The NAP program not only helps protect land for the long term, it helps create a land tenure system that is conducive to exploring and implementing ecosystem and regional management schemes (Figure 1).

Natural resource protection and management are long-term efforts requiring time and energy commitments not often found in other projects. Recovery of vegetation following removal of ungulates or increases in populations of rare plants or animals after directed management actions may take several years to become detectable. Restoration projects often take years before results are discernible. To help ensure that critical management activities and funding do not stop prematurely, the NAP program requires long-term commitments from both the state and the private landowner. However, it is also necessary to be flexible and follow a policy of "adaptive management" when it becomes clear that management actions are not achieving desired results. One of the keys to striking this balance is to have adequate, regular monitoring programs to assess the effectiveness of management actions and to direct program objectives.

Program description

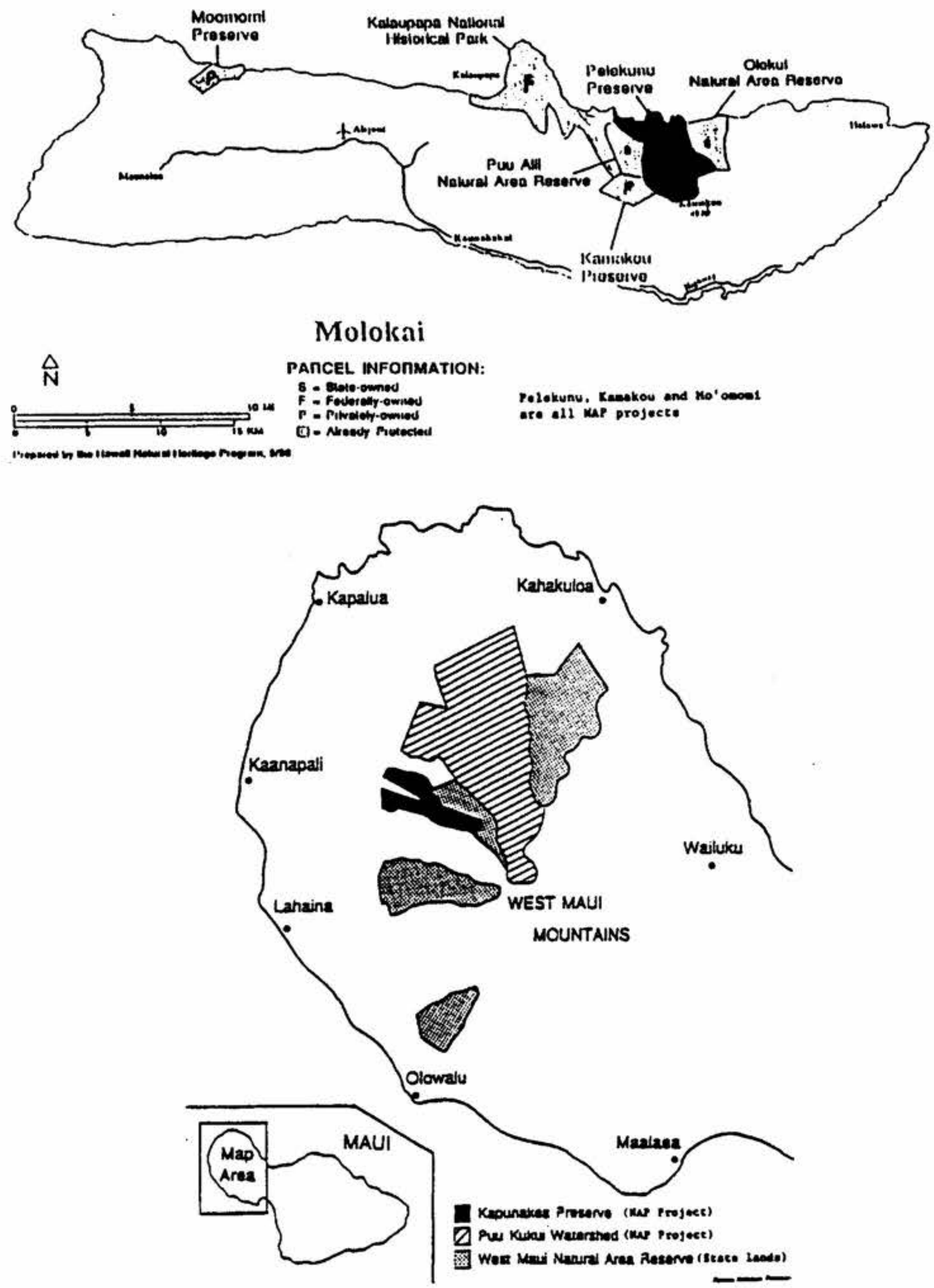
An applicant for the NAP program must be a private landowner or a cooperating entity. A "cooperating entity" is a private, nonprofit land-holding organization or any other body deemed by the DLNR as satisfactorily able to assist in the identification, acquisition, and management of natural area reserves. Lands must be of "natural area reserve quality," which might include intact native Hawaiian ecosystems, essential habitat for endangered species, or areas within the protective (P) subzone of the Conservation District. Areas that are at the ends of the spectrum (e.g., clearly high-quality or clearly degraded) are easily identified, whereas areas that fall in the middle are often hard to define. A working group is currently discussing the acceptance criteria for this program, as well as the complementary FS program, to provide clarification of the vague term, "natural area reserve quality." The NAP program can provide support for a full range of management activities to protect, restore, or enhance significant native resources or geological features. In addition, the program can provide support for the development of long-range management plans. The program is administered by DLNR

Table 1. First six fiscal years of NAP program showing state and private expenditures and number of projects.

	FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997
State expenditures	$153,554	$293,787	$339,990	$773,664	$927,089	$1,002,260*
Private expenditures	$76,777	$146,894	$169,995	$386,832	$463,544	$501,130*
Number of projects	3	3	4	7	7	7

* = estimated

Figure 1. The Natural Area Partnership Program helps create opportunities for ecosystem management.



Division of Forestry and Wildlife (DOFAW) staff, although all on-the-ground activities are carried out by either the private landowner or the cooperating entity. Draft rules governing the administration and implementation of the program are currently awaiting public hearings before becoming finalized. Currently, the following multi-step process to implement the program has been established:

(1) The applicant submits a preliminary proposal indicating the intent and nature of the natural area management considered.

(2) The Natural Area Reserves System (NARS) Commission reviews the preliminary proposals and selects applicants eligible to prepare a detailed long range management plan.

(3) The draft long-range management plan is reviewed by the NARS Commission and DOFAW staff. An environmental assessment is completed for all projects to obtain public input.

(4) The final management plan is submitted to the Board of Land and Natural Resources (BLNR) for project approval and a six-year funding authorization.

The first three years of the program were funded by state general fund appropriations. In 1993, a dedicated source of state funding was established by the state legislature utilizing an increase in the conveyance tax, which is levied each time real estate property is bought or sold. Since fiscal year (FY) 1995, all project funding has come from this special fund. Table 1 shows program funding levels and number of projects since program inception.

Current projects

The following seven projects were funded in FY 97:

Kamakou Preserve

Landowner: Moloka'i Ranch, Ltd.
Managing Partner: The Nature Conservancy
Entered NAP Program: FY 1995

This 2774-acre project helps regional protection efforts for both the native natural communities and the watershed area found in East Moloka'i. Thirty-seven of the plant species are rare, with 18 of these species listed as federally endangered. In addition, Kamakou protects habitat for five native forest bird species and five rare native land snails. The primary management focus is to prevent degradation of the native forest by reducing feral ungulate damage, limiting the spread of nonnative, habitat modifying plants, and preventing wildfire. Feral ungulate control activities utilizing both staff and the general public have maintained ungulate activity levels below 10 percent in the more accessible management units but has not yet achieved the 10 percent activity level in the more remote units. A "Five Year Weed Control Plan" has been completed and on-the-ground control activities on the top three priority weeds are under way. Research and surveys continue to provide baseline data and new information for management decisions. Public outreach programs are conducted with both on- and off-site activities (The Nature Conservancy of Hawai'i 1996a).

Kanepu'u Preserve

Landowner: Dole Food Company, Inc.
Managing Partner: The Nature Conservancy
Entered NAP Program: FY 1992

Kanepu'u Preserve on Lanai comprises 590 acres in seven disjunct units and represents the last major remnants of a dryland forest community that once covered large portions of Maui, Lana'i, Moloka'i and Kaho'olawe. Ten rare plants, six of them federally listed, have been reported from the preserve. Protection from axis deer, removal/control of nonnative plant species, and the use of the preserve as a focal point for dryland forest restoration research and study have been and will continue to be the primary management activities. Volunteer public hunters control axis deer in all fenced units, with six out of seven units currently deer-free. Recovery of native vegetation following deer removal has been documented. Control of nonnative weedy trees, particularly *Schinus terebinthifolius*, has been implemented in several units. Rat control stations have been established. Restoration trials, as well as a number of physiological and ecological experiments, have been conducted, although at a slower rate than originally planned due to lack of available planting stock. A revised restoration plan, based on current knowledge, will be completed in FY 97 and will serve as the basis for expanding restoration efforts and trials. Completion of a self-guided nature trail in FY 97 as well as the existing volunteer docent-lead preserve hikes provide educational outreach opportunities for the general public (The Nature Conservancy of Hawai'i 1996b).

Kapunakea Preserve

Landowner: Pioneer Mill Company, Limited

Managing Partner: The Nature Conservancy
Entered NAP Program: FY 1992

This 1264-acre preserve is a component of regional protection efforts for the important watershed area and native communities found in the West Maui mountains. Containing 10 native-dominated communities, 24 rare species of plants (five are federally listed), as well as four rare snail species, the preserve's upper elevations are recognized as among the highest-quality native areas in the state. Preventions of new introductions and the control of both animal and plant nonnative species are the primary objectives of preserve management efforts. Ungulate control efforts were intensified after an increase in animal activity levels was noted, and a reduction in activity levels was achieved. Control efforts on the nonnative guava (*Psidium* spp.), blackberry (*Rubus argutus*), and tibouchina (*Tibouchina herbacea*) have been implemented. Public outreach and education efforts include public lectures, docent-led interpretative preserve hikes, and volunteer work trips (The Nature Conservancy of Hawaii 1996c).

Mo'omomi Preserve
Landowner: The Nature Conservancy
Managing Partner: The Nature Conservancy
Entered NAP Program: FY 1995

This 921-acre project on Molokai contains one of Hawaii's best remaining dune ecosystems with associated rare coastal plants. Seven plant species and one native community are considered rare. Green sea turtles, Laysan albatrosses, and Hawaiian monk seals are known to utilize the area. In addition, Mo'omomi also contains significant archaeological, paleontological, and cultural resources. Ungulate control activities include maintenance of fences to exclude domestic cattle from entering the preserve, as well as the maintenance of axis deer exclosures, which are being used to help formulate an appropriate deer management program. Nonnative plant control activities include a kiawe (*Prosopis pallida*) removal program and removal of *Reichardia tingitana*, a small herbaceous species that threatens the integrity of the dune ecosystem. Protection of important cultural sites continues through cooperative efforts with the Hawai'i Historic Preservation Division and local community groups. Community outreach programs include preserve hikes and off-site activities (The Nature Conservancy of Hawai'i 1996d).

Pelekunu Preserve
Landowner: The Nature Conservancy
Managing Partner: The Nature Conservancy
Entered NAP Program: FY 1992

Pelekunu Preserve, located on Moloka'i's north shore, is a 5759-acre preserve established to protect the free-flowing Pelekunu Valley stream system, which is one of the best in the state. It is also part a larger regional management effort that provides protection to more than 22,000 contiguous acres on Molokai. The preserve contains nearly all the native Hawaiian freshwater fish, crustacean, and mollusk species. In addition, 27 rare plant species, five endemic forest birds, and two endemic land snail species have been reported from the area. Protection of the watershed by reducing ungulate damage and reducing the spread of nonnative plants are the primary management activities. The use of volunteer public hunters to replace the use of snaring and aerial hunting while still maintaining the same low level of animal activity was started several years ago and continues to be utilized through the Moloka'i Hunting Test Working Group. Although results indicate good control of pigs, an increase in numbers of goats has prompted a focused effort on reducing goat numbers through public hunting as well as a discussion of alternative control techniques for goats. Public outreach programs continue with public lectures, preserve overlook hikes, and the support of intern and summer youth programs (The Nature Conservancy of Hawai'i 1996e).

Pu'u Kukui Watershed Management Area
Landowner: Maui Land & Pineapple Company, Inc.
Managing Partner: Maui Pineapple Company, Ltd.
Entered NAP Program: FY 1994

With more than 8600 acres, Pu'u Kukui WMA is a critical component of regional protection efforts on West Maui that include more than 13,000 contiguous acres. Fourteen native natural communities, two of them rare, are found in the preserve along with more than 40 rare plant species and six endemic species of snail. Primary management efforts are focused on the removal of feral ungulates and the control of nonnative plant species. Feral ungulate control efforts have reduced animal activity levels to nearly zero in the high-priority upper elevation regions of the preserve. Vegetation recovery has been documented in previously disturbed areas. Recent sightings of both axis deer and goats near the preserve boundary have prompted intensified efforts to ensure that these species do not become established. Weed population control measures for a number of priority species, including *Clidemia hirta*, *Psidium* spp., and *Tibouchina herbacea*, are under way (Maui Land and Pineapple Company 1996).

Waikamoi Preserve
Landowner: Haleakala Ranch Company
Managing Partner: The Nature Conservancy
Entered NAP Program: FY 1995

This 5230-acre project helps increase regional protection efforts for the important watershed and native species habitat found in the East Maui Watershed Area. This reserve provides critical habitat for 13 native birds, eight of which are federally listed as endangered. Fourteen native natural communities, two of them rare, are found in the preserve along with 25 rare plant species. The primary strategy of the protection of Waikamoi is to reduce damage to vegetation and soils by removing all ungulates. Ungulate control activities include maintaining low pig activity levels as well as detection and subsequent removal of axis deer, which first appeared in the preserve in FY 1995. Construction of new fences in the area through the East Maui Watershed Partnership project will help control the ingress of pigs from downslope into Waikamoi. Control of habitat modifying weed populations continues with emphasis on species that have had prior control efforts. In addition, considerable effort has been devoted to miconia (*Miconia calvescens)* control and monitoring to prevent its establishment in the preserve. Development and implementation of appropriate monitoring and analysis techniques of natural resources on both a preserve and watershed scale have been a high priority. A cooperative research project with DOFAW, U.S. Fish and Wildlife Service, and USGS Biological Resources Division continues to survey for and describe the life histories of endangered Maui forest birds. Volunteer work trips and docent-led hikes provide educational opportunities for the general public (The Nature Conservancy of Hawaii 1996f).

Future directions and issues

Several issues or concerns have arisen during the first five years of the program. Some are programmatic, while others deal with specific projects. There are no easy or even "right" answers to these issues but they must be addressed if the NAP program is to reach long-term sustainability. Resolution of these issues will likely be achieved through a combination of on-the-ground efforts by the cooperating entities as well as changes in both the statutes and the administrative rules. A description of several issues follows.

* In the past, consideration and incorporation of community concerns into natural resource management programs has not been addressed as well as it might have been. Community-based management programs require a concerted effort and often take a long time to set up. Community advisory councils and facilitated working groups have been established and should help managing partners address local concerns in the coming years. This issue is also clouded by the fact that although the lands are private and involvement in the program is voluntary, the use of state funds trigger greater review by the public than landowners may have been used to.

* After the first several years of project funding, it has become clear that little is known of the restoration ecology of the dryland forest ecosystem on Lana'i; consultation and collaborative restoration efforts with other resource managers may improve the efficiency and success of this important project. Adequate documentation of the restoration efforts is essential to ensure that future managers benefit from current efforts.

* Long-range water development plans for Moloka'i have potential ramifications for Pelekunu and its undiverted waters. The state and land owner must be fully aware of all proposed or even potential activities to avoid competing and possibly counter productive state-funded programs.

* Partnerships, such as the East Maui Watershed Partnership, which is a group of seven agencies, organizations, and landowners, will become increasingly important as ecosystem-level issues are addressed. Ecosystem issues are complex and cut across political, legal, and geographic boundaries. Often no one agency or organization is equipped to handle the issue in its entirety thus making cooperative partnerships a vital necessity.

* After five years of the NAP program, a number of programmatic issues have arisen. The need to clearly develop land quality acceptance criteria and the need to help landowners who either cannot or choose not to commit their lands in perpetuity but who still wish to participate in cost-sharing conservation programs is a must. In addition, issues of allocation of finite funding resources not only between projects within the NAP program, but also between complementary cost-sharing

programs such as the NAP and FS programs must be discussed and resolved.

The NAP program has been very successful in its first five years and has established itself as a viable mechanism for helping Hawaii's private landowners conserve important natural resources. The challenge of the next five years is to maintain the strong foundation we have built while attracting new participants and ensuring strong funding support from the legislature. DLNR needs to successfully integrate the NAP, FS, and other cost-sharing programs into a series of private landowner incentives that will reduce the fragmentation of the Hawaiian natural landscape. Working together, government and private landowners can slow and perhaps even reverse the decline of the Hawaiian flora and fauna.

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Environmental Policy and the Public

Gary Gill, Hawai'i Office of Environmental Quality Control

Not long ago, our country was wracked by dramatic environmental disasters. Smog choked our urban centers. Plant and animal species, including our national symbol the bald eagle, were being pushed to extinction. Drinking water was polluted with sewage and harmful chemicals. Rivers caught fire. Homes built on toxic waste dumps caused birth defects in children.

Our country was booming economically. In the glory days of post-war prosperity, Americans reveled in the gluttony of consumerism. Modern American culture has the pop-top, disposable, planned-obsolescence, shop-until-you-drop, consume-all-you-can mentality woven into almost every corner of our national fabric. Household items cannot be fixed—we must throw them away.

Soon we learned that there was no "away" left to throw things. We began to gag on our garbage as our landfills overflowed. People could now see that the great frontier had been conquered and the natural resources our grandparents assumed to be limitless were being lost forever. Seeking a more sustainable and responsible way of life became not just a moral conviction for the benefit of our cousin species or future generations, it became a necessary step to protect our own health and survival.

America's Democracy slowly began to respond to the new environmental ethic and awareness growing in the public consciousness. Laws were passed to assure the careful and healthful use of limited resources. We now live in a country where almost every aspect of the natural environment is regulated and controlled. The continent is buffered from the pressures of human population by a thicket of red tape and regulation.

Any business discharging pollutants into the air or water is governed by volumes of rules and laws. The use of land and water is carefully scrutinized by government. CWA, CAA, SDWA, CERCLA, RCRA, FIFRA, TSCA, MPRSA, UMTRCA, NPDES, NEPA—the nation's law books are clogged with an alphabet jumble of regulations, each governing its own corner of the environmental house.

The law I will speak to you about is one of the first-born in the new age of environmentalism. It is the Environmental Impact Statement law, Hawai'i Revised Statutes (HRS) Chapter 343, sometimes referred to as HEPA, the Hawai'i Environmental Policy Act. I call HRS 343 the "mother of all environmental laws." Not just because it came before many of the more specific anti-pollution laws but because it lays the democratic cornerstone on which the other laws are built. The philosophy behind environmental impact statements runs to the core of our nation's democratic traditions. An Environmental Impact Statement is a living example of our country's trust in an educated populace.

The law describes certain kinds of development projects that must undergo an environmental study before they can be built. For example, any project that uses state or county funds or any development on land designated for conservation by the state is required to prepare a study.

Some small projects can be declared exempt from the law. Many projects that are not likely to have a significant effect on the environment can be built after completing a relatively simple Environmental Assessment. Large projects like a convention center or new airport or resort hotel that will likely have a significant environmental impact must complete a full Environmental Impact Statement prior to beginning construction.

When a draft Environmental Assessment or Impact Study is published, the public is asked to comment on the content and adequacy of the document. The law requires that the project proposer respond to all comments in the final document.

My office, the Office of Environmental Quality Control (OEQC), gives notice of these documents and encourages public participation through the publication of our twice-a-month bulletin, *The Environmental Notice*. Subscriptions are free, and we post the document on the Internet. About 1000 people, everyone from environmental activists to professional planners and elected officials, receive our newsletter in the mail.

The last step in the review process is the acceptance of the final environmental study. Either a government agency or the Governor must accept a Final Environmental Impact Study as being complete before a project can proceed. If a member of the public believes that a document is incomplete or that proper procedures were not followed, he has the right to sue in court to stop a project until all the provisions of the law have been followed.

An EIS is designed to bring the best possible scientific analysis together with concerns and knowledge in the public. The result should be enlightened decision making. That is the theory, but does it work in practice? Are better decisions made just because the law requires the project to be the subject of an environmental study and public scrutiny? Or, is an EIS just another bureaucratic burden borne by developers and a disincentive for economic development?

Some environmentalists would argue that many developers treat the EIS as a procedural technicality and not a planning tool. The law, they say, lacks the teeth to stop irresponsible development projects that will harm the natural environment and the human community. Many in business would argue that the law needlessly consumes vast sums of money and time and thus hinders the rights of property owners.

Somewhere between those polar perceptions lies the reality of our environmental review system. Our EIS process serves as an early warning system that encourages community participation in decision making and guarantees a citizen's right to information. Vigilant people depend on the disclosure required by the law to learn what developers are planning for their community. Citizen protectors of the environment help to guarantee that any significant impact on the natural ecosystem is scientifically scrutinized and measured.

And while the requirement to prepare an EIS does not ensure a developer will conform with the public's preferences or agree to "sustainable" development, it does encourage planners to avoid harmful impacts on the environment and be more sensitive to community concerns. Although a development project is rarely abandoned because of the findings in an EIS, it is safe to say that most designs are improved and environmental impacts more likely mitigated because of the process.

For example, take the county road project in Puna on the Big Island of Hawai'i. The county government proposed buying a private dirt road and improving it to ensure ambulance and fire protection services to the community. Well, what could be the environmental impact of such a well-meaning project?

The project required an environmental study. Word of the road plans got out to the community. My office was soon deluged with calls and faxes from all corners of the state and even from around the globe, raising dire concern about the road project. Some residents knew that under this road lay an extensive network of lava tubes and caves, including the longest such cave in the world. Inside these dark caverns dwell a unique array of rare bugs. Heavy equipment used to build roads has been known to crush through the tops of these lava tubes and disappear into the dank depths of ancient lava flows. This is an obvious danger to the bulldozer driver but also a threat to the subterranean ecosystem.

The public outcry was such that the county took notice and established new procedures to protect the cave ecosystem under their new road. If not for our EIS system and its guarantee of community participation and comment, one of Hawai'i's unique natural treasures and even a human life could have been jeopardized. This is just one example of how an educated and involved public is crucial to a democracy, and within a democracy, crucial to the preservation of the natural environment. Neither the bureaucrats embedded in government agencies nor the advocates of land development can be trusted to consistently make enlightened land use decisions. Only to the extent that the public cares about environmental preservation and has access to vital information, can we ensure appropriate government policy.

Chapter 343 is the method we use to ensure that the people themselves are empowered as environmental police. The law strikes a balance between a developer's desires and the needs of the community of living things. But although the environmental assessment of development projects will assist developers to make correct choices, the law does not stop development. The law merely requires that studies be performed before some types of development can take place.

Let's take a look at the impact that centuries of development has had on the environmental health of the Hawaiian Islands. The following data was collected by my staff, student interns, and the Environmental Council to help assess the environmental health of the Hawaiian Islands today. We call them indicators. They indicate that we have a very long way to go before we can claim we are sustaining our environment. In the past 5 years domestic potable water use has increased more than 6.5 percent in the state. Over the same time our *de facto* population has increased by 3 percent. Our use of drinking water is increasing twice as fast as our population. Clearly, government's efforts to encourage water conservation have failed.

Statewide, 11 percent of our drinking-water wells have been polluted by pesticides or other man-made chemicals.

Of the nearly 2 billion tons of garbage generated in Hawai'i each year, less than one-fifth is reused or recycled. And all the major landfills in the state have less than 10 years of capacity left.

As we speak, the State of Hawai'i, although blessed with rich resources or solar, wind, and ocean energy, remains about 95 percent dependent on the importation of fossil fuel, oil and coal, for our energy needs.

Last year, 82 separate oil spills took place in Hawai'i.

Of all the plants established in Hawai'i, only about one-half are native to the islands. Six in ten of the remaining natives are rare or endangered in some way. Over 100 native plants have already become extinct.

Due to the rising seas and constant construction too near the coastline, O'ahu has seen approximately 24 percent of its natural sandy beaches narrowed or lost in the past 70 years.

Can we sustain Hawai'i's tourism-based economy without clean water to drink and without clear oceans to swim in? Will tourists come and spend their money here if the unique nature of our islands has been paved over?

The Hawai'i of today is not the Hawai'i I was born into. Today, our native people are finding their traditional fishing grounds and walking trails blocked by new resorts and luxury housing developments.

Today's Hawai'i is not the Hawai'i many visitors expect to find when they venture here. The palm tree groves have been displaced by high-rise hotels. The surf sites are crowded. The agricultural land is paved with shopping malls, and traffic chokes roadways.

The environmental protection laws of the state depend upon the enlightened participation of an educated public to ensure that proper decisions are made by the people's government. This quick look at the many environmental challenges that confront our state, and our many failings to grapple with them, suggests that our leaders need more enlightenment and our people need a better education. I hope this presentation has made one small contribution to that cause.

Questions

Q: Are you aware of the plasma-burning facility on Kaua'i that's being constructed to burn waste, and is there any future view of looking at that technology for more of Hawa'ii's overall trash problem?

A: I'm aware of it. I don't profess to be an expert or directly involved in that regard. You know here on O'ahu, which I am more familiar with because of my time on the city council, 80 percent of our solid waste is shredded up and burned and converted to energy. I personally believe that combustion is probably going to remain, and rightfully so, one component of our waste management strategy. However, we're doing very little statewide now to promote economic development in the recycling industries. You know, handling composting, yard waste, and turning plastic into lumber and building materials is still in its infancy, and we should be far ahead of where we are. There is new technology in combustion, and I don't know the details of the plasma plant, but the state gets involved in the broad planning sense and most of that work is done at the county level.

Q: What are your thoughts and strategies for non-point source pollution as far as your office is concerned?

A: I have to enter in a little caveat here. Many of the detailed issues, non-point source pollution or solid waste or clean water, are handled by other divisions in the Health Department. Although OEQC has a very broad and impressive name, it was because we were there first, and then many of these programs came up under different mandates. The Health Department has different divisions to handle each of those separate issues. So, I can only tell you in a very broad-brush manner what's going on with non-point source pollution management. Was there a particular issue that you wanted to address in that, or did you just want hear about non-point source pollution, because you could go on all day on that subject?

Q: Mainly dealing with watersheds or aquifers.

A: Well that's the way planning is going. It makes particular sense here in Hawai'i, the whole ahupua'a land management system that the Hawaiians devised out of necessity and their own enlightenment over the years. It still makes a lot of sense, and I think we see the state moving in that direction. We have plotted the acquifers on GIS. As we look to polluted run-off and how to manage it, you do look in watershed blocks. The most work is going on, that I'm aware of, on the Ala Wai Canal Watershed, because it's the biggest, most visible, and probably one of the most polluted watersheds in the state. I had the opportunity to speak to some delegates from nations around the Pacific Rim and Tahiti and Australia and talk about sustainable development, and I just had to look out the window (at Waikiki) and see what sustainable development is not. If they didn't believe me, I invited them for a swim in the Ala Wai Canal. They didn't take me up on that. So if we can learn how to clean up the Ala Wai Canal, we'll learn how to clean up virtually every watershed in the state. It's going to be very costly. It's going to require a change of human activity. People have to realize they can't just put chlordane in their gardens and under their house and spread their fertilizer wildly in the back of Manoa if they're going to preserve the water quality in Manoa Stream and in the Ala Wai Canal. It's a big education effort, a big concentration of resources, but as far as I know the Ala Wai Canal watershed is the test case that we're working on.

Q: I'm interested to know how your office relates with the planting of forests. Is it necessary to have environmental statements? To what degree?
A:That's a very good question. The two triggers that you're going to stumble across with forestry projects is any use in the conservation district, if you require a CDUA permit, you may or may not need to perform and environmental assessment. We're grappling right now with the Forest Stewardship Program. That's the use of state funds, so is that a trigger for an Environmental Assessment? Likely it can be; it depends on the nature of the activity. One other element that I didn't really get into, for example, the trigger for a study, is the use of state or county funds, but you use state funds to buy staples, and a xerox machine and paper supplies and that obviously doesn't trigger an Environmental Assessment. There are broad categories of activities which are exempt although they may use state funds. How that works is, each department has an exemption list of the kind of activities that they perform on a routine basis that they know don't have a significant impact on the environment. They disclose those projects or those activities, which may be trimming the trees in the park or mowing the grass or minor landscaping activities, realigning conduits, things like that. You have to look at the exemption list of that agency to see if that activity is exempt or not.
Q: We're kind of missing the point here. What I'm asking basically is, if I want to plant a thousand acres of trees, am I going to have to do an Environmental Impact Statement to be able to get permission?
A: Are you using state funds?
Q: You're saying only if you're using state funds?
A: Yes, if you're on private land and you don't require any rezoning or reclassification and you're using your own money, go for it. You might need some other kind of permits.

Q: Gary, do you think the process as mandated by a 343 is working, or is it pretty much confined to other agencies and maybe public interest groups. Like the community effort you referred to in Puna, is that the norm or is that an anomaly that just seemed to happen on that project?
A: I think the system is working. I think it needs constant refinement. There are huge windows that are gaping open for certain projects to go through without any review. For example, there's no trigger for a power plant, there's no trigger to study a sewage treatment plant. Both of these things you would consider to normally have major impacts on the environment. They're going to release toxins into the air or the water. There's no provision in the law to perform a study on those and consider all the mitigation measures prior to their development. If, for example, you have a power plant in Campbell Industrial Park, which is zoned insdustrial and you're using all private money for it and you're not on the coastline, there's no way for us to consider the impacts of having yet another smoke stack at Campbell Industrial Park. They'll just go and do it and they'll go through to the permit level. The Clean Air Permit is administered by the Health Department, and they have very little discretion about saying yes or no to the project at that point. All they can say is you have a smoke stack and you have to remove this much particles from the air before you get your permit. There are refinements that are needed, but 343 is a very important fundamental element. Not just to protect the environment but to ensure community involvement and participation. We get that all the time. There may be 50 to 60 percent of the projects that come through our office that are not controversial, and we're getting rid of a bunch of those just because it's overlapping bureaucracy. For example, DAGS was bringing in these Environmental Assessments

for putting chain link fences around school yards. They don't need to do that. A lot of the little things that don't need to be done, we're helping the agencies save their time and paperwork and just go and do the project. But many other things that you wouldn't suspect, like the Puna road project, the convention center, the Kaiwi Park situation with the golf course out at Queen's Beach, the Le Jardin School, many of these things are going through public review very actively. If the law weren't here to ensure public participation, you would see a revolt in the communities when they say, "Who allowed this and how come we didn't know about it?" So, for the very least, even if we're talking about community concerns and not directly environmental concerns, the law plays a very important role.

Soil and Water Conservation Districts (SWCD) of Hawaii

Francis Pacheco, Hawai'i Association of Conservation Districts

The Soil Conservation Act was enacted by Congress in 1935 to control soil erosion and promote water conservation during the "Dust Bowl" conditions of the 1930s. This Act instructed the states and territories to form Soil and Water Conservation Districts to care for the farm lands. There are nearly 3000 districts which have been created in the 50 states, the District of Columbia, Puerto Rico, the Virgin Islands, Guam, the Northern Marianas, and Micronesia. The appropriate role of the districts is to take available technical, financial, and educational resources and focus them to meet the conservation needs of the local land users. In this regard, the directors of the SWCD assist the farmers with their conservation plans to meet the requirements of county grading ordinances, the state's Nonpoint Source Pollution Management Plan and the conservation provisions of the Food Security Act.

The authority to establish the districts as governmental subdivisions of the state is in Chapter 180 of the Hawaii Revised Statutes. To achieve their mission, Chapter 180 permits the districts to aid land users with equipment and materials for construction work; conduct surveys and investigations; initiate, construct, improve, or maintain projects; sell, acquire, or manage properties; effect agreements or litigation; develop or approve conservation programs and plans; establish fees for services; and require or receive materials, services, or funds to extend services.

Natural Areas Working Group

William T. Stormont, Division of Forestry and Wildlife, Hawai'i Department of Land and Natural Resources

The Natural Areas Working Group (NAWG) began as a means of involving various community interests in discussions regarding the management of state-owned Natural Area Reserves on the Big Island. Through monthly facilitated group meetings, coupled with community meetings, the NAWG published a report in March 1995 outlining its process of issue identification, recommendation development, and specific action formulation. A primary action taken has been the development of regionally-based groups having the same functional representation as the NAWG. Hunters, land managers, resource users, environmentalists, researchers, landowners, and elected officials now make up two separate regional groups: the Kohala Forest Management Group and the Upper Puna Volcano Regional Forest Management Advisory Council. These groups represent what may be the cutting edge of public land use planning. At a minimum, they offer an opportunity for dialogue and shared information exchange.

Real Property Tax Assessments of Native Forest in Hawai'i County

Keiko Bonk, Hawai'i County Council

I feel privileged to be a speaker here today, rather than a participant, as a change. I've attended many of these conferences over the years as a councilwoman and learned a great deal. I've been asked to speak on a very interesting and provocative subject today: taxes. It's not one of my fortés in life, but, however, as a public servant interested in the forestry industry as well as protecting our native ecosystems here in Hawai'i, I was motivated to get involved in this issue.

For decades, county tax policies were identified as a major factor contributing to the destruction of our native forests. Native forests and all forests, for that matter, were assessed at the open market or the so-called "highest and best use" level. This discouraged people from getting their land forested. At the same time, a landowner could get a giant tax break if they could put the land into pasture, which encouraged many people in Hawai'i to cut down our forests. Although the problem was identified decades ago, nothing was done. The usual excuse was that it would cost the county too much money if we started to do something about this. So no one wanted to do the study to find out actually how much it would cost.

As Chairwoman of the Hawai'i County Council, I initiated a study and submitted legislation to change our tax laws, and I was motivated to do this through attending this forum of the Hawai'i Forestry Association, but also I was motivated by many other people in the community, including the environmental community and people involved in other agricultural endeavors, to change the tax laws.

The legislation was originally designed to do three things. First, create a new tax category for a native forest. Second, to simplify the tax system and create tax incentives for commercial forestry and diversified agriculture. Third, to close tax loopholes that allow people to get an agricultural investment when they were not engaged in any commercial agriculture. The council and the administration initially opposed all of these three goals, but eventually passed a piece of legislation that created a new tax category for native forests and a number of other revisions that would make it easier for people to restore native forests. The other goals of the initial legislation which I introduced are still stalled in the finance committee, and they haven't passed out of finance committee since the Native Forest Bill part was passed.

The key to getting these legislative changes started was done by a study initiated by myself and carried out by a special assistant named Michael Christopher. He also had a staff of university students as well as part staff from the legislative auditor's office in the county council's jurisdiction, but also we worked together with the Hawai'i Forestry Industry as well as ranchers and other people involved in agriculture and the other parts of the community to form a coalition of resource people in order to write this legislation, and we also worked together with the tax office itself to get information to put together this legislation.

The first thing that was done was to overlay a vegetation map of Hawai'i over a tax key map to identify what forests there were and what the impact would be in terms of our tax assessment. The vegetation map was produced by the Cooperative National Parks Resource Studies Unit in conjunction with the Botany Department of the University of Hawai'i at Manoa and the United States Fish and Wildlife Service. The map is commonly referred to as the Jacobi Map because its named after Jim Jacobi, who many of you know is a scientist that works up at the national park under,I believe, the Biological Service. The Office of State Planning produced the overlay map using their GIS computer, but we had to give the state Division of Forestry and Wildlife credit because OSP at the time was under attack by a lot of my fellow council members, as well as other people in the state.

The computer was set to define a native forest as 60 percent or greater native species forest cover, and that means that at least 25 percent had to be tree cover. Out of 131,185 tax parcels, we initially identified 3850 parcels that were potentially covered with at least 5 acres of native forest. There were tens of thousands of other parcels that contained some native forests but didn't meet the requirements of Bill 160, which became Bill 259. Most of these parcels were in Puna, where the land had been subdivided into 1- and 3-acre lots. Many of the 3850 parcels were owned by the state or the federal government and so were exempt from the property taxes. The final sort left us with only 389 parcels ranging in size from 5 acres to 115 or so acres. Many of these parcels had only a small portion in native forests.

The overall revenue impact of the creation of the native forest category was shown to be a maximum of $322,124 per year. Realistically, it would probably be half that. The cost is so modest because most of the land that met the criteria was already being assessed as pasture or conservation land. If it wasn't pasture the revenue impact was neutral, since the change in the law gave native forests the equivalent of a pasture assessment. If the land wasn't conservation, the revenue loss would be minimal; the areas where there would be a large tax loss by the county were exactly those areas which we most wanted to protect, but were instead encouraging land owners to deforest . . . areas where there was a great deal of land speculation, such as Kaloko Mauka and places like that on the Big Island.

The bill also made it possible for large landowners who had been grazing cattle and forests in order to get a pasture assessment to remove the cows without being penalized, provided that they met the 60-percent requirement. The bill also made special provisions to make it possible to get a native forest assessment for land that was being actively restored. The Native Forest Bill passed, and as a result, in Hawai'i County if you have at least 5 acres of native forest you can have it assessed at the lowest agricultural assessment level, which in effect means the same as getting a pasture assessment. Persons wishing a more detailed account of the revenue impact analysis can get a copy of this analysis in book format from Hawai'i County; it's called "The Revenue Impact Analysis of Implementation of Bill 16095, Draft 3."

While the passage of this bill is a good start, there are still many things that can be done with our tax codes and zoning if we are going to see a full recovery of our forests here in Hawai'i. I would strongly recommend that the people here as well as people in the industry start to pursue some of these other changes. The tax changes originally included in Bill 160 could have affected our this industry a lot more. For instance, some of the issues regarding longer dedication periods can still be addressed, closing loopholes in the system as I suggested earlier, reducing the number of agricultural categories, and allowing the fallowing of land. Closing the loopholes in the agricultural tax assessment system would generate between $5 million and $29 million per year in additional county revenue. This would more than offset the cost of the native forest category and strengthen our commercial agriculture and silvaculture industry. Changing our tax policies to encourage good farming and good forestry practices would also provide jobs and strengthen our economy without creating service and infrastructure costs.

These are only the beginings of what could be done if there was a genuine effort by elected officials to accomplish these things. So, I am suggesting (I'm not an elected official anymore) that we urge all elected officials, not just those in Hawai'i County, but across the state to start pursuing these incentives and changing our lives to protect the forests here in Hawai'i.

Questions

Michael Buck: I'd like to thank Keiko and everyone in this room that worked on the tax bill. It's been a long time coming. Can you give us an update on what's the current county tax policy for tree farms or commercial forest development on sugar lands in terms of property tax assessment or the other piece of the puzzle that you're working on.

Keiko Bonk: As I mentioned earlier, that part of the legislation is still stuck in the finance committee, and it's changed around since I was involved in it. It has to pass out of finance committee. What needs to be done is for everyone to write testimony or do some political urging of the present council and the future council that will be sworn in on December 2 to start pushing that legislation. It creates a tree farming category; it starts incorporating some of the good practices that I was talking about.

Q: So people who are planting trees on sugar land right now, what kind of property tax are they being charged?

A: Its highest and best use as far as I understand, because there's no category for tree farming.

Mike Robinson: I don't think the question's answered yet. There are a couple of people here who might be able to answer that. There is a forestry category established under the current law, and it was really a setting of what is the correct assessment. I think it's been low-

ered, but how far down I'm not sure.
Bill Cowern: I think that happened through the Board of Appeal. I think there was an appeal of the Prudential plantings which created a different tax level for that particular operation. I don't believe it applies statewide, but it certainly sets a precedent.
Representative from County of Hawai'i, Real Property Tax: Tree farms are currently covered under the law, that was put in as a separate section before Bill 160. It's true that through the appeal process Prudential is now getting a forest rate. The new revision is out of committee,Thursday is hopefully its final hearing, and it will establish a category for forest.

Q: What's the rate?
A: $500 per acre for Prudential, and category rates haven't really been established. That's the assessment so the taxes equate to $5 per acre.

Q: For Mike Tulang, what's the area of responsibility for the soil and water conservation districts? Is it all lands or just certain lands?
Mike Tulang: It's generally all private lands. I just wanted to comment on the $500 per acre assessment. I think the deliberation at the county was to ensure that it was the plantation rate of agriculture to ensure that the county wouldn't experience a drop in revenues when the plantations went out. That's the rationale for the $500 per acre.
Steve Smith (Hamakua Timber): That $500 rate is without a 20 year ag dedication. We are looking, and have in fact applied, for dedication of that property. That hopefully will change the thing again in a year or two. I think it was a very encouraging sign from the County of Hawai'i, and I would like to thank all the people on the review panel and in the administration and the council who have supported our efforts to get an equitable tax rate to encourage both large-scale and small-scale silviculture efforts.

Conservation District Rule Update

Edward Henry, Division of Land Management, Hawai'i Department of Land and Natural Resources

The State Conservation Land Use District: What is it, and how do the law, administrative rules, and processes operate? Additionally, what is the Conservation District Review Update?

First, let's start with some basic understanding of the State Conservation District. There are a total of about 4,051,398 acres of fast land within the State of Hawai'i. The State Land Use Law, Chapter 205 HRS, segments this land within four major land use districts: urban, agricultural, rural, and conservation.

Chapter 205, HRS, provides that the Board and Department of Land and Natural Resources administrate the State Conservation District, while the county jurisdiction administrates the Urban, Agricultural and Rural Districts.

As of 1993, about 49 percent of the land statewide was classified within the State Conservation District. This land area is predominately upper mountain regions, watersheds, forest reserves, some river/stream waterways, and coastal shorelines. It includes both public and private land holdings.

The first set of administrative rules for the State Conservation District was established in October 1964, identified as Regulation 4. The rule established two subzones: restricted watershed and general use. In the restricted watershed subzone, land uses were restricted to water and forestry resource development, the installation of transmission facilities, and government programs and activities.

In 1968, Section 41 of Chapter 183 HRS was established to provide a more legal basis for the department to administer the State Conservation District. Following the preparation of a Conservation District Plan in 1977, Regulation 4 was revised to provide for four subzones: protective, limited, resource, and general, with permitted land used identified. A special subzone is also identified for such areas as Sea Life Park.

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A conditional use permit was also established which would allow uses that may be permissible under certain conditions, as determined by the Land Board.

Regulation 4 was replaced by Title 13, Chapter 2, HAR, in 1981. Very few amendments were proposed to either the law (Chapter 183-41 HRS) or the administrative rules (Title 13, Chapter 2 HAR) for the next 12-year period.

Now we come to the Conservation District Review Project. Beginning in the spring of 1993, the department initiated a project to review the then-existing law (Chapter 183-41 HRS) and the administrative rule (Chapter 2) to see if possible amendments or revisions were warranted. The department assembled a group of 26 parties in a Project Advisory Committee representing state and county government agencies, the legal and planning profession, land owners, Hawaiian organizations, and environmental and special-interest groups. They assisted the department in developing a report entitled "The Discussion Document" in November 1993, which identified a number of specific recommendations including the need to formulate a new Law specific to the State Conservation District and to draft administrative rules that provided for major and minor land use permit processes. It also identified the need to further the review project with more substantial planning effort.

Following that report, the department prepared a bill for the 1994 Legislature which would establish a new legal basis for the administration of the State Conservation District. This bill was passed and coded as Chapter 183C HRS.

With a new law, the department initiated the undertaking of formulating new administrative rules. This was done in the spring and summer of 1994 with the assistance of the Conservation District Review Project Advisory Committee. They helped to formulate and generally support the new administrative rules, knows as Title 13, Chapter 5, HAR, which the Land Board, and then-Governor John Waihe'e, approved in December 1994.

The new Chapter 5 rules are much different from the old Chapter 2 rules. There are a number of specific areas to highlight. First, commercial forestry and agriculture are specifically listed as "identified land uses" in the State Conservation District. The new rules also defines what type of proposed land uses are minor and require minor permits to be reviewed by the department, versus more intense land uses requiring Land Board review. Commercial forestry is listed as an identified land use in the Resource Subzone requiring a management plan, as provided by specific components in the rule. All commercial forestry Conservation District applications will be forwarded to the Land Board for decision making. However, most data collection is considered a minor land use and can be reviewed by the department.

The department's report: "The Process of Revision and Proposed Changes," prepared in November 1994, highlights the changes between Chapter 2 and Chapter 5 rules and contains a rationale for making the revision.

The Conservation District Review Project is continuing with the assistance of a consultant. We are now focused on reviewing known resource attributes for areas situated within each of the four major subzone categories. The objective is to affirm, or recommend, changes to the subzone regime and zoning maps as may be warranted. An overall management plan for the Conservation District is also being pursued. We anticipate having a draft management plan and draft subzone maps in the spring of 1997 for public review.

Following public and agency input, the department will be forwarding a report to the Land Board for review and approval. Subsequent revisions, or as pertinent, may be made to Chapter 183C HRS and to Title 13, Chapter 5 HAR.

With regard to whether the new law and rules for the Conservation District will assist or hinder private landowners, we have not yet experienced an application for commercial forestry. But we are continually reassessing our rules and procedures to determine the efficiency and consistency of departmental processes.

Your input in this endeavor is encouraged.

Historic Sites

Holly McEldowney, Division of Historic Preservation, Hawai'i Department of Land and Natural Resources

I would like to briefly cover three major topics. The first is a summary of the major state and federal laws that apply to historic sites and the role played by the state Historic Preservation Division in implementing these laws. Second, I will briefly outline the process by which our office reviews projects for their impact on historic sites. Third, I'd like to emphasize the kinds of information we need from applicants when we are reviewing proposals and making our assessments. The sooner we have adequate information in these proposals, the faster the process will go.

Both state and federal laws require that impacts on historic sites be considered for most private-sector projects that require permits or those receiving government funding and for most projects undertaken by government agencies. The state Historic Preservation Division has a mandated role in implementing both the federal and the state historic preservation laws. If the federal government is involved in a project either through funding or permits compliance with Section 106 of the National Historic Preservation Act is probably required. Section 106 is implemented by regulations which set out the process by which historic sites are identified, evaluated, and their treatment determined. In bureaucratic shorthand, this is just usually referred to as Section 106 or 106, so if you hear that, you know they're discussing the federal process.

The way the federal review process is set up, the state Historic Preservation office plays a major role in reviewing proposed projects. For example, in various steps in the process our office must be consulted or we must be given the opportunity to concur that the project will or will not have an affect on historic sites. For the projects being discussed here, I think federal funding is probably the action that would most likely trigger the federal historic preservation law. But, it would also apply to projects on federal lands or those for which federal permits are required. The state laws governing historic sites are found in Chapter 6E of Hawai'i Revised Statutes.

For our purposes here, today, two sections of this law are particularly important. Section 6E-8 applies to all projects undertaken by state and county agencies which may have an affect on historic sites. It requires these agencies to obtain written concurrence from the state Historic Preservation Division before a project commences. Essentially, this applies to all projects receiving state funds, or any taking place on state lands. Section 6E-42 says that the state Historic Preservation Division shall be given the opportunity to review and comment on a range of undertakings or a range of action undertakings by state and county agencies. These generally involve permits, licenses, land use changes, subdivisions, and other entitlements. This is one means by which we've become involved in reviewing many projects that require zoning or grading and grubbing permits. So, to recap it very briefly, if there is a federal involvement in Section 106, the National Historic Preservation Law, if there's a state or county involvement, the process will probably begin with one of two sections of Chapter 6E, and both mandate the participation of the state Historic Preservation Division.

I will now try to very briefly the summarize historic preservation review process, only emphasizing the major elements of the process. Essentially, the state review process parallels that of the federal regulations. I generally like to tell people that it's like filling out your state and federal tax forms. The form looks the same and the approach is essentially the same even though there are some differences. The first step in the review is to determine whether any historic sites are present in a project area. If we know that none are present or that they are highly unlikely, our office will concur that we have no concerns and the project can commence; essentially, no further work is needed. If we know that there are historic sites in a project or feel that it is very likely, then we generally ask that what we call an inventory survey be conducted of the project area. We have staff archaeologists on all the major islands, and they may be able to assist applicants with field inspection to determine if the survey is needed. This would be particularly appropriate if we are unsure whether there are sites in an area or we believe the likelihood is very low. Of course, this would depend on the staff members, their availability, and their current workload, but it is a service we hope we can provide. Because most lands have not been surveyed for historic sites, our assessments on whether or not a survey is needed is based on predictions. And these predictions are largely derived from known site distributions and particular regions and our knowledge of prehistoric and historic Hawaiian land-use patterns.

Most of the archaeologic inventory surveys that are conducted are conducted by private consulting firms, so that's the first step: whether sites are present or not. If they are, if the survey is conducted or we know sites are present, the next step is identifying these sites. The identification phase occurs during the inventory survey and includes locating, describing, and documenting any historic sites found in a project area. During the survey, essentially, the entire project should be inspected. For the purposes of the federal and state laws, a historic site is one that is older than 50 years old. As you may be aware, in Hawai'i, that is really a variety of sites that can even include buildings, include ditches, trails, small rock mounds, burial sites, shrines, house sites, or agricultural field systems.

Step three is the evaluation phase, once a site has been identified, it should be evaluated. There are four criteria that we use for evaluating the significance of sites, and I won't go into these here, but I would like to make one point about the significance evaluation. Significance evaluations are essentially a planning tool that help determine the fate of a site or how it will be treated in the future. The way the criteria are applied, essentially all historic sites are significant for one reason or another. This does not mean, however, that all sites that are determined significant must be preserved, or that they're necessarily spectacular. For example, some relatively crude sites could be determined as significant. The meaning of significance evaluation is often misunderstood by the general public, and some land owners get very irate when they're told that they have significant sites, thinking that they won't be able to use their land, but often we do have ways to deal with them.

So once we have determined the significance of a site, the next step is determining the treatment of these sites, and treatment can be a range of options. A historic site can be destroyed if we've collected all the information we need to know about it. If it's particularly important or a good representative site/type important to the Hawaiian community, we generally ask that it be preserved and protected by some sort of buffer zone or long-term management plan.

The last step is actually implementing these treatments, and we often call these treatments mitigation measures because we're mitigating the impact on them. One word of caution is that sometimes historic sites are discovered in a project area where we did not expect them, and if this happens, particularly during ground-altering activities, please call our office and we can send a staff person to inspect the site. This is particularly important in the case of burials, because the law mandates that our office be notified when burials are inadvertently discovered.

Finally, I'll mention some major points that are very important for us to see when we're reviewing applications. If you're writing a proposal or filling out an application, it's very important to describe the past land use history of a project area, particularly if the ground surface has been mechanically altered in the past, such as if it's been heavily cultivated with sugarcane or papaya orchards or it's been cleared by bulldozing. Because if the areas have been heavily altered in modern times, the likelihood of historic sites is extremely low. Also, you can have good descriptions of the location, topography, and elevation of the project area, because these are the factors that help us the most in trying to predict what sites we expect in an area, and the density of the sites.

The Endangered Species Act: Private Land Strategies for Working Together

Margo Stahl, U.S. Fish and Wildlife Service

The State of Hawai'i has the dubious distinction of being the "endangered species capitol of the U.S." with the latest tally as follows:

PLANTS:
- 272 endangered plants
- 10 threatened plants
- 10 candidates
- 293 species of concern

ANIMALS:
- 77 endangered animals
- 4 threatened animals
- 28 candidates
- 363 species of concern

This focus on numbers of species sometimes diverts our attention from the stated purposes of the Endangered Species Act of 1973 (ESA), which are to ". . . provide a means whereby the **ecosystems** upon which endangered species and threatened species depend may be conserved. . . ."

Understanding the implications that this holds for land development and the legal, political, and social arena that exists today requires some basic understanding of the key provisions of the Endangered Species Act. Several key provisions of the ESA deserve review: the species listing process, the Section 9 prohibition on the take of listed species, the Section 7 consultation process, and the Section 10 incidental take permit process. Knowledge of the flexibility of the ESA helps private landowners learn of three tools to conserve endangered species on private land: Conservation Agreements, Safe Harbor Agreements, and Habitat Conservation Plans.

Government intervention in the protection of America's endangered and threatened species is relatively recent, with passage of the Endangered Species Act about 25 years ago. Fish and Wildlife Service biologists have since been sensitized by knowledge that the vast majority of these species are on private, not public, lands. Although this nation has made considerable progress with endangered species conservation over the past 25 years, the task is not complete. The Secretary of the Interior recognizes that implementation of the Act should be improved by building stronger partnerships with states and local governments, and especially with private industry and individuals.

Before an animal or plant can be placed on the federal endangered and threatened species list, threats to the species from habitat destruction, pollution, over harvesting, disease, predation or other natural or man-made factors must be reviewed and evaluated. This review process provides many opportunities for public input from concerned citizens and organizations, the scientific community, and all levels of government. The rulemaking process can also end in the Service's refusal to place a species on the list or designate critical habitat, once all the facts are known through this fact-finding, public process. After an animal is placed on the list, it cannot be possessed, taken, or transported in interstate or international commerce without special permission. "Take" is defined in the ESA, making it illegal for anyone to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect any threatened or endangered animals, or attempt to do so. "Harm" may include significant habitat modification where it actually kills or injures a listed animal through impairment of essential behavior. Federal prohibitions under the ESA for the destruction of listed plants on federal lands are restrictive, but on non-federal lands, harm to listed plants is only illegal if such harm is in knowing violation of state law.

Section 7 of the ESA requires that all federal agencies do not undertake activities that will jeopardize the continued existence of listed species or result in destruction or adverse modification to their critical habitat. Through the Section 7 consultation process, the ESA allows the taking of listed species incidental to an agency action if such taking does not jeopardize the species. In these cases the federal agency is required to adopt terms and conditions and reasonable and prudent measures identified by the Service to minimize the level of incidental take on animals. In addition, Cooperative Agreements, sometimes referred to as Safe Harbor Agreements, can be signed between a private party and the Service in which the Service in essence takes responsibility for any incidental take (intra-service Section 7) which might occur during the time the Cooperative Agreement is in effect.

Habitat Conservation Plans can also be implemented through Section 10 of the ESA, and incidental take permits are available when non-federal activities will result in "take" of threatened or endangered species. Such a conservation plan must accompany an application for an incidental take permit. These plans are often referred to as "HCPs". The purpose of the HCP and permit is to allow these activities by determining and minimizing the level of "take" and mitigating for that take to the maximum extent practicable.

The Service, through the provisions of the ESA, can provide such exemptions to private landowners to legally proceed with activities that would otherwise result in illegal take of a listed species while still meeting agreed-upon Fish and Wildlife goals. The administration has shown its desire to assure fair treatment for private landowners by issuing ten principles that outline "user friendly" mechanisms for building new partnerships and strengthening existing ones through a fair, cooperative, and scientifically sound approach. Some of these principles include the need to provide quick, responsive answers and certainty to landowners; to treat landowners fairly and with consideration; to create incentives for landowners to conserve species; and to minimize social and economic impacts. In addition, on August 11, 1994, Secretary of the Interior Bruce Babbitt issued a "no surprises" policy associated with habitat conservation planning on private lands. This policy assures landowners that in the event that an unlisted species addressed in an approved conservation plan is subsequently listed pursuant to the ESA, no further mitigation requirements should be imposed if the conservation plan addressed the conservation of the species and its habitat as if the species were listed pursuant to the ESA. The "no surprises" policy was intended to provide assurances to non-federal landowners participating in habitat conservation planning that no additional land restrictions or financial compensation will be required from an HCP permittee for species adequately covered by a properly functioning HCP.

A suit challenging this policy, however, was recently filed by the Biodiversity Legal Foundation, the Spirit of the Sage Council, and others, claiming that the Fish and Wildlife Service has violated its duties under the ESA. In Hawai'i, application of Habitat Conservation Planning and other mechanisms to exempt purely private incidental taking is pending resolution of the inconsistencies with current state law that does not specifically allow a state exemption process for incidental take.

Many private landowners are not aware of the federal assistance programs available to help them in their habitat restoration, conservation, and management efforts. Conservation Agreements can allow development to occur with protection of a species assured to the point that it may never require placement on the list of endangered or threatened species. The private lands "Partners for Wildlife" program, administered by the Fish and Wildlife Service, is a land-stewardship program that provides financial and technical assistance to private landowners desiring to restore wildlife habitat on their lands. As such, the program helps private landowners to conserve the nation's biodiversity. In addition to cost-share payments, the types of assistance include design and management of restoration projects, dirt moving, reseeding, and advice on soil and water quality improvement, water management, native plant revegetation, and grazing management. Funding for this program has been increasing over the years and private landowners are encouraged to contact the Fish and Wildlife Service Private Lands Coordinator if they may be interested in this partnership opportunity.

The ESA, as amended and with new policies, provides a number of mechanisms—seldom used in the past—to resolve or avoid apparent conflicts between the needs of species threatened with extinction and the rights of private landowners. A number of private parties in Hawaii have taken full advantage of these programs. The Service is grateful to the landowners of Kai Malino, Kealia, and McCandless Ranches who have worked tirelessly to protect the last remaining 'alala on their lands. The same debt of gratitude is extended to Kamehameha Schools/Bishop Estate, which is seeking innovative ways in partnership with the Fish and Wildlife Service to protect endangered species on their lands. Similarly, the Service appreciates the cooperation of Chevron, Inc. in a restoration program for endangered Hawaiian stilts on O'ahu. The Fish and Wildlife Service Pacific Islands Office looks forward to expanding its partnerships with private landowners, in cooperation with the state, as we seek to protect, enhance, and recover endangered and threatened species in Hawai'i.

State of Hawai·i Endangered Species Protection

Carol J. Terry, Division of Forestry and Wildlife, Hawai'i Deptartment of Land and Natural Resources

Hawai'i is known as the endangered species capital of the world. With just 0.2 percent of the land area of the U.S., Hawai'i has over 31 percent of the country's listed endangered species. Hawai'i currently has 302 federally listed species, with several hundred more that are species of concern.

Dealing with Hawai'i's endangered species is an enormous problem. Of our 33 native forest bird species, 21 are endangered. They include such unique species as the crested honeycreeper (once found throughout Maui and Moloka'i, it is now restricted to wet forests on East Maui); the 'akiapola'au (which has a fragmented distribution limited to a few koa/'ohi'a forests on the Big Island); and the nene (whose numbers are recovering well on Kaua'i but not on the other islands).

We 'currently have 263 plant taxa that are listed as threatened or endangered. Over 100 of these endangered plant species are represented in the wild by only 20 individuals, or less, or a single isolated population.

There are also several hundred species of invertebrates that are in danger of becoming extinct. Some are officially listed as endangered, such as the 41 species of O'ahu tree snail; others are not, such as the 74 other species of snails and over 300 species of insects and arthropods that are threatened by extinction but are not officially listed as endangered, such as the happyface spider.

The threats to Hawai'i's native species are numerous, but largely they are due to non-native invaders, such as invasive weeds like banana poka and miconia, both attractive plants that can take over a watershed and destroy the native forest and habitat for wildlife. Predation by introduced insects, rats and mongooses, and feral dogs and cats also take their toll on native plants, snails, and birds. In addition, diseases that were brought by these invaders infect both endangered plants and animals.

There are plenty of other threats to our native species. One of the very worst—that we know of—is the brown tree snake. This long, thin, nocturnal predator has devastated the fauna of Guam, wiping out almost all of its native bird species.

But one of the most serious threats to Hawai'i's endangered species is the public's expectation that state personnel are solely responsible for recovering endangered species—coupled with our restrictive endangered species laws that focus on individual plants and animals and effectively preclude large-scale, long-term habitat planning by the private sector.

Hawai'i's endangered species are protected by Chapter 195D of the Hawai'i Revised Statutes and Chapter 124 of the Hawai'i Administrative Rules. These laws and rules say that with regard to endangered and threatened species, it is prohibited to possess, injure, kill, destroy, transport, or export, sell or offer for sale any endangered or threatened species of wildlife or plant, or attempt to do so. *Except*, the DLNR may issue temporary licenses to allow any of these prohibited activities, as long as the activity is for scientific purposes or enhances the propagation or survival of the affected species. [§195D-4 (e), (f), §124-3 (b), -4(a), (b)]

It is apparent that the intent of these regulations is to protect threatened and endangered species by protecting individuals. But although they currently protect individual plants and animals, they are hampering the recovery of the entire species. This is because no species lives in a vacuum. Each one is part of a community, and in many instances the species cannot survive when that community is no longer intact. That's why endangered insects are as important as endangered birds. The current Hawai'i endangered species laws address individuals, not the communities in which those individuals live.

Consider endangered species recovery as being composed of three phases. The first is recognition and protection of the endangered species. The second is their recovery, and the third is proper management so they don't become endangered again.

It seems as though Hawa'ii's original endangered species laws were written to address that first phase, the recognition and protection of species that were likely to become extinct without human intervention. And those initial laws have served their purpose, saving individuals with the future goal of recovering the species. However, at least in Hawai'i, we seem to be stuck in that first step—we are concentrating on saving individuals. However, it is time to move on to that second step: recovering the species. And now that we have the knowledge to actually begin recovery, we are discovering that the laws that were so useful in protecting endangered species are now hindering that recovery.

The current laws focus on individuals, they don't address habitat planning and they don't address the need for assistance and cooperation from the private sector. Implicit in these laws is the notion that protecting and recovering endangered species is solely in the hands of—and only the responsibility of—state personnel.

Anyone who knows anything about our state government knows that we will never have sufficient personnel and resources to do all that is necessary to save Hawaii's endangered species. And besides, endangered species don't belong just to DLNR employees, they belong to all of us, and we should all share the responsibility of not allowing them to become extinct.

Something is wrong with the system if our endangered species laws are preventing landowners from planting native trees and re-creating native forests for fear of creating such good habitat that endangered species will be encouraged to live there.

We need to expand our endangered species laws to allow for the private sector to help with the challenge of saving Hawaii's unique native species, including endangered ones.

Hawai'i's Coastal Nonpoint Pollution Control Program

Randy Rush, Hawai'i Department of Health

Background

In recent years, it has become increasingly clear that the nation's coastal waters have serious water quality problems. Virtually everywhere, the problems result from what is commonly called *polluted runoff* or *nonpoint source pollution*. These terms both refer to pollutants that enter a body of water as a result of water, such as rainfall and irrigation, flowing over the surface of the land and picking up pollutants such as sediments, chemicals, and nutrients.

In 1990, the U.S. Congress adopted new requirements for coastal states that are designed to protect coastal waters from polluted runoff and restore coastal water quality that has deteriorated because of nonpoint source pollution. All land use activities that contribute or have the potential to contribute to polluted runoff, including forestry, must be addressed by this new program.

The new requirements—called Section 6217 of the Coastal Zone Act Reauthorization Amendments—specify that states with Coastal Zone Management (CZM) programs must develop and implement *coastal nonpoint pollution control programs*. Federal guidance, containing management measures, provides the foundation for state programs. *Management measures* are akin to goals which states must address through the implementation of regulatory and nonregulatory nonpoint source pollution control mechanisms. Land and water users must implement these management measures through the use of *best management practices* (BMPs) on the ground.

The intent of the coastal nonpoint pollution control program is to build upon, rather than duplicate, existing programs. In Hawai'i, the array of existing programs at the federal, state, and county levels will be loosely bound together in a "network" under the rubric of the coastal nonpoint pollution control program. Ultimately, there will be one statewide program for the management and control of polluted runoff, elements of which will be implemented by the existing programs at the federal, state, and county levels.

This program differs from the traditional pollution control programs mandated by the Clean Water Act in that it is preventive rather than reactive. Instead of waiting until it's a water quality problem downstream and trying to trace it upstream to its source, this program asks that everyone take preventive measures to minimize the amount of polluted runoff leaving their individual properties.

How Hawai'i is developing its coastal nonpoint pollution control program

In Hawai'i, the CZM Program has taken the lead role in developing the state's program, with the Department of Health assisting as resources permit. In developing this program, we have had three interrelated goals:
1. To develop a program that is practically and economically feasible, given Hawai'i's environmental, political, economic, and cultural realities.
2. To create an appropriate mix of regulatory and non-regulatory mechanisms with which to implement the program. Various assessments have concluded that Hawai'i is already over-regulated and under-managed, and we do not want to contribute unnecessary or inappropriate layers of regulation to this already complex system. Rather, we are seeking to develop a program that coordinates among and streamlines existing processes and fills gaps.
3. To involve affected parties (stake-holders) in the program development process. These are the folks that have the expertise and experience to help keep the program grounded in reality.

To involve people in the program development process, we organized a working group and five focus groups. The working group addressed the broader issues of program development, such as monitoring and enforcement. The focus groups discussed the management measures for each of the six categories of nonpoint pollution sources. There was a broad representation of interests on these focus groups. The forestry focus group gathered and evaluated specific information and made recommendations for implementation of management measures, as needed.

Putting it all together: proposed implementation

Due to the small base of commercial forestry operations, forestry in Hawai'i is not currently a significant contributor to polluted runoff. However, the management measures for forestry are still relevant to Hawai'i because there is the potential for significant growth in the forest products industry in the near future.

There are 10 forestry management measures that address:

-preharvest planning
-streamside management zones
-road construction/reconstruction
-road management
-timber harvesting
-site preparation and forest regeneration
-fire management
-revegetation of disturbed areas
-forest chemical management
-wetland forest management

Generally, the program management plan recommends that the implementation of the forestry management measures build upon existing regulatory and non-regulatory mechanisms, with an emphasis on encouraging participation in voluntary, incentive-driven programs. It also recommends that existing laws, regulations, and incentive programs be reviewed and amended to improve agency coordination and to optimize their effectiveness for forestry activities. As forestry activities increase and BMPs for forestry are further developed, other implementation mechanisms may be considered that more directly address forestry's contribution to polluted runoff.

The management plan specifically makes the following preliminary recommendations:
1. Develop a tree farm property tax classification.
Work with the counties to develop a county tree farm property tax classification for land dedicated to sound forest management based on approved plans. This will provide a powerful incentive for land users to participate in the State Tree Farm Program. While the County of Hawai'i has already initiated this process, it needs to be completed. In addition, the value of existing or growing forest trees should be exempted from assessed value for property taxes, eliminating a tax incentive for premature harvest and recognizing the longer rotation ages needed for forest management.
2. Provide adequate financial support for research and development activities, education, and technical assistance.
3. Support coordination among agencies. This includes drafting formal memorandums of understanding between agencies having technical and management expertise with respect to forestry practices and polluted runoff

control, and drafting statutory or regulatory amendments, as needed, to implement the organizational structure, provide program funding, enact a "bad actor" law, and establish incentive mechanisms.

4. Facilitate the direct lease of state lands most suited to forestry in order to encourage responsible forest management. A direct lease recognizes the high up-front costs and long-term return on investment inherent to forestry operations which normally work to a disadvantage during a bid process. In order to secure a direct lease on state lands, however, a land user should be required to develop and implement a management plan specifying best management practices for nonpoint source pollution control.

Questions to the panel

Q: I'm curious to know about propagation of endangered species by private individuals and are the laws being revised to make it possible for private landowners to propagate the native species in their area for the enhancement of these species?

Carol Terry: The state regulations are currently being revised and I know they address propagation by individuals of endangered species. So that's in the works.

Q: Any idea how long before that happens?

Carol Terry: Do you work for the state government? It took us three years to get the game rules changed.

Margo Stahl: I might also add that captive propagation is a tool in our arsenal of recovery, but it has to be carefully weighed against some of the other recovery methods that we use. Actually, it's a last resort in many ways, captive propagation.

Comment: It looks like here in Hawai'i we're at a lot of last resorts.

Q: In the determination of endangered species, what levels of public participation does the act accommodate? We're often concerned particularly in commercial operations with the timing of that assessment. It's very costly to farmers and ranchers. We're not talking about the big guys. We're talking about Joe Sakamoto up in Kona coast, and he's waiting to plant his crops. He cannot wait four months for his crops to go in. Can you address this?

McEldowney: If it's the federal law, you are mandated to consult with the public, and particulary with native Hawaiian organizations, which does add to the time and the cost that you raised. The balance between time and cost I don't think we come to terms with in many respects, because archeology is labor-intensive in many ways. I'd like to encourage that whenever possible projects can be planned in areas that have already been disturbed in the past; that would help tremendously in the process and also save the resources. I realize that isn't always possible, given land ownership and so forth. It is still a dilemma that we have to come to terms with.

Margo Stahl: The endangered species list has to go through public scrutiny and involvement. In fact many of our plants and animals are petitioned for listing from other organizations. We don't usually necessarily do that recommendation first; it comes from the public sector. Because we are subject to the National Environmental Policy Act, most of our activities are under the scrutiny of NEPA and EIS and EA, and those have a public review process, so we have a heavy public participation process.

The Ahupua'a: An Introduction

Sam Gon III, The Nature Conservancy

Ahupua'a is the name of a land division with origins in ancient Hawaii. Some have defined the *ahupua'a* as a political and ecological unit of land, designed to meet the food, material, and cultural needs of the human community living within it.

As such, the *ahupua'a* revolved around an ideal of self-sufficiency for the people living within its boundaries. The ecological side of the *ahupua'a* concept is reflected by the range of habitats captured within its boundaries, providing for a huge diversity of foods, materials, and cultural needs.

In general, most people familiar with the concept of the *ahupua'a* picture a large piece of land with a broad elevation range, usually extending upward to the summit peak or ridge-crest, and extending downward beyond the coast to include the boundaries between the reef edge and the ocean deep (the so-called *mālolo* zone, where the flying fish leap in the wake of the canoe). The boundaries between adjacent *ahupua'a* usually run along natural boundaries such as ridgelines, edges of valleys, or gulches. Thus, whether an occupant wanted to go fishing, gather medicinal herbs, grow *kalo*, or fell trees for firewood or canoe-building, one did not have to go beyond the boundaries of the *ahupua'a*. Similarly, one might expect to find *heiau* for appropriate religious observance in each *ahupua'a* on an island, such that most major ceremonies and protocol affecting the occupants could be conducted without leaving the bounds of the *ahupua'a*.

These kinds of generalizations sometimes lead to an oversimplification of the *ahupua'a* concept. The huge variation of elevation, moisture, and topography in the Hawaiian islands means that there are as many exceptions to the general picture of the *ahupua'a* as there are general rules.

For example, the pie-shaped wedge model of the *ahupua'a* that fits the pie-shaped island of Kaua'i doesn't fit so well elsewhere. Sometimes entire islands comprised only a part of a single *ahupua'a*. The ancient boundaries of the *ahupua'a* of Makena included all of the island of Kaho'olawe, as well as part of southern Maui. Sometimes an *ahupua'a* extends beyond the bounds of a single mountain range. The *ahupua'a* of Wai'anae in ancient days included both the leeward valley of the same name in the Wai'anae mountain range, but also extended eastward to include a flag of land that reached to the summit crest of the Ko'olau mountains. The ancient ahupua'a boundaries went up to Ka'ala and then down again into the plateau and then up again to the summit of the Ko'olau mountains, so that's not your typical *ahupua'a*. On Lana'i, several *ahupua'a* might behave normally, like Maunalei and Kamoku, the two northernmost ones. But then you have these strange ones like Kaunolu and Kalulu that go straight across the island from coast to coast and take advantage of the different ocean conditions on the north coast of Lana'i versus the south and west costs of Lana'i.

The myth of the complete self-sufficiency of the *ahupua'a* should be addressed here. Although the typical *ahupua'a* might provide for a variety of marine and terrestrial resources, no single *ahupua'a* could be expected to provide for every possible resource, simply because sometimes some resources (such as certain plants or animals) might be only found on a particular island or a particular region or a particular *ahupua'a*. In a more specific example, though broad-ranging, koa-bearing regions were much richer on the island of Kaua'i, as in Koke'e, rather than on the island of Moloka'i (where today as in historic times, koa was scarce or nonexistent).

Similarly, there is a conception that all *ahupua'a* are essentially ecologically equivalent, with some variations in size or shape to compensate for different land conditions. The classic example given is that *ahupua'a* in dry regions might be larger to compensate for sparseness of vegetation, relative to *ahupua'a* in wetter areas. In fact, *ahupua'a* of dry leeward districts would provide a very different set of resources than *ahupua'a* occupying wet, windward valleys. The different native grasslands and shrublands of the dry zones yielded medicinals and materials just not found in the wet sides. For example, the best sources of *pili* grass for thatching came from leeward *ahupua'a* such as Waimea on Kaua'i or in Kīpāhoehoe in Kona on the island of Hawai'i. The best hala groves were found along the windward shores, on well-drained basalt slopes, such as at Wai'anapanapa on Māui.

That being the case, among the different *ahupua'a* there would be incorporated the full range of activities and infrastructure that was typical of Hawaiian culture, but in strikingly different ways. Wet valley bottoms were put into *lo'i kalo* (wet terraced agriculture), making use of *'auwai* (irrigation canals) to take advantage of perennial surface waters running in streams. In drier regions without reliable surface water resources, agriculture switched to dryland *kalo* or *'uala* (sweetpotato), the management of which was closely tuned to seasonal patterns of rainfall.

Such adjustments of lifestyle driven by the differences in an *ahupua'a* give a hint of the wide variety of ways that different *ahupua'a* might serve their occupants. On leeward Moloka'i, you would have the best fishpond systems and flat reef systems in the archipelago. And if a *kalo* farmer in Wailau, on the wet side, had a liking for dried *he'e* (octopus) caught on the reef flats along the coast at Kaunakakai, so might a fisherman in Kaunakakai *ahupua'a* have a particular liking for *poi* from the wetland *lehua* variety of *kalo* found in abundance in Wailau. The two might meet at Mapulehu *ahupua'a* and exchange their favorite items.

These specializations were the basis for lively intercourse between *ahupua'a*, between the larger districts, or *moku*, and between the island groups, as the saying goes, "*mai ka 'ō'ili ana ka lā i Kumukahi a ka lā iho aku i ka mole 'olu o Lehua,*" from the appearance of the sun at Kumukahi (the easternmost point on the island of Hawai'i) to its setting at the pleaseant base of Lehua Island (on the western end of the main islands).

When it came to koa, and especially koa forests yielding trees large enough for oceanic voyaging, only the largest islands with elevations extending well into the montane zone (that is, above 3000 feet elevation) included *ahupua'a* that could provide such trees; in addition, these trees were growing in the *waokele* the upland forest zone, normally the realm of gods, the *wao akua*, and *kapu* (forbidden, prohibited, or sacred to the point of special protocol) to humans. Access to the zone was not for the *maka'ainana* (any common person) but for *kahuna kalai wa'a* (the *kahuna* that specialized in canoe-building) assigned by the *ali'i* to choose trees appropriate for the *wa'a kaulua* (double-hulled canoes).

The distinction between the *kahuna* of special knowledge and those *kahuna* dedicated strictly to religious observances was by no means precisely drawn. There was none of the dichotomy of religion and technical specialization that marks modern western society. All activities in the *ahupua'a* of ancient times were conducted with keen observance to religious *kapu*. Access to land required lifting of *kapu*, either by protocol accessible to the common person (that is, in the retinue of ritual that Hawaiians of all classes could conduct) or through the actions of *kahuna* or *ali'i*.

Keen attention to the state of the land and its resources allowed for the setting of *kapu* designed to restore balance between different aspects of the natural world, including human beings. Other panel members will explore this relationship further.

It was during the larger ceremonies, such as the observance of the *Makahiki*, that the ecological and political aspects of the *ahupua'a* were most clearly integrated. The social hierarchy in ancient Hawai'i meant that the chiefs of greatest rank ruled over entire islands, groups of islands, or *moku* comprised of several *ahupua'a*. The *ahupua'a* were governed by lesser chiefs and land managers (*konohiki*) who oversaw the rights to resource use and agriculture within an *ahupua'a*, advised and given structured protocol by the hierarchy of *kahuna*. Decrees and tasks were generated top-down in the governmental and religious structure, and the resources of the land were generated to support the *maka'ainana*, as well as collected and brought forward in offering to the *akua* and *ali'i*. During the *Makahiki* (the beginning of the Hawaiian year, marked by the rising of the *Makali'i* constellation at sunset) a procession circled the island, moving from one *ahupua'a* to another, and at the boundaries of each, the populace, under decree of the *ali'i* and *kahuna*, and under the guidance of the *konohiki*, offered a portion of the bounty of the *ahupua'a*, consisting of those resources generated by the *ahupua'a* in the course of the year, whether feathers from forest birds, edible crops, fish, or even stone adzes if the *ahupua'a* included a quarry site, as did Kaluako'i *ahupua'a* on Moloka'i.

By the same token, the details of the resources and special features of each *ahupua'a* were well known to the *kama'aina* of an *ahupua'a* and the *konohiki* of that (and of neighboring) *ahupua'a*, and on upward through the hierarchy of chiefs. The *ali'i* would know which *konohiki* to contact if they needed particular items, such as logs of koa, and the search would include that subset of *ahupua'a* famous for the best koa trees.

In summary, the *ahupua'a* was a unit of human geography that reflected a keen awareness of the huge range of natural resources passed from generation to generation of inhabitants. While the *ahupua'a* allowed for a certain level of general resource self- sufficiency for its inhabitants, it also took advantage of neighboring and regional resource specialties that were the basis for regional and interisland trade, and it was a part of a nested set of land units that reflected a hierarchical mode of government.

It is a testimony to the utility of the *ahupua'a* as a land unit that so many of the ancient *ahupua'a* boundaries have survived from pre-contact times to the present day. Now, in like manner, other panel members will explore in more detail the relationship between native Hawaiians and the land, and the system of laws and practices that have extended from ancient times to the present.

The *Ahupua'a* System and Canoe Making

Benton Keali'i Pang, 'Ahahui Malama i ka Lokahi

I'll discuss canoe making as it was practiced in ancient times and how it's sort of been applied today by the Polynesian Voyaging Society. I will also discuss some of the rights and responsibilities that we feel Hawaiian organizations and non-Hawaiian organizations can help out in preserving our koa forests, as well as where we as a community in Hawai'i can go from here.

The koa forests were an extremely important resource for Hawaiians. There is sort of a dichotomy between where the Hawaiians lived, called the *wao kanaka*, and the *wao akua*, those forested areas which were important to the gods. The chiefs, who were walking representations of the gods, were not owners of the resources nor owners of the land. They were more stewards or trustees of these resources. So, in these *wao akua*, these dominions of the gods, strict protocol has to be followed in order to enter them for gathering koa, medicinal plants, house-construction plants, bird catching, and the like.

There was strict *kapu* here. One of the values practiced in ancient times was that of *kapu* prohibition. And there were also places that were free, *noa*. These were the habitation areas where Hawiians could freely walk and converse with one another and sometimes even gather plants. There was also the *'ai kapu*, which prohibited men and women from eating with one another. So there was prohibition, but there also were places that were considered *noa*, or free. There were also the values of *'ike*, knowledge, and that of *malama*, or stewardship that in order to know what to gather, you have to know sometimes the life cycle, you have to know the qualities of, say, the wood, if you are gathering for weapons, or for canoes. Also, you had to know that after you gather the resource, what are you going to do give back, the *malama*, the stewardship responsibilities. Are you going to clear around that patch of *olonā* and enhance it, make it larger, or are you going to use some other aspect of conservation which would make sure the resource is there when you or your family member goes back to collect those resources.

In the *ahupua'a*, there was this balance of *lokahi*. There were terrestrial resources and there were ocean resources, and they all belonged to the *ahupua'a*. So ocean-land balance is very important to Hawaiians, and this comes to them from genealogical chants. The spirituality of Hawaiians is talked about in the genealogical chants, where the Hawaiians were born from, the different species both marine and terrestrial which had counterparts with one another. For every land species there was an ocean counterpart, and after the evolution of these species came the Hawaiian people. So Hawaiians, in the religious aspect, looking at natural resources in the land in the ocean, were actually born from it. The resources were actually a part of them, sometimes regarded as our *kupuna*, our ancestors, sometimes regarded as our *'aumakua*, or spirits.

Like all aspects of Hawaiian culture, the gathering of koa for canoe-making was a religious undertaking. The specialist here was a guild of woodcutters or wood craftsmen called *kahuna kalai wa'a*, those men who carved the canoe, or the *wa'a*. Once a tree was found in the forest by one of these *kahuna kalai wa'a*, he would come down from the forest to tell other men that there's a tree that they could possibly use for making a canoe. All the men would sleep in the *hale mua*, the men's house, and would make certain prayers and offerings to the gods. The next day they would proceed up into the forest. The number of these men were many, because you needed men to sharpen the adze heads as the tree was being cut, you needed men to lash the adzes as they were being cut because it would take quite a long time, and then you needed special carvers to know how to precisely carve out this large koa tree into a dugout canoe.

Before entering the forest, chants were given by the *kahuna kalai wa'a*. Once permission was granted from *Ku* of the forest, which was the god of this forest region, they would come to the base of the koa tree and again they would sleep together and make specific offerings of red fish, pig, and coconut, and the next day, the third day, they would proceed to cut the tree. Once the tree was felled, they would wait for a sign, and the sign is that of the *'elepaio* bird. Those of you who are zoologists know that the *'elepaio* bird is a very territorial bird and, we say locally, *niele*, it likes to see what's going on in its territory. So, the Hawaiians saw this as a sign that the bird is checking the koa tree to make sure it's fit to be cut into a canoe. The *'elepaio* bird would come to fly on top of this felled koa tree and peck at it or not peck at it. If it pecked, the *kahuna kalai wa'a* would know that that log was infested with insects, and the men would then return back to their houses and wait for another day to cut down a tree. If the *'elepaio* bird did not peck at the tree, then the partial hewing of the log would continue.

Now this *'elepaio* bird was also seen as a sign of Lea. Lea is the wife of Ku. Remember Ku is the god of the forest, so the dualism here is his wife, Lea, also has an important aspect in the making of the canoe tree. And this is kind of important in that there is so much dependency on a female goddess for this particular activity. You don't find this very often in other aspects of Hawaiian culture and especially in resource gathering.

The canoe was almost completely made up in the forest. After felling the tree, the branches were cut off, it was debarked, and it was shaped. To get it down to the canoe shed, which always was located near the coast, it took a large group of people and this would now include women and sometimes even children to help pull and push the log from the upper forest (and sometimes this could be more than 3000–4000 feet in elevation) down to the coast. They would use the cordage from the *hau* tree or sometimes *'ākia*, which are very fibrous plants, and lash it onto the canoe, and there would actually be a type of steersmen guiding the log down the hill or down the mountain, making sure it didn't hit any large rocks or trees. It was actually a sort of fun affair. I think it woud be very similar to the stamping party of making a *lo'i*, if you're familiar with that, so a large group of people would come out and help.

Then the canoe would be further fashioned at the canoe house. The other parts of the canoe would be put on: the gunnels, the seats, the decking, the mast, if need be. So, the koa was always looked at as an important resource and even into the ocean when it took its first float, the *kahuna kalai wa'a* would give his blessing and then the canoe would then be lifted of the *kapu* and would hopefully be free to make either safe journey for inter-island or safe journey for fishing.

That's one aspect of use of the koa tree in ancient Hawaiian culture, and it's been tried to be applied today by the Polynesian Voyaging Society with the making of the Hawai'i Loa; however, the *kahuna kalai wa'a* could not find large enough koa trees in our Hawaiian forests because, I think, of so much degradation and changes in our forests. They couldn't find large enough koa logs to make the double-hulled canoes that would be good enough for ocean voyaging.

The *Ahupua'a* System and Native Gathering Rights

Nahoa Lucas, Native Hawaiian Legal Corporation

Aloha kakou. There are three sources for the assertion of native gathering rights under state law. First is Article 12, Section 7, which was passed by the voters here in Hawai'i in 1978 as a result of the Constitutional Convention that was held. Second is HRS Section 7-1, which is the Statute of Ancient Origin passed in 1850 to assist the native tenants who made claims to the *kuleana*, and third is HRS Section 1-1, which is also known as the Hawaiian Usage Exception. The law has been criticized in the past for not keeping up with the pace of protecting traditional and customary rights.

Since 1978, however, there have been three cases. One is Kalipi versus Hawaiian Trust; the case was decided in 1982 by the Hawai'i Supreme Court. The second is Pele Defense Fund versus Paty; the case was decided in 1992. The most recent case is Public Access Shoreline Hawai'i versus Hawai'i County Planning Commission, also known as the PASH case, which was decided in 1995.

These three cases helped to strengthen and protect claims made by native Hawaiian practitioners and also helped to guide judges, attorneys, and members of the community towards resolution of these claims which have been asserted by native practitioners. I'd like to focus today on the PASH case, because I believe it provides some clear guidelines on how to assess these types of cases. We must remember, however, that PASH cannot be looked at as a panacea to native Hawaiian gathering claims. Each claim will depend upon the specific facts of each case.

In PASH, a native Hawaiian member of PASH, Mahealani Pai, sought an administrative hearing before the local county planning commission on the developer Nansay's request for a shoreline management area permit, claiming that Nansay had failed to assess the impacts of the resort on Mahealani Pai's and other members' right to access and gather. The Supreme Court in PASH made two initial observations that are very important. Number one, it said that agencies are bound to the same extent as a court under Article 12, Section 7 to protect those traditional and customary rights, which opens up a whole new door for agencies, both state and county, and imposes upon them the requirement that before it even gets into court, agencies must take action to assess the impact on these rights.

The PASH court noted initially that any claims, that imposing an assessment of these rights, before property is to be developed is a taking, is not justified because these rights have existed since time immemorial; in other words, these rights were here long before anyone else came and therefore, before the Constitution was set up, which imposed the "taking-without-just-compensation" requirement and therefore these are pre-existing rights, so there is nothing to take.

It's also important to remember that in the PASH case it did not say that the PASH members are entitled to the right, but only that they are entitled to go into court or to come before the agency to prove the existence of that right; that's a very important difference, a major difference. And so that case, by the way, was remanded back to the Hawai'i County Planning Commission for a hearing, but Hawai'i County Planning Commission never did hold a hearing because Nansay withdrew its permit. So the issue is still up there, the same as in the Pele Defense Fund Case. The Pele Defense Fund court said that if you can prove that these rights exist, then you'll have a claim, and remanded it down to the trial court. I was co-counsel along with several other attorneys and actually tried that case before Judge Amano in August of 1994, and we're still waiting for a decision. We are still waiting for a determination as to what actually constitutes, and I assume or I imagine that, either way, this case will be going back on appeal before the Supreme Court.

The most commonly asked questions about gathering rights can be answered through PASH. One of the questions is, "What rights are protected?" Well, the language of Article 12, Section 7, is very broad. It says, "All rights customarily and traditionally exercised for subsistence, cultural and religious purposes." That's a very wide area, and the Supreme Court says that these rights are entitled to protection. One of the sub-questions within that is, "Can commercial use be considered a subsistence or cultural purpose?" The question hasn't been answered. Who is protected under the Article 12, Section 7 rights? Under the language of Article 12, Section 7, it says "persons of Hawaiian ancestry"; however, the issue arose in the Pele Defense Fund Case, "What about non-Hawaiian spouses?" Or in-laws who accompany Hawaiian practitioners? You have a family and they want to accompany or they have learned through other Hawaiians how to fish, how to gather; are they entitled to these rights? The PASH decision specifically leaves that open, says that we are not deciding that, because that's not before us. That's an issue that again will be decided at a later date, and of course it was raised in our Pele Defense Fund Trial. So, hopefully, the judge will decide that issue as well.

How do you prove the existance of these rights? Well, the PASH court simply says that they must be continuous, they must be certain, and they had a couple of other requirements in there which were similar to the law based on custom. They also say that it must be from "time immemorial," which is standard language to proving the existence of a custom. However, the court said that the phrase "time immemorial" must mean at least since 1892, which was the date that the Section 1-1 was passed. So, at least with regard to proving the existence of custom here in Hawai'i, you have to show that the custom or activity was in existence prior to 1892. This raises another issue in proving the existence of custom: do you have to show that your father, grandfather, and great grandfather specifically gathered or specifically conducted an activity on that specific site, or do you simply have to show that it was an activity that was performed by Hawaiians prior to 1892? There's a big difference in terms of the burden of proof, and that's another issue that has not been decided yet.

Well, you say, this language of Article 12, Section 7 is so broad and it looks like the Supreme Court's decision is going to open the floodgates to all native Hawaiian practitioners, are there any limitations on the exercise of these rights? Yes, there are several. One is that the exercise of these rights must be reasonable. Now, whether reasonable to the practitioner, reasonable to the landowner, or reasonable to the judge, the court did not say. But, again that's going to be a factual inquiry which is going to depend on the facts of the case.

Also, the court said that the activity must be traditional. What is a traditional activity? Certainly, I think, we can all agree that fishing or gathering *'ōpae* are considered traditional activities, but what about pig hunting? Traditionally, Hawaiians never did hunt pig. They were always domesticated, and it was only later that it evolved into an activity that is now very popular. Is that considered a traditional activity? The PASH court did not address that.

The third limitation imposed by PASH and also by Kalipi and the Pele Defense Fund case is that the land must not be developed. Once it's developed, the exercise of those rights ends. Now, what is "developed"? The PASH court again did not say we are not going to go into the different stages or gradations of what constitutes developed property. It's simply to say that once it becomes developed, gathering rights end. So again on the spectrum of what could be developed, certainly a subdivision in Manoa would be a developed property, but what about an abandoned geothermal well site which was initially cleared but has now been abandoned and now a native forest is starting to retake the site?

The fourth condition is that the landowner must show that there is actual harm as a result of this activity. Again, what constitutes "actual harm"? Is it actual, in-fact injury to your business interests, or is it a simple assertion that well, we don't want you to come on the property just for safety and liabilty concerns, without showing more. That hasn't been answered. Once an owner can show that there has been some actual harm, the court says that there must be a balancing of the interests of the native Hawaiian or the practitioner versus the landowner, and a balancing of those interests will then result in work towards resolving those claims.

Finally, the limitation on the exercise of gathering rights is that the rights are subject to regulation by the state. Now, there are no administrative rules or laws that specifically regulate the gathering activities of native Hawaiians, and I sure wish there were, because they'd give a lot of guidance to attorneys and even native Hawaiians in this area. There has been asserted by at least one landowner in recent proceedings, the Al'i' Perogative, that it's a claim implicit in the reservation of rights in favor of the tenant is the ability of the *konohiki* or the landlord to regulate those rights. Not enough research, I believe, has been done in this area, at least for me anyway, to understand this Ali'i Perogative, but there have been claims made on that.

Finally, the last two questions are, first, Can we live with these rights? And my answer is a resounding "Yes!" The second is, Where do we go from here? And I say we go forward, that's the only way we can go.

The *Ahupua'a* System and Education

Eric Enos, Cultural Learning Center at Ka'ala

'Ano 'ai, aloha. We all contribute something to the whole, to the concept of what the ahupua'a is; every one of us in this conference has one part of the solution. I think that the biggest issue, the biggest challenge, is how to look at it holistically. We have scientists, we have landowners, we have conservationists, and we all have to live in this *ahupua'a* together, so the challenge is before us.

We have to bring it back to the community and the general public, so that we're not isolationists, not elitists, not a large landowner just dealing with my little *kuleana*. Your *kuleana* affects the *kuleana* of all the people that live in this *ahupua'a*. What you do up in the forests affects what happens to the people who gather at the reefs. Some say, "Well, this is the job of government," but as we all know, we cannot leave it to government, because it is of the people and all of us.

So, that comes right back down to the communities, and it comes back down to the idea of education. It has got to happen in the schools, and if these curriculums and these ideas are not being developed in the schools, then we do not have a public that is educated about the conservation of our whole ecosystem. If it's not integrated into our science and biology and botany and these things that happen in the classrooms, then where are our decision makers going to come from? The future really is in the aspect of getting it into our schools.

Let me give you a couple of examples of what we're trying to do to rebuild and restore the *ahupua'a*, a modern-day *ahupua'a*. I'm going to describe our community in Wai'anae. We have a project in the mountains, about 97 acres. It once was the "*poi* bowl" of the entire Wai'anae coast. We've gone up there and brought some water down and restored some taro terraces, but in the process, we have had to take a look at the whole watershed itself and to begin to look at how do we culturally, spiritually, economically, physically, and biologically understand the process of rebuilding this watershed. It has to include from our *kupuna* all the way down to those yet unborn generations to come.

This whole concept becomes integrated into the educational curriculum itself; and then we have to go into our schools. We just started a Hawaiian studies program at Wai'anae High School. That's a first. We have a community of 40,000 people, half of it is Hawaiian, half of the population is 25 years old or younger, and there was no Hawaiian studies program at all. So, how do we as citizens of Hawai'i understand this concept that we're talking about, the *ahupua'a*? Where do we learn these things? Where do we learn about responsibilities? We can throw up rights all we like but if we don't understand the role of the forest and the responsibilities we have in that forest, the idea that if we gather we have to be able to put back two-fold. And where are these things taught?

It's very important for us in developing a curriculum. We are doing that now, right in the schools in our Hawaiian studies program that we just started. We include archaeology; our students are going out into the field, into the *lo'i* itself, into the agriculture complex. We're not doing it in front of a bulldozer. We have to learn our history. The students themselves are involved in recovering their past, the richness of their past. I think most of our sites have already been destroyed.

We're going into resource areas like Ka'ena Point Reserve, the Reserve at Pahole. We're dropping in behind Makua. We're starting programs of partnership with different trusts and foundations. For example, Sam Cook has donated some money for us to help us shuttle the kids back and forth; that's very important. We're working with Queen Lili'uokalani Children's Center and we're starting programs of backyard nurseries of native plants to reforest and to use as native plants in the landscape, so there is an economic arm to it, and a spiritual arm to it. By growing these plants and collecting the seeds, we can reforest our dry forest in Wai'anae.

It's a two-fold thing: putting back and making it to come forth in the land itself. In that is values, the values of the earth, the values of families working together. And this ties in to a program we're doing with backyard aquaculture. We have 25 families raising fish in their backyards. It's all part of the whole communal aspect of working cooperatively, finding consensus, developing partnerships with business, with government, with the whole aspect of what a community is. And it's part of developing strong communities that are educated and tied back into a spirituality of the earth.

These values are universal values, they're not just Hawaiian values. They're values that tell us that the earth is a very special place. We cannot just view forest as an economic resource. It's a biological resource, it's a spiritual resource, it's the home of our gods and our ancestors. All of us, all of our common ancestors share this. It's not only the forest, it's the understory that we gather from, and they are rich resources for economic uses; the gathering of the *palapalai*, the gathering of the different kinds of trees that grow with the koa, and the role of the birds and all those things that live in it. This is the education we are working toward.

I'd like to credit to Mike Buck and the DLNR for supporting us on the backyard nursery project and working in Wai'anae on community conservation issues. We're in the process of developing these cultural access issues .

Additional remarks by Kealii Pang

Our organization, 'Ahahui Malama i ka Lōkahi, has been involved in dialogue between government agencies, the Hawaiian community, and landowners in trying to promote educational awareness of Hawaiian conservation values and how they can still be applied today by many of us in protection of our natural resources. We held a hula conference last year and another one will be held in February. We brought forth for the first time, the hula community, the people that use the forest resources for hula as well as conservationists and other Hawaiian organizations to talk together about this forest that is under great stress. We are responsible for part of that stress. What are we going to do about it? We looked at ways of developing gardens, of putting these halau in contact with botanical gardens. We are looking at current forested lands, forest reserves, taking plots and seeing if halau can plant and maintain their own plots. Other user groups include the laau lapa au, the medicinal practitioners, as well as an upcoming group, the Hawaiian martial art of lua. These people are interested in some of our very special native hardwoods, many of which are endangered. We are trying to take responsibility to dialogue and network with these Hawaiian user groups to look at how these resources can be correctly utilized. As Pua Kanahele said at the conference, "If you don't know how to pick from the forest, stay out." This came from a very respected kumu hula which took some people aback..But we feel the forests are very special but we can still practice the hula using backyards. We can also use alien plants. We're slowly working up towards working some plots of land. We appreciate all of your help in being involved.

Questionsfor the panel

Q: I come from Hāna, Māui, and just in the last few months we've had native Hawaiians arrested for exercising their traditional access rights. We've had blockage of traditional access trails intentionally by developers. We've had desecration or burials. I believe the ahupua'a system would help in resolving these issues. My question for you is, can you put forward some ideas how we can have this ahupua'a system and the konohiki system incorporated into our Western thinking so it can work with the government we have now?

Nahoa Lucas: I don't have an answer for you off the top of my head. When those kind of claims are made, usually we are right there defending the native Hawaiian and getting right of access. I think they need to be looked at in a more holistic perspective. A lot of that's going to depend on the landowner. What I've always advocated is that there needs to be some sort of traditional code instead of regulations, whether it be private or public, which sets it out in the regulatory framework, which allows people to see that these are the responsibilities. There were responsibilities for the konohiki as well, and they all have to be brought out. We can't just keep talking about them in general terms. People have got to see how they operate.

Q: Nahoa, would you care to speculate when Judge Amano may come to a decision?

Lucas: Your answer is, I don't know. We've even stopped calling her. I don't know if its her caseload or other reasons. Both myself and the Campbell Estate's attorney, we don't know what we're doing, we're kind of at an impasse right now. Hopefully, we'll get something out of it soon. She did indicate to us in January this year that she was going to rule, and we did submit proposed findings of fact and conclusions of law, and we're still waiting.

The Value of Forests

Paul H. Brewbaker, Economics Department, Bank of Hawai'i

Aloha and mahalo for your invitation to speak and participate in this symposium on the future of *Acacia koa*, an indigenous species with a lot going for it. I hope my insights will complement the many perspectives brought together here by the Hawai'i Forest Industry Association.

One of my biggest problems with being on the luncheon speaking circuit is that typically there are two types of audiences to whom I am asked to make presentations. The first are those who have a general interest in current economic issues or phenomena. For these audiences my task is relatively easy because things economic change constantly, and I usually have the advantage of having kept closer track of them than those to whom I am speaking. In this case, the most difficult task is choosing a title to the presentation, because things change so fast.

The second kind of audience are those who have much more knowledge of the subject than I do, but for some reason have been convinced that I have something meaningful to contribute. For these audiences the task either involves a lot of homework or careful selection of things that the economic perspective renders in a different light from that to which the audience is accustomed. Imagine preparing presentations for the Consulting Engineers Council, the Hawai'i Crop Improvement Association, or the American Appraisal Institute-Hawai'i Chapter, and you'll see what I mean.

For this symposium, falling into the second category, I would like to choose a few ideas that economists familiar with natural resource issues think about, and a few ideas that economists not so familiar with natural resource issues think about. This is mostly because I will run out of good ideas if I stick with natural resource economics. It is also because the issues raised by longterm forestry investment are also prevalent outside the natural resource arena.

In speaking from a prepared text rather than extemporaneously, I am breaking my usual mold. This is being drafted on a long trip outside the country, so by the time I have heard what others are talking about at this symposium it may well become extemporaneous.

Simple issues: the Market

The simple way of thinking about the value of a koa forest is to distinguish between the market value of the forest and its nonmarket value. The market value of the forest is relatively straightforward: it is the yield in revenue obtained by selling harvestable forest products in the market(s) for those products. This may be lumber, but one can expand to include applications in various crafts involving woodworking, carpentry, and the like. Nowadays, we should probably expand the scope of our thinking to include a variety of manufactured wood products, those lighter but stronger fabrications of building materials now being developed in forest products laboratories. The point is that the market value of the forest is derived from the underlying value of wood products it can support, from the demand for its downstream forest products.

Some, maybe most, of these market values are unlikely to be relevant to the owner of a koa stand unless she is in fact the owner of a vertically-integrated firm in which production of the raw material, koa logs, is linked to downstream, within-firm alterations of the raw material, whether sawn timber, paneling, cabinets, or furniture. In this case, value-added along the chain of production is internalized, captured by the single owner.

Typically, vertical integration is not going to obtain. The owner of the koa stand may have very little interest, financially speaking, in what happens after the forest is logged and trucked away, other than getting the next rotation into the ground and enhancing the value of the underlying land. One of the reasons policy-makers in Hawai'i have been inclined to be attracted to large, offshore, corporate timber concerns is that they raise the prospect of scale and scope sufficient to solve a land-use problem which will otherwise pose enormous coordination problems, should policy-makers instead be required to weave together solutions based on small, specialized, entrepreneurially-oriented firms interested in a specific piece of the action.

While large concerns will contribute substantially to the challenges Hawai'i faces in the transition of economically non-viable plantation or pasture uses of land, a policy framework capable of accommodating the small producer should also be crafted. Large concerns will internalize the costs—and benefits—of vertically-integrated production, but small concerns will give Hawai'i, and especially the small geographic and political jurisdictions that neighbor island communities represent, flexibility and variability of opportunity that was lacking during a century or more of plantation-oriented economic development through early statehood. An environment in which both big and small producers can thrive is less likely to suffer the distortions induced by monopoly or monopsony (monopolization of outputs or inputs).

(I might add that policy-makers might also want to consider minimizing their interventions in these emerging markets for koa wood production and products, as a rule of thumb, since interventions create their own unique distortions to market signals.)

(As an additional aside, I think it is worth noting that the rapid development of microprocessor-based applications will overcome many of the cost hurdles that large corporate organizations used to have an advantage dealing with. Because of the falling cost of information management and communication, small organizations have within their reach more powerful tools to overcome the scale economies once supportive of larger organizations' structures in which coordination problems were overcome by specialization. In addition, getting products to market will inevitably be managed electronically for any koa wood products we might now be thinking about planting to produce. Small producers will have greater electronic access to end-user markets for their products than ever in coming years.)

The least restrictive policy environment for the development of koa woods products and markets will generate the greatest benefits for those producers interested in koa production and the communities they inhabit. These conditions do not exist in Hawai'i, the only state I know of that had to pass a law to ensure that one has the right to harvest a tree one plants for commercial purposes. It would be a shame if *Acacia koa* did not succeed commercially in Hawai'i, but rather did succeed in some Third World competitor. The importance of Hawai'i having the first shot at commercially viable koa silviculture or agroforesty is underscored by a long list of predecessor Hawai'i crops (pineapple, sugar, macadamia nuts, even orchids and anthuriums to name but a few) which have had to face international competitive challenges.

Not-so-simple issues: External benefits

Much discussion yesterday was to have focused on technical issues surrounding the commercial development, propagation and cultivation of koa. Today's discussion will have broadened the focus to include some nonmarket issues. For forests, the increasing recognition of these nonmarket, economic aspects is significant. There are two directions in which the forestry economics literature on this has evolved. The first is the increasing sophistication of dynamic analysis developed in the last half century. During this time, optimal control theory, in particular, has significantly advanced the sophistication of modeling of renewable natural resources including forests.

The second has to do with the recognition of the economic value of natural environments. The recognition of nonmarket economic values contributed by forests is symbolized by the first and second editions of Colin Clark's classic *Mathematical Bioeconomics*, in the second edition of which the section on the Faustmann model of optimal rotation (Faustmann 1849) has appended a discussion on externalities and notes on modeling the joint production of timber and environmental benefits (Clark 1990), in place of an optimal thinning model, I might add. We now pay attention to the production of wildlife habitat, watershed, and aesthetic amenities, not to mention global atmospheric change, in a way previously ignored in formal, forestry economic analysis.

For some of us the elegance of these elaborations of the models themselves is the primary attraction, but I think it can be fairly said that society has revealed its collective preference for formal inclusion of these items in the economic calculus of natural resource valuation through the political process, just judging by the rhetoric of modern political campaigns, if not the actions of elected officials.

However, we are a long way from a satisfactory, meaningful preference revelation mechanism involving society's willingness to pay for the production of these external benefits of forests. The problem, in the economic way of viewing things, is that there is a missing market. There is no market for environmental amenities, and we observe people's willingness to pay for them at best indirectly, as in the valuation of homes or other real estate assets with desirable locational attributes.

When markets are missing, economists recommend creating markets in which willingness to pay (or accept compensation) can be manifested. As one tangential renewable resource management example illustrates, the allocation of primary water use rights (e.g., extraction and wholesale distribution) by impaneled commissioners listening to expert witnesses in contested-case proceedings is unduly costly and cumbersome, and ultimately allocatively inferior to, a system of revocable, tradable primary water-use permits allocated by electronic auction, to which a derivative system of water-use futures and options would add intertemporal preference revelation. We need to approach the public management of forest development with an open mind to market-oriented solutions.

Perversely, the ill-recognized nonmarket benefits of forests actually add a selling point for someone trying to pitch a forestry investment. The reality is that society is much more willing to enjoy environmental benefits at someone else's expense than it is to shoulder the cost of those investments itself. Private sources of capital, unable to capture these returns, tend to underinvest as a result. This leads me to commend efforts to adapt the regulatory and policy framework to recognize the contributions that investors in commercial koa forests make to the production of environmental externalities in the calculus of social net benefits that ultimately should guide regulatory and public policy decisions. Forest developers should not be penalized *ex post* for the production of habitat, watershed or aesthetics when harvest time arrives, and yet be unable to capture the present value of their future external contributions *ex ante*. Yet, I believe this is exactly what the treatment of prospective forest investors boils down to. One can write down a model that says that the optimal tax on a forest is negative.(1) (This is presumably the logic of the forest incentives programs discussed at breakfast this morning.) It is important to frame this in a meaningful public policy posture towards forest investment. Educating policy-makers is crucial, as administrators of natural resource policies in Hawai'i I'm sure agree; many are the strongest advocates of these policies. We all need to educate our legislators, who want to learn.

More not-so-simple issues

I will mention only three more issues, as they are to be reckoned with in the future of koa forestry, at least from the economic perspective. Not to bore you with jargon, but the three are: (1) nonlinearities, (2) asymmetric information, and (3) uncertainty.

Nonlinearity. The minute you take an optimal forest rotation model and plug in a nonlinear growth function for the tree, your brain starts to hurt. We all use logistic growth models because they tend to abound in nature, thank goodness, but also because lurking in some textbook is an analytical solution to the continuous-time problem (by separation of variables, if I recall) that guides the construction of a numerical solution of a discrete-time equivalent. In short, the optimal stopping problem of choosing a date to chop down the tree that maximizes its value, the integral of all discounted future values, market and nonmarket, is not just complicated, it's nonlinear. What that basically means is that things can change in a hurry: what at one point in time may not look valuable may very shortly thereafter suddenly appear valuable. (Note that I'm still talking about the deterministic case in which we have perfect foresight of all future states of the world.)

We need to come to grips with nonlinearity in our analysis of koa forest investment prospects because nonlinearity enters intrinsically into the question of the forest's value. This straight-line stuff will simply not do. As a concrete example, we need a proper analysis of the parameters of koa's growth function under managed, agronomic conditions made possible by several current and past trials in koa production. Financial feasibility analysis must be grounded firmly in an understanding of the growth properties of koa under modern cultivation. The observation that old growth koa under competing conditions in native forests must be at least 40 years old before commercially viable harvest is warranted is uninformative as to the optimal stopping time for a koa grown in homogenous stands under fertilization and pest control. *Acacia koa* may be a fast-growing woody legume, and we don't even know about it! And of course, there are lots of koas; basic research must receive higher levels of public investment. One compelling nonlinearity is the prospective movements of market prices for tropical hardwoods in an era of global deforestation. The economic implications of deforestation probably cannot be unwound in our lifetimes. Those of you who remember Hotelling's Rules (Hotelling 1931) recall that an exhaustible resource price should rise at more than the real rate of return on alternative assets to be worth holding rather than harvesting. Forests fall into that category of renewable resources with life-cycles long enough to be, for one human generation, quasi-exhaustible. How much will she who plants a koa forest today benefit, when harvested two decades from now, from the dramatic rise in tropical hardwood prices during the interim, if unmitigated by the development of substitutes?

Asymmetric information. Asymmetric information is a subject on which a background in banking might contribute to understanding where another might not. Asymmetric information is the name economists give to a common phenomenon in which one economic agent has more (or different) information than (from) another. Borrowers often know more about their creditworthiness than lenders. Old investors often know more about a company than new investors. Management often knows more about a company's financial health than labor. The result can be economic transactions entered into that do not yield the win-win outcomes ordinarily associated with market allocation through voluntary exchange.

Because of information asymmetries, banks do their homework on prospective borrowers to learn what borrowers already know but may have an incentive not to reveal to a prospective lender. This limits "adverse selection." Covenants and conditions in loan documents assure that borrowers face compatible incentives; collateral reduces "moral hazard" by creating additional incentives for the borrower to pay back the loan.

How does this affect forests? I believe one of the most significant stumbling blocks to the commercial development of koa forests in Hawai'i is the provision of long-term financing. One simple case in point: How are you going to talk an investor or lender into providing capital for an asset that generates no cash flows and whose return is generated in a lump sum after 20–30 years? There are several answers, one of which is a large firm that can internalize the lack of cash flow by enjoying other returns, such as tax advantages. Another is to produce joint products, like an "eco-tourism" service provider who sells educational benefits and, when you think about it, generates a prospective repeat visitor interested in seeing the forest as it matures.

This cash flow problem is surmountable, but the more generic asymmetric information problem must still be dealt with. Those assembled here know many times more about koa than does a prospective financier. The asymmetric information problem looms large. How are you going to convince an investment banker to package something like a zero-coupon security to finance the planting of a commercial koa forest whose returns do not arrive for a couple decades? Zero-coupon securities are not uncommon—they are a popular college investment vehicle, for example—packaging them for trees has not been done, to my knowledge. In my dream world I can see a state government-guaranteed, tax-free municipal bond-type mutual fund investing in privately-issued, zero-coupon securities to finance commercial koa plantings, sold to small investors, kama'ainas, and those whose hearts are in Hawai'i, who want to see further propagation of indigenous forests. Hey, I can even imagine selling the fund over Internet to the "green" investor community. "A koa mutual fund to go with that cup of Starbuck's coffee, ma'm?" But can anybody talk Salomon Brothers or Hawaiian Trust Company into it? We must figure out a way to do so, or come up with an alternative, like equity investments. Waiting for a Kiwi conglomerate or mainland insurance company to do it may not be the best answer to the forestry financing dilemma. Speaking as Chairman of the Council of Revenues, I would guess there is no near-term capital financing for koa available from the state's General Fund revenue stream.

Uncertainty. By now the principal uncertainty you are facing is: will I ever finish this presentation? I do want to mention uncertainty just to give you a flavor for what it means to take it into consideration formally in the analytics of forestry economics. If we live in a nonlinear universe, we surely live in a stochastic one. Another addition to Clark's second edition of *Mathematical Bioeconomics* is the introduction of a chapter on stochastic resources models, considering the effects of uncertainty on renewable resource harvests. Forests burn down randomly, and though this may have only second-order effects on harvest strategy, "the cumulative risk of [catastrophic destruction] does bias the [optimal] rotation towards earlier harvests."

Investment under uncertainty raises similar technical issues. Think of how asymmetric information complicates investment activity, giving rise to the existence of financial intermediation itself. Now imagine adding the complications of not having a lot of basic botanical or agronomic knowledge about koa and then consider the implications of global warming for hurricane frequency and intensity, or the mysterious pattern of cohort senescence observed in a genus like *Metrosideros* or suggested by koa dieback. Future prices and costs are inherently unknown, as are the nature of future consumer preferences over wood products and future government regulations.

One interesting newer approach to the understanding of the interaction of uncertainty and investment poses an investment as a kind of real option, like the financial options traded in many futures exchanges today. Planting a tree gives you the right, but not the obligation, to harvest at some date T, to exercise a "call" on your option to harvest. Option valuation techniques can be applied to price this option, in effect, to determine the value of a forest. Whether increasing uncertainty improves or worsens prospects for koa forest investment depends on whether it increases or decreases the value of the real option: it is not necessarily bad for investment to have increasing uncertainty. Banks routinely test the sensitivity of their portfolios and, in essence, the value of bank stock by running Monte Carlo simulations involving thousands of interest rate shocks, to "fill out the distribution," so to speak, of possible future valuations. There is no computational barrier to approaching the valuation of forests in a similar manner.(2)

For example, increasing uncertainty about the future of tropical hardwoods prices because of deforestation might raise the value of the option to harvest an indigenous Hawaiian hardwood in 20 years. "Keeping the option open," so to speak, by planting koa forests today, allows the future to reveal itself to us and for us to learn in a way that could not be possible if we don't plant now. Research and development outlays today could go a long way to improving the value of those options, particularly if investments in planting and research are explicitly designed to further our knowledge of optimal koa forest management. "Learning by doing," after all, is what made sugar and pineapple Hawai'i's economic mainstays for two or three generations.

Conclusions

The value of a forest has lots of meanings. I've suggested a few economic aspects of that valuation. Koa seems to be to be a natural gamble for Hawai'i to take, though I have my biases on the issue. Perhaps the greatest legacy we can leave to our descendants in Hawai'i is the knowledge that we accumulated about koa forestry by giving it a try.

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Notes

1. Ken Judd of Stanford University has models that says the optimal tax on capital should be negative even without external benefits.
2. Though I haven't read the literature that closely, my guess is that a stochastic optimal control problem maximizing the value of a forest by choosing a harvest date subject to the biological growth dynamics of the forest inventory and price dynamcis subject to Brownian motion, i.e. a stocahstic diffferential equation, can be solved in a straightforward manner. An interesting elaoration would be to add a Poisson shock (like a hurricane or pathogen) to the equation of motion for the tree stock.

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]

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[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.

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[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 unicatum*). 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/seeding 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.

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[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 gain 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.

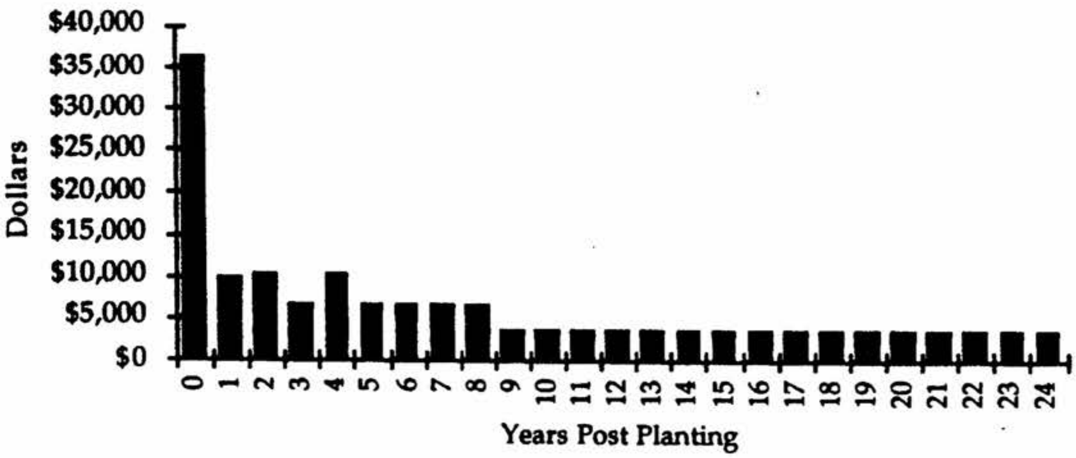
OTHER COSTS

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 bags[16] (2" diameter x 12" length) are filled with soil or potting mix[17] 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 Adee, 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 importance[22] 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

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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 Adee (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:

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[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 $MgSO_4$ 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 truck 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 form[33] 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 (Scowcroft & 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.

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[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] Scowcroft 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 25[38] 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 tress 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 funding[42] 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

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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
Labor Costs					
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
Other Costs					
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
Capital Costs					
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
Labor Costs					
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
Material Costs					
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
Labor/Contract Costs					
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
Material Costs					
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
Labor Costs					
Seedling Preparation	1	40	labor hrs	$11.42	$452
Transplanting	1	333	labor hrs	$11.42	$3,805
SUBTOTAL					$4,257
Material Costs					
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
Labor Costs					
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
Material Costs					
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
Labor Costs					
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
Material Costs					
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 fee[48] 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 wastage[51] 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

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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 slash[64] 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

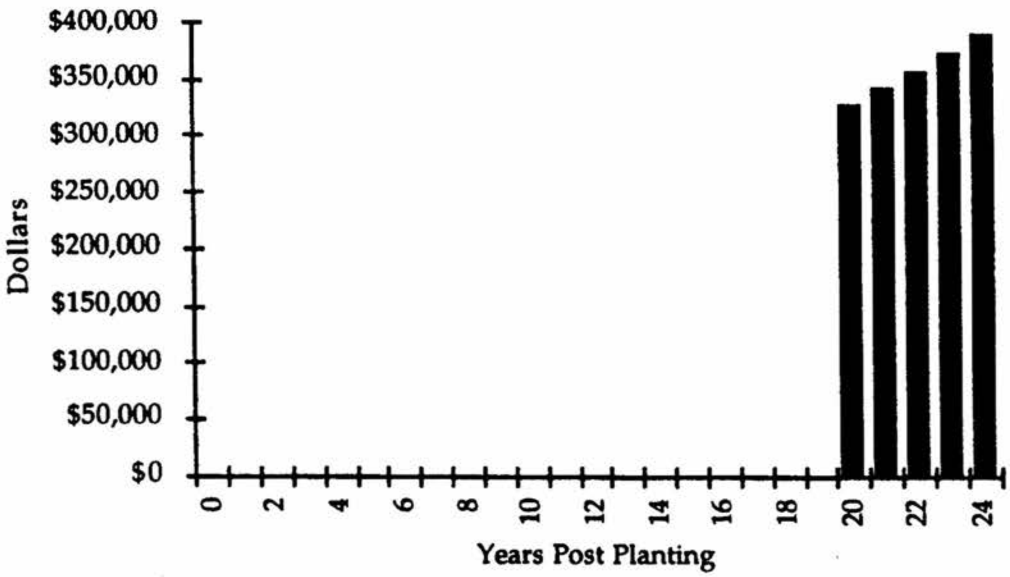
[63] In 1995 dollar terms, this stumpage fee is equivalent to $2.73 per board foot.
[64] This is the branches and other residue left on a forest floor after the cutting of timber.
[65] No accounting is made of wood potentially recoverable above the first fork. If a tree is curly, branches of 4 inch diameter 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 production[68] and break-even price[69] 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 instruments[70] and the stock market.[71]

Table 10: Economic Results - Base Case Assumption Set

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

	Costs		**Harvest**		**Wood Amount**		**Stumpage Fee**	
Item	**Increase**	**Decrease**	**Late**	**Early**	**Low**	**High**	**Low**	**High**
Net Present Value								
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
Break-Even Analysis								
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
Internal Rate of Return								
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.

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[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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Marketing Koa

W. Lloyd Jones, Martin & MacArthur

I spoke earlier in this symposium as President of HFIA. Now in these remarks I am changing hats and speaking as CEO of Martin & MacArthur, which is my paying job.

At Martin & MacArthur we have three businesses. All of which depend on koa. We have a distribution business selling hardwood lumber and plywood and picture framers supplies. We make furniture—both residential and for hotels. We have retail stores, including one at Aloha Tower Marketplace that sells our furniture and gift items by over 300 craftspeople.

We are not unique in any one of these businesses, although I don't know of anyone else with the same combination of businesses. My perspective is that of an organization that is dealing with the end-users of koa. I will try and give you some facts about what the marketplace is telling us, and I'll try lay out some of the economics of these businesses in Hawai'i.

We use a lot of koa, which we buy from various cutters and millers of lumber. I cannot answer the question that is frequently asked, "How much is koa?". Price varies tremendously by grade and quality. We sell solid koa at retail at prices ranging from $8.40/bft to almost $30.00/bft. The things that influence the price are grade (number of knots and defects per board), width, length, (everyone wants long, wide boards), color (dark, rich, red wood commands a premium), figure (amount of character and definition in grain—bland koa can look like monkeypod), and degree of curl (fiddleback, the characteristic that gives koa its wonderful luminescence). This amount variation in price of a type of wood is unique to koa.

I looked up our records, and the price we pay today is three times the price we paid 10 years ago for like grades.

The threefold change in price has caused some changes in the use of koa. There are not accurate figures on koa usage, and I hope that the Department of Agriculture will include forest products in its statistical surveys of agricultural crops. So the estimates we have of useage are "guestimates." My guestimate is that there is now approximately one third the koa cut annually as there was 10 years ago. The laws of economics are inevitable. Previously, much was used in millwork on the Mainland by designers who used it in their palette as a very beautiful albeit pricy wood. It is now only used in very special, very limited applications.

Our major use for koa is for picture frame molding. Approximately two thirds of the wood we purchase goes to picture frame molding. We think that, industry-wide, perhaps as much as one third of the koa cut goes to picture frame molding. In an attempt to conserve koa, three years ago we introduced a product that is a thin veneer over a finger joint poplar substrate. Even though we believe this product to be cost-competitive, we still sell solid koa two to one over veneer. Our customers, picture framers, tell us that much of the buying public still demands solid koa.

In our lumber distribution business, we sell numerous species of wood. We have tried to be supportive of the spirit of HFIA's annual woodshow and carry Hawaii-grown woods other than koa. Although over 100 species of wood were in the woodshow, we can only carry wood that we have some degree of confidence will have a continued supply. There is no use carrying a wood that our customer cannot purchase when he comes back a month or two later.

We offer conventional hardwoods imported from the Mainland, Hawai'i-grown woods. and imported exotics. The prices change with market forces. In our experience, other than koa, the list of Hawai'i-grown woods represents less than 2 percent of the wood we sell. The imported exotics represent probably twice that quantity. There is just not a big demand for exotic woods.

We have tried to introduce some Hawai'i-grown woods into our furniture lines. We have tried Hawaiian ash, curly kamani, and curly mango. The only one of these that has had any acceptance has been the curly mango. We have been able to sell perhaps 1 or 2 percent of the furniture we make in mango. There has been no acceptance of kamani or Hawaiian ash.

A more significant trend has been the use by Mainland designers of alternate woods for public-area furniture of hotels when designing "Hawaiian furniture." We are seeing lots of furniture that is designed based on traditional Hawaiian furniture designs. but is built with a less expensive wood than koa. The recent remodel of Kahala Mandarin is an example of this, where most public-area furniture is stained Honduras mahogany but designed after historic Hawaiian pieces.

Now let me touch on the trends we see at our retail store, particularly what we see at Aloha Tower Marketplace. There we are dealing with a clientele that is one third local and two thirds visitor. As well as our furniture, we sell the works of over 300 of Hawai'i's craftspeople, probably two thirds of whom are working in koa. With the increase in value of koa, and the increased skill and sophistication of these craftspeople, this is a growing business. Locals and visitors alike treasure something made of koa (especially, fine work). It not only is beautiful, but it speaks of Hawai'i. Despite our best efforts to introduce other woods, it is koa that sells. When we buy wooden pens for example, we might buy a batch of 50 koa pens and five from other woods. When the 50 koa pens are sold, there will be two or three non-koa pens left.

Even in an item as subjective as a turned bowl, where the skill and art of the bowl-turner is so important, we still sell many more koa bowls than all other woods combined.

I think the craftsmen that make a living from woodworking and who do such fine work in non-koa woods in the Woodshow will tell you the same thing—making the non-koa pieces for the Woodshow is a diversion, then they go back to koa to make a some money.

In summary, my first message is that koa sells. It sells because it is beautiful and because it conveys the magic of Hawai'i. For a long time into the future, koa will dominate any hardwood forestry in Hawai'i. Second, premium grades of koa are important. The scientists and foresters who can tell us how to grow premium koa are as important as the scientists and foresters who can increase yield.

Koa Economics and Resource Values

Ed Winkler, Winkler Wood Products

I will discuss koa economics and marketing focussing particularly on stumpages and values of the resource base itself. That's where I think all of the economics come from. If a landowner doesn't make the decisions to plant trees or protect his forest so that the trees will grow, we won't have any koa as a resource base, and there won't be any economics. I'm just going to focus on what happened with the royalties over the past 16 years, and it's quite interesting.

First of all, I would like to acknowledge one of the greatest things that has happened over the past 16 years in the County of Hawai'i, and that is when finally we got a councilperson, Keiko Bonk, who literally went to work for us and actually made changes to the county tax structure in regard to property taxes. That is something (which maybe some of you people aren't aware of) that has been a tremendous disincentive to forestry in Hawai'i. And even more beyond that, I think it was a detriment and a serious problem to our ecosystems, a problem many people have been working on for 20 years and more. It took 20 years to make that change, and I'm really pleased that it finally came about. But that change didn't come about on its own. It took work from everybody, including a lot of people that I see here, who worked on committees and made presentations and wanted to make the change. All it took was someone in the county to hire someone to physically figure out how it would work. HFIA, for example, put a lot of emphasis on that over the past few years, had a committee working on it, and spearheaded that kind of tremendous change.

As with a lot of the things that can happen in regards to our forest, it is important to come together in partnerships and learn to make changes and make the proper changes and do things together and not apart. I think that the only way that there is going to be economic-based forestry of any sort in the state of Hawaii is through partnerships, through large landowners and small landowners and Hawaiian groups and industry folks and end-user folks all coming together and determining what are our real needs are and what are our long-range goals.

In regards to royalties, for example, when I first started working in the koa forest in 1978, I was felling trees for a timber firm out of Hilo called Campbell Burns, and one of the main management goals in the area that we were cutting at that particular time, and in a couple of other areas where I was also harvesting timber, was to improve the pasture lands. As a logger, from a logging family, I grew up in the forest and learned to love the outdoors and the forest, and I thought this policy of cutting down trees and improving pasture lands, rather than allowing more trees to grow or planting more trees or doing anything for the forest, but to improve pasture, was kind of a very short-sighted type of management system.

I was relatively new to Hawai'i. I had moved to Hawai'i in 1974, and logging brought me to Hawai'i, logging eucalyptus plantations on the Hamakua Coast. By 1978, when I started physically working koa forests, I had seen that type of management situation going on and had the opportunity to get around on the Big Island and see many other forests where the management decisions of those particular times was, basically, in my mind, for the development of pasture lands. The cattle had for many, many years, been eating all the seedlings, and new forest couldn't grow, the forests were all dying out.

It seemed really silly to me that some landowners and other people didn't have a longer-range goal in mind. I had the opportunity to work on some lands in 1980, on Bishop Estate Lands, who initially had started some plantation work on Keauhou Ranch in 1977 and a little bit earlier; they did a couple of plots even earlier, prior to 1977, a couple of three-acre parcels and five-acre parcels where they fenced it off as little test sites for canoe log and for curly-type trees. And then they did some bigger areas where they fenced off the cattle in 1977, a couple hundred acres for their initial sites where they were re-foresting. Bishop Estate was not going into this venture for economical reasons; there is no question about that. The value of the resource base in itself was so minuscule that there was no way that they could fathom and even project out in the long-run that they'd harvest those trees and they would be economically-viable type of situation. Bishop Estate could not have been going into it for that because at that point in time, the royalties Bishop Estate was selling their trees for was about $100 a thousand[board feet], which is very, very minimal.

When I first started cutting koa on that ranch in about 1980, I thought that price was very, very low. The wholesale price that larger users would be buying, basically green koa, selected better koa, good grade, good value koa was about $900 a thousand. I think maybe at that point in time the retail of kiln dry koa was probably around the order of $1500 to $1750 per thousand board feet. I started cutting on that ranch, worked out a land license with Bishop Estate and started harvesting behind Campbell Burns, material that they left behind. I saw an opportunity where I felt I could recover resource and still make a living and started my business up around 1980 between there and Kapapala Ranch, a couple of different areas. I started selling koa and trying to market green koa when I first started, on the wholesale level, selling to whomever for about $1500 a thousand. I was paying Bishop Estate, going behind what Campbell Burns had left behind, and paying Bishop Estate, at that early stage, at about $225 a thousand board feet, over double what Bishop Estate was paying them for basically the prime timber on the same lands.

I felt at that point in time that koa, relative to other hard woods around the world that I was familiar with, was, relatively speaking, quite low in price. I knew that the stumpage values were tremendously low, and the idea of cutting down trees to improve lands for pastoral uses seemed to terrible to me. I cut on that property for quite a number of years, on that parcel and various other Big Island parcels as well. By 1990, the price of koa had gone up quite a lot. The royalties by around 1990 were anywhere from about $550 to $750 a thousand, so basically it went up in five years time from $100 to $700 a thousand.

The larger users were buying wholesale, green lumber after it had been harvested and cut into boards, for around $3250 a thousand. The retail level for kiln-dry, selected, better lumber at that time was about $4700 to $4500 per thousand board feet, a pretty good increase. The royalties were going up, and by 1990, there was a lot more interest in the community.

By 1990 we had had a couple of conferences, a lot more people were interested with what's going on with koa. How long does it take for koa to grow? People in

1980 said it would probably take a hundred years for a koa tree to grow before you could harvest it. It wasn't worth anything in 1980 and at $100 a thousand and a hundred years for it to grow, my gosh! they thought, "Let's get rid of these trees and this forest so that we can make better pasture lands and put more cattle on it." By 1990, things had changed a bit, and people were taking a little more serious look into how quickly a koa tree can grow. The thought by that point in time was maybe 40 to 80 years that it would take it to grow. My feeling was that the cycle for growing those trees was still a lot less than that.

Today, 1996, another six years from 1990, the price of koa is as high as $3 a board foot, $3000 per thousand for royalties for koa. I think maybe the price of koa on the stumpage value has reached a high point at $3 a board foot. I don't imagine that, on a world-market level anyway, competing with other hardwoods around the world, it's going to go up too much more than that in the near future. It's very possible that it could go considerably higher yet, but you would be looking at selected types of koa, more of the curly type, real fiddle-back figured, and maybe if it went higher the lower grade would be reduced quite a bit.

So, on the average, it's probably at a pretty high level at this point in time. I don't think it's at a peak. I don't think it's at a spike where it's going to drop down tremendously, although there maybe some minor fluctuations in the value of koa, meaning that the value right now could be anywhere from $2 to $3. And maybe in some areas of koa where people are harvesting, I think they're paying as low as 85 cents, which is 850 dollars thousand. What is the price of wholesale? The price of wholesale koa, $3 a board foot right now for royalties. The wholesale price right now for the larger-volume sales is running on the order of about $6 a board foot. The retail of koa for kiln-dry stocks is running about $10 a board foot.

What has happened over the past 16 years is that the value has shifted to the positive side of the landowner or the person that's growing the trees or has the forest, which is really good, which is the way it should be, at least that kind of balance in nature where landowners can now take a serious look at protecting their forest from the economic standpoint, from the koa resource. So, it's changed quite a lot over the last 16 years from $100 a thousand to $3000 a thousand, from a wholesale level of $900 to $6000 a thousand, and at those levels, if you really think about it, you're now looking at the royalty figure or the stumpage value at about fifty percent of the value of the wholesale, which is, relatively speaking, quite high, I think, in regard to the average of what you do get out of koa forests. I think it's a real good value and a real good thing and I think the future is good for our whole industry. I look at the positive side of things. I think with the right management and the changes that need to come in our community and working together and figuring out problems that we have with the Endangered Species Act.

The problem is, how can you protect your land and hold it in conservation and those type of uses for perpetuity and not get any kind of economic return on it? Well, basically you really can't. You really, really can't. But there's got to be some way that landowners like, for example, Bishop Estate, can realize the benefit that they should be realizing for protecting lands for the whole public use for watershed reasons. And those are just a few issues that we need to continue to talk about and discuss, and changes need to be made. From an economic and marketing standpoint, I think the future looks good.

When I first started working in koa and marketing koa in 1980, it was really interesting. The main buyers of koa at that time were asking for $1.50 a board foot, and the largest manufacturer of koa was selling it for $900 a thousand board foot and here I am, the new man on the block, asking $1.50. I needed that in order just barely to survive. My costs were tremendously higher; I'm just a small company. I thought it was worth it. That's my feeling of the resource and how beautiful it was, and then the larger user says, "Well, you can't sell koa for that. Nobody's going to buy it." And I went around to people and I recall selling curly koa for $2 a board foot green, and I cut it for one person, a log for one person, and he was happy to get it. It was the first time that curly koa got sold for that kind of a price. He was tickled to death to have that resource. And I learned some good lessons, that you can't undervalue it. And he turned around and made it into an economical thing. He didn't lose any money on it; he made money on that venture. The price of it needed to go up, the value had to go up.

People that are selling furniture in the industry right now have to realize that the landowner has got to be able to protect his trees, protect his land, and grow the trees, and that's where all the cost and value come from, is right from the basic start. You also have to have the right attitude about when the pricing structure is going up. You have to compare it to what's really out there. You can't replace koa. Koa, culturally for the state of Hawai'i, is an absolutely marvelous resource, and that's why the price structure can go where it has gone over the last 16 years. There's no sense to it. The economists cannot make sense of what's happened with the price. The only thing is, it's carrying the value, because for one thing it should. It's one of the most beautiful woods in the world, not just in Hawai'i, and culturally for Hawai'i, you cannot replace it. People really love it and respect it here in Hawai'i, and they always will. There'll always be a tremendous market for koa in Hawai'i.

Questions following panel on fiscal realities

Q: [to Tom Loudat] You had 34,000 board feet as your assumption [yield per acre]; what number of trees, what size per acre?

Loudat: To the best of my recollection, it was harvesting 76 trees per acre, assuming a 15 or 20 foot bole, and that was all you were really harvesting. [Refers to the table in the report.]

Q: [to Lloyd Jones] I'm interested in having you reflect a little more seriously on what you mean by quality. Are you saying, for example, curly is number one and everything else number two?

Jones: Of the characteristics that are driving price up, curly is certainly one you can put your finger on pretty easily. There's a grade below that has got nice figure and a lot of black in it, a lot of streak, a lot of character; all of that is high quality. The color is important; the dark, rich red commands a premium over the blond koa. Again, I challenge the scientists to give us some knowledge: is it genetic, is it the soil, the environment, trace elements? What causes those characteristics?

Q: [to Loudat] In years 20 to 25 I didn't see any harvesting costs in your plantations. How are you going to harvest, and what is the cost?

Loudat: It just assumes a stumpage fee. Someone like Ed comes in and pays you the stumpage fee and he incurs all the costs of harvesting. You can do other types of arrangements, but that's the one that's most typical.

Q: [to Peter Simmons] All the koa that's coming into the saw mills and these stores, I'm assuming it's all coming from native forest? There's no plantations yet that have harvestable koa? Is that true?

Simmons: Well, I can let these fellows say, but to me it's pastures. Ed?

Ed Winkler: Yes, I'm not aware of any koa that's coming in from what you'd really call a native forest. All the koa right now currently is being harvested off of pretty much open pasture lands. Historically, where I've cut, for example on Bishop Estate lands, was all pasture lands. It had been in pasture lands for many, many years. Where koa forests are—and people have the misconception that koa comes out of the forest, and the fact of the matter is that where koa is being harvested these days is not out of a real forest situation—it's coming out of very depleted, degraded lands that have been managed for other things that the forest.

Summary: Koa Stewardship

Peter Simmons, Forestry and Natural Resource Department, Kamehameha Schools/Bishop Estate

Hawai'i County . . . sugar transition . . . no more sugar, sugar's out . . . what's coming in? We have diversified ag; we have eucalyptus plantations. You might think initially that the eucalyptus plantations have nothing to do with koa, but I think you'd be mistaken. The kinds of quality scientists that have come in to analyze the project have been interested in our koa. These are people of worldwide reputation, soils people, harvest people, stewardship people, people that have seen other acacias. I'm very excited about the potential of them coming in and stirring our pot a little bit.

Mauka Kona . . . cattle industry transition. Thousands and thousands of acres that used to be stuffed to the gills with cattle are not anymore. What's going to happen to those lands? Transition. We've got 1400 different species of grasses we've brought into the state of Hawai'i over the years. Kikuyu grass is the main one that's left up there . . . a fire hazard; how are we going to handle it? What about grass competition in our koa? The state of Hawai'i made a start at a transition at Kapapala. They stopped, then they started again, now they've stopped. They need to start it up again and get that model going.

Maui County . . . I sense from the presentation by Bart that there's a growing interest. We see Maui Land and Pine and Haleakala Ranch . . . Ulupalakua Ranch was mentioned as someone who has investigated and done a little bit of work . . . and of course the National Park dominates the natural resource over there.

O'ahu . . . transitional? I hope not. The fear I have is that the koa dieback from whatever pathogen (if the right one's been identified) could be extremely serious business. Some are now looking at the economics of fiber and are looking at water problems. The two-spotted leaf hopper is giving us problems in the 'uluhe.

Kaua'i sugar land . . . again, we heard that koa is currently not the replacement crop of choice. Primarily for genetic reasons, that we don't have a reliable seed source that will produce high-quality koa in a short time, but I hear that some experimentation is possible. And then again, transition at Koke'e—it sounded a lot more positive than I expected. So that's my stewardship round-up.

Comments

Stephanie Whalen: The sugar industry took a massive decline in a very short period of time which was, I think, unexpected by much of the community. We're now in a crisis mode and it allows us to make some changes. It took 20 years to get some tax changes; when the sugar land became available, it precipitated a change. I think that is giving us an opportunity. It seems like our systems, whether private or public, all resist change. If you look at any organization, it never makes a change until there's a crisis to deal with. This crisis is what's allowing an opportunity right now for the forest industry. There's a "window of opportunity," and I hope that we can meet the challenge and take some steps in this crisis to make some changes that are needed.

Michael Buck: I'd like to make one comment, because I think I heard a couple of guffaws when people talked about eucalyptus plantations. We've had a hundred years of monoculture, clear-cut-and-burn agriculture, and I can't believe some people say, "You're not going to plant those eucalyptus in monocultures and harvest them every six years!" It took us over 300 years to deforest that land, and putting trees on the ground is the first step. I think we're looking for a strategic mix of both short-term and long-term, but if we don't get something growing in that ground, you will have houses. So I think it's important that people be realistic about the mix of trees as they come on. Forest restoration is not something that happens overnight, so people need to be realistic about who's going to pay for these trees, and lets start pushing for a strategic mix of trees that get on the ground in the sugar lands.

Peter Simmons: One other thing I heard, maybe the phrase is overused but it's "over-regulated and under-managed." Anyone who's trying to do business in Hawai'i knows how those two work. I think in this time when we have an opportunity for a new beginning that there shouldn't be guidelines and that we should allow things to run wild. It's a time for creativity, a time to try new things. We'll be encouraging a lot of our lessees on the integrated, diversified ag to try high-value trees as their windrows. That's something that we haven't done in the past, and that's just one example of trying to become a little more innovative. It may be more complicated to write up the lease in terms of who owns the milo, kamani, kou, and koa if it's a shorter-term lease, because they need windrows and we need hardwoods. So it's a time to be creative and look at creative solutions and opportunities. One of my fears when we saw the CZM presentation was that the potential for overregulation is with us, also.

Mike Tulang: I'm going to ask a question to, maybe, Peter. If I was a landowner, and I was to plant, say, eucalyptus or even koa in agricultural land, and say the trees come up and they provide a jump-off area for endangered species, and I've invested 40 years of my time and 40 years of my dollars. What do you think about the idea for industrial forestry zoning in agriculture? Do you think investors would be willing to look upon that as a positive move? Maybe Paul can also add in.

Paul Brewbaker: I'll just comment that the way economists look at the economy, there are several wedges in the right hand corner of the pie chart that we collectively label goods-producing industries. They are agriculture, forestry, fisheries, manufacturing, and construction. There's a sense in which we ought to see them all in the same framework, and that ought to be part of the way we regulate them. I don't know if we need to industrially zone ag land, forested land, but maybe we should recognize that what it's there for is to produce goods and not have any misconceptions about that.

Peter Simmons: I think that the U.S. Fish and Wildlife Service's recent administrative rules allow that kind of thinking, where you can basically make a contract, with the federal government anyway, that secures a certain part of the risk. Several of us, I hope all of us, will be working on the state law so that we can have some continuity. I think your point is a good one, Mike.

Comment from the audience: Peter, you mentioned windbreaks. After listening to Holly's presentation about nitrogen fixation in koa trees, I'd like to suggest that you also encourage your lessees to use an alley cropping system using koa rows and farming between them until the trees are big enough, eventually harvesting the trees, being able to produce the trees and cropping together at the same time.

Peter Simmons: I think that's a really good idea. I think it comes under the gross heading of agroforestry, and it's an idea that takes both a willing landlord and an innovative lessee.

Summary: Research Programs

Kathy Ewel, Institute of Pacific Islands Forestry, U.S. Forest Service

I'd like to address four different areas. I think any research program that is based on managing, that tries to teach us more about managing a tree species, ought to include at least these four dimensions. And what I'd like to do is go through each of these very briefly and just to summarize what we learned in this area, in this conference.

Now the first one is the basic biology and ecology of the target species, and here I think the big message came from Tom Conkle's talk, where he documented what I think we generally knew but hadn't really seen in black and white before, that there is a great deal of heterozygosity in these different populations, and we saw this manifested several different times; perhaps Don Gardener's fungi demonstrated that also. In addition, Robin Harrington's talk about natural disturbances and their effect on koa was quite interesting in part because it told us that we may not understand as much about the disturbances themselves, as well as the responses we see. Those of you who didn't take a good look at the poster outside by Paul Scocroft and his colleagues should, because it summarizes a great deal of useful information about basic koa ecology, in looking at reforestation.

The second category is management, and again I think Tom Conkle indicated that we should be reforesting with seed that is native to a particular area and Jim Silva and Jean Conrad, I think, backed this up with the high degree of height-specificity that they saw in their data. We spent a fair amount of time on genetics, and this was quite interesting, but it's also interesting that at one end of the time spectrum we have the seedlings that Dr. Sun is following, and Dr. Brewbaker's hybrids that he's following. They take a while to grow; the tissue-culture techniques that Dr. Nagai discussed are very powerful, but she cannot use mature material and so, I think, we're still not able to take proven winners and [reprodcue] them using tissue culture. But obviously this is a very promising technique and one that should be pursued.

One of the major management areas that we talked about (and this impinges a bit on the third area, how koa, the target species, interacts with other species) is the area of competition and weed control. Sally Rice said that koa seedlings will come up through kikuyu grass, but I think those seedlings may be the only ones in all of Hawai'i to do that, because Gene Conrad's study was very heavily compromised by kikuyu grass. Nick Dudley spent a fair amount of time talking about mulching versus herbicides. Jim Fownes and Kevin Grace, in both the talk and in the poster, demonstrated that grazing is really most helpful in weed control and that some aspects are more beneficial than others. Mike Robinson suggested that perhaps koa could be used to shade out gorse, but then Jim Fownes also showed us that there's a lot of mortality among what Sally calls the "teenage" trees. So here's an area where I think that it would be very useful to have a model to look at the advantage of shading out gorse or other species on one hand versus the cost of planting and maintaining a densely stocked stand on the other.

The two studies on nutrient relationships were very interesting, both from a management viewpoint and from a basic ecology viewpoint. Holly Pearson showed that nitrogen fixation probably is most important before age 12, and Jim Silva suggested that the effects of fertilization have really ended by age 16, and this suggests that perhaps we ought to be looking at these nitrogen-phosphorus relationships more closely, perhaps to tailor management recommendations for particular sites.

Now in the third category, competition or interaction with other species, Don Gardner's discussion on the types of fungi was very interesting, as was the question of how dieback exists as a disturbance, how it affects habitat for other species, which I think would be a very important area to follow up on here. The poster by Susan Miyasaka and her colleagues called our attention to the symbiotic relationship between koa and mycprrhizae; that perhaps again could be exploited. Now this third area, how koa interacts with other species, I think is a very important one, and I think that the research community has given it short shrift. Mr. Bosworth pointed out in his presentation yesterday that we really don't have the luxury of considering any of these species by themselves. And if you go back to the 1986 koa symposium, Ron Walker commented on the striking correlation between the distribution of koa and native bird habitats. Now, if you go up to Hakalau and talk to people there, you find out that branch cavities are essential for ʻākepa. We heard about branch cavities and how you get around having branch cavities. Here again, a model demonstrating the trade-offs between pruning and not pruning would be very appropriate and might be very helpful in helping us decide how we might manage a given stand for different kinds of products in different areas. By the same token, the birds at Hakalau, the endangered species, are found more at one end than another; is this related to foliage nutrients? Does this affect the kinds of insects that are feeding on the tree and then are fed on by the birds? Mike Robinson showed us pictures of these corridors of koa trees that they hope will help to re-establish, to move the koa forest down. Who is going out to those corridors of koa trees and looking at whether or not they work for birds, whether they work better for exotic mammals? This is the research opportunity that we ought to exploiting, that looks at how the koa forest interacts with other species. I think that we just have to face the fact that what we're doing in koa forest is very likely to affect the survival of endangered species. I can understand Bill Cowern's concern about the tracking of endangered species, but I think we have to be pro-active in understanding these ecological relationships and then addressing the difficult policies that may be associated with it, because if we don't do it, someone else will, and I think it's more likely to be to our advantage to hit this kind of problem head on.

Now, we also learned very little about the fourth area: how a managed forest fits into a larger landscape. Here we're talking not just about a physical landscape, but we're also talking about a sociological landscape and an economic landscape. Here, I think, there's a lot of opportunity and not much research. There's not very much money out there for evaluating traditional forest management strategies, but people are interested in seeing resource managers interacting with sociologists, with economists, in trying to develop not necessarily answers but strategies to coming up with answers to these difficult kinds of problems. And I think that Bill Libby's observations about the current differences between Hawaiʻi and New Zealand in meshing the forestry and conservation needs on forest lands really merits much more careful consideration by the forest community.

So, I'd like to dwell briefly on this last area, because I don't know how many of us appreciate the fact, but I think that it's extremely important for foresters to be pro-active in these kinds of areas. We cannot sit around and wait for people in other disciplines to move in, because public sentiment, for instance, in something like the spotted owl rests first with something like wildlife habitat and not with managed forest. Even though we're certainly meeting society's needs, we are still perceived as creating the problems, as being timber beasts. So, if Hawaiʻi is going to move ahead with koa forest management, then the forest industry, together with state and federal agencies, has to work more actively—starting now—with wildlife and other interests in line right from the very beginning.

I think this is a tremendous opportunity, partly because we have a very active and vibrant community of evolutionary ecologists and wildlife biologists here with us, and I think there are plenty of good economists, sociologists, both here and on the Mainland, that we can bring into these studies.

I congratulate the researchers who presented such an informative session, and I ask the research community in general, including myself, to try to look critically at broader issues. I also ask the Hawaiʻi Forest Industry Association and interested and concerned individuals to actively seek out opportunities to bring together researchers and managers from these different disciplines to articulate and address the problems that are looming larger and larger on the horizon.

Comments

Mike Robinson: I don't know exactly how we do it, other than spending more money on it, but I know what I'd like to see done. As a forester who has practiced in many different parts of the world, including here in Hawaiʻi, and written plans for management of koa and other timber land, I'm very frustrated by the lack of research we have here. I know on the Mainland it's a very envious situation, where there is 40 years of research to back up your decision-making. There's charts, there's biologists that can communicate very clearly to you how many snags per acre to leave, whether they're hard snags, soft snags, what kid of bird you're going to protect by leaving that snag, what diameters of logs to leave on the ground for small critter habitat; we don't know any of that stuff over here. I've tried to piece some of that stuff together, but you talk to the experts and they don't know, and that's the question that comes up. So part of our role on this side of the table is to create a future, so I would hope as quickly as possible we give the land managers the tools they require to make those good decisions. That's going to require a lot of research, but the kind of research that answers those really tough questions quickly. I hope we put our research dollars into exactly those questions that resolve the biggest issues. How can we address the sustainability issues, the environment, the economy, the sociocultural needs of our community? How can we resolve those interfaces where they come together? How can we cut koa and protect the endangered speices? Or how can we create endangered species habitat which in theory would do away with the endangered-species issue because we've got 10,000 more acres of koa forest out there? And how can we pay for that . . . maybe through some sort of sustainable harvesting? I think it can be done, but we don't have all the answers, so everyone's being very conservative about how they approach the issue.

Stevie Whalen: I want to draw from some of my experience with the sugar industry, and one of the positive things has been their financial commitment to research. Industries here in Hawai'i are isolated from federal funds, and we don't have a lot of research dollars coming into the state. This is a time when national research dollars are diminishing because of various social programs that are taking up a bigger part of the budget. It's important to look to making the financial commitment to meet it, taking that risk, but accepting the responsibility of directing the research and getting the type of work that they felt needed to be done for the industry to move ahead. That's the advantage of funding your own activities, and those in the private sector recognize that. Other industries put 2 percent of their gross income into research, and until the agricultural industry, which forestry is a part of, makes that commitment, we're not going to move ahead at any faster rate than you do under the use of public funds, which takes a longer process. The sugar industry used their funds to leverage public funds when they got into economic difficulty. The public sector now requires the private sector to match everything. Until the industry comes to the table to develop research, it's going to be a slow process. I feel we now have the opportunity and the attention, so the industry has to look at some kind of assessment process to come up with the funding to get the research done.

Michael Buck

We're so glad that Kathy Ewel has come to Hawai'i. We hope that she finishes her Kosrae work quickly so she can spend more time here. I think that level of analysis tells you there's some new kids on the block. I think it's criminal that in this state, the eleventh largest forest in the whole U.S. and America's only tropical forest, we don't have a forestry school or forest management classes. When I compare other state forests, our state management agency gets less support, because it's just not there right now. We are actually paying the resource agency, with the help of HFIA, to put on a course at UH Hilo. The students want it, and students would love to come here. We'd love to have an internship program working with the university to get people into the forest. I really hope that out of this initiative we can hire people and people can come and do vocational training, internships as well as higher education. The issue of koa at the landscape level is very important and the roles of public and private lands within that context needs to be discussed and refined for koa to be part of a stable forest industry here.

Cynthia Salley: How many private landowners are there here at this symposium who either have potential forest or native forest they are managing right now? . . . (show of hands) . . . fifteen. On behalf of all of us, I want to thank you all, because basically this whole symposium has been put on for our benefit. I guess indirectly what I'm saying is that there is a whole component that is missing here, and that's private landowners. And perhaps as we get into some of our discussions later on maybe we'll realize why they're not here. In order to carry on everything that we've been talking about, the research, the stewardship, you're really talking about the private landowner, because Mike Buck has already told us that the state can't do it. We're all that's left.

Kathy Ewel: I think there's one partial solution that's available to us and that is, from a newcomer's standpoint, I think there's a certain amount of parochial-ness in the way we approach research in Hawai'i. I think we ought to draw more heavily on our colleagues on the Mainland. Holly Pearson is from California, she's a graduate student, she's not from Hawai'i, but her research is very appropriate to Hawa'ii. I think we can call on funds and talent available on the Mainland to address research problems that we consider to be important that we can help guide. We don't need to worry so much about finding the money here. There is a broader range of talent available to whom we can communicate our concerns and call for help. It can't do anthing but benefit us.

Summary: Policies, Laws, and Community Involvement

Carl Masaki, Hawai'i State Division of Forestry and Wildlife

Although we do have incentives that will help landowners plant forests, they're running out of money, or they're unfunded. So unless we get more money into the Forest Stewardship Program, that incentive program is basically taken. From there we moved into the environmental assessment by Gary Gill and other county, state, and federal regulations.

And as far as the policies are concerned, they're a little more flexible than the law and they can be modified fairly easily. Paul Brewbaker said that maybe the state should look at planting more koa. But, because the sugar lands that are coming on the market right now are in low-elevation areas, I think research should look at developing a seed for lowland koa, so that way the lower-elevation lands can be planted to koa and if the state cannot lease its maybe acres, maybe they should look at planting trees.

Mike Buck mentioned that we have about 46,000 acres of plantation forest. It was our predecessors before us that had a vision that if they did plant something during their day, that maybe economic development would be possible at a future date. As Lloyd Jones said, koa is king, it's the premier wood, so we should look at planting more koa, instead of looking at other high-quality hardwoods that we would have to develop a market for and maybe compete with areas where it grows native.

The laws have to be changed by the legislature. I've been to many koa conferences and symposiums and I think the people that we're not inviting are the people that make the laws and the policies. When the conferences end, everybody says, "Great conference." We learned a lot, but then we have to wait another five years, another ten years before another conference and then we talk about the same things and we complain again and nothing gets done. I'd like to add to what Ed Winkler said about former councilwoman Keiko Bonk. She was invited to a forestry symposium, she went out ono field trips and she went ahead and did it. I think if we invite legislators and people from the county government and the federal government, talk to them, have them in the audience, have them see what the concerns and issues are, maybe we can change something, and it doesn't have to take 20 years. I think I see only one person here from county government. Other than that, I don't see any legislative person in the audience. I think we need to change our ways, we need to invite the people that make the policies and the laws to attend the conferences, so things can be changed.

As far as community involvement, we heard from Bill Stormont. He went through a really trying process in trying to do something, and then the community got up in arms and said "No, we don't want to do that, we want hunting." Then it was brought about that he had a natural area working group. I think this is probably the wave of the future, and all government agencies should take note that we are trying to do something. We have to have community involvement. On the panel that talked about education, Eric Enos said that education is the key. We can talk to people, we can talk to legislators, but I think that the education process has to start very early on. We have to educate the students, we have to educate the legislators, and we also have to educate the communities, because unless they know what we're doing, it's going to become very difficult to do what we want to do.

I came up with several recommendations. The responsible agencies should take it as a mandate that they should go back and look at it and try to do something about it and not wait for the next koa symposium to again hear the same problems. If the requirements of the federal government, the state government and even the county government are the same, there's a lot of duplication of effort, then I think it should be changed so that it becomes easier for the applicant to apply for a grading permit or a CDUA or something like that. We need to collaborate among the responsible agencies. I see this happening, and I've been working for the Division of Forestry for over 27 years and this year is the first time in my career that we've had five state agencies working together. We have the Department of Land and Natural Resources, we have the Department of Labor Industrial Relations, we have the Department of Hawaiian Home Lands, we have the Department of Agriculture, and we have the Department of Business, Economic Development and Tourism sitting down at the table, cooperating and collaborating on a forestry issue.

Added to these five state agencies are three federal agencies. We have the U.S. Forest Service, the Natural Resource Conservation Service, and Rural Development. So, we have eight partners at the table, and we're trying to do something to help the economy, and the first step is to hold this Governor's Forestry Conference so that we can share the same vision. The second day will be broken down into workgroups where we can look at the issues, look at the concerns and form committees to get them resolved.

Conferences are excellent forums to exchange information, and a lot of the conferences have been putting out really good information, but I think we need to take the next step and resolve issues and concerns. As I mentioned, the policy- and law-makers are missing from this forum, and we should make every effort whenever we have a conference to invite those policy makers to participate, because they're the ones that can really change the policies and the laws.

Comments

Mike Tulang: I couldn't agree more that the Governor's Conference will be an opportunity to put together all that we've learned the last two days and actually make a voice as a coalition, partnerships, or as individuals coming together and just load those focus groups up.

Mike Robinson: Policy, regulations, public involvement, I think all of these are currently barriers to having more koa trees out on the ground. After listening to this morning's presentations, if you accept public monies to do something on private land, you have to go through five separate processes to make your project work. If you're on conservation land, you have to go through four separate processes, and even on ag, urban, or rural lands you have to go through three of them. These are costs. You have to hire somebody or do it yourself. You have to take time off to go down, fill out the form in triplicate, give it to this agency, wait three months while they approve it, run it by everybody else, then you go do it again with somebody else. The form looks different, but the process is oftentimes the same. I think that in the ideal future of encouraging forest management in Hawai'i, we have a very streamlined process. We know the questions we have to answer, we know the issues we have to resolve. It would be very nice just to be able to do a one-stop-shop, fill out one set of forms, if that's really what's required, but do it one time and be done with it. Make it as cheap as possible for those that have to do it.

Peter Simmons: I believe we did invite our legislators, and we give them lunch. I think it's important to reflect for a moment on the successes that I think we've had legislatively as a result of these conferences, and why I think they're worthwhile. We've got a Forest Stewardship Program that was discussed, I think, at the Forestry 2000 Conference, that became a reality. The NAPS program, another one, real property tax, and I give Keiko Bonk terrific credit for that, but it was no accident that the timing was set, that the stage was there, that we'd had significant pressure applied through the years by many, many people in this group, to finally bring that about. And also the right to harvest. These are just a few, and there may be others that I'm missing. We do have some teeth that are not quite meshed right in the gears to make these programs work right and smooth. We've got, through no fault of Hawai'i's, a set of federal administrative rules for the Endangered Species Act that are user friendly, and people are locking and loading on the state issues. These are all important issues that we've been able to address as a community over the last 10 years. I agree, I would like to see more legislators, and I think we've got to find other ways. Free lunch . . . they just don't respond to that like they used to. Maybe there's a few other ways to do it.

Michael Buck: We also had a Tropical Forest Recovery Act, which really helped lay out a menu, but because of that we got a half-million dollar add-on with the help of Senator Inouye and the U.S. Forest Service this year, and then I've just heard from the state side that Governor Cayetano is going to put the half-million dollar match to that in the state budget this year. So that is some legislative support. Part of the Governor's conference this January is to help guide what's the best use of that. So there's some juice on the table to make it happen. It really behooves all of use to make the best use of that, to make sure that one-year program is a four- or five-year program. We're having a lot more support than we used to.

Paul Brewbaker: I'd like to underscore that. I get a little sense of what's happening over there in the capitol district from the work I do. Ten years ago, my second assignment in the economics department at the bank was a request from Senator Matsuura to look at why the forest industry hadn't taken off. I wrote this great paper and I never saw it again. But I must say that in the last year or two, forestry keeps coming up when you're talking with legislators, when you're talking with people in the government, now more than ever. So, I think that in the same way . . . the property tax situation in Hilo, the constant pressure, the fortuitous decline of sugar, a politician in the right place at the right time . . . we may be there in the more general sense of opportunities for more favorable treatment by the legislature of forestry industry issues.

Mike Tulang: We have a great opportunity with a whole bunch of new faces in the legislature. Certainly in Hawai'i County we have some new faces, and again new opportunities. I think the councils are becoming very business-oriented, now that Hawai'i County went to five/four Republicans. I think there's a good sense of fiscal responsibility, of forging the strategic financial plan. The posture and atmosphere are changing. Maybe with less money, we're doing a better job.

Summary: Economics

Paul Brewbaker, Bank of Hawai'i

The first point is that unquestionably the market for koa wood products looks really good. To me, prices are no mystery; you have supply shrinking, demand growing. That's a natural for the current situation, for prices to be strong. For the near term prognosis? Anybody know where some koa forests are coming on-line? I don't, so I don't see the price dynamics changing in the near term. There's a danger. Will prices rise to a point of exclusivity? Where people just don't buy koa anymore, they can't afford to anymore? That would be a real shame. And then looking down the road aways, the question is when and if future koa comes on-line, what would be the effect at that point on prices? I'm reminded of the 1981 tax reform, in which accelerated depreciation and investment tax credits all came on-line at the same time. Jim Nabors and a bunch of guys flew out to Hawai'i, planted a bunch of mac nut trees, and eight or ten years later their first harvests came on-line and crashed the macadamia nut market.

So, we have to be thinking of some of those dynamics. The solution, it seems to me, looking down the road again, is while the near-term focus, I think, rightly should be on production and understanding production and, concurrently, R&D to go with it. Eventually, we have to think about the marketing side, developing new markets, capitalizing on the emergence of consumer markets in a place like Asia, where attention to quality is something that's already a part of the consumer preference set, and also to capitalize on the Hawai'i brand-identity. I saw one of these chocolate macadamia nut boxes, the cheap chocolate with chunks of junky mac nut they can't sell, priced at $9 a box. Every airport I go through, I look in the duty-free store and see how much their macadamia nut chocolates are: $9 a box is the going rate for a box of chocolate mac nuts from Hawaii. My point is, brand identity sells. And if we can do it with junk mac nuts in chocolate, surely we can do it with the beautiful woods that we have.

Finally, we need to continue to pay attention to fine-tuning the tax and regulatory environment for forestry. It's not just forestry, it's the whole corporate culture, as we would say in the private sector, of government. Did you know it takes seventeen forms to teach a course at the University of Hawai'i for one semester? That's what you do to be a lecturer, fill out 17 forms, swear an oath of allegiance. I don't understand that, but it's the mindset. And it's changing. The administrators are on our side. These are the people who are advocates within the public sector for the kind of changes we seek. We need to work together now to get the legislative momentum in our direction as well. We need to pay attention to quantifying those non-market environmental benefits that a lot of today's discussion focused on and, maybe, on creating ways to capture, to allow producers, growers, and landowners to capture some of those benefits deriving from what they've produced for the community. And we need to continue to pay attention to capitalizing on forest production and restoration to achieve some of the cultural and educational objectives that have been raised today as well.

Comments

Mike Tulang: Peter, do we have time to get people back together before the Governor's forestry conference?
Peter Simmons: This time of year it would be rough to get people back together. I look through the audience and I know most of the people here. I think we all do; maybe over the years we've become too familiar. As these issues come up, I think it's important to ask a second question. If you hear that there's something going on with Kamehameha Schools/Bishop Estate forest land that you are upset about, if you hear about a bill that you can't understand why anyone would be for, rather than showing up at the legislature to go beef it out and kill it, it would be a lot more productive to try to give that phone call, to reach out a little bit to people you know in the conference here or others. Perhaps, it might be some of the wildlife biologists who aren't heavily represented here that may not understand an issue of why we want to promote commercial koa forestry. If they come to the legislature, it'll be a problem. We need to be able to reach out in that kind of networking.

Skip Cowell: These two days have been very interesting to me. I've listened to speakers and to people talking back and forth, I've listened to [Cynthia Salley's] comments, and I agree with her wholeheartedly. When people have asked where they can find land, how they can do partnerships, they're turned down by the state. When we started our TREE project, we wanted to have a few acres to take children up and show them the forest. As we talked about this in our soil and water conservation district, more people became interested in what we were doing. One of the things we had to come to grips with is that there is no money from the state or local or federal government to make it happen.

We have a vehicle, the Tropical Forest Recovery Act. That's public law, it's supposed to happen, the Governor's supposed to appoint a place where this center will be to do the research on exactly what you're asking, and I haven't heard a lot about that here. That's public law. And every person on this island, lives within a soil conservation district. That's how we got going. There's 16 districts in the state. There are five directors from each district plus associate directors. Once you go ahead and join a group like that and you can start saying we have a plan, let's do something, there's a watershed out there. HACD is a partner with DLNR. We're supposed to working with them. So there's a natural conduit whereby you can go to a district and say let's plant trees. I don't know whether they're going to let you cut them down right now. If you stop and look at public sentiment, anybody that you talk to, do they believe that we need clean air or we need clean water? Of course they do. Why don't you champion the first cause that will get them to think that they need to work with you? Out of that comes the next step, to go ahead and put something together, to work with the private landowners. I'm sure that Bishop Estate would probably at some point lease some land. It's a good thought.

The other group of people we need to work with is HARC. Those are the research people that get paid for a project, then they shut down and move on to the next one. They don't just keep going along for years and years. We have the vehicle whereby we can do a lot of things, and if you can take advantage of it, a lot of these dreams can come true.

Kathy Ewel: I'd just like to add one factor to the economic equation and that's something we've hardly talked about, but it's certainly a product we ought thinking about, and that's the potential for ecotourism. For creating a forest that's a commercial forest in the sense that it attracts and sustains people interested in seeing the different kinds of plants and animals that it holds.

Mike Robinson: I want to propose a possible economic model for the future. I've been to a couple conservation conferences, and I constantly hear the lament, "If we only had another $10 million, we could protect this, or if we only had another $6 million, we could do this." I remember doing some research as director of HFIA, that our very small industry pays something like $7 million a year in taxes. It would be kind of nice to kick at least a part of that back into the forest where these guys make a living and perhaps help perpetuate not only their own livelihoods but acquire some of the environmental protection we all know we need, yet can't seem to afford.

Michael Buck: One part of my law says we're supposed to make the forest reserve self-sufficient, yet another part of my law says all income from the forest reserves goes back to the general fund. This year, again, we're going to try one more time to have a law that allows income from the sale of seedlings at the nursery and from the forest reserve to go back into the forest system for overall forest management, for creation of demonstration forests and environmental educational materials talking about sustainable forest management. Hopefully, people will show up, and we'll try to take at least the registration list from this conference and make sure people have a copy. Second, I was talking to Paul, and if he could get that mutual fund set up, I bet we could find some pieces of state land to actually use and maybe have some timber on it to start an asset right away. I think those type of things from a different sector of the community would really show some of the legislators that this is serious. I like the concept. I'm ready to enlist.

Paul Brewbaker: I'll just follow up with a little comment on the funding question. I think the boom is going to be lowered on the visitor industry, the tourism sector as it's called, which has pretty much been free-riding off the government gravy train for a long time in the way that the Visitor's Bureau is funded. The principal concern that's being raised within the government, over at DBEDT where they've been looking at this question, is why there isn't more cost-sharing of destination promotional expenditures that the state is largely bearing. The model that they're moving toward, which I think is perhaps appropriate for this industry, is some form of collective giving. The way you structure that giving is important as well. Mike raised the question of the general fund versus the special fund set-up. Maybe one legislative proposal to float out there is to create special funding in which industry taxation of some form actually goes to funding research or development. That's the classic form of a special fund, a dedicated revenue source with funds dedicated only to specific uses. We use it for all other kinds of infrastructure investments, primarily in the transportation arena. It makes sense to do it in investments in the environment as well.

Margarita Hopkins: These two days have been fruitful, and it's very nice to interact with different experts from different aspects of this industry. There are so many frustrated people out there trying to sort out the different forms that they have to fill out. In order for us to be able to cut down on those forms, we at the County of Hawaii have been working very closely with DLNR and HFIA to come up with some idea of the type of forms they are requiring, so when they come to the counter we will be acknowledging or we will be accepting those forms, so they don't have to repeat it. We are very sensitive to that. In regards also to the comment regarding inviting legislators, it is a good idea, so they understand what this industry entails. You shouldn't stop there. Don't expect that what you need will happen. You still have to follow up. The reason why those things happened in the county was because HFIA had been working on those issues for quite some time, and following up. They just didn't let it go and wait for legislators to act, because they don't have as much knowledge and the ability to synthesize and come up with a policy.

Q: Could you broaden your definition of forestry to include orchard tree crops, whether it's macadamia nuts or oranges or apples, or other annually harvested projects?

Peter Simmons: When we were working on the Tropical Forestry Recovery Plan, I suggested this, and it wasn't the right time. I feel strongly that we have leadership, a variety of leadership within our industry, but one thing we lack is a way of expressing what we feel in our hearts. We know about the rare biology, the cultural aspects, the economy; everyone here knows what's in your heart. I think we need a challenge. We need to say in a loud, collective voice that we want to reforest 20,000 acres with koa in our lifetimes. You might think this is a big challenge, but it's not a big challenge. We could do something of this order, but we just have to say that we're going to do it. Some of it's being done regardless. It's a leadership challenge to say that, by golly. one way or another, we don't know how we're going to get there today, but we're going to plant, or enrich, 20,000 acres of former koa land, and we're going to do it together. I don't know how we're going to send a letter like that to the governor that we're going to take on a challenge like that collectively throughout the Hawaiian Islands. I think it takes that kind of a statement that we're going to do it. Then we go and find our way.

Skip Cowell: I think that what Peter said is a very, very good idea. If we go ahead and have one good thing come out of this, we're going to have a letter come from HFIA to the governor that we're going to put in 20,000 acres in the next 20 years.

Mike Tulang: All those in favor of the motion say aye. Okay, it's carried. Any opposing make for the door.

Summary: The Way Things Could Be

Cynthia Salley, McCandless Land and Cattle Co.

A few weeks ago, there was an article in the paper by Ron Wall, in which he told about the dilemma he faced, in a bookstore, as he viewed two books near each other, one titled "How To Get What You Want" and the other "How To Want What You Have."

It seems to be appropriate as a starting place for me today: "How To Get What You Want," or is it "How To Want What You Have"? As the only private landowner on this panel, whose holdings include native forest, I think that I need to address or support the "How To Want What You Have" part of the dilemma, because more than likely the other esteemed panelists here will be addressing the "How To Get What You Want" issue, and they will be talking about my land.

In reality, I already want what I have, but, I want to keep it. The "it" here, is the prototype native forest in West Hawai'i. It might not be perfect, but it's the best there is. Every time I turn around, somebody, or some agency, or some law is chipping away at our ability to manage it, and is making it more tedious and more costly and sometimes downright impossible to practice good stewardship. So, this panel's topic, "The Way Things Could Be," goes hand in hand with "How To Keep What You Have."

My utopian, pie-in-the-sky ideal is to have us all—private landowners, government agencies, and environmentalists—be able to communicate when required, collaborate when necessary, and respect each others' positions at all times, in an atmosphere of cooperation, honesty, and trust.

So much for ideals, let's move on to something that maybe there's a reasonable hope for. What will it take to make it work?

I would hope for more tax revision. I understand that Hawai'i County has a new ordinance pertaining to taxes on forest land. So far, it is the best-kept secret on the island. This information needs to be distributed. We need to know how far it goes, what does it include, what hoops do we need to jump through in order to take advantage of it? Do we have the potential to harvest down the line? Tax revision is absolutely necessary. No one should be penalized for having forested land, or for reclaiming pasture and planting koa.

I would hope for an amended Forest Stewardship Plan. The present plan is a good idea, but it can't help landowners like us, because we've been such good stewards of our land over the years, we don't qualify. There is no plan that can help us get better. We were turned down for a Forest Stewardship Plan because we were too pristine and intact. We weren't turned down right away. No, we had to go through the whole bureaucratic process—many months of process—before being told that we were at the wrong window. We need a clearinghouse for the small landowner, so we can know in which line to stand. The Forest Stewardship Plan needs to be amended to be inclusive, not exclusive. All forest and potential forest land needs to be included. This can't happen soon enough, because the grant-gluttons are eating up all of the money.

I would hope for changes in endangered species acts: the federal law and the state law are out of sync with each other and with the private landowner. To get cooperation from the private landowner, both laws need to be nonthreatening and friendly to those affected by them. Both need to include incentives for the private landowner, such as the unconditional right to selectively harvest areas which were previously reforested. The private landowner needs incentives to protect endangered species on their land.

I would hope for a large prototype forest, on state land, run by state foresters and biologists. This is long overdue. If the bureaucrats and environmentalists are going to continue to try to control us and tell us what to do, then they need to have a prototype or template where they have put their book-learning into practice. I want a place where I can go and see results from management tools that are more effective and efficient, both experientially and economically, than those that I am using. The state needs to be the prototype.

I would hope for a central clearinghouse and network for research. This should respond to the needs of the growers and users of Hawaiian woods. Koa research: What are the results of genetic tests? What effects does fertilizing have on the wood? Do koa seeds grow true? Is curly koa genetic or environmental? How long before I know the results, and how do I find out about them? Fire research: What, how, who, where, and when? What is the plan and what are the hazards? How is it to be accomplished? Who has identified the problems, and who is in charge? Where is the clearinghouse and when will it come together?

I would hope that inheritance tax laws would change, in order to be an incentive for preservation rather than development. Because of the laws, the next generations are precluded from preserving their inherited land and are forced to sell it.

Lastly, I propose that HFIA is the perfect entity to act as the clearinghouse for these issues I have mentioned. It is a private organization with no personal or hidden agenda. Its mission includes conservation and economics, both of which are vital to the perpetual and continuous life of the forest.

Comments:

Michael Buck: I just want to follow up, it's not a rebuttal. Concerning the issue that Kathy Ewel brought up about the landscape level, we need to refine and understand the difference between private and public land. Even though they're the same color on some of those maps, they're not the same. They have different clientele and different constituencies. One issue is, there is a group that is trying to reform the Endangered Species Act. Not weaken the act, but make it so private landowners could put native koa forest back on their property. That is the number one issue. Unless that changes, it's going to be very hard, so I urge all you to participate within the legislative process when that issue comes up. Finally, the "state" is you guys, the state is not me. There is a relationship between what happens on public land and private land. You in your collective wisdom have given the state five foresters on the island of Hawai'i to manage half a million acres of forest land. That's your land. I understand where Cynthia Salley's coming from, and she's earned that right to say that. If we keep referring to the state as "they," you need to understand that that's *your* underfunded agency. I just want to add my aloha for our employees out here who don't really have the resources to do the job. It's interconnected. If the state isn't managing its public lands well, that puts more pressure on private lands. The bulk of the biodiversity should be protected on public lands. That's how issues are coming down all over the world. If you don't fund the state to manage your resources on your own lands, then that puts more pressure on other things. It's very easy to attack the state, but look in the mirror. That's your land we're managing. We're not doing it that well because you're not there in support of your land when it's time to allocate.