Hawaii's Seed Crop Industry: Current and Potential Economic and Fiscal Contributions

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July 2009

EXECUTIVE SUMMARY

The research objective of this study is to update our 2006 study of the Hawaii seed crop industry's economic and fiscal contributions to the State of Hawaii. To this end we have provided:

- Background information about the technology used by the industry locally and internationally,
- Details of Hawaii's seed crop industry with comparisons to other Hawaii sectors and subsectors,
- The economic contributions of the seed crop industry.

Our primary research conclusion is that Hawaii's seed crop industry makes significant ever increasing economic and fiscal contributions to the state's economy generally, and most particularly simultaneous contributions to the agriculture, life sciences and high technology subsectors. In so doing, the Hawaii seed crop industry generates various positive externalities to the state, the value of which has not been assessed in this study. Seed crop industry economic contributions to the state should continue to increase given anticipated industry investments in Hawaii, which will assist achievement not only of economic policy objectives but other objectives as well, the various positive side effects of this industry operating in Hawaii.

Background Information

The origin of the Hawaii seed crop industry can be traced approximately 50 years ago to the 1960s when several seed crop companies first located themselves in the State of Hawaii. Hawaii offered and continues to offer a unique factor set, including:

- Year-round growing conditions allowing up to four crop cycles per year
- Availability of a highly skilled agricultural workforce
- Availability of land and water
- A stable political and economic environment.

This factor combination gives Hawaii a competitive advantage over other U.S. mainland and international locations for the seed crop industry. This competitive advantage has resulted in the location of 45 companies which comprise the industry, some of which are international leaders in the advancements of agricultural science. Seed crop farmers are located on Hawaii, Maui, Kauai and Molokai. These farmers use both conventional as well as biotech plant breeding methods to grow seed crops. The primary seed crop grown in Hawaii is corn, all of which is exported to both North and South America for further development and ultimate worldwide distribution. In the complex system of worldwide food production, the stop in Hawaii adds value to the seed product in the form of improved and increased crop production.

The seed crop industry uses conventional plant breeding techniques to a significant extent. Because of limitations of this method the industry also uses genetic engineering technology. This technology allows greater flexibility with respect to the transferability of specific traits to plants with the simultaneous exclusion of undesirable traits. Because

of their preciseness, genetic engineering plant breeding practices can be regarded as a significant technological advancement over conventional plant breeding practices. Traits most commonly engineered into plant varieties in Hawaii include increased insect and disease resistance, resistance to common agricultural herbicides and increased yields.

The Hawaii Seed Crop Industry

Industry Growth

The seed crop industry in Hawaii currently consists of 10 farms that cultivate seed corn, soy bean, wheat, sunflower, and other seed crops. Seed corn comprised 96.1% of the value of the seed crop industry in 2008. Hawaii's seed crop industry has grown dramatically since its beginning. This dramatic growth is best seen observing the growth in value of the Hawaii industry. Figure 1 charts the value of the seed industry since its inception.

Figure 1: Hawaii Seed Crop Industry Value

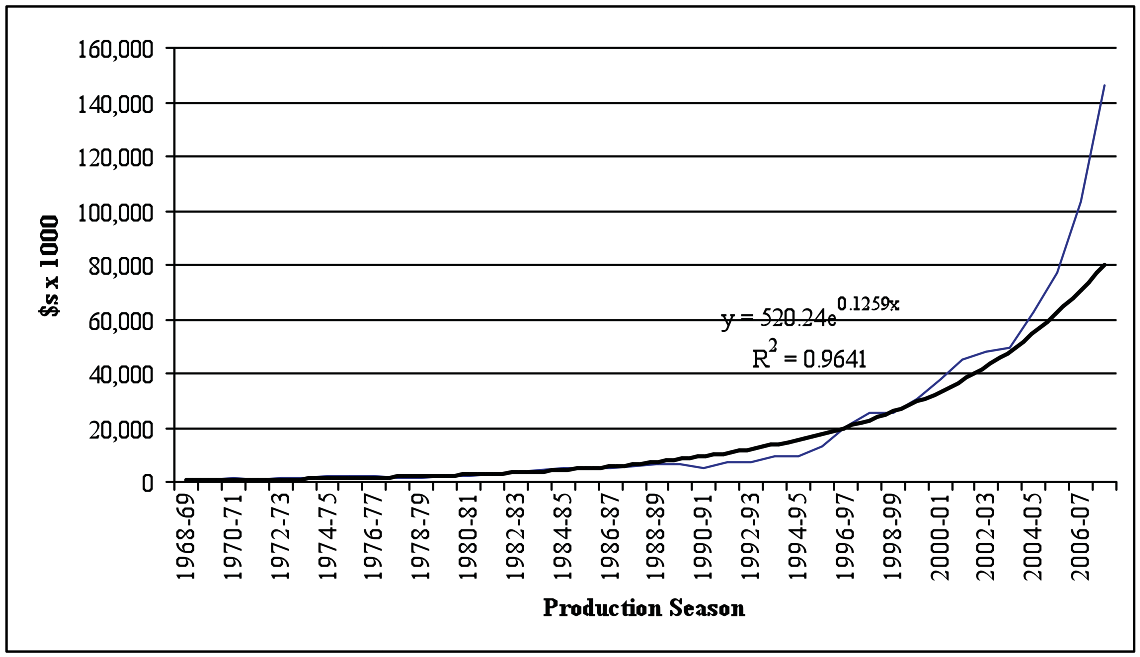

Chart Note: The vertical axis measures seed industry annual Hawaii expenditures and the horizontal axis the production year of the expenditure. The bold line represents the (exponential) trend of the reported industry value shown by the non-smoothed line.

It is noteworthy that our seed crop industry forecast growth in 2006 of 43% from 2005 to 2008 was significantly exceeded by actual industry growth. Seed crop value shipments increased 133% from 2004-05 to 2007-08, an average annual increase of 33%. The authors are unaware of any other industry or economic subsector in Hawaii exhibiting such exponential growth.

Factors Leading to the Growth of Genetically Engineered Plants

There are numerous factors leading to the growth of genetically engineered crops in the United States as well as in an increasing number of economies around the world. These include economic factors, demographic and development factors, environmental factors, climate change factors, energy factors, regulatory factors, animal feed factors and new genetically engineered crop factors. Other factors contributing to adoption are synergies from the formation of biotech clusters, growth in innovations and the commercialization of patents.

Growth factors are intensive as well as extensive. They are intensive in the scientific sense as biotech R & D is at the cutting edge of scientific research. The profusion of patents related to biotech research attests to this as well as the multitude of applications for biotech. These applications are categorized into eight separate general applications. These are: classical biotechnology, food production, biopulping, fuel, bioplastics, genetic counseling and gene therapy, pharmaceuticals for prevention, treatment and diagnosis.

The multitude of applications as well as the significant uptake worldwide of the technology and its products attests to the extensive nature of biotech research. Add to the intensive and extensive nature of the factors leading to the growth of biotech Hawaii's unique competitive advantage to not only provide the wherewithal to allow expression of the technology, but also production of biotech products, and one can readily understand why the Hawaii seed crop industry has thrived. This growth should continue given the unique combination of factors leading to biotechnology research and resultant product use, and Hawaii's competitive advantage. This combination should maintain Hawaii's position as a worldwide high technology leader.

Seed Crop Industry Growth and Value Contrasted

Hawaii's seed crop industry average annual value growth since 1968 (14.2%) greatly exceeds Hawaii's general economic growth as measured by GSP (7%). This growth rate difference is even more dramatic since 1998. More significant is the seed crop industry's contribution to Hawaii's agricultural sector of the economy. At current farm value levels, the Hawaii seed crop industry's value contribution to the agricultural sector makes it:

- The largest agricultural commodity with a value contribution that exceeds the contribution of pineapple, the second largest commodity, by almost 90%, and sugar, the third largest agricultural commodity, by 180%. Both sugar and pineapple are agricultural subsectors in significant decline as indicated by their recent and longer term negative growth rates.
- The fastest increasing agricultural commodity of only three with recent positive growth rates. Fruits and vegetables are the only other two commodity groups showing any positive growth which is negligible compared to the exponential growth of the seed crop industry.
- An agricultural subsector providing almost 30% of the total value of all Hawaii produced crops.

The seed crop industry's average annual growth rate since 1984 is 11.2%. In contrast are the growth rates of significant agricultural comparables in Hawaii.

- Major Hawaii agricultural subsectors average annual growth rates are:
  - Sugar -9.6% per year
  - Pineapple -4.2% per year with more precipitous declines recently
  - Diversified agricultural 1.8% per year.
- Major Hawaii diversified agricultural subsector annual growth rates are:
  - Nursery 1.0% per year
  - Seed crops 11.4% per year
  - Other diversified agricultural -0.7% per year.

The seed crop industry not only is the largest agricultural subsector but also currently comprises 38.1% of the diversified agricultural crop value. This makes the seed crop industry the largest diversified agricultural industry in the state. Nursery was the largest diversified agricultural subsector in our 2006 report. Additionally, the seed crop industry annual growth rate exceeds that of all other Hawaii agricultural crops or subsectors. The Hawaii seed crop industry is and has been a significant contributor to the agricultural sector of the economy.

A footnote to the existence and growth of the Hawaii seed crop industry and its contribution to the agricultural sector is that this industry has received no governmental support in the form of subsidies, targeted tax credits, tax breaks, etc. to locate and operate in Hawaii. The contribution to the Hawaii seed crop industry is solely due to Hawaii's natural resource competitive advantage and ability to generate three to four crop cycles per year for research.

Jobs

Job Number and Distribution: As of its most recent reporting for this analysis, the Hawaii seed industry employs 1,863 individuals of which 1,065 (57%) are full time employees and 798 (43%) are part time jobs. Relative to Hawaii comparatives the seed crop industry:

- Has a significantly higher proportion of agricultural-related jobs (71.3% industry-wide, 76.6% for Oahu and 68.7% for the neighbor islands) than Hawaii comparatives (1.2% statewide, 0.4% for Oahu and 2.9% for the neighbor islands);
- Has a significantly higher proportion of professional-related jobs (26.9% industry-wide, 21.6% for Oahu and 29.6% for the neighbor islands) than Hawaii comparatives (15.2% statewide, 17.2% for Oahu and 22.1% for the neighbor islands);
- Has a significantly higher proportion of "high tech" (Research & Science) jobs (14.1% industry-wide, 12.6% for Oahu and 14.9% for the neighbor islands) than Hawaii comparatives (5.2% statewide, 6.2% for Oahu and 2.6% for the neighbor islands).

By its mere existence the seed crop industry contributes to generally-stated Hawaii public policy objectives which includes the following:

- Economic diversification not only statewide but in particular on the neighbor islands where economic diversification is less than on Oahu;
- Creating jobs in a green industry, agriculture;
- Maintaining prime agricultural lands in agricultural use with little if any incentive to convert these lands to alternative use because of the seed crop industry's significant productive, profitable use of these lands in agriculture;
- Creating high-tech jobs.

It merits acknowledgement that the seed crop industry makes a significant contribution to achieving the public policy goals noted at no cost to the State. Rather this contribution is a natural response by market participants to put to productive use Hawaii natural and other resources that otherwise at best would be idle, thereby making no economic, public policy or other contribution to the State.

Job Growth: Seed crop industry job growth since the authors' 2006 study has been significant, especially when contrasted with statewide employment changes.

- Seed crop industry
  - Industry-wide = 73.0%
  - Full-time jobs = 268.5%
  - Part-time jobs = 1.3%
- Hawaii State
  - Statewide = 1.1%
  - Professional = -0.5%
  - Agriculture = -16.7%

The seed crop industry's "high-tech" jobs (i.e. professional) increase dwarfs what has happened overall for the State. Further, the seed crop industry agriculture job increase of 1.3% since our 2006 study stands in marked contrast to the statewide agriculture job change of -16.7% since this time.

The seed crop industry job increases have occurred in a Hawaii employment environment that has at best been lackluster since 2005 as noted and has generally declined since 2007.

- Overall statewide job growth has declined -2.4% since 2007.
- Most sectors of the economy experienced insignificant or negative job growth since 2007.
- The agriculture sector of the economy has experienced significant negative job growth.

Most noteworthy of the job data that merits reiteration is the 16.7% decline in jobs for the agricultural sector of Hawaii's economy versus the positive growth in seed crop industry job growth in this sector. It can further be noted related to jobs that:

- At current employment levels, the seed crop industry provides 22.7% of all agricultural jobs in the State;
- Of this 22.7%, 77.7% are on the neighbor islands;

- Proportionately more of the total seed crop industry jobs on the neighbor islands are full-time than on Oahu;
- Proportionately fewer of the total jobs on the neighbor islands are in agriculture with proportionately more in the professional category, most particularly research & science as compared to Oahu.

Employee Compensation:

Earnings: Overall average earnings for the seed crop industry are comparable with the statewide average. This is exceptional given that a much higher percentage of seed crop industry employees work agriculture-related jobs versus statewide. Agricultural jobs are among the lowest paid of all employment sectors of the economy. The significantly higher proportion of seed crop industry agricultural workers suggests that the seed crop industry average earnings should be significantly lower than statewide and island averages. That this is not the case implies that the seed crop industry pays a higher than average wage scale to its workers than one would expect based on statewide and per island averages.

Aside from the direct economic contribution to the State of seed crop industry high relative wage scales, such wage scales attract professionals most particularly high-tech workers which contributes to economic diversification. This contribution is not only to statewide economic diversification but within state due to the proportionately higher-than-Oahu wages of the neighbor islands, which have less diversified economies than Oahu.

Benefits: The seed crop industry provides a more generous benefits package than would be expected based on benchmark comparables. Overall, seed crop industry benefits as a percentage of earnings exceed the national average by:

- 27.3% for all workers,
- 32.3% for full-time workers,
- 29.7% for part-time workers.

In sum, seed crop industry compensation packages are more generous than Hawaii comparables across all comparable types.

Economic Contributions of Hawaii Seed Industry

Total Economic Impact of the Hawaii Seed Industry

Table 1 shows the total economic impact (i.e. direct + indirect + induced) impacts of the Hawaii seed industry to the state economy.

Table 1: Total Direct and Indirect Economic Impact of the Hawaii Seed Industry

Items	Direct Contributions	Indirect/Induced Impacts	TOTAL
Total Output (Sales)	$173,820,068	$167,734,817	$341,554,885
from Annual Expenses	$146,270,000	$142,429,806	$288,699,806
from CAPEX	$27,550,068	$25,305,011	$52,855,079
Labor Income	$83,777,863	$53,248,241	$137,026,104
from Annual Expenses	$68,313,567	$53,248,241	$121,561,808
from CAPEX	$15,464,296		$15,464,296
Employment	2,372	793	3,166
Direct Contributions	-	-	-
Full-time	1,065	453	1,518
Part-time	798	340	1,138
CAPEX	-	-	
Full-time	509		509

Table 1 shows the following.

- The total output from annual expenses attributable to the Hawaii seed crop industry equals $341.6 million. This amount measures the total dollar value of seed industry transactions that occur within the State related to their business. Seed crop industry total output equals approximately 25% of the total output of Hawaii's crop sector.
- Seed crop industry activities result in the generation of total labor income equal to $137.0 million. This amount equals approximately 30% of the total labor income of Hawaii's crop sector
- Total Hawaii employment attributable to expenditures of the seed industry is approximately 2,597 full-time equivalents assuming part-time employment is 1/2 of full-time. As a percentage of Hawaii's agricultural crop sector employment, seed crop industry direct employment generates 37% of the total jobs in this economic subsector.
- Industry CAPEX over the next 10 years exceeds the previous 10 year amount by 91%. The current 10 year forecast seed crop industry CAPEX also exceeds the industry's estimated CAPEX reported in our 2006 study by 93%.
- On a sub-regional basis (i.e. Molokai or West Kauai) seed company expenditures and jobs as a percentage of local totals would have a much larger economic impact than occurs relative to the comparisons made herein. This is even more significant when discussing the agricultural sector, which generally comprises a much larger percentage of total economic activity and employment in Hawaii rural areas.
- The economic impact of the seed crop industry we measure is conservative given the high likelihood of the industry contributions not measured in our study in the

form of an increased knowledge base for Hawaii's life sciences sector stimulating more local investment in research & technology and related job creation.

Tax Revenue Contributions

In total on an annual basis, we estimate that Hawaii seed industry activities currently generate $13.8 million tax revenues to the State per year. This represents an increase of 87% over seed crop industry tax contributions we measured in our 2006 study.

Economic Diversification

Slightly more than 20 years ago Hawaii's agricultural sector contributed 2% of Hawaii's GSP. This percentage currently and in our 2006 study is less than 1%. This declining trend shows no sign of abating as attested to by Table 1's declining job numbers in agriculture. The Hawaii seed industry has potential to reverse the downward trend of agricultural as a contributor to Hawaii economic activity maintaining this source of statewide as well as per county economic diversification. This is due to the following:

- Seed crop industry growth exceeded our 2006 forecasts and continues its exponential growth. This is in marked contrast to the vast majority of Hawaii private sectors and subsectors most of which have experienced recent negative growth.
- Expected seed crop industry CAPEX which will exceed the previous 10-year CAPEX by 91% with 100% of this increased CAPEX on the neighbor islands. Industry estimates of the next 10-year CAPEX also exceed what the industry estimated in our 2006 study by 93% or by a factor of almost 3 to 1 in favor of the neighbor islands.
- Scientists in Hawaii are convinced that the costs associated with the risk of damage to Hawaii's fragile ecosystem are far outweighed by the benefits generated by this segment of the economy.

FOREWORD

This study was commissioned by the Hawaii Farm Bureau Federation with funding provided by the Hawaii Crop Improvement Association (HCIA). Hawaii seed industry data was collected by the Hawaii Field Office Management Team of the U.S. Department of Agriculture's National Agriculture Statistics Service (USDA-NASS) led by Director Mark Hudson. This approach assured non-disclosure of firm-specific, proprietary data and removed any data biases. Seed company data reported in the study represents industry totals with no firm or island-specific data disclosed, a detail confirmed by USDA-NASS personnel previous to public release of this study.

The authors wish to thank the organizations and individuals noted for their assistance and contribution to this study.

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STUDY RESULTS

I. Introduction

The origin of the Hawaii seed crop industry can be traced approximately 50 years ago to the 1960s when several seed crop companies first located themselves in the State of Hawaii. The key attractions offered by the state included round the year growing conditions, availability of a highly skilled agricultural workforce, availability of land and water and a favorable climatic regime that permitted multiple generations of seed crops per year. Other favorable factors included the state's stable political and economic environment.

The Hawaii seed industry in the study is represented by the members of the Hawaii Crop Improvement Association (HCIA). These include companies such as BASF, Monsanto, DowAgro Sciences, DuPont/Pioneer Hi-Bred International, and Syngenta, which own and operate seed farms on various isles [28]. They are a part of the life sciences industry in the State of Hawaii which now includes over 45 companies. The companies are spread over the agricultural, neutraceutical, environmental bioremediation, human therapeutics and the marine sciences subsectors.

The seed industry is strongly associated with commercial and research biotech activities in Hawaii and generated an estimated $146 million in economic value in the state during 2007/2008. It is an important source of high-tech jobs and economic growth in the state. Of the other six important and high valued agricultural crops in the state, viz. pineapple, sugarcane, coffee, papaya, dendrobiums and anthuriums, only papaya has commercial biotech varieties in production [44]. There have been several experimental biotech trials for other crops including sugarcane, coffee, dendrobium and anthuriums.

The research focus on the six crops has fallen into four general areas of interest. Research activity has included crop protection against fungi, viral and bacterial diseases [44]. Other important research activities have focused on improving product quality (seven) while improving agronomic characteristics has been the target in two of the research activities over the past 15 years. There have also been some field tests for improving pharmaceutical protein in sugar cane. A survey done of the general public by the University of Hawaii College of Tropical Agriculture and Human Resources (CTAHR) regarding genetically modified organisms (GMO) research has shown that the public favorably views genetic engineering applications that are aimed at finding disease resistance and other measures that improve nutritional content and care for the environment.

The seed crop companies are located on Oahu, Maui, Kauai and Molokai and directly employ almost 2,000 employees annually. HCIA member companies use both conventional as well as biotech plant breeding methods to grow the seed crops. Besides corn, other seeds cultivated include soybeans, sunflower, wheat and rice varieties.

During 2007/2008 there were ten seed farms that cultivated 6,010 acres in the state. Of this acreage 1,810 acres were used for nursery, 4,410 acres for seed increase, and 60 for grow-out or observation. Total out shipments of seed amounted to 16,140 pounds valued

at $146.2 million. Approximate value of seed corn was $140.5 million and other seed crops accounted for $5.7 million. The seed industry hit the $100 million mark during 2006/07, surpassing pineapple and sugar to become the top crop in the state.

Hawaii exports seeds to both North and South America [44]. The seeds exported from Hawaii do not immediately enter production agriculture. They are destined for further propagation and testing in mainland fields. The seeds comprise the parent stock that farmers will utilize in the subsequent two to three years. During its development phase in Hawaii, the seed corn picks up the latest stock of genetic improvements. As such in the complex of worldwide food production, the stop in Hawaii adds value to the product each iteration, thereby supporting improved and increased crop production to meet ever-increasing food demand.

The focus of this study is the seed crop industry in Hawaii. Over the last five years it has continued to grow at an exponential rate and is a significant driver of the life sciences biotechnology industry in Hawaii and remains the primary driver of overall growth in Hawaii's agricultural sector [28]. This 2009 research is an update of our 2006 study entitled "Hawaii's Agricultural Biotech Industry: Current and Potential Economic and Fiscal Contributions and Policy Implications." The update yet focuses only on quantifiable economic aspects of this industry. Our literature update continues to reveal a range of factors that need to be meaningfully assembled and evaluated by decision makers in order to make careful assessments of the contributions of the seed crop industry to the State of Hawaii. For this purpose, we have included pertinent information and a framework for integrating risk assessments with extended or social benefit/cost analysis. Such an analysis would be beneficial not only for the seed crop industry in particular, but also the life sciences biotechnology industry in Hawaii generally—the most promising economic growth sector moving forward in time.

II. **Approach**

As with our earlier study, the focus of our current research is to capture and update the economic value of the contributions of the seed crop industry to Hawaii's economy. The present study does not include the contributions of agricultural technology crops such as pineapple, sugarcane, papayas, coffee, macadamia nuts, dendrobiums, anthuriums and other floricultural products. The value of the economic contributions of the seed crop industry to the Hawaii economy is estimated using State of Hawaii proprietary data and the 2005 state input-output tables. Through this analytic process, we examine and analyze the growth of the seed crop industry, employment generated and growth contrasted with other economic sectors, paid compensation including benefits, and tax contributions of the industry. Such an analytic approach can be used to study the economic contributions of the entire life sciences industry to the state economy or that of any of its constituent parts. Our present study is thus limited to one subsector of the life sciences industry, namely the seed crop industry which is both research intensive as well as technologically innovative at the cutting edge of applied science. Our estimate of the economic contributions to the state economy is based on the operational costs of the seed crop industry as well as the projected capital expenditures over 10 years.

Of the total acreage under seed crops in Hawaii, approximately half of the crop acreage utilizes conventional breeding practices while the other half involves genetic engineering crop breeding methods. It is not possible to estimate economic contributions to the state economy by each of these methods because producer accounting practices do not allocate costs separately by breeding method. Thus, the study estimates the economic contributions of the seed crop industry with no allocation of values by breeding method [28]. As mentioned earlier, our analysis also excludes the contributions of other biotech sectors of the economy such as marine products, human therapeutics and environmental bioremediation. While our study could be interpreted to include the economic contributions of the biotech sector in its entirety, it does not. Used as such would cause a serious understatement of the economic contributions of the entire life sciences (biotech) sector to Hawaii.

III. Plant Breeding and the Seed Industry

During most of the nineteenth and twentieth centuries, conventional plant breeding practices contributed tremendously to the growth in agricultural productivity through open pollinated (OP) varieties or hybrid varieties [19]. Although conventional plant breeding has been an important tool to scientists, the practices associated with it have had their shortcomings. One such limitation is that breeding is limited between plants that can sexually mate with each other. Thus, the traits that can be added extend only to those that already exist within the species.

Another important limitation is that under conventional breeding practices when plants are crossed there can be a transfer of other traits beyond the traits of interest. Such a transfer of traits may include undesirable traits that actually limit crop yields. Creation of new varieties of crops through conventional plant breeding may involve random exchange of as many as 30,000 genes, a number commonly referenced for corn plants. [1] Thus, eliminating undesirable traits through conventional plant breeding becomes a time consuming and ultimately expensive process relative to genetic engineering technology.

Genetic engineering, recombinant DNA technology or gene splicing technology offers scientists a more precise method to improve plant genes [19]. It is different from conventional plant breeding practices where all of a plant's genes are impacted. Genetic engineering breeding techniques are more precise because they afford scientists a direct method to develop plants and foods with beneficial traits without risking the introduction of undesirable traits. These techniques involve molecular cloning and transformation which enables scientists to alter the structure and characteristics of genes directly. Genetic engineering plant breeding practices can be regarded as a significant technological advancement over conventional plant breeding practices.

In Hawaii, scientists use both conventional plant breeding technology as well as genetic engineering technology to develop parent seed lines that are subsequently used to

[1] It is informative to footnote that conventional breeding's "random exchange of as many as 30,000 genes" can involve gamma radiation and chemical mutagenesis to induce mutation. One can characterize these techniques as "shotgun" approaches used by scientists to develop (mutagen) hybrids with desired characteristics given the gene number involved .

produce commercial quantities of hybrid seed on the U.S. mainland. Traits most commonly genetically engineered into plant varieties in Hawaii over the past 12 to 15 years involve increased insect and disease resistance, resistance to common agricultural herbicides, as well as increased yields [33]. The traits introduced have had positive environmental externalities as they reduce pesticide use and encourage reduced or no till farming. This reduces rural entropy without reducing crop productivity or yields. Besides affording cost savings to farmers, consumers also benefit by obtaining food that is more nutritious, healthier and potentially better tasting.

IV. The Hawaii Seed Crop Industry

Hawaii's Competitive Advantage

Hawaii's climate has provided a competitive edge in attracting seed companies to the Aloha state. Although the main growing season on the islands is from November through June, the all-year growing climatic condition facilitates seed producer cultivation of three to four crops cycles per year. This expedites the development of new plant varieties with desirable traits fairly quickly. With an existing sophisticated science and technology infrastructure, a favorable climatic regime, and a stable economic and political environment, Hawaii possesses a competitive advantage over other U.S. mainland and international locations for the seed crop industry.

Seed Industry and Growth

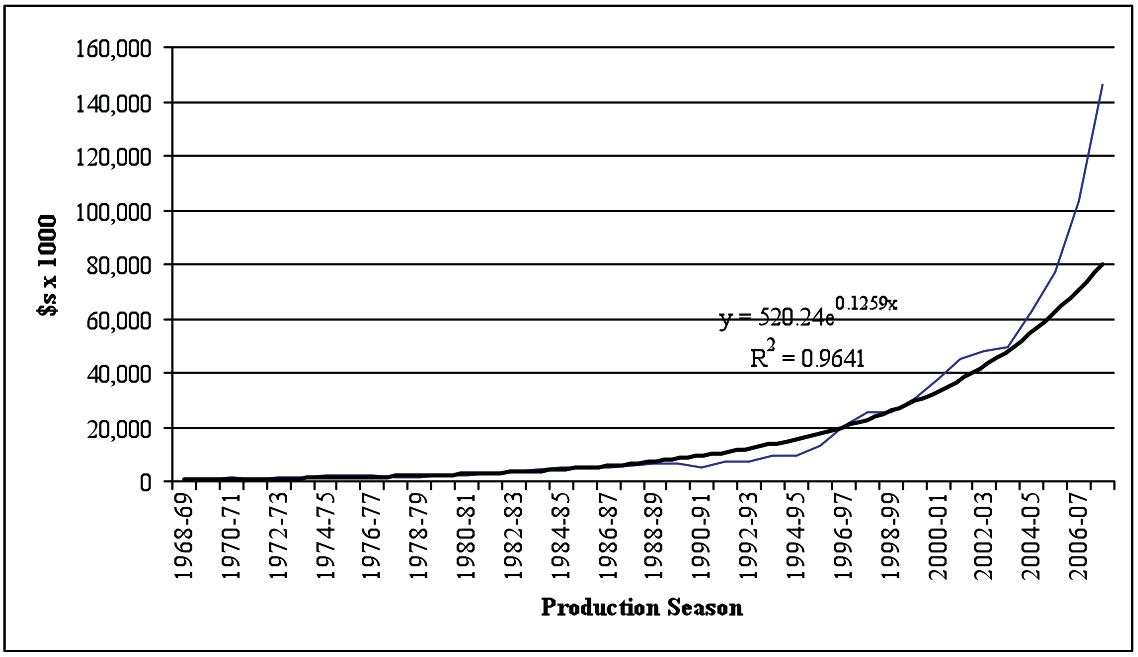
Background: The seed crop industry in Hawaii consists of 10 farms that cultivate seed corn, soy bean, wheat, sunflower, and other seed crops [59]. Seed corn comprised 96.1% of the value of the seed crop industry in 2008. Scientists in Hawaii use both conventional breeding practices as well as genetic engineering techniques in developing corn hybrids. Seeds developed in Hawaii are exported to South and North America for subsequent worldwide use. Hawaii seeds developed are bred for herbicide and insect resistance.

Industry Growth: Hawaii's seed crop industry has grown dramatically since its beginning as indicated by the following:

- Total seed crop acreage increased from 405 acres in 1968-69 to 6010 acres in 2007-08. This is:
    - A total increase of almost 1,400%
    - An average annual increase of 9.3%.
- The total outshipments of seeds increased from 80,000 pounds in 1968-69 to 16,140,000 pounds in 2007-08. This is:
    - A total increase exceeding 12,000%
    - An average annual increase of 14.2%.
- Between 1968-69 and 2007-08 the total value of seed crops increased from $450,000 to $146,270,000. This is:
    - A total increase exceeding 32,000%
    - An average annual increase of 14.2%.

This data indicates that Hawaii's seed industry is experiencing exponential growth. This dramatic growth is best seen by observing the growth in value of the Hawaii seed industry. Figure 1 charts the value of the seed industry since its inception.

Figure 2: Hawaii Seed Industry Value [28]



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Factors Leading to the Growth of Genetically Engineered Plants

There are numerous factors leading to the growth of genetically engineered crops in the United States as well as in increasing number of economies around the world. These include economic factors, demographic and development factors, environmental factors, climate change factors, energy factors, regulatory factors, animal feed factors and new genetically engineered crop factors. Other factors contributing to adoption are synergies from formation of biotech clusters, growth in innovations and the commercialization of patents.

The factors leading to the growth of genetically engineered plants are discussed more fully in Appendix I. A review of this section will reveal that these factors are intensive as well as extensive. They are intensive in the scientific sense, as biotech R & D is at the cutting edge of scientific research. The profusion of patents related to biotech research

attests to this as well as the multitude of applications for biotech. These applications include:[2]

- Classical Biotechnology, in use for thousands of years, which is the production of bread, cheese, vinegar, marinades, wine and beer using fermentation by microbes, including: yeast, bacteria, molds and fungi.
- Food Production which is the use of genetic engineering (gene splicing) and techniques, such as DNA mapping, to develop improved livestock and crops for greater yield and better quality, as well as new crop varieties with reduced impact on the environment.
- Biopulping which is a new example of industrial biotechnology for fiber using a fungus to convert wood chips to paper pulp while reducing energy use and pollutants.
- Fuel which is the use of biotechnology to speed the production of ethanol for gasohol, methane for natural gas and crops for biorenewable fuel.
- Feed stocks – bioplastics which, instead of petroleum, allows the use of biorenewable materials such as starch from corn or whey from cheese-making to make plastics. The industry uses microbes or their enzymes to convert biomass to feedstocks—building blocks for biodegradable plastics, industrial solvents and specialty lubricants.
- Genetic counseling and gene therapy which allows prospective or current parents to learn about diagnosing and treating inherited diseases and whether their children may inherit such diseases.
- Pharmaceuticals: prevention and treatment which uses vaccines, antibiotics and therapeutics produced by microbes, plants or animals.
- Diagnosis which uses biotechnology to speed diagnosis of genetic disorders or infectious diseases and early detection of pregnancy. For example, strep throat can now be diagnosed in 20 minutes rather than in two days.

The multitude of applications as well as the significant uptake worldwide of the technology and its products attests to the extensive nature of biotech research. Add to the intensive and extensive nature of the factors leading to the growth of biotech Hawaii's unique competitive advantage to not only provide the wherewithal to allow expression of the technology, but also production of biotech products, and one can readily understand why the Hawaii seed crop industry has thrived. As a component of the Hawaii biotech industry, the Hawaii seed crop industry has responded to the biotech growth factors growing exponentially as noted above. One would expect this growth to continue given the unique combination of these growth factors and Hawaii's competitive advantage. This augers well for continuing Hawaii's position as a worldwide high technology leader with the incumbent socio-economic benefits to the State resulting from this position.

Seed Crop Industry Growth and Value Contrasted

Contrasting Hawaii's seed crop growth rates and value with other Hawaii economic indicators places the industry in perspective.

[2] See http://www.biotech.wisc.edu/Outreach/poster/apmaster.html for more details.

- The broadest measure of economic growth in the State is Hawaii Gross State Product (GSP). GSP growth was:
    - 7.0% or 25% less than the seed industry's growth from 1968-2008
    - 3.6% or 75% less than the seed industry's growth from 1998-2008**.**
- At current farm value levels, the Hawaii seed crop industry's value contribution to the Hawaii agricultural sector make it:
    - The largest agricultural commodity with a value contribution that exceeds the contribution of pineapple, the second largest commodity, by almost 90%, and sugar, the third largest agricultural commodity, by 180%. Both sugar and pineapple are agricultural subsectors in significant decline as indicated by their recent and longer term negative growth rates.
    - The fastest increasing agricultural commodity of only three with recent positive growth rates. Fruits and vegetables are the only other two commodity groups showing any positive growth, which is negligible compared to the exponential growth of the seed crop industry.
    - An agricultural subsector providing almost 30% of the total value of all Hawaii produced crops.

In contrast to the growth rates of other agricultural subsectors in Hawaii, which have been flat or declining, the seed crop industry has experienced exponential growth as noted. Figures 2 and 3 demonstrate the contrasts.

Figure 2 shows the value of the major Hawaii agricultural subsectors over the period. In average annual percentage terms two of three subsectors have been in steady decline and the third has increased at a tepid pace. The real average annual growth rates are:

- Sugar -9.6% per year (the "……" line in Figure 2)
- Pineapple -4.2% per year with more precipitous declines recently (the "___" line in Figure 2)
- Diversified agricultural 1.8% per year (see "----" line in Figure 2).

Figure 3: Farm Value (x1000) of Major Hawaii Agricultural Subsectors (2007 dollar amounts)

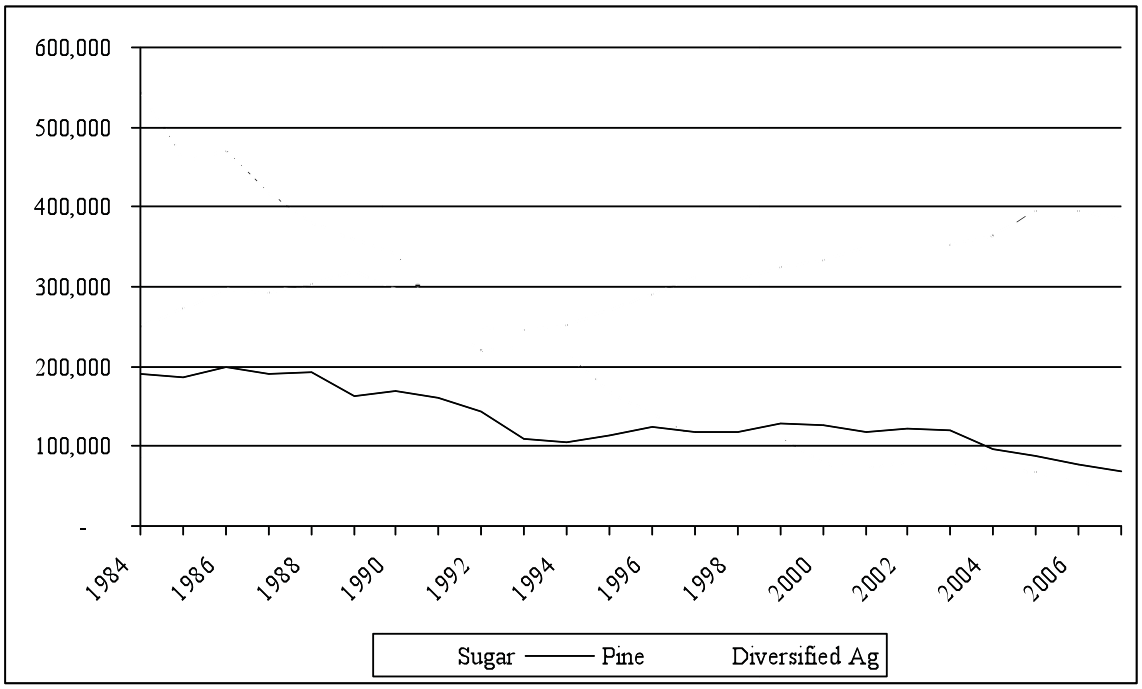
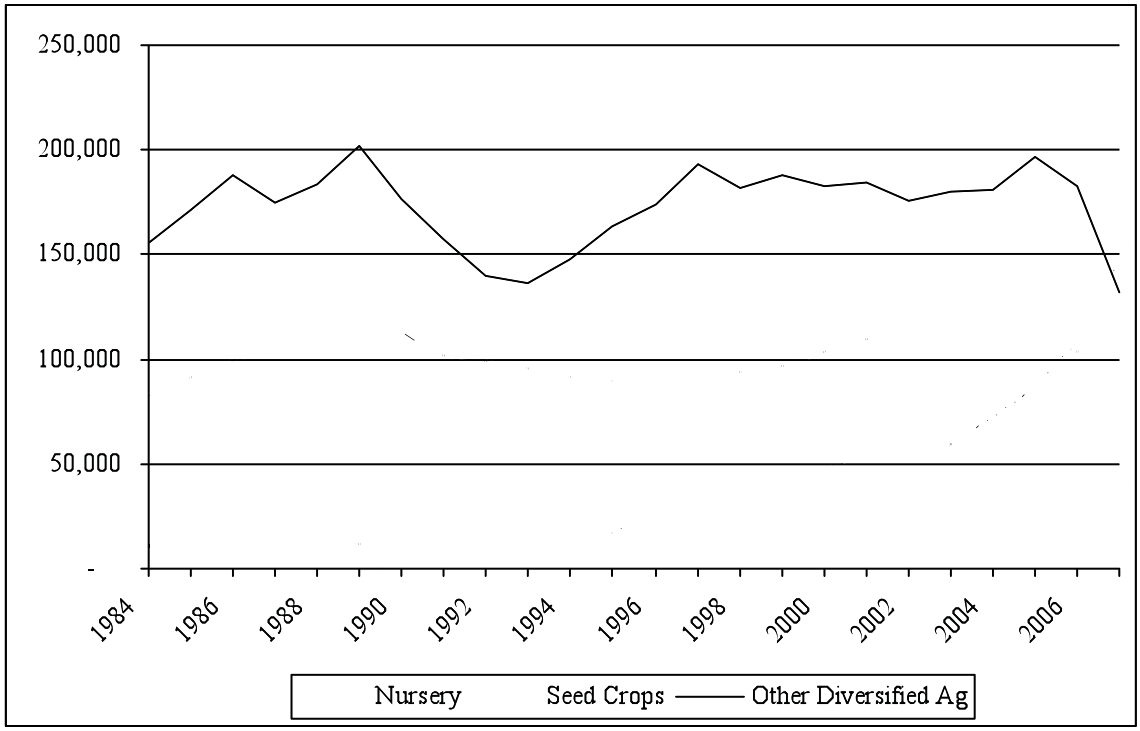


Figure 3 shows the value of the major Hawaii diversified agricultural subsectors over the period shown. The seed crop industry not only is the largest agricultural subsector but currently comprises 38.1% of the diversified agricultural crop value. This makes the seed crop industry the largest diversified agricultural industry in the state. Nursery was the largest diversified agricultural subsector in our 2006 report.

Of the three reported diversified agricultural subsector categorizations, seed crops by a factor of more than five have the largest average annual growth rate from 1984 to 2007. These growth rates are:

- Nursery 1.0% per year (the "___" line in Figure 3);
- Seed crops 11.4% per year (the "……" line in Figure 3);
- Other diversified agricultural -0.7% per year (see "----" line in Figure 3).

Figure 4: Farm Value (x1000) of the Diversified Agriculture Subsectors (2007 dollar amounts)



It would seem a fair statement, all data considered, that the primary reason Hawaii's diversified agricultural subsector has experienced positive growth since 1984 is due to the existence of the seed crop industry. More generally, the average annual rate of decline of Hawaii's total crop value (-2.8%) would have increased by almost 50% (to -4.1%) without the existence of the seed crop industry. Unquestionably, the Hawaii seed crop industry is and has been a significant contributor to the agricultural sector of the economy [24, 25, 34]. If current trends continue, this contribution will increase dramatically.

A footnote to the existence and growth of the Hawaii seed crop industry and its contribution to the agricultural sector is that this industry has received no governmental support in the form of subsidies, targeted tax credits, tax breaks, etc., to locate and operate in Hawaii. The contribution to the Hawaii seed crop industry is solely due to Hawaii's natural resource competitive advantage and ability to generate three to four crop cycles per year for research. Seed crop industry businesses have prospered as attested to by the growth of the industry with the consequent economic benefits to Hawaii's agricultural sector and the State generally.

Jobs

Job Number and Distribution: As of its most recent reporting for this analysis, the Hawaii seed industry employs 1,863 individuals of which 1,065 (57%) are full-time employees and 798 (43%) are part-time jobs. The neighbor island proportion of full-time employees (59.5%) exceeds that for Oahu (52.3%). The distribution of seed crop

industry jobs across different occupational categories with the corresponding distribution for Hawaii comparatives are the following:

- Management
  - Seed crop industry
    - Industry-wide 10.7%
    - Oahu = 7.3%
    - Neighbor islands = 12.3%
  - Hawaii comparatives
    - Statewide average = 1.5%
    - Oahu = 1.9%
    - Neighbor islands = 0.4%
- Office & Administration management
  - Seed crop industry
    - Industry-wide 2.1%
    - Oahu = 1.7%
    - Neighbor islands = 2.4%
  - Hawaii comparatives
    - Statewide average = 8.5%
    - Oahu = 9..1%
    - Neighbor islands = 7.2%
- Research & Science
  - Seed crop industry
    - Industry-wide 14.1%
    - Oahu = 12.6%
    - Neighbor islands = 14.9%
  - Hawaii comparatives
    - Statewide average = 5.2%
    - Oahu = 6.2%
    - Neighbor islands = 2.6%
- Agriculture-related
  - Seed crop industry
    - Industry-wide 71.3%
    - Oahu = 76.6%
    - Neighbor islands = 68.7%
  - Hawaii comparatives
    - Statewide average = 1.2%
    - Oahu = 0.4%
    - Neighbor islands = 2.9%

Noteworthy observations of the distributions are the following.

- The seed crop industry:
  - Has a significant majority of jobs in the agricultural sector industry-wide, for Oahu and for the neighbor islands;
  - The neighbor islands have a greater portion of professional-related jobs than Oahu and a lower relative portion of agricultural jobs;

    - The neighbor islands have a greater portion of "high-tech" jobs in the form of Research & Science than Oahu.
- Relative to Hawaii comparatives the seed crop industry:
    - For all seed crop comparatives and overall the seed crop industry has a significantly higher proportion of agricultural-related jobs (71.3% industry-wide, 76.6% for Oahu and 68.7% for the neighbor islands) than Hawaii comparatives (1.2% statewide, 0.4% for Oahu and 2.9% for the neighbor islands);
    - For all seed crop comparatives and overall the seed crop industry has a significantly higher proportion of professional-related jobs (26.9% industry-wide, 21.6% for Oahu and 29.6% for the neighbor islands) than Hawaii comparatives (15.2% statewide, 17.2% for Oahu and 22.1% for the neighbor islands);
    - For all seed crop comparatives and overall the seed crop industry has a significantly higher proportion of "high tech" (Research & Science) jobs (14.1% industry-wide, 12.6% for Oahu and 14.9% for the neighbor islands) than Hawaii comparatives (5.2% statewide, 6.2% for Oahu and 2.6% for the neighbor islands)

What one derives from the jobs distribution information is the significant contribution the seed crop industry makes to generally stated Hawaii public policy objectives[3] by its mere existence. These include the following:

- Economic diversification not only statewide but in particular on the neighbor islands where economic diversification is less than on Oahu;
- Creating jobs in a green industry, agriculture;
- Maintaining prime agricultural lands in agricultural use with little if any incentive to convert these lands to alternative use because of the seed crop industry's significant productive, profitable use of these lands in agriculture;
- Creating high-tech jobs [51].

It merits acknowledgement that the seed crop industry makes a significant contribution to achieving the public policy goals noted at no cost to the State. Rather this contribution is a natural response by market participants to put to productive use Hawaii natural and other resources that otherwise at best would be idle, thereby making no economic, public policy or other contribution to the State.

Job Growth: A significant observation related to employment is the increase in seed crop industry jobs since the authors' 2006 study, especially when contrasted with statewide employment changes.[4]

[3] See http://hawaii2050.org/images/uploads/HRS226_StatePlanningAct.pdf for details about Hawaii public policy goals and objectives.

[4] It merits clarification in making the comparisons that the data used in our current study and in our 2006 study was gathered for the specific purposes of these studies. The 2006 industry jobs data that we used represented what was current at the end of 2005. The current study uses data collected in 2009 and thus can be considered current jobs data.

- Seed crop industry
    - Industry-wide = 73.0%
    - Full-time jobs = 268.5%
    - Part-time jobs = 1.3%
- Hawaii State
    - Statewide = 1.1%
    - Professional = -0.5%
    - Agriculture = -16.7%

Not only is the seed crop industry jobs increase exceptional but the increase is primarily for full-time jobs. One could reasonably surmise that a significant cross-section of the seed crop industry full-time employment increase falls within the "professional" category which includes "high-tech." The seed crop industry's "high-tech" jobs increase dwarfs what has happened overall for the State. Further, the seed crop industry agriculture job increase of 1.3% since our 2006 study stands in marked contrast to the statewide agriculture job change of -16.7% since this time.

The seed crop industry job increases have occurred in a Hawaii employment environment that has at best been lackluster since 2005 as noted and has generally declined since 2007. Table 1 shows the following related to job growth since 2007.

- Overall statewide job growth has declined -2.4% since 2007;
- Most sectors of the economy experienced insignificant or negative job growth since 2007;
- Significant job growth sectors include:
    - Education & health services
    - Government;
- The agriculture sector of the economy has experienced significant negative job growth.

It is noteworthy that the significant job growth sectors statewide are sectors dependent on the productive capacity of the economy for their lifeblood. Productive sectors of the economy were generally in decline especially so since 2007. Most noteworthy of the job data that merits reiteration is the 16.7% decline in jobs for the agricultural sector of Hawaii's economy versus the positive growth in seed crop industry job growth in this sector. It can further be noted related to jobs that:

- At current employment levels, the seed crop industry provides 22.7% of all agricultural jobs in the State;
- Of this 22.7%, 77.7% are on the neighbor islands;
- Proportionately more of the total seed crop industry jobs on the neighbor islands are full-time than on Oahu;
- Proportionately fewer of the total jobs on the neighbor islands are in agriculture with proportionately more in the professional category, most particularly research & science as compared to Oahu.

Employee Compensation:

Earnings: Average annual earnings in the State of Hawaii across all occupations are:

- Statewide[5]
  - Statewide average = $41,630
  - Agriculture sector average = $30,960
- Neighbor Island[6]
  - Overall average = $38,750
  - Agriculture sector average = $28,530
- Oahu[7]
  - Overall average = $42,730
  - Agriculture sector average = $34,550

The comparables for the Hawaii seed crop industry are:

- $39,824, for the industry-wide average
- $41,767 Neighbor Island average
- $35,200 Oahu average

Industry-wide average earnings for the industry are comparable with the statewide average. This is exceptional given that a much higher percentage of seed crop industry employees work agriculture-related jobs versus statewide. Agricultural jobs are among the lowest paid of all employment sectors of the economy, as exemplified above when comparing earnings in the agricultural sector to statewide or neighbor island averages. The significantly higher proportion of seed crop industry agricultural workers suggests that the seed crop industry average earnings should be significantly lower than statewide and island averages. That this is not the case implies that the seed crop industry pays a higher than average wage scale to its workers than one would expect based on statewide and per island averages.[8]

The Neighbor Island average earnings of seed crop industry workers is greater than the statewide and Oahu-specific averages, which is surprising given average wages of the neighbor islands relative to these comparatives are generally less. It is even more surprising given the high proportion of agricultural workers in the neighbor island seed crop industry in contrast to neighbor island averages.

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[5] See http:/ this is a benchmark Bush and/stats.bls.gov/oes/2008/may/oes_hi.htm

[6] See http://stats.bls.gov/oes/2008/may/oes_1500001.htm

[7] See http://stats.bls.gov/oes/2008/may/oes_26180.htm

[8] The proprietary industry data used for the analysis does not provide sufficient detail to calculate average earnings for different occupational categories such as agriculture. Thus, we can only make inferences about relative earnings of the seed crop industry and the Hawaii comparatives based the data that we do have.

Aside from the direct economic contribution to the State of seed crop industry high relative wage scales, such wage scales attract professionals, most particularly high-tech workers, which contributes to economic diversification. This contribution is not only to statewide economic diversification, but also within-state due to the proportionately higher-than-Oahu wages of the neighbor islands, which have less diversified economies than Oahu.

Benefits: The seed crop industry benefits percentages of earnings are the following.

- All workers
  - Industry-wide = 35.0%
  - Oahu = 33.9%
  - Neighbor Islands = 35.4%
- Full-time workers
  - Industry-wide = 37.7%
  - Oahu = 34.8%
  - Neighbor Islands = 38.7%
- Part-time workers
  - Industry-wide = 27.5%
  - Oahu = 32.2%
  - Neighbor Islands = 24.8%

Hawaii comparables are not available. However, the Bureau of Labor Statistics publishes benefits data for all workers and specific occupational averages.[9] Several of these are the following.

- All workers
  - Total private sector = 27.5%
  - Full-time = 28.5%
  - Part-time = 21.2%
- Professional & related
  - All = 23.1%
  - Full-time = 25.2%
  - Part-time = 19.3%

Regardless of the comparative the seed crop industry provides a more generous benefits package than would be expected based on benchmark comparables. Overall, the seed crop industry benefits as a percentage of earnings exceed the national average by:

- 27.3% for all workers,
- 32.3% for full-time workers,
- 29.7% for part-time workers.

[9] See: http://www.bls.gov/news.release/ecec.toc.htm
Subtracted from the reported total benefits value is "paid leave" and "supplemental pay" to make the benchmark comparable to the seed crop industry.

Another interesting footnote, at least for full-time workers: neighbor island benefit packages are more generous than for Oahu.

V. Economic Contributions of the Hawaii Seed Industry

Unlike most other commodities that are directly sold where produced, seed produced in Hawaii is not sold in Hawaii. However, Hawaii is an important part of the research and development of new seed hybrids and varieties that are produced and sold to farmers around the world. Thus as noted, the seed industry's Hawaii expenditures, not sales, measure the (direct) transactions of this industry. To quantify the total economic impact of the seed industry in Hawaii requires not only measuring the value of these direct transactions but also indirect and induced transactions attributable to the industry.

Direct Impact

The direct impact of the Hawaii seed industry is the economic impact attributable to the firms that make up the industry through their (direct) operating expenditures for employees and other expenditures related to research and development and growing seed in Hawaii, and the industry's capital expenditures (CAPEX) within the State.[10] Table 2 shows direct impact amounts of the industry.

Table 2: Seed Industry Direct Economic Contributions to Hawaii[11] [6]

Items	Amounts
Annual Operating Expenses	
Total	$146,270,000
Labor Income Portion	$68,313,567
Employment from Operating Expense	1,863
Full-time	1,065
Part-time	798
Capital Expenditure Budget	
Last 10-years (2009$)	$164,154,739
Next 10-years	$275,500,680

Highlights from the data presented in Table 1:

- Collectively, seed firms have operating expenditures totaling $146.3 million of which $68.3 million (46.6%) is for labor income.

[10] The 2005 Input-Output multiplier used to estimate the job creation from seed crop industry annual CAPEX expenditures is the average of the multipliers for: agriculture, mining & construction, real estate and rentals and professional services.

[11] Note: The "Labor Income Portion" is a categorization of annual operating expenses to highlight this particular expenditure given its significance to policy-makers. Data are for the most recent fiscal year.

- Seed crop industry total output equals approximately 25% of the total output of Hawaii's crop sector.[12]
- Seed crop industry agriculture labor income equals approximately 30% of the total labor income of Hawaii's crop sector.[13]
- As previously discussed, the seed firms employed 1,863 workers of whom 1,065 are full time workers and 798 are part-time workers, and of which 71% or 1,307 are in agriculture-related activities. Total agriculture employment within the State based on the most recent data available (see Table 1) equals 5,750, suggesting that the percentage seed industry's percentage of agricultural employment equals 29.4%.
- The analysis estimates the total job count of Hawaii's agricultural crop sector to be 4,957 currently using Table 1 data and 2005 input/output model data. As a percentage of Hawaii's agricultural crop sector employment, seed crop industry direct employment generates 37% of the total jobs in this economic subsector.
- Expenditures from the seed industry capital expenditure budget (CAPEX) have direct economic impacts on Hawaii's economy when the expenditures are made. These direct expenditures result in the creation of jobs and the generation of in labor income, which are presented below.[14]
- Industry CAPEX over the next 10 years exceeds the previous 10 year amount by 91%. The current 10 year forecast seed crop industry CAPEX also exceeds the industry's estimated CAPEX reported in our 2006 study by 93%.

Indirect and Induced Impacts

Besides the direct impact, the Hawaii seed industry (direct) operating and capital expenditures create ripple (i.e. multiplier) effects in the economy by generating revenues, jobs, salaries and taxes in the form of indirect and induced impacts. In order to grow their crops and perform research and development, the seed industry stimulates economic activity in other sectors of the economy such as contract research organizations, input suppliers, equipment suppliers, utilities etc., when purchases are made from these other sectors. The revenues accruing to businesses in these "support" sectors are referred to as indirect impacts of seed industry direct expenditures.

An induced impact of the Hawaii seed industry is created when workers and owners of these (indirect) companies purchase goods and services in the Hawaii economy through wages, salaries and other forms of income derived from their "support" of seed industry firms. The economic ripples (i.e. multiplier effects) generated through these expenditures are the induced impacts. Table 3 shows the estimated (indirect + induced) multiplier impacts of current seed industry direct expenditures in Hawaii.[15]

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[12] According to the 2005 Input-Output model total Hawaii crop sector output (2009$) equals $596.1 million.

[13] According to the 2005 Input-Output model total Hawaii crop sector labor income (2009$) equals $222.0 million.

[14] To reiterate, for purposes of incorporating the economic impacts of these expenditures into the analysis, expected CAPEX are assumed made in equal increments over the seed crop industry 10-year budget period

[15] The 2005 Hawaii State Input-Output model is used to estimate the indirect and induced multiplier effects reported.

Table 3: Multiplier (Indirect + Induced) Impacts of Current Seed Industry Direct Expenditures in Hawaii

Items	Annual Operating
Total Output (Sales)	$142,429,806
Labor Income	$53,248,241
Employment	2,656
Full-time	1,518
Part-time	1,138

Total Economic Impact of the Hawaii Seed Industry

Table 4 shows the total economic impact (i.e. direct + indirect + induced) impacts of the Hawaii seed industry to the State economy.

Table 4: Total Direct and Indirect Economic Impact of the Hawaii Seed Industry (Tables 2+3) (CAPEX = Capital Expenditures)

Items	Direct Contributions	Indirect/Induced Impacts	TOTAL
Total Output (Sales)	$173,820,068	$167,734,817	$341,554,885
from Annual Expenses	$146,270,000	$142,429,806	$288,699,806
from CAPEX	$27,550,068	$25,305,011	$52,855,079
Labor Income	$83,777,863	$53,248,241	$137,026,104
from Annual Expenses	$68,313,567	$53,248,241	$121,561,808
from CAPEX	$15,464,296		$15,464,296
Employment	2,372	793	3,166
Direct Contributions			
Full-time	1,065	453	1,518
Part-time	798	340	1,138
CAPEX			
Full-time	509		509

Table 4 shows the following.

- The total output from annual expenses attributable to the Hawaii seed crop industry equals $341.6 million. This amount measures the total dollar value of seed industry transactions that occur within the State related to their business.

- Seed crop industry activities result in the generation of total labor income equal to $137.0 million.
- Total Hawaii employment attributable to expenditures of the seed industry is approximately 2.597 full-time equivalents assuming part-time employment is 1/2 of full-time. This translates to less than 1% of total current private sector employment in Hawaii of 614,350.[16]
- On a sub-regional basis (i.e. Molokai or West Kauai) seed company expenditures and jobs as a percentage of local totals would have a much larger economic impact than occurs relative to the comparisons made herein. This is even more significant when discussing the agricultural sector, which generally comprises a much larger percentage of total economic activity and employment in Hawaii rural areas.

It merits noting that our measures of the economic contribution of the seed industry make no accounting of the dynamics of its knowledge creation. Such knowledge creation leads directly to increased research and development and synergistic interactions within the life sciences industry that also result in increased local research and development and related economic activities. These positive externalities of the seed industry are not measures in our study.

Tax Revenue Contributions

Total estimated taxes generated by Hawaii seed industry activities within the State are presented in Table 5. Table 5 shows the estimated tax amount by industry activity type and tax source. In total on an annual basis, we estimate that Hawaii seed industry activities currently generate $13.8 million in tax revenues to the State per year. This represents an increase of 87% over seed crop industry tax contributions we measured in our 2006 study.

Table 5: Fiscal Impact of the Hawaii Seed Industry (CAPEX = Capital Expenditures)

Tax	Annual Operating	CAPEX	TOTAL
GET	$5,306,847.53	$1,199,754.80	$6,506,602.33
Income Taxes	$3,421,222.98	$773,458.94	$4,194,681.92
All Other	$2,563,094.44	$579,456.04	$3,142,550.48
TOTAL	$11,291,164.95	$2,552,669.78	$13,843,834.74

Economic Diversification

Slightly more than 20 years ago Hawaii's agricultural sector contributed 2% of Hawaii's GSP. This percentage currently and in our 2006 study is less than 1%. This declining trend shows no sign of abating as attested to by Table 1's declining job numbers in

[16] Source: See Table 1

agriculture. The Hawaii seed industry has potential to reverse the downward trend of agriculture as a contributor to Hawaii economic activity maintaining this source of statewide as well as per county economic diversification. This will come from two sources, direct seed crop industry expenditures and capital expenditures (CAPEX) in Hawaii.

As noted, seed crop industry growth exceeded our 2006 forecasts and continues its exponential growth to currently, which exceeds the growth of all other economic sectors and subsectors in Hawaii. In fact, while the recent growth of the seed crop industry has been significantly positive, the vast majority of private economic sectors and subsectors have experienced negative growth rates.

More important for future Hawaii economic growth as well as economic diversification is the seed crop industry's anticipated CAPEX. The seed crop industry estimates that its CAPEX expenditure for the next 10 years will exceed the previous 10-year CAPEX by 91% with 100% of this increased CAPEX on the neighbor islands. This more recent industry estimate of the next 10-year CAPEX also exceeds what the industry estimated in our 2006 study by 93% or by a factor of almost 3 to 1 in favor of the neighbor islands. Such anticipated CAPEX expenditures will make significant contributions to overall as well as within State economic diversification.

Among other issues, Boyd (2008) notes that Hawaii's extraordinary biodiversity along with the problem of invasive species associated with genetically modified organisms probably make it the least likely place to grow the controversial genetically engineered crops [6]. But scientists in Hawaii are convinced that the costs associated with the risk of damage to Hawaii's fragile ecosystem are far outweighed by the benefits generated by this segment of the economy. These benefits include contributions to economic growth and diversification, employment generation, high income for workers, tax contributions and capacity to find effective solutions to the problems of pests and disease for traditional exportable crops such as papaya fruit from Hawaii and for other staples grown on the U.S. mainland.

VI. Conclusion

The unequivocal conclusion of this study is that the Hawaii seed industry makes significant economic and fiscal contributions to Hawaii's economy as the largest agricultural commodity and the largest diversified agricultural crop produced in the state. The industry's contribution has increased somewhat dramatically since our 2006 study. Currently, the seed industry makes direct local expenditures of $173.8 million per year for research and development, contracts with local research organizations and local purchases of infrastructure, input supplies, and farm equipment. These direct expenditures added to indirect and induced impact from these expenditures lead to $341.5 million of economic activity. This activity generates $137 million in annual labor income and over 5,000 jobs. To place this finding in historical context, the local seed industry's value contribution to the state currently exceeds that of sugar and pineapple combined by 27%.

The potential for the Hawaii seed industry's continued exponential growth is significant. In the broadest context there is a growing worldwide demand for seeds grown by the Hawaii industry. In response to this demand, the seed crop companies operating in Hawaii are significantly increasing not only their operating expense levels, but also their capital expenditure (CAPEX) levels. These companies are investing in Hawaii, which bodes well for continued growth and economic contributions to the State.

Hawaii's seed crop industry is currently Hawaii's primary mode of participation in the growth of the life sciences biotechnology industry—the engine powering expected world economic growth for the next several decades. It would seem reasonable to forecast that Hawaii's life sciences biotechnology industry could become the fastest growing economic sector and one of the largest sectors of the state's economy leading to the newest biotechnology cluster in the nation, if not the world.

All possibilities and what is actually occurring taken together suggest that the seed crop industry has potential to play an ever more important role in the state's economy. Its growth will also advance Hawaii's technology sector through the development of an increasingly sophisticated technology-based infrastructure and trained workforce.

# # #

Table 1-- JOBCOUNT, BY NAICS INDUSTRY: ANNUAL AVERAGES, 2000 TO 2007

[Data rounded to nearest 50. Totals may not add due to rounding or residual categories. Data are according to the North American Industry Classification System]

Industry	2005 1/	2006 1/	2007 1/	Current	2005-Current	2007-current
Nonagriculture, wage & salary	601,700	617,050	623,550	608,600	1.1%	-2.4%
Natural resources, mining, construction	33,400	36,500	39,000	33,900	1.5%	-13.1%
Manufacturing	15,200	15,300	15,200	14,300	-5.9%	-5.9%
Durable goods	4,450	4,500	4,600	4,500	1.1%	-2.2%
Non-durable goods	10,800	10,800	10,600	9,800	-9.3%	-7.5%
Trade, transportation & utilities	117,700	121,000	121,300	114,300	-2.9%	-5.8%
Wholesale trade	17,600	18,050	18,400	18,350	4.3%	-0.3%
Retail trade	69,250	70,050	70,100	68,300	-1.4%	-2.6%
Transportation, warehousing & utilities	30,850	32,950	32,800	27,650	-10.4%	-15.7%
Utilities	2,900	2,950	3,000	3,100	6.9%	3.3%
Transportation & warehousing	27,950	30,000	29,800	24,550	-12.2%	-17.6%
Air transportation	10,150	10,100	9,800	7,150	-29.6%	-27.0%
Information	10,800	10,700	10,750	9,450	-12.5%	-12.1%
Telecommunications	3,900	4,200	4,200	3,850	-1.3%	-8.3%
Financial activities	29,300	29,950	30,050	28,850	-1.5%	-4.0%
Finance & insurance	16,500	16,850	16,900	16,400	-0.6%	-3.0%
Real estate, rental, leasing	12,800	13,100	13,150	12,400	-3.1%	-5.7%
Professional & business services	74,200	76,800	76,050	73,850	-0.5%	-2.9%
Education & health services	69,850	71,200	72,800	74,600	6.8%	2.5%
Education services	13,600	13,900	14,150	14,950	9.9%	5.7%
Health care & social assistance	56,300	57,250	58,650	59,650	6.0%	1.7%
Ambulatory health care services 2/	22,550	22,700	23,000	23,600	4.7%	2.6%
Hospitals 2/	14,050	14,050	14,450	13,750	-2.1%	-4.8%
Nursing & residential care facilities	6,650	6,700	6,800	7,050	6.0%	3.7%
Social assistance	13,050	13,800	14,350	15,300	17.2%	6.6%
Leisure and hospitality	106,300	108,200	109,850	103,100	-3.0%	-6.1%
Arts, entertainment & recreation	11,550	11,650	12,050	11,000	-4.8%	-8.7%
Accommodation & food services	94,800	96,550	97,800	92,150	-2.8%	-5.8%
Accommodation	38,750	39,150	39,150	35,700	-7.9%	-8.8%
Food services and drinking places	56,050	57,350	58,700	56,400	0.6%	-3.9%
Full-service restaurants	28,800	29,400	30,400	28,850	0.2%	-5.1%
Other services	25,200	26,100	26,550	27,150	7.7%	2.3%
Government	119,650	121,250	122,000	129,100	7.9%	5.8%
Federal	31,300	31,850	31,650	32,600	4.2%	3.0%
Department of Defense	16,350	16,650	16,350	16,850	3.1%	3.1%
State	71,150	71,950	72,400	77,800	9.3%	7.5%
Education (DOE & UH)	47,350	47,550	48,100	52,800	11.5%	9.8%
Local	17,200	17,450	17,950	18,700	8.7%	4.2%
Agriculture	6,900	6,950	6,500	5,750	-16.7%	-11.5%

1/ Data were benchmarked in March, 2007.

2/ New series from 2001.

Source: Hawaii State Department of Labor & Industrial Relation; Hawaii State Department of Business, Economic Development & Tourism, Statistics & Data Support Branch, *Databook* (annual).
Current Hawaii job numbers are from http://www.hiwi.org/

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APPENDIX I

Factors Leading to the Growth Of The Biotech Industry

Economic Factors

Fernandez-Cornejo (2008) has summarized the experience of the first 12 years of adoption of genetically engineered crops by US farmers [10]. Specifically, US farmers have used insect resistant (Bt) crops such as Bt corn and Bt cotton and herbicide tolerant (HT) crops. According to USDA surveys the main reasons for adopting GE crops as stated by US farmers have been:

- To increase yields
- To save management time and make other practices easier
- To decrease pesticide input costs

The USDA used econometric models to examine the impacts of genetically engineered crops on yields, pesticide use and returns while controlling for input and output prices, weather, infestation levels, farm size, managerial ability and other production practices. The studies revealed that lowered pesticide use was associated with adoption of GE crops. It resulted in 19.1 million fewer pesticide acre-treatments or a 6.2% decrease. The total amount of active ingredient pesticide reduction amounted to 2.5 million pounds. Adoption of HT soy beans allowed use of herbicides with lesser toxicity (1/3) and less persistence that was only ½ of the herbicides it replaced. Another important revelation was that adoption of HT soybean resulted in higher off-farm household income as well as total farm household income. This suggested that farmers who adopted HT soybean benefited from savings in management time resulting in higher income from off farm activities.

Brookes and Barfoot (2009) evaluated the global socio-economic and environmental impacts of GM crops from 1996 to 2007 [7]. Their study focused on farm level economic effects, the production effects, the environmental impact resulting from changes in the use of herbicides and pesticides and the contribution towards reducing greenhouse gas (GHG) emissions. They note that agricultural production systems are dynamic and vary with time. A key change in the production system appears to be in the case of adoption of HT soy bean. Even before GM HT soy bean was available, producers were switching to no/low till production. This required greater reliance on herbicide based weed control. The GM HT technology seems to have facilitated this switch over. Overall, crop biotechnology seems to have made significant impact on farm income. This is due both to enhanced productivity and efficiency gains.

In 2007, the global farm income benefit from biotech crops was $10.1 billion. This was equivalent to adding 4.4% in value to global production of the four main biotech crops: soy bean, corn, canola and cotton. The increases in farm incomes for the four crops were as follows: for HT soybean $3.9 billion, for IR and HT cotton $3.2 billion, for HT and IR corn $2.5 billion and for HT Canola $ 0.35 billion. The cumulative farm income benefit globally from 1996 to 2007 period was estimated at $44.1 billion. Of the total cumulative farm income increase, about $20.5 billion (46.8%) was due to yield gains and second crop facilitation and the remaining due to lowered costs of production. Within the yield gain component, 68% were derived from GM IR varieties and the remaining from GM HT crops. The six highest farm income gains from biotech adoption over the 1996-2007 period have been for the following countries: the US ($19.7 billion),

Argentina ($8.1 billion), China ($6.7 billion), India ($3.1 billion), Brazil ($2.9 billion) and Canada ($1.6 billion). Of the GM crop farm income benefits for 2007, $4.3 billion accrued to developed countries and $5.8 billion to developing countries. The cost of accessing GM technology in developed countries was $3.1 billion (34% of total technology gains) while it was approximately $1 billion in developing countries (14% of total technology gains)..

The non-pecuniary benefits for HT crops included increased management flexibility, facilitation of switchover to no/low till farming, reduction in the occurrence of "knock back" phenomenon, improved weed control and elimination of damage caused by soil incorporated residual herbicides in follow-up crops.

The non-pecuniary benefits for IR crops included significant reduction in production risk from pest damage, "convenience benefit" due to fewer pesticide applications, savings in machinery used for spraying, improved product quality, improved health and safety for farm workers, and shortening of the growing season.

In 2007, the additional crop production due to positive yield effects by biotech crops amounted to 14.46 million tons for soy beans, 15.08 million tons for corn, 2.01 million tons for cotton and 0.54 million tons for Canola. The cumulative addition to production for biotech crops from 1996 to 2007 period has been estimated at 67.80 million tons for soy beans, 62.42 million tons for corn, 6.85 million tons for cotton, and 4.44 million tons for Canola. If biotech crops were unavailable, maintaining global production levels in 2007 would have required additional conventional crop plantings of 5.89 million hectares of soy beans, 3 million hectares of corn, 2.54 million hectares of cotton and 0.52 million hectares of canola.

Demographic and Development Factors

According to Surman (2009), economist Graham Brookes told the All Party Parliamentary Group on Science and Technology in Agriculture that after 11 years of widespread use, GM crops had done more to help protect the environment than any other single technology [48].

Around the world 13.5 million farmers planted GM crops in 2007 producing more than 5 billion pounds in wealth. GM technology could be a panacea for what the government's chief scientist described as a perfect storm where a growing population, scarcity of water, and failing energy sources would create a global crisis of dire consequences.

Lomborg (2009) notes that shortly after the Second World War, scientists using conventional breeding practices were able to develop high yielding varieties (HYV) of crops [27]. These HYV used in conjunction with other complimentary inputs such as irrigation water, fertilizers, pesticides, herbicides and mechanized farming practices helped usher in the Green Revolution. World grain production increased by an astonishing 250% between 1950 and 1984 but the revolution's benefits have largely tapered off.

Another Green Revolution could result from genetic engineering plant breeding practices based on genetically modified (GM) crops. They hold out the potential for drought and disease resistance and also bring about consumer focused improvements such as staple crops fortified with extra nutrients. GM crops can help alleviate poverty, increase rural jobs and income to small and marginal farmers and help combat malnourishment thus promoting the achievement of the Millennium Development Goals (MDGs) of the United Nations.

Kolady and Lesser (2008) have stated that the private sector is investing $2.5 billion annually in agricultural biotech [26]. Developing countries are spending about 5% of the above total. Less developed countries (LDC s) cannot spend too much money on biotechnology because novel traits are costly, they face high regulatory costs, they have poor technology transfer regime due to lax IPR regulations, they lack human capital and have a shortage of R&D infrastructure. However, there is a silver lining. Biotech companies are involved in humanitarian donation and partnerships in LDCs. Monsanto donated virus resistance technology to the Center for Research and Advanced Studies in Mexico so that they could develop virus resistant local varieties. They were not affected by the small scale farmers who grew the local varieties as they did not reach into the commercial markets.

Monsanto also has a 26% share in Mayhco in India. Monsanto donated pest resistance technology to public institutions such as Tamil Nadu Agricultural University (TNAU), University of Agricultural Sciences (UAS) and Dharwad Agricultural University to develop Bt hybrid eggplant. The Bt hybrid eggplant resulted in 48% higher yields, and high returns. It also resulted in 52% less pesticide use and 39% fewer sprayings.

Environmental Factors

Research by Brookes and Barfoot (2009) demonstrated the environmental benefits of global biotechnology [7]. In terms of environmental impact, since 1996 the use of pesticides on the biotech crops globally was reduced by 359 million kilograms of active ingredients (8.8% reduction) and the overall impact associated with herbicide and pesticide use by these crops reduced by 17.2%.. About 52% of the environmental benefits have accrued to developing countries

Climate Change Factors

The impact on greenhouse gas (GHG) emissions due to global biotech crop adoption comes from two sources according to Brookes and Barfoot (2009).. The first being reduced fuel use due to less frequent herbicide and insecticide applications and a reduction in the energy use in soil cultivation due to adoption of no/low till farming practices [7]. In 2007, the reduction in carbon dioxide emission was estimated at 1,144 million kg of carbon dioxide arising out of reduced fuel use. The cumulative reduction from 1996 through 2007 has been estimated at 7,090 million kg of carbon dioxide.

Secondly, the use of no till or reduced till practices has increased with the adoption of biotech crops. As a result, tractor fuel usage is greatly reduced and at the same time soil quality is enhanced and levels of soil erosion greatly diminished. This helps retain more

carbon in the soil and thus lowers GHG emissions. Based on the rapid expansion of no/reduced till farming practices in North and South America, an additional 3050 million kg of soil carbon is estimated to have been sequestered in 2007. This is the equivalent of 13,103 million tonnes of carbon dioxide not released into the global atmosphere.

Hopson (2008) makes the case that 3 tiers of global warming reductions are required [18]. These involve raising vehicle standards, reducing miles traveled and having cleaner fuels. The US uses 20 million barrels per day of oil and imports 60% of its oil needs at $1 billion per day. Cars and trucks use 40% of the oil causing global warming pollution. Conventional bio-fuels, advanced bio-fuels and cellulosic bio-fuels can contribute towards reducing global warming. In order of their contributions, Corn ethanol (average), bio-diesel, corn ethanol (best) and cellulosic ethanol can decrease lifecycle global warming pollutants by 15% to 85%. Carbon price differential would be about -40 cents /gallon of gasoline equivalent for corn ethanol (best) at $50 per ton carbon price differential versus gasoline. In 2007, 25% of corn crop was used for ethanol production.. By 2022, it is estimated that corn based ethanol production will be ramped up to 36 billion gallons.

Energy Factors

McElroy (2008) Targeted Growth Inc. is using crop biotechnology to create dedicated fuel crops as renewable sources of energy [30]. Companies such as DuPont, Dow and Cargill are retrenching/financing efforts in the crop based bio-fuels. Other Start ups are reinventing themselves as energy companies in order to secure government and oil company financing. Examples include: CRES, Mendel, Targeted Growth, Inc.

There is an attempt to deal with climate change phenomenon by developing a carbon neutral economy. Opportunities and sources for creative financing for plant based climate solutions (e.g. Arcadia Nue Rice) are part of carbon trading scheme which also includes deploying sexy abiotic stress tolerance technology e.g. MSN-BASF, a German based agri-energy corporation.

New bio-fuel crops are being targeted for marginal lands and super efficient bio-fuel crops are being targeted for prime lands. According to Gutterson (2008), corn is a good "model crop" for the energy grasses such as switchgrass and Miscanthus in order to build cellulosic ethanol production capacity in the country [13]. The high value biotech traits from corn are intrinsic yield (enhanced photosynthetic efficiency) and drought tolerance and water use efficiency.

Poteet (2006) completed a report on bio-diesel crop implementation in Hawaii. The report contains information on potential lands on various islands that could be used for crop production or oilseed bearing crops [38]. The 22 candidate crops could be used to extract the necessary oils for the transesterification process into bio-diesel. The report recommends field trials with germ plasm specifically selected to suit each delineated location as the next step to gather data on production capacity before an economic analysis can be conducted regarding the feasibility of the project

Organizational Factors

Philips (2008) notes that the Biotechnology Industry Organization (BIO) represents over 1000 biotechnology companies, academic institutions, state biotechnology centers and other associated organizations in the US and 31 other countries [39].

BIO members involved in the research and development of healthcare, agricultural, industrial and environmental biotechnology products. BIO has been responsible for 40,000 field trials and 9000 permits completed.. According to BIO, there can be trade disruptions due to zero tolerance policy in some markets together with asynchronous authorizations. At a minimum regulatory requirements must be met in the United States, Canada and Japan before commercialization of a new commercial product

Regulatory Factors

According to Turmer (2008) from 1987 through 2005, the USDA authorized 17,332 field tests [54]. The USDA granted 74 products non-regulated status by 2008. Herbicide tolerance and insect resistant traits dominate commercially produced lines. Of these products, 37% are for herbicide tolerance (HT), 28% for insect resistance (IR), 16% for product quality (PQ), 11% for virus resistance (VR) and 8% for agronomic properties (AP. Products granted non – regulated status by Animal and Plant Health Inspection Service (APHIS) include the following:

Corn – HT, IR, AP
Soybean – HT, PQ
Cotton – HT, IR
Potato – IR, VR
Tomato – PQ
Squash – VR
Rice – HT
Canola – HT, AP, PQ
Papaya – VR
Sugar Beet – HT
Flax – HT
Chicorium - AP
Tobacco - PQ
Alfalfa - HT

In 2007 USDA published the EIS on new regulatory alternatives for public comments.

Animal Feed Factors

Much of crop production is used as feed for the livestock industry. This includes 80% of the corn produced in the United States and 70% of the soy beans grown world wide (Seed Biotechnology Center, 2009). Crop biotechnology will incorporate traits in transgenic crops in the future that will enhance food and feed qualities [57]. Transgenic crop traits that are scheduled to appear in the marketplace over the next five years which includes reductions in toxins and anti-metabolites, increased digestibility, and improved nutritional quality. Biotechnology can help: 1) reduce Phytic acid levels that reduce the availability of phosphorous and other minerals; 2) reduce the lignin content to increase digestibility; 3) incorporate edible vaccines via feed to promote the health of the livestock; 4) Improve amino acid balance in proteins to optimize better animal nutrition; 5) express digestive enzymes directly in transgenic feed crops; and 6) develop high oil corn that will improve animal performance. Growers, shippers and end users are working

to ensure that transgenic crops with these output traits are kept segregated from conventional crops.

New GM Crop Factors

The National Association of Wheat Growers (2009) announced the goal of synchronized biotech introduction of GM wheat by US, Canada and Australia [32]. This has been a sensitive issue in major export market areas in Europe and Asia. The Association noted the slow growth trend in wheat yields relative to other crops and the lack of public and private investments world wide in wheat research

It is clear in reviewing this section, that there are a number of factors contributing to the significant development and growth of crop biotechnology industry both nationally and globally. Hawaii, by virtue of its climate, resources, infrastructure and governmental institutions, is in an enviable position to capitalize on these national and global trends. One can expect that Hawaii will experience accelerated growth throughout the second decade of crop biotechnology.

Another important development is the growth of biotech clusters around the country. They are a source of synergistic interactions between capital, human resources and technology in various subsectors of the life sciences industry. Hawaii is lagging behind other regional hubs in the development of its cluster. It has not quite attracted even 1% of the estimated $2.5 billion funds invested annually. However, by virtue of being at the crossroads of the Pacific region, Hawaii has the potential to develop a major biotech cluster within the state. The seed crop industry has great potential to contribute to the overall growth of the life sciences industry in Hawaii. Some recent developments are summarized below.

Biotech Clusters, Patents and Innovation

The number of biotech places and clusters continue to grow both within the United States as well as internationally (Salisbury, 2008). There are currently 11 established and nine emerging biotech regions in the world [45]. These regions continue to grow both due to reputation as well as incentives offered by state and national governments.

The established biotech regions are centered in Boston/Cambridge, San Francisco Bay Area, San Diego, Florida, Washington DC, Singapore, Wisconsin, Pennsylvania, New Jersey, Ontario, Canada and the Research Triangle in North Carolina. The emerging biotech clusters are developing in Texas, Denver/Boulder, Tennessee, St. Louis/Kansas City, Alabama, China, India and New York.

Within Hawaii a report by Batelle, BIO and Biotechnology Institute (2008) on State Bioscience Initiatives noted that the research, testing and medical laboratories subsector had a specialized location quotient of 1.26 and grew at the twice the national rate since 2001 (up 36%) [51]. A local quotient greater than 1 implies local employment is greater than expected (in comparison to the national economy reference group) and this "extra" employment is basic. These extra jobs export their goods and services to non-local areas which, by definition, make them basic sector employment. Employment in bioscience

related occupations in 2006 was 2,490 which ranked it 39th in the country. The number of agricultural, food, and nutritional scientists and technicians accounted for 390 jobs. About 100 educational degrees were awarded in the above areas in Hawaii during 2006.

According to the report, Hawaii academic research expenditures on biosciences reached $85.8 million in 2006 and were most heavily concentrated in the medical sciences. Spending on agricultural sciences R & D amounted to $15.7 million. The bioscience share of total R & D represented 33.3% of total spending in the R & D category. Venture Capital (VC) investments of $54.7 million in the biosciences industry were most heavily concentrated in medical diagnostics followed by pharmaceuticals. Only $5.7 million of the VC funds were invested in Hawaii biotech area between 2002 and 2007. Between 2001 and 2006, the state garnered 2964 patents making it 12th among all states far ahead of its population rank. The patents were led by pharmaceuticals, surgical and medical equipments and biochemistry. The Hawaii agricultural biosciences sector obtained 115 patents between 2002 and 2007.

The High Technology Development Corporation (2009) prepared a second and final report to the Hawaii legislature on the High Technology Incubation Center in Kakaako pursuant to the provisions of Senate Bill 896 enacted into law in 2007 as Act 150 Session Laws of Hawaii 2007 [17]. The report notes the criticality of an incubation center such as the one in Kakaako in order to help commercialize research and technologies by private technology companies without which there can be no growth in the life sciences and biosciences research and development industry in the state.. An estimated 1000 new living wage jobs could be created within the facility itself which is now on hold due to unsuccessful negotiations with the land owner. Technology related job growth in Hawaii in 2005 increased by 5.4% over 2004, bringing the total of technology jobs to 13,813 in the state. Wage growth in technology companies increased by 15.2% during the period between 2001 and 2005. Research and development activity job growth has been the strongest component of Hawaii's tech sector increasing by 36% between 2001 and 2005, four times faster than all private job growth.

Further evidence of Hawaii's emergence in the biosciences field was reported by Phillipidis (2008). He pointed out that a vibrant life science industry was blooming in Hawaii's fertile soils based on numbers released by the Hawaii Science and Technology Council (HiSciTech) that quantified for the first time the size and scope of 10 tech-based sectors in the state [40]. These 10 sectors driving Hawaii's technology sector included: information and communication technology, defense/aerospace, engineering services, environmental technologies, life sciences excluding agricultural biotech, agricultural biotech, ocean sciences, renewable energy, digital media and astronomy. There are about 1900 technology companies operating in the state. The average salary in the life science industry was $63,623 relative to the $45,963 average earnings in the state overall in 2007. The two life sciences categories that lagged behind the state tech average were $54,532 for biotech and $53,866 for agricultural biotech

There were a greater percentage of jobs generated though by agricultural biotechnology companies than traditional drug discovery biotech between 2002 and 2007 because of the emergence of the seed corn industry as a predominant subsector in Hawaiian agriculture. Gibson of the Hawaii Sciences Technology Institute noted that there was also some

convergence between biotech and energy companies such as the Kuehnle Agrosystems Co. LLC. The drug discovery bio field accounted for 7970 jobs and agricultural biotech accounted for 4833 jobs of the total 31,306 tech jobs in Hawaii in 2007.

Graff (2008) points out that the US accounted for 50% of the World Intellectual Property Organization (WO) patent applications related to agricultural biotech between 1980-2005 developing countries less than 5% and Europe 30-35% [12] The US Patent and Trademark Office (2009) posted a document showing that a total of 185,244 patents were granted during the 2008 calendar year [58]. This number represented a 1.3% increase over the previous year total in 2007. Approximately 49.7% of all patents were of US origin. In order of rank, the greatest number of patents were granted to California, Texas, New York, Washington, Massachusetts, Michigan and Illinois. Hawaii had the largest percentage (23.2 percent) increase from 2007 to 2008 in the nation. Hawaii obtained 82 patents in 2007 and 101 patents during 2008 for a total of 183 during the biennium period.

Appendix II

Previous Biotech Economic Impact Studies

Middleton and Segarra (1997) assessed the economic impacts of crop biotechnology in the risky cotton production system in the high plains of Texas [29]. Their farm level studies utilized quadratic programming techniques to model alternative scenarios including a base scenario and a biotechnology scenario which had input from an expert panel. Their results showed that biotechnology would significantly contribute to the profitability of farms in the High Plains of Texas.

The European Commission's Directorate General for Agriculture and Rural Development (2000) studied the economic impacts of genetically modified crops on the agri-food sector [52]. The synthesis of the reviewed literature in this report was aimed at uncovering the pace and extent to which sowings of GM crops had developed, ascertaining the economic reasons for the rapid adoption of GM crops by farmers and studying the consequences of citizen/consumer reactions and food supplier initiatives.

At the national level, the economic contribution of biotechnology industry on the US economy has been estimated by Ernst and Young (2000) using input-output analysis [8]. The Federal Reserve Bank of Dallas has published regional assessment of biotechnology impact in *The Southwestern Economy* in 2002 [64]. A study completed of the biopharmaceutical industry contributions to the state and US economies in 2004 estimated the contributions to be about $172.7 billion which included $63.9 billion in real output, $67.8 billion in indirect impacts and $40.9 billion in induced impacts [43]. The industry also generated 2.7 million jobs amounting to 2.1% of total employment in the U.S.

Loudat and Kasturi (2006) conducted research funded by the Hawaii Farm Bureau on Hawaii's seed crop industry that provides GM seeds to US mainland growers [28]. The method employed by the authors was also input-output analysis for the study of direct, indirect and tertiary impacts on the Hawaii economy. They estimated total benefits to the State of Hawaii of $144 million dollars.