Planning for Sustainable Tourism

Part III: Economic & Environmental Modeling Study

Volume III: Technical Report

Prepared for

DBEDT
THE DEPARTMENT OF BUSINESS, ECONOMIC DEVELOPMENT & TOURISM
STATE OF HAWAII

P.O. Box 2359 - Honolulu Hawaii 96804
Street Address: 250 South Hotel Street, 4th Floor

by:
R.M. Towill, Inc.
October 2005

PLANNING FOR SUSTAINABLE TOURISM IN HAWAII
Economic and Environmental Assessment Modeling Study

MODELING TECHNICAL REPORT

DATA AND METHODS

ANALYTICAL TOOLS AND METHODOLOGIES

Prepared for:
The Department of Business, Economic Development, and Tourism
Research and Economic Analysis Division
State of Hawaii

Prepared by:
R. M. Towill Corporation
420 Waiakamilo Road, Suite 411
Honolulu, HI 96817

October 10, 2005

This report has been cataloged as follows:

Hawaii. Dept. of Business, Economic Development and Tourism.
Planning for sustainable tourism. Honolulu: 2005.

Multiple volume report by various authors.

1. Tourism-Planning-Hawaii. 2. Tourism-Government policy-Hawaii. 3. Sustainable development-Hawaii.
G155.H3.H32.2005

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

The Economic and Environmental Modeling Study is Part II of a larger study conducted for Department of Business, Economic Development and Tourism, State of Hawaii. The overall purpose of this study is to analyze approaches to managing tourism so as to sustain the environmental and social vibrancy of Hawaii. Part I, prepared by Carter Burgess Inc., consists of an Infrastructure and Environmental Overview Study. Part II (including this report), prepared by the R.M. Towill Corporation, contains the Economic and Environmental Modeling Study. Part III, prepared by John M. Knox & Associates, focuses on Socio-Cultural and Public Input. This part of the project involves the development and use of tools for measuring changes in the economy and the environment.

The purpose of this report is to describe the data and methods and models portraying the interactions between the state's economy, the tourism sector, and the environment. Economic data from 1997 are used to develop a baseline. The baseline is used as a benchmark against which forecasts of population growth and economic change can be compared against. The forecasts are produced with model of the state's economy known as a Computable General Equilibrium (CGE) model. With this tool, the effects of various policy changes can be simulated. Further details on the data, methods and models are contained in the technical appendices.

The CGE model provides a numerical method to estimate the impact of alternative visitor expenditure growth scenarios on the overall economy or on specific sectors. The model was used in this report to estimate the economic impact of increases in visitor spending, from $1 million to over $1 billion This study provides new projections related to infrastructure demand, such as water, solid waste, and energy, and contains estimates of key economic variables for the State and Counties over time.

The CGE model, is specific to Hawaii's economy and has been designed for simulating the economic effects of alternative tourism expenditure scenarios. It simulates the behavior of all consumers and producers in an economy and provides results that incorporate the impacts throughout the economy. The model uses three key assumptions from mainstream economic theory: households make optimal purchasing choices for their well-being; producers maximize their profits; and markets respond so that supply equals demand. A feature of the model is that it forecasts changes in the economy and adjustments to those changes. The model calculates adjustments on a year-by-year basis. The model uses the time series data for growth in population, workforce, federal spending, capital accumulation and visitor expenditure, developed by University of Hawaii Economic Research Organization (UHERO), as inputs over a thirty year period. The model is sensitive to a wide range of interactions, both within the economy and between Hawaii and the rest of the world. The structural equations of the model are provided in an appendix. It has the following features.

- Households supply factors (wage labor, proprietor labor, and other value added) to and receive payments from Hawaii producers;

- Hawaii firms employ local factors (wage labor, proprietor labor, and other value added) as well as imports in the production of commodities which are supplied to households, visitors, Hawaii government, federal government (civilian and military), and exports;

- Equilibrium supply and demand conditions are simulated in every market sector simultaneously to provide a comprehensive and integrated representation of the economy;

- The scenario models are updated annually using observed data and UHERO long range forecasts to 2030;

In this general equilibrium model, industry produces goods and services to sell to other firms, residents, government (state and local, federal civilian, and federal military), investment, and purchasers residing outside the state (exports, visitors). The output is produced using primary factors (employed labor, proprietors, and capital), intermediate products, and imports. The demand for primary factors is supplied by Hawaii residents and the residents receive payments from industry. Residents, in turn, demand goods and services from local industry as well as from imports from outside the state. Hawaii state and local government collects taxes on economic activity and from residents, and demand goods and services from industry. It is important to note that this is a model of the State's economy whereby federal expenditures and revenues are exogenously determined. Market prices adjust until the economy is in an 'equilibrium' state in which the quantity of primary factors, goods, and services demanded is equal to that supplied.

In addition to being able to trace through the impacts of visitor spending on wages, income, and the interactions between various economic sectors, the model also allows for the measurement of the effects of visitor spending on prices and inflation. In addition to these effects, the modeling procedure also provides a quantitative approach to examining government taxation and spending.

Yet the real value of this approach involves the ability to analyze various constraints affect the economy. In addition to looking at the impact of rising prices, the model allows for the modeling of alternative scenarios related to labor force growth as well as constraints brought on because of other limits to growth and expansion. In addition to labor, the supply of infrastructure services (water, sewer, electricity, solid waste, etc.) also have an impact on how new growth can be supported.

The value of the CGE model lies in its ability to consider a wide range of factors affecting various economic agents across the entire economy. It recognizes the important contributions of not just visitors to our economy, but also the effects of households, firms, government and other economic agents who interact in our economy. In this way, we are able to provide a more comprehensive view of the effects of changes in visitor spending over time.

1.1 Visitor Expenditure Scenarios

The CGE Model is designed to examine visitor expenditure scenarios. A change in visitor expenditures is modeled as an exogenous shock. Visitor expenditures are not determined by conditions within the Hawaii economy. UHERO based the visitor expenditure projections on estimated occupancy rates and the estimated relative price difference between a Hawaii vacation and other destinations. Visitor purchases are modeled much like exports where the demand for

Hawaii-produced commodities is external to the state. An increase in visitor income shifts the demand for Hawaii goods and services and thus generates an increase in the quantity of tourism products supplied. Primary factors (labor, proprietor effort, and capital,) as well as intermediate goods are drawn to these markets in order to meet the new demand.

A ripple effect is created throughout the economy. The increase in demand for visitor-related commodities is accompanied by rising marginal costs in visitor related sectors, and relative prices increase. Costs are impacted throughout the economy, not just in the goods and services provided exclusively to visitors. For example, the increase in visitor entertainment spending generates an increase in demand for entertainment workers, proprietors, and capital. In order to attract new labor and capital from elsewhere in the economy, wages, profits and capital returns will rise and costs throughout the entire economy will adjust. Additionally, the money earned by those working in the visitor related sectors is subsequently spent on other goods and services. In other words, a new general equilibrium is reached with new market-clearing prices.

The CGE Model dataset includes expenditure profiles for visitors by origin, including tourists from the US-East, US-West, Japan, Canada, and other international locations. Tourism scenarios involving a change in the composition as well as the level of visitor expenditures can be considered.

1.2 Household Impacts

The CGE model recognizes the importance of key economic agents - not just the visitors and businesses that provide goods and services to them, but also households who supply labor to the various industries affected by visitor spending. Households are characterized by two key economic decisions. They decide in which sectors to supply labor and capital, which determines household income levels. They also decide how to spend their income on commodities. Both decisions depend on the prices that prevail in the economy as well as the preferences of the households. Incorporating consumer and labor market theory into the model provides a general equilibrium representation of household behavior based on microeconomic theory.

The contributions to the economy can be seen in terms of direct visitor spending (when a visitor purchases a good or service), indirect spending (when a business purchases goods or services needed in their production process) and induced spending (that which results from the increase in household income attributable to increased visitor spending). The CGE model allows for more comprehensive modeling and estimation of these effects. While traditional input-output models can capture some of these effects through the use of different multipliers, the model provides a method of looking at the entire economy instead of focusing just on visitor spending or its secondary impacts as measured through indirect or induced effects.

1.3 Price Impacts

Within the CGE model, prices of all commodities and factors (wage labor, proprietors, and capital) adjust in response to economic conditions. Producers respond to prices in their employment decisions as well as in the choice of output levels. Households likewise adjust labor supply in response to employment conditions at the commodity level. Consumers, both household and visitors, adjust their expenditures based on the prices that prevail in the marketplace. In the model's general equilibrium framework, prices adjust automatically until supply and demand are in balance in each market in the economy.

Inflation will not be proportional across commodities. Different prices will change at different rates. Some commodity prices increase faster than others. Some prices may decline in real terms. Real returns to primary factors will change as well, favoring factors that are used relatively intensively in the visitor sector. Because the demand is generated by an injection of new dollars (dollars not earned in Hawaii), visitor expenditures will naturally generate a certain amount of price inflation.

1.4 International Impacts

For modeling purposes, in order to maintain a global general equilibrium, a balance of payments is assumed whereby the current account deficit (imports less exports) is assumed to be fixed in real terms. Of course in reality, the balance of payments may well be influenced by levels of visitor spending.

Import and export prices are assumed not to depend on Hawaii's economic conditions. Hawaii is a small, price-taking, economy relative to the global economy. Nominal trading prices are fixed. In addition, Hawaii uses the dollar as a means of exchange and thus operates as if it is in a 'fixed exchange rate' system. As Hawaii's price levels increase relative to the rest of the world, the relative price of imports and exports falls. Thus we will both demand more imports and supply less non-tourism exports. Another way to say this is that tourism allows us to meet our import demand while reducing our reliance on exports. The increase in visitor demand represents what economists refer to as a "terms of trade improvement" for Hawaii.

1.5 Government Impacts

In this model, the government represents an important producing agent as well as an important set of sources of final demand.

The State and Local Government (SLG) is modeled as demanding a fixed set of goods and services corresponding to a Leontief utility function. In other words, inputs enter in fixed proportion in order to produce a unit of output (zero elasticity of substitution). In the sensitivity analyses, the level of government demand is held fixed so as not to mix fiscal expansion or contraction with other impacts on the economy. This is accomplished with an endogenous lump-sum transfer to households.

When looking at the economy over time (Hawaii 2030 analysis), SLG expenditures change to maintain a balanced budget. That is, government expenditures are assumed to rise to meet expanding indirect business tax collections. In the model, SLG maintains a balanced budget through transfers of lump sum tax payments from households and indirect tax collections imposed on businesses. Indirect tax collections change endogenously as production levels change. It is important to note that indirect tax rates vary across sectors and visitor-related sectors happen to be taxed at levels above average.

The federal government, both civilian and military, demands goods and services from Hawaii in keeping with national objectives. The federal government is assumed to purchase Hawaii goods and services according to Leontief utility functions. In the sensitivity analyses, federal expenditures maintain a fixed quantity of purchases. In the Hawaii 2030 analysis, federal expenditures rise at a rate forecasted by the UHERO. Federal expenditures do not rely on the level of Hawaii federal taxes collected. It is important to note that while export demand is perfectly elastic (price is fixed), federal government demand is assumed to be perfectly inelastic at any given point in time. Given the magnitude of expenditures in Hawaii owing to its strategic location, this assumption is deemed the most realistic representation.

In addition to being represented as a “column” (a final demander) in the Input-Output Table, government is also represented as “row” (a supplying agent). In this way government also provides services (for a fee) to the private sector. Government is a particularly important intermediate sector to the provision of transportation (air, ground, and water).

The government sector (including both state and local and federal government) is a large employer in the state, accounting for 22% of Hawaii jobs and 33.2% of compensation to employees. Government jobs appear to provide above average levels of compensation to workers.

1.6 UHERO Forecasts

In order to produce forecasts over time, the model uses the long-range forecasts provided by the UHERO as inputs to the CGE model. UHERO forecasts final demand generated by economic conditions external to Hawaii’s economy. Projections include visitor demand from the U.S. East, U.S. West, Japan, and other international markets. UHERO also provides projections for growth in military and federal government expenditures, capital accumulation and the labor force. It is important to note that the determinants of population growth in Hawaii are complex and depend on factors beyond the local economy. Mainland and international markets, military spending, international visa restrictions and conditions within other Pacific Islands, and other factors can affect migration to Hawaii and other economic conditions. The model incorporates these projections as “shocks” to the Hawaii economy and provides estimates of real and nominal output, gross state product, household expenditures, factor compensation, utility use, sector-level supply and demand (intermediate and final) and other economic variables. It provides a portrait of the level and composition of economic activity within Hawaii.

In order to provide realistic 10-, 20-, and 30- year projections, key parameters from UHERO’s long range forecasting model were built into the CGE modeling framework. As a robustness test, the model was found to successfully generate growth rates in Hawaii inflation and real Gross State Product (GSP) that are within a margin of error of UHERO’s independent projections. Thus the long-range forecast and the CGE model both produce compatible macroeconomic growth rates when projections of population, federal government expenditures, visitor expenditures, and capital accumulation growth rates are compatible.

The model provides 10-, 20-, and 30- year projections with calibrated real gross state product growth rates and inflation rates that correspond to rates predicted independently by the UHERO long-range forecast. The model provides a robust representation of the Hawaii economy and captures economic responses to an increase in visitor expenditures.

1.7 CGE Model Projections

The CGE Model provides a tool to consider assumptions regarding external forces affecting Hawaii's economy. In the Hawaii 2030 analysis, assumptions for low, base, and high visitor expenditure growth and the associated labor force growth are considered. Changes in the mix of tourism, the level of tourism growth, or the county-destination of visitors can be examined. The model also provides projections for water, petroleum, electricity, and utility gas demands by households, visitors and industries, as well as the amounts of solid waste generated by each of these sectors under alternative visitor growth scenarios. The model translates alternative levels of visitor spending into environmental impacts expressed as 10-, 20-, and 30- year projections for water, energy, and solid waste infrastructure demand.

The model provides projections for changes in real and nominal GSP, labor compensation, proprietors' income, and Hawaii consumer price index. It also provides the percentage change in sector-level output, and labor employment by sector.

1.8 General Description of How the CGE Model Works

The model is calibrated to 40 sectors, but results are aggregated to 13 sectors plus imports for the purposes of presentation. As described above, the increase in visitor expenditures represents an injection into Hawaii's economy rather than a source of spending from income that has been earned from primary Hawaii factors.

The increase in visitor expenditures is allocated across sectors. Important components of visitor demand include hotels, air transportation, wholesale and retail trade and restaurants. Imported demand is fairly significant.

The demand shock generates changes in demand for intermediate goods and services in the economy. The increase will be greatest in non-tradable sectors including real estate, other services, trade and utilities. Imported intermediate demand increases significantly.

The increase in demand for Hawaii value added (labor, proprietors, and capital) translates into higher household income levels. In a general equilibrium model, private household expenditures will rise to meet new income levels (less savings and transfers). It is important to note that prices are also increasing for Hawaii-made goods and services when value added costs go up. Hence, imports are an important outlet for new household spending. Other important expenditure items are real estate, other services and trade.

In a sensitivity analysis, it is assumed that government will purchase a fixed quantity of goods and services. That is, the government will purchase a fixed bundle of goods and services and the price of that bundle will change in response to economic conditions. It is important to note that SLG services are an important component of Federal Government expenditure. In the Hawaii 2030 scenario, SLG expenditures rise corresponding to increases in revenues received.

The closure rule for external market balance is that the current account deficit that is maintained by Hawaii is fixed in real terms and that the exchange rate and international prices are also fixed. This is a standard 'small economy' assumption. Hawaii receives 'foreign exchange' from exports, visitor expenditures, and federal government expenditures. In the model, the nominal increase in visitor and federal spending triggers a reduction in exports. Note that the nominal cost of production in Hawaii increases as returns to primary factors increase while export prices are assumed to be unchanged by local Hawaii conditions (export demand is perfectly elastic).

The CGE model will calculate the nominal change in total demand by sector in response to the visitor expenditure shock. The model also calculates the total supply (or cost of production) by sector generated by the visitor expenditure increase. A check of the model is a comparison that the nominal value demanded is equal to the nominal value supplied in each sector and across the economy. The results will not be exactly equal but should compare well to within 5 to 7 dollars. It should be noted that because the model is deriving a numerical solution rather than an analytical (closed form) solution, there is an iterative procedure involved at reaching the new equilibrium for the $58.7 billion economy. The consistency and robustness of this model at a fine level can therefore be confirmed.

1.9 CGE Model Results: An Example – The Impact of Visitor Spending on Government

The government sector provides an interesting example of how the model arrives at a new equilibrium. Although the calibrated input to Government from a visitor expenditure increase is small, the model will calculate a much larger increase in output. It might seem striking that a small visitor increase would generate such a large demand response.

This impact is better understood from a close look at the impact of the expenditure increase and at the closure rules in place in this model. The visitor expenditure for government captures the fees that they pay on various publicly provided services. Indirectly, final demanding agents generate an indirect demand for government services. Included are harbor and airport services and other public services that are provided for a fee to the private sector. Households also increase expenditures on fee for government services. Some government services are 'exported'.

The total cost, or the supply value, of providing government services increases. The bulk of the increase in government cost is value added, reflecting the importance of labor in the cost of government.

1.10 Report Organization

The remainder of this report is organized as follows. Section 2 provides brief background material on sustainable tourism. Section 3 provides an overview of the baseline 1997 data as well as the equations related to the general equilibrium model. Section 4 contains a description of the UHERO long-range economic and population projections for 10, 20, and 30 year planning horizons with the CGE model. Conclusions and recommendations regarding the use of the model are provided in Section 5.

Accompanying this document is a set of technical appendices. Appendix 1 provides a detailed review of the literature on sustainable tourism. Appendix 2 describes the economic and environmental data sources for the model. The methods are contained in the third set of appendices. Appendix 3-1 provides the equations of the computable general equilibrium model. A portion of the Economic and Environmental Modeling Study involves the computation of the direct and indirect demand for water, utility gas, petroleum, electricity, and solid waste disposal services associated with resident as well as visitor expenditures. This methodology is presented in Appendix 3-2. The model uses the long-range projections provided by the UHERO. A summary of the UHERO population projection methods are provided in Appendix 3-3. UHERO visitor expenditure projections are provided in Appendix 3-4. The economic and environmental data associated with the baseline model were mapped to a detailed Hawaii grid structure using the spatial allocation modeling techniques presented in Appendix 3-5.

2. BACKGROUND ON SUSTAINABLE TOURISM

This section of the report summarizes some of the key concepts related to sustainable tourism and identifies the need for an integrated approach for understanding the relationships between tourism, the economy, environment and community.

2.1 General Definitions

The definition of sustainable tourism can be derived from the more general definition of "sustainable development" which arose out of the World Commission on the Environment and Development Report, Our Common Future (Oxford University Press, 1987), otherwise known as the Brundtland Report. The basic idea of this report was that development should not be concerned with just attaining maximum economic growth, but with achieving fairness, both between individuals and groups in society (intra-generational equity) and also across generations (intergenerational equity). Sustainable tourism, therefore, is concerned not just with the economic viability of the visitor industry, but also with the larger impacts on the economy, the environment, and society.

2.2 Economic, Environmental and Socio-Cultural Perspectives

There are at least three different notions behind the sustainable tourism movement. One emphasizes "economic sustainability". Another focuses much more on "environmental sustainability." A third perspective is more oriented towards socio-cultural and community issues. In addition to describing the historical development of arguments related to sustainable development, the literature review also discusses some important measurement and methodological issues.

2.3 Other Useful Concepts

The literature review conducted for this study identified a number of relevant themes and concepts, see Appendix 1. In addition to the literature on conservation and resource management, there have been many efforts to link the natural environment to economic growth. There have also been a number of tools employed over the years to measure the relationships between the environment, economy, and society. Cost-benefit analysis typically focuses on minimizing short-run average costs or maximizing net social benefits. There are, no doubt, difficulties with the measurement of environmental costs and benefits as well as capturing them across time and space. Environmental goods create special challenges. It may be useful to distinguish between use and non-use benefits, between direct and indirect benefits, and between market and non-market benefits. When markets for goods and services exist, it is possible to examine the relationships between prices and quantities. However in the absence of such markets, as is often the case with environmental goods and services, there are techniques for revealing preferences. Typically, these methods involve interviewing consumers or observing their behavior and willingness to pay. While it would have been useful to conduct some hedonic price models or contingent valuation studies for this project, due to time and budgetary constraints, these approaches were not used.

Carrying capacity approaches were also considered early in this study. There are generally two ways of approaching carrying capacity. One emphasizes physical limits, such as the capacity of production system to supply tourism services. Another way of approaching carrying capacity is to examine the perceptual limits, the "tolerance of visitors by host populations" (Johnson and Thomas, 1996). Inherent with carrying capacity approach are a number of problems. The basic notion of carrying capacity is fraught with difficulty. There is a degree of uncertainty over the actual physical capacity of a given environment, due to the difficulty of measuring the stock of environmental goods and because of the mediating role played by infrastructure. Infrastructure services, moreover, can be influenced by changes in technology or environmental regulations which may affect the nature, cost, and the output. With carrying capacity studies, there is a need to reconcile the physical limits with the psychological limits perspectives.

Another possible approach considered in this study is the ecological footprint concept, developed by Wackernagel and Rees (1996), see Appendix 1. While it has a certain appeal and has been applied in many different settings throughout the world, and future extensions of this project may entail developing these arguments for Hawaii, this approach may be more appropriate for studying agricultural or land intensive activities more so than tourism. The "footprint" of a given population is defined as the "total area of ecologically productive land and water used to produce all the resources consumed (food, fuel, and fiber) and to assimilate all the wastes generated by that population." The difficulty in Hawaii with using the ecological footprint methodology is that most of the goods in Hawaii are imported. The ecological footprint methodology doesn't adequately allow for distinguishing between traded and locally produced goods and services.

2.4 Input-Output and CGE

The primary long-range model used by the Department of Business, Economic Development, and Tourism (DBEDT) is the Hawaii Population and Economic Projection and Simulation Model. This model was first developed in 1978 and has been continuously updated over the years. This model is used by DBEDT and other state agencies to forecast Hawaii demographic characteristics and key economic indicators. DBEDT also maintains an input-output model, discussed in the Hawaii Input-Output Study: 1997 Benchmark Report. This model can estimate the impact on value added and jobs associated with exogenous (external) changes in final demand. Total output, total earnings, and employment (job) multipliers are computed for each sector using the RIMS II (Regional Input-Output Modeling System) method. This technique was first introduced by the Bureau of Economic Analysis (BEA) in the 1970s and was enhanced in the 1980s. As the results can be computed using spreadsheets, it is a convenient and powerful tool for analyzing many policy questions. The system is an appropriate tool for the assessment of ‘partial equilibrium’ scenarios. The BEA provides the following description of the use of RIMS II multipliers:

> *BEA's RIMS multipliers can be a cost-effective way for analysts to estimate the economic impacts of changes in a regional economy. However, it is important to keep in mind that, like all economic impact models, RIMS provides approximate order-of-magnitude estimates of impacts. RIMS multipliers are best suited for estimating the impacts of small changes on a regional economy. For some applications, users may want to supplement RIMS estimates with information they gather from the region undergoing the potential change. Examples of case studies where it is appropriate to use RIMS multipliers appear in the RIMS II User Handbook. (http://www.bea.doc.gov/bea/regional/rims/)*

Based on the review of the literature, it is apparent that there is a need for better integration of economic, environmental, and socio-cultural data into the analysis of tourism policy. There is a need to use a broad array of tools and models in order to better understand the interactions between tourism and the economy, environment, and community. Input-output analysis helps to capture first-order effects associated with changes in visitor spending. It is also important to measure the impacts associated with the use of natural resources and labor through price and other effects. The input-output analysis can also be extended by CGE modeling or other techniques. While the starting point for analysis may be the initial allocation of resources and the interrelationships between households, firms, and government, the effects of changes in the state’s economic structure, the visitor industry or in the regulatory environment need to be modeled and analyzed. With tools such as CGE modeling, the differences between the old state, vis-à-vis the new one, can be measured in terms of the changes in prices (for residents or visitors), quantities consumed and produced, employment levels, profits, and other economic quantities. As such, equilibrium models can be used to assess the net welfare changes for affected groups in society.

As with most other empirical economic models, there are also limitations associated with the use of a CGE model. No empirical economic model is perfect. In its attempt to comprehensively capture all the various economic sectors and agents, as well as prices and quantities throughout the State, CGE modeling is both data intensive and complex. There are different assumptions, many of which can change the results of the modeling effort. Unlike partial equilibrium approaches which can be done with a spreadsheet program, CGE modeling requires more specialized software and extensive programming skills.

3. HAWAII SUSTAINABLE TOURISM CGE MODEL

The Hawaii Sustainable Tourism CGE model provides a tool for analyzing the economic and environmental impacts of various tourism scenarios. The CGE models the relationship between visitor expenditures, jobs, industry composition, and growth using an applied general equilibrium model of Hawaii.

In this section the assumptions regarding the model are described as are the adjustments for the purposes of modeling visitor spending scenarios over the long-term in Hawaii. The model also provides a method for estimating the infrastructure demand of a mature tourism destination. The key data requirements for the model are also summarized.

In order to assess the effects of the alternative tourism and labor force growth scenarios a Social Accounting Matrix is assembled that describes the flow of goods, services, and factors through each economy in a baseline year. For each production sector, the purchases of intermediate inputs and primary factors (labor and capital) are provided. Demand in each sector is a combination of intermediate demand and final expenditures by households, government, exporters, and investors. Baseline conditions are derived from a 1997 Input-Output table comprised of 131 industrial sectors, three factor markets, and 11 agents of final demand, as described in Appendix 2. Summary data are given in Tables 1 and 2. Table 3 provides an overview of initial, or baseline, infrastructure use by sector. The Social Accounting Matrix is supplemented with additional data on visitor expenditures, population, and infrastructure.

Appendix 3.1 provides additional detail related to the modeling equations. Hawaii is modeled as a small and open economy, in which visitor expenditures generate a significant share of foreign exchange. Visitors demand a bundle of goods and services, such as hotels and restaurant meals, many of which are not importable. Goods are produced under perfect competition and constant returns to scale using intermediate commodities, imports, labor, and capital. Final demand is generated by households, visitors, various government entities, and exports. Within this context, prices are calibrated to clear markets

Imports enter into the utility function and production function as a composite commodity. Sensitivity analyses are performed in order to evaluate the model's performance and to test the robustness of results under alternative assumptions regarding visitor expenditures and labor supply. We specifically examine the sensitivity of economic response according to different levels of visitor spending and growth of the labor supply. In the long-run, consumers and producers will substitute between tradable locally produced goods and services and imports. The CGE model builds in this assumption and also incorporates UHERO long range projections and simulates economic results for 10-, 20- and 30- year planning horizons. Over the long-run, the model also allows for an adjustment in labor force levels. As visitor spending increases, the demand for labor also rises. In-migration to Hawaii increases. If, on the other hand, visitor spending decreases, then the demand for labor diminishes. These interactions are captured through a series of low, baseline and high labor force and visitor spending projections. Added to these projections are UHERO's estimates for capital accumulation and Federal spending in Hawaii.

Table 1: Structure of Output and Production in Hawaii, 1997

Industry	Output	Inter-industry demand	Inter-mediate Imports	Compen-sation of employees	Proprietor income	Other value added	Jobs
Total	$58.7 bil	$14.4 bil	$5.7 bil	$21.6 bil	$2.1 bil	$14.9 bil	742,231
Agriculture	1.4%	1.9%	1.4%	1.3%	1.8%	1.0%	2.9%
Construction	6.0%	7.9%	11.1%	5.8%	11.6%	1.7%	4.5%
Manufacturing	5.8%	5.9%	28.8%	2.4%	2.2%	2.4%	2.4%
Air Transportation	3.5%	4.8%	5.3%	2.4%	0.3%	3.5%	1.4%
Other Transport.	2.6%	4.5%	4.0%	1.7%	1.2%	1.8%	1.9%
Entertainment	1.4%	1.8%	1.8%	1.4%	3.0%	0.8%	2.7%
Golf	0.4%	0.6%	0.3%	0.4%	0.0%	0.2%	0.5%
Hotels	5.9%	7.6%	3.4%	5.9%	1.7%	5.7%	5.6%
Real Estate	15.4%	13.7%	2.9%	1.8%	17.6%	41.0%	3.9%
Restaurants	3.9%	5.5%	5.2%	3.7%	2.0%	2.3%	6.8%
Trade	10.4%	9.9%	8.2%	11.1%	9.6%	10.9%	14.9%
Other Services	25.8%	30.3%	23.4%	27.2%	48.9%	17.3%	29.8%
Utilities	2.9%	4.1%	2.5%	1.6%	0.1%	4.1%	0.8%
Government	14.6%	1.5%	1.4%	33.2%	0.0%	7.3%	22.0%

Source: *The Hawaii Input-Output Study, 1997 Benchmark Report*, Department of Business, Economic Development, and Tourism, State of Hawaii, March 2002 (updated August 2003).

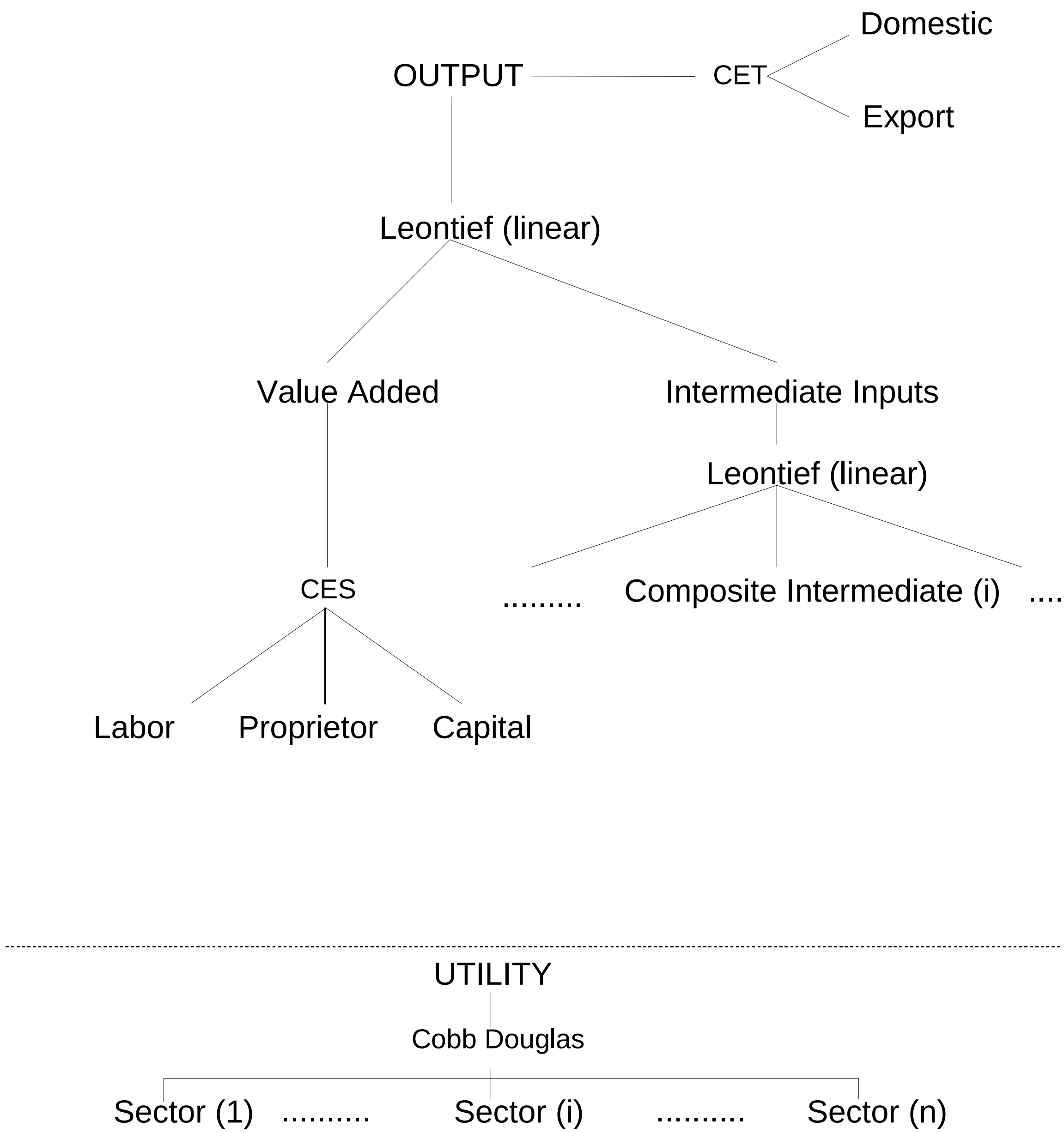
Note that Gross State Product (GSP) is equal to Total Value Added

Table 2: Household and Visitor Expenditures in Hawaii, 1997

Industry	Household Expenditures ($ million)	(%)	Visitor Expenditures ($ million)	(%)
Total	$24,962.0	100.0%	$10,931.0	100.0%
Agriculture	122.0	0.5%	18.4	0.2%
Construction	0.0	0.0%	0.0	0.0%
Manufacturing	683.0	2.7%	296.2	2.7%
Air Transportation	337.9	1.4%	1,555.2	14.2%
Other Transport.	406.3	1.6%	536.3	4.9%
Entertainment	207.3	0.8%	569.4	5.2%
Golf	88.5	0.4%	141.3	1.3%
Hotels	170.0	0.7%	3,247.4	29.7%
Real Estate	5,211.4	20.9%	239.7	2.2%
Restaurants	1,017.1	4.1%	1,126.2	10.3%
Trade	2,998.3	12.0%	1,278.0	11.7%
Other Services	7,832.2	31.4%	439.8	4.0%
Utilities	595.3	2.4%	0.0	0.0%
Government	264.9	1.1%	45.6	0.4%
Imports	5,027.8	20.1%	1,437.6	13.2%

Source: *The Hawaii Input-Output Study, 1997 Benchmark Report*, Department of Business, Economic Development, and Tourism, State of Hawaii, March 2002 (updated August 2003).

Figure 1: General Diagram of Production and Utility Functions



3.1 Consumer Behavior

A general diagram of production and utility factors is contained in Figure 1. There are two types of consumers in the economy, residents (*r*) and visitors (*v*). This report uses the term "household" and "resident" interchangeably. In the economic literature "consumers" are often referred to as "households." The economy produces *n* commodities and imports a composite good *m*. The Cobb-Douglas utility function for the type-*h* consumer is given by

$$U_h = \prod_i C_{hi}^{b_{hi}} \qquad \sum_i b_{hi} = 1 \quad i = 1, \ldots, n \tag{1}$$

where C_{hi} is consumption and b_{hi} the income expenditure share of $i = 1,..,n,m$ by consumer $h = r,v$.

Consumer *h*'s demand for domestic tradable goods and imports are assumed to follow a nested utility function, given by the following equation.

$$C_{hi} = [\theta_{Dhi} D_{hi}{}^{(\varepsilon_{him}-1)/\varepsilon_{him}} + \theta_{Mh} M_h{}^{(\varepsilon_{him}-1)/\varepsilon_{him}}]^{\varepsilon_{him}/(\varepsilon_{him}-1)} \tag{1.a}$$

Where ε_{him} is the Armington constant elasticity substitution between tradable good *i* and imports by consumer *h*. D_{hi} is sector *i* demands for domestic (Hawaii) produced and M_h is imported demand by consumer *h*.

A single representative resident maximizes utility (U_r) subject to the following budget constraint

$$\sum_i p_i C_{ri} = p_L L + P_R R + P_K K + \overline{p}_{fx} BP - T_r \tag{2}$$

where prices p_i represent the market prices for imports and commodities $i = 1,..n$, m respectively. The resident derives income from factors of production including labor (*L*), proprietor income (*R*), and capital (*K*), where p_L, p_R, p_K are the market price of the respective factors. The resident pays a lump-sum tax (T_r), net of transfer payments, to the state and local government. The resident also receives foreign exchange ($\overline{p}_{fx} B$) from a balance of payment deficit, described below in equation (13).

It is important to note that household income (and thus expenditures) for the representative resident are not equal to labor compensation, as shown in equation 2. Household expenditures ($\sum_i p_i C_{ri}$) may be higher or lower than labor income (p_L *L*), depending on other sources of income and transfers.

A representative visitor with exogenous income (I_v) maximizes utility (U_v) subject to the budget constraint

$$I_v \equiv I_{v0}(1+\lambda_v) = \sum_i p_i C_{vi} \tag{3}$$

where I_{v0} is the initial visitor expenditure and λ_v serves as an exogenous visitor expenditure shock parameter.

3.2 Production and Sales of Goods and Services

Final output (Y_j) in sector j = 1,.., n is produced according to a nested production function comprised of intermediate inputs (Z_{ij}) of commodity i, composite imports (M_j), and value added (V_j). The first level is a Leontief production function

$$Y_j = \min[Z_{1j}/\alpha_{1j},...Z_{nj}/\alpha_{nj}, V_j/\alpha_{vj}] \quad (4)$$

where a_{ij}, a_{vj} are unit input coefficients for intermediates and value added respectively.

Importable commodities are assumed to substitute for tradable Hawaii-produced commodities according to the following Armington constant elasticity of substitution production nest.

$$Z_{ij} = [\theta_{Dij} D_{ij}^{(\varepsilon_{ijm}-1)/\varepsilon_{ijm}} + \theta_{Mi} M_i^{(\varepsilon_{ijm}-1)/\varepsilon_{ijm}}]^{\varepsilon_{ijm}/(\varepsilon_{ijm}-1)} \quad (4.a)$$

Where ε_{ijm} is the Armington constant elasticity substitution between tradable good i and imports by producer j. D_{ij} is sector i demands by producer j for domestic (Hawaii) produced and M_i is imported demand in sector i.

A sub-production function describes the substitutability between labor (L_j), capital (K_j), and proprietor income (R_j) in producing real value added (V_j) in each sector j, where σ_j is the constant elasticity of substitution (CES) among value added variables.

$$V_j = [\alpha_{Lj} L_j^{(\sigma_j-1)/\sigma_j} + \alpha_{Kj} K_j^{(\sigma_j-1)/\sigma_j} + \alpha_{Rj} R_j^{(\sigma_j-1)/\sigma_j}]^{\sigma_j/(\sigma_j-1)} \quad (5)$$

Commodity Y_j is differentiated for sale on domestic and international markets, as given by a constant elasticity of transformation (CET) function between domestic (D_j) sales and exports (X_j).

$$Y_j = [\beta_{Dj} D_j^{(\varepsilon_j-1)/\varepsilon_j} + \beta_{Xj} X_j^{(\varepsilon_j-1)/\varepsilon_j}]^{\varepsilon_j/(\varepsilon_j-1)} \quad (6)$$

In this function, ε_j is the elasticity of transformation and β_{Dj}, β_{Xj} are parameter shares.

3.3 Government Revenue and Expenditures

Three government agencies procure goods and services in the economy: the state and local government (denoted *SL*), the federal military government (denoted *FM*), and the federal civilian government (denoted *FC*). Each government type purchases domestic commodities (G_{gi}) and imports (G_{gm}) according to a Leontief utility function to assure a constant level of public provision is maintained, where g = *SL, FM, FC.*

The state and local government depends entirely on the economy for the tax base.

$$\sum_i p_i G_{SLi} + p_m G_{SLm} = \sum_i p_i Y_i \tau_i + T_r \tag{7}$$

A primary source of revenue is the State's goods and services tax (τ_i) on the sales (Y_i) of commodity i. The state and local government also impose a variety of taxes, such as property and income taxes, on residents.

The budgets of the federal government agencies are assumed to be completely independent of state economic conditions. In the case of Hawaii, this is a reasonable characterization. Hawaii has unique strategic assets, such as Pearl Harbor. Federal military expenditures, moreover, are determined by factors outside the state, such as international political conditions. As a relatively small state, federal civilian expenditures are not well-correlated with federal taxes paid by Hawaii residents. In the model, federal inflows are assumed to adjust endogenously to assure that federal government objectives are maintained. Thus, the federal public sector budget constraints are given by the following equations

$$\sum_i p_i G_{FMi} + p_m G_{FMm} = I_{FM0}(1+\gamma_{FM}) \equiv I_{FM} \tag{8}$$

$$\sum_i p_i G_{FCi} + p_m G_{FCm} = I_{FC0}(1+\gamma_{FC}) \equiv I_{FC} \tag{9}$$

where the sum on the left-hand side represents the cost of public expenditures. The terms I_{FM0}, I_{FC0} represent initial federal revenue inflows and γ_{FM}, γ_{FC} represent exogenous income multipliers for military and civilian agencies, respectively.

3.4 Market Clearing Conditions

Constant returns to scale and perfect competition ensure that the producer price (p_j) equals the marginal cost of output in each sector j. In addition, the State and Local Government collects a general excise tax (τ_j) on sales. This in turn implies that the value of total output equals producer costs, where p_L, p_K, p_R, equal the market price of labor, capital, and proprietor income respectively.

$$p_j Y_j (1+\tau_j) = \sum_{l=1,..,n} p_l Z_{lj} + P_L L_j + p_k K_j + p_R R_j + p_m M_{Yj} \tag{10}$$

The labor force L is identically determined by an initial endowment of $\overline{L}_0$ and an exogenous growth rate γ_L. In equilibrium, labor is fully employed when the quantity of labor supplied equals to that demanded (L_j) across all sectors $j = 1, \ldots, n$. Note that labor is assumed to be fully mobile across sectors

$$L \equiv \overline{L}_0(1+\gamma_L) = \sum_j L_j \tag{11}$$

Likewise, proprietors (R) and other value added (K) are fully mobile across sectors. Factor supply is determined by initial endowments $\overline{R}_0$, $\overline{K}_0$ and an exogenous growth rate γ_R, λ_K. Given the competitive nature of the model, all factors will be fully employed in equilibrium. The following market clearing conditions hold in the factors markets:

$$R \equiv \overline{R}_0(1+\gamma_R) = \sum\nolimits_j R_j \tag{12a}$$

$$K \equiv \overline{K}_0(1+\gamma_K) = \sum\nolimits_j K_j \tag{12b}$$

Sector j output, which supplied to the domestic market (D_j), is demanded by consumers $h \in \{r,v\}$, government agencies $g \in \{SL,FC,FM\}$, and industries j = 1,..,n.

$$D_j = \sum\nolimits_h C_{hj} + \sum\nolimits_g G_{gj} + \sum\nolimits_l Z_{li} \tag{13}$$

A balance of external payments (BP) is maintained under the assumption of a fixed (dollar) exchange rate ($\overline{p}_{fx}$), where $\overline{p}_{fx}$ is the price of foreign exchange, the exchange rate. The quantity of imports (M) are thus constrained by the inflow of dollars obtained from visitor expenditures (I_v), federal government expenditures (I_{FM}, I_{FC}), Hawaii exports (X_j), and visitor expenditures. It is assumed that the economy is a small price taker on world markets and thus import and export prices are perfectly inelastic.

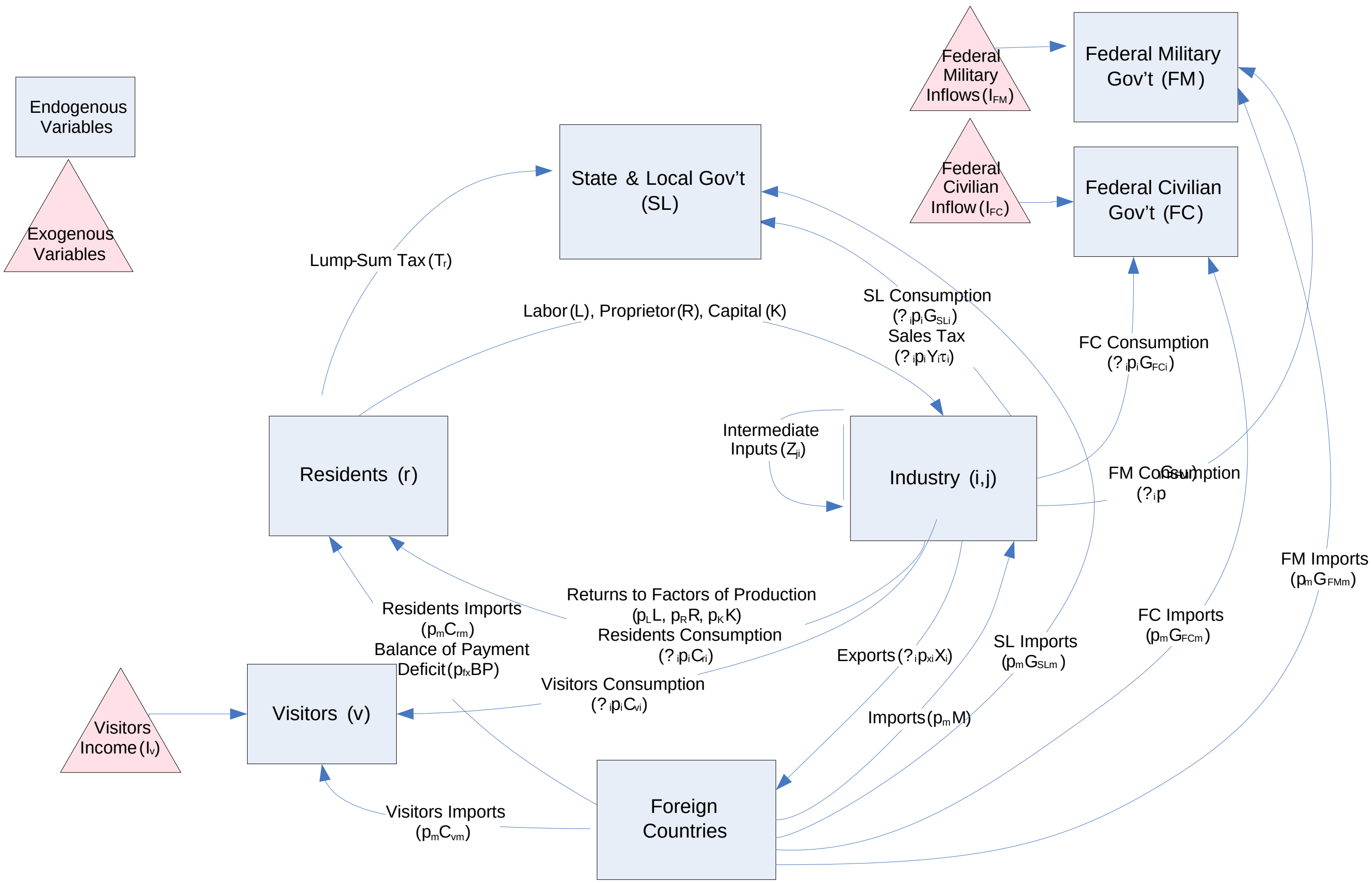
$$\overline{p}_{fx} BP = \overline{p}_m M - I_v - I_{FM} - I_{FC} - \sum\nolimits_j \overline{p}_{xj} X_j \tag{14}$$

A schematic representation of the general equilibrium model of Hawaii's economy is given in Figure 2. Elasticity parameters are given in Table 3. The computable general equilibrium model thus represents a classic Walrasian system. In this particular system, there are 40 commodities markets and three factors markets. Given the convexity of the production and expenditure sets, there exists a unique vector of equilibrium prices at which markets clear (supply is equal to demand). Changes in parameters of the system induce an optimal response on the part of producers and consumers resulting in a new vector of market-clearing equilibrium prices. The model is estimated numerically using the GAMS (General Algebraic Modeling Systems) – MPSGE platform.

Table 3: Elasticity Parameters

Elasticity	Description	Value	Comments
σ^{Ex}	Import Elasticity wrt producers purchase of intermediates	4	
σ^{Im}	Export elasticity wrt domestic price for the sale of producer's goods	-1	Cobb-Douglas Preferences, inverse relationship
σ^{Y}	Income elasticity of demand for local goods and services	1	Cobb-Douglas Preferences
$\sigma_i^{p_j}$	Cross-price elasticity for goods from different industries	1	Cobb-Douglas Preferences
$\sigma_i^{p_i}$	Own-price elasticity for goods and services	-1	Cobb-Douglas Preferences, inverse relationship
$\sigma^{K,L}$	Elasticity of substitution between capital and labor	-1	Cobb-Douglas Preferences, inverse relationship
$\sigma^{Z,V}$	Elasticity of substitution between intermediate industries and value added	0	Leontief Preferences
$\sigma^{Z,M}$	Elasticity of substitution between intermediate industries and composite imports	0	Leontief Preferences

Figure 2: General Equilibrium Model of Hawaii's Economy



Computable General Equilibrium Model

3.5 Substitution of Imports

The CGE model allows for the substitution of imports for tradable Hawaii commodities, both in industrial production as well as in household and visitor expenditures. Tradable sectors of the 131 sector Input-Output table are identified, Table 4. The way in which these goods enter into consumption and production has been described earlier.

Table 4: Tradable Commodities

Sector	Sector Number (of 131)
Crops	1-7
Animal	8-14, 16
Commercial fishing	15
Food processing	26-35
Clothing manufacturing	36
Chemical manufacturing	41
Other manufacturing	37-40, 43-48
Information	57-63
Finance, business, professional	80-82, 87-98, 100-101

4. UHERO LONG-RANGE FORECASTING MODEL FOR HAWAII

This section describes projections for visitor, population, and economic growth. Independent projections were developed by UHERO. A sequential process was used by UHERO to derive visitor spending levels. Visitor arrivals were first estimated on the basis of variables such as the Gross Domestic Product (GDP) of the origin country, the relative cost of a Hawaii vacation, exchange rates, and supply constraint factors such as the occupancy rate. The length of stay was determined based on ARIMA models that assumed that deviations from recent average length of stay are transitory. Visitor spending was based on the application of daily average person levels of spending, broken into two categories – lodging and all other expenditures.

4.1 Population and Employment

Information regarding UHERO estimates used for model inputs such as overall population and job growth, military employment, and Federal civilian government expenditures are contained in Tables 5-8. The model incorporates growth in these factors in their 10-, 20- and 30- year projections. As noted earlier, there are structural adjustments in labor force forecasts based on levels of economic activity. As economic conditions such as visitor spending or Federal expenditures in Hawaii improve, the demand for labor also rises and in-migration increases. Downturns are met with slower growth and out-migration.

Base visitor expenditure growth estimates, as well as low and high visitor expenditure growth, are provided over the thirty year time horizon in Table 5-8. The methodology used by UHERO is described in Appendix 3-4. Projections were developed for visitor arrivals, daily census, and visitor expenditures for various categories of tourists visiting the state and each of the four counties. Table 5 contains actual and projected levels of nominal visitor spending from 1997 to

2030. The baseline projections increase from $10.9 billion (1997) to $28.5 billion (2030) an increase of 160.3%.

On any given day, visitors to Hawaii account for roughly 13 percent of the state's de facto projections for population. In addition to total visitor arrivals, the state's resident population must be considered. Resident population projections were developed using the cohort component method to forecast population by both age and sex, at the County-level, described in Appendix 3-3. This method is used by the US Social Security Administration and the US Census Bureau. The population projections from the UHERO demographic model have been integrated into the UHERO long-range forecasting model to produce a consistent set of visitor expenditure (Table 5) and employment projections for Baseline, Low, and High forecasts to 2030, provided in Table 6. Table 6 shows the UHERO projections for employment over the same period. For the baseline, the total job count goes from 564,137 (1997) to 753,448 (2030) an increase of 33.6%.

4.2 Federal Expenditures

UHERO forecasts of growth in federal government expenditures, both military and civilian, as well as capital accumulation, provided in Table 7. Table 7 reveals that the total armed forces stationed in Hawaii is projected (by UHERO) to grow from 44,500 (1997) to 53,300 (2030) while armed forces labor earnings is projected to grow from $1.3 billion to $3.1 billion over the same period. Federal civilian government expenditures are expected to rise from $982.8 million (1997) to over $2.4 billion (2030)

4.3 Capital Accumulation

Table 7 also contains the Capital Accumulation Index which is projected to rise from 100 in 1997 to 173 in 2030. The CGE model incorporates annual 'base' projections on employment, visitor expenditures, and federal civilian and military expenditures. The capital accumulation index represents growth in both the capital stock and capital productivity. The capital accumulation index is entered in the market clearing conditions of the model as one of the factor endowments. Thus technological change over time is incorporated into the model through UHERO growth projections of capital productivity.

Table 5: Nominal Visitor Expenditure Projections to 2030

	Low Projection		Base Projection		High Projection	
	$ million	Cum % change from 1997	$ million	Cum % change from 1997	$ million	Cum % change from 1997
1997*	$ 10,931		$ 10,931		$ 10,931	
2003	11,362		11,362		11,362	
2010	13,773	26.0%	14,501	32.7%	15,243	39.4%
2020	17,948	64.2%	20,138	84.2%	22,541	106.2%
2030	23,891	118.6%	28,457	160.3%	33,860	209.8%

Source: UHERO Projections; *actual.

Table 6: Employment Projections to 2030

	Low Projection		Base Projection		High Projection	
	Jobs	Cum % change from 1997	Jobs	Cum % change from 1997	Jobs	Cum % change from 1997
1997*	564,137		564,137		564,137	
2003*	591,800		591,800		591,800	
2010	609,043	8.0%	637,941	13.1%	651,503	15.5%
2020	634,727	12.5%	702,642	24.6%	737,397	30.7%
2030	656,669	16.4%	753,448	33.6%	814,709	44.4%

Source: UHERO Projections; *actual

Table 7: Macroeconomic Projections to 2030

	Total Armed Forces		Armed Forces Labor Earnings		Federal Civilian Government Expenditures		Capital Accum-ulation
	($ thous)	Cum % change from 1997	($ thous)	Cum % change from 1997	($ thous)	Cum % change from 1997	Index
1997*	44.5		1,350.7		982.8		100
2010	48.8	9.6%	2,182.1	61.6%	1,535.8	56.3%	120
2020	50.3	13.0%	2,590.1	91.8%	1,955.9	99.0%	147
2030	53.3	19.7%	3,111.6	130.4%	2,437.8	148.0%	173

Source: UHERO Macroeconomic Forecasting Model of Hawaii, *actual

Table 8: Population Projections to 2030

	Low Projection		Base Projection		High Projection	
	Pop.	Cum % change from 1997	Pop.	Cum % change from 1997	Pop.	Cum % change from 1997
2000	1,212,000		1,212,000		1,212,000	
2003	1,232,000		1,232,000		1,232,000	
2010	1,271,000	3.19%	1,319,000	7.11%	1,336,000	8.5%
2020	1,330,000	7.96%	1,420,000	15.26%	1,451,000	17.84%
2030	1,381,000	12.12%	1,488,000	20.81%	1,540,000	25.08%

Source: UHERO Projections;

5. CONCLUSIONS AND RECOMMENDATIONS

In this section of the report, issues and concerns regarding the method and results are addressed. Key aspects of the approach to validation are also described. The report concludes with some caveats and limitations of the methods and techniques as well as some recommendations for future improvements in the modeling approach.

5.1 Validation

A standard approach to validation of the model was employed. In addition to replication of the benchmark data (as described in more detail below), a number of sensitivity analyses and comparisons with forecast results were performed in order to assess the robustness of the model and the reasonableness of the results.

The benchmark data set was compiled for the year 1997. As is typical of computable general equilibrium models, there is thus only a single observation which represents the Hawaii economy. Upon calibration, the observed data should also be a uniquely identified equilibrium solution of the CGE model, given the functional forms and elasticities that are specified in the model. As noted by John Shoven and John Whalley, 1992, Applying General Equilibrium, Cambridge University Press (Page 105-6):

> "A prominent feature of calibration is that no statistical test of the model specification is used, because a deterministic procedure of calculating parameter values from the equilibrium observation is employed. The procedure thus uses the key assumption that the benchmark data represents an equilibrium for the economy under investigation. In contrast to econometric work, which often simplifies the structure of the economic model to allow for substantial richness in statistical specification, here the procedure is quite the opposite. The richness of the economic structure allows only for a much cruder statistical model that, in the case of calibration to a single year's data, becomes deterministic."

Because of the use of deterministic calibration rather than stochastic estimation, there do not exist econometric estimation methodologies for computable general equilibrium systems. This is due to the nature of the data set (the use of a single observation of data) as well as the complexity of the economic model. "Validation" of a computable general equilibrium model involves a replication check, whereby the benchmark data are reproduced as an equilibrium calibration of the functional form representation of the model. This replication check was conducted and verified. In addition, the following validation checks were performed. It is confirmed that:

- The model provides equilibrium outcomes whereby supply is equal to demand in all markets in terms of both value and quantities.
- The model provides equilibrium outcomes whereby household income equals household expenditures and visitor incomes equal visitor expenditures.
- The model provides equilibrium outcomes whereby total imports minus total exports, federal government expenditures and visitor expenditures equals the benchmark balance of payments.
- The model is able to generate the 1997 benchmark data as an equilibrium outcome – the replication check.

Like other mathematical, computerized models, the results may be sensitive to the modeling assumptions selected. The robustness of the model was checked by varying assumptions and then comparing outcomes to achieve a model that best reflects the conditions in Hawaii's economy in response to visitor expenditure growth. Key modeling assumptions tested over the course of the project include the following:

- Labor force assumptions. An analysis was conducted to compare perfectly elastic and perfectly inelastic labor force assumptions. Long range projections compared low, base, and high growth in the labor force.

- Imports. A model in which imports enter production as a Leontief intermediate goods were compared to a model in which imports enter as a nested CES structure and are substitutable with a bundle of tradable Hawaii produced commodities.

- State and Local Tax Revenues. A model is compared in which state and local tax collections are an outcome of the model and government expenditures adjust endogenously to one in which government expenditures are fixed and tax rates are adjusted to maintain a set spending level.

- Federal government expenditures. A model was compared in which Federal spending grows at a forecasted rate to one in which federal spending is fixed at 1997 levels.

The CGE model is verified by comparing key endogenous macroeconomic model variables with equivalent variables forecasted by the UHERO long-range forecasting model. Variables include household expenditure, gross state product, and Hawaii consumer price index. The 30 year projections are remarkably compatible, with differences in the UHERO and model indicators within 5% confidence intervals.

In this report, the tools and methods utilized in this study have been described. This project has brought together a number of different methods and techniques in order to estimate the effects of changes in visitor spending and also to devise an policy tool for measuring economic and environmental conditions. This technical report also contains a set of Appendices describing the mathematical models, forecasting tools, and spatial allocation techniques. In addition to the CGE model, the specifications of the population and tourism forecasting techniques, infrastructure and environmental assessment techniques are provided.

5.2 Limitations

There are important caveats to the use of this model. First, the model has been designed to capture the impacts of changes in visitor expenditure and should be used exclusively for this purpose. Consideration of other exogenous shocks would require separate robustness analysis to insure that the model is appropriate for these shocks. For example, changes in the composition of military expenditures would require the collection of supplemental data and consideration of the linkages between military spending and Hawaii's economy. A careful analysis of changes in the tax structure would require a more complete fiscal database and description of the incidence of taxation.

Likewise, the model would be expected to be used in an environment that encourages import-substitution. We are confident in the economy's ability to substitute away from Hawaii produced goods towards imports. We are less confident in the economy's capacity to expand import substitution industries significantly, say if there were a significant downturn that would lower factor price levels in Hawaii vis-à-vis the rest of the world. Hawaii imports a wide variety of goods and services that are presently not manufactured within the State. We would not anticipate that marginal reduction in factor costs would generate significant investment in these industries.

As with any economic model there are limitations with the CGE model presented in this report. In addition to being data intensive and requiring sophisticated software and programming skills, the models are limited by the quality of the data and assumptions used by the modeler, and hence the results presented in this report should be interpreted and used with caution. The CGE model was developed as a tool to be used in conjunction with other models and forecasting tools which, over time, will be improved.

5.3 Conclusions

The CGE Model allows for more comprehensive modeling and estimation of these effects. While traditional input-output models can capture some of these effects through the use of different multipliers, it provides a method of looking at the entire economy instead of focusing just on visitor spending or its secondary impacts as measured through indirect or induced effects.

In addition to being able to trace through the impacts of visitor spending on wages, income, and the interactions between various economic sectors, the model also allows for the measurement of the effects of visitor spending on prices and inflation. In addition to these effects, the modeling procedure also provides a quantitative approach to examining government taxation and spending. Yet the real value of this approach involves the ability to analyze various constraints affect the economy. In addition to looking at the impact of rising prices, It allows for the modeling of alternative scenarios related to labor force growth as well as constraints brought on because of other limits to growth and expansion. In addition to labor, the supply of infrastructure services (water, sewer, electricity, solid waste, etc.) also have an impact on how new growth can be supported.

The value of the CGE model lies in its ability to consider a wide range of factors affecting various economic agents across the entire economy. It recognizes the important contributions of not just visitors to our economy, but also the effects of households, economic sectors, government and other economic agents who interact in our economy. In this way, we are able to provide a more comprehensive view of the effects of changes in visitor spending over time.

The CGE model can be used to perform sensitivity analyses on the economic impact of scenarios involving changes in visitor expenditure, labor force or a combination of both. With proper training the modeler can also perform sensitivity analyses on changes to other sectors of the economy.

The CGE model can be used to perform analyses utilizing updated population, visitor expenditure and Federal Government Expenditure projections from the UHERO 30-year projections. The 30-year economic impact of a change in any one of these variables or combination of these variables can be estimated.

The CGE model is a flexible tool that has been designed to consider the economic and environmental impacts of a range of tourism growth scenarios over 10, 20, and 30 year planning horizons. Key topics of analysis would include the following:

- How the real gross state product would expand under alternative tourism growth projections.

- How real household income would expand, overall and on average, under alternative tourism growth projections.

- At what point visitor growth will cause a county to hit a bottleneck given current infrastructure availability in water, solid waste, and electricity capacities.

- At what point will existing visitor accommodations be insufficient to absorb the projected tourism demand in each county.

The model is designed to consider changes in the existing mix of tourism expenditures within each county as well as by the type of visitor (US, Japan, and other international). Modifications to the model could include updated projections for population growth, visitor growth, and other macroeconomic parameters. The model could also be tailored to consider other forms of tourism including cruise ship, business, wedding, or timeshare tourism as more data on visitor expenditure patterns becomes available. Other extensions could include updates regarding county-level infrastructure capacity, visitor plant inventory plans, or residential growth plans.

5.4 Recommendations

It is recommended that the state conduct additional household surveys to obtain labor, income, and household expenditure data. At present, the Input-Output table provides only aggregate level of household demand. It would be useful to have a breakdown of spending according to household income level to conduct further income distribution and incidence analyses. On the production side, it would be most useful to have labor costs disaggregated into various skill types, separating for example between managerial and other labor categories. Moreover, it was discovered that existing spatial databases did not have adequate information on the location of job types throughout the state.

In the process of compiling these data and formulating the economic model of the state, it also became quite apparent that the public sector activities are not adequately accounted for in the Input-Output tables. Of particular concern and interest are the levels of spending, employment, and activity for public education, parks and recreation services, police and fire, airports, public transit and other important government services. It is recommended that future input-output studies address these data deficiencies.

Also there is a need to furnish more complete, detailed information on the source of indirect business taxes. It would be most useful to distinguish between general excise taxes, transient accommodation taxes, fuel taxes, property taxes, customs duties and other fees rather than treat them as an aggregate sum. Addressing these data deficiencies would greatly improve the choice and reliability of policy instruments that could be analyzed.

APPENDIX 1. LITERATURE REVIEW

The *Economic and Environmental Modeling Study* is Part II of a larger study that is being conducted by the State of Hawaii, under the guidance of DBEDT, the *Sustainable Tourism in Hawaii Study*. The *Modeling Study* involves the construction of a set of economic and environmental models developed specifically for Hawaii. The purpose of the modeling study is to analyze various methods of managing tourism so as to sustain the environmental and social vibrancy of Hawaii. Data are being collected and assembled on detailed aspects of Hawaii's present economic, social, infrastructure and environmental conditions.

This literature review surveys various tested methods of approaching sustainable tourism and development. The modeling study will draw upon important methodologies and insights that are discussed in this review. However, it is clear that there are significant gaps to date in the standard methodologies that have been used in the context of environmental and tourism planning. The researchers involved in this project are therefore applying various modern methodologies and techniques of data analysis, drawn from science, economics, and urban planning, to model the impact of tourism on Hawaii's environment and economy.

The literature on sustainable development is large. In part, this is due to the multi-disciplinary nature of the subject. Scientists from many different fields as well as economists, urban planners, geographers, political scientists, sociologists, and those interested in government and public policy have contributed much to the theoretical development and application of sustainable development concepts, ideas, and methodologies. Moreover, the subject of sustainable development centers on important issues involving the environment, economy, and society. As a result, any attempt to summarize this vast and expanding field of inquiry is likely to be inadequate.

One way of organizing the literature on sustainable development is to identify a number of key ideas or major themes around which the various readings and papers might be clustered. Following this approach, we have identified nine major groupings with which the literature of sustainable development might be discussed: 1) historical perspectives; 2) international development perspectives; 3) economic development perspectives; 4) conservation and resource management; 5) scientific perspectives; 6) issues related to data and measurement; 7) political perspectives; 8) planning and policy analysis perspectives; and 9) tourism management perspectives. What follows is an abbreviated discussion of some of the key themes and ideas contained within this literature.

1.1. Historical Perspective

In the late 1700's Thomas Malthus (1798) published his treatise linking the dynamics of population and economic growth. Concerned with how British population growth could be sustained on a finite amount of land, his work set the state for others who would look at the limits to growth. The Mathusian perspective focused on how geometrically-increasing populations outrun the stock of food supplies, leading to famine, poverty, and eventual population decline. While these dire predictions did not necessarily materialize, due to underestimated reserves and efficiency producing technologies, Malthus' work did help to establish the basis for population studies.

The concern for the relationship between humans and the natural environment has been longstanding. It gained momentum in the U.S. between 1850 and 1920 with increased industrialization and urbanization and concerns regarding both the prudent and scientific use of natural resources as well as the preservation of wildlife habitat and natural landscapes. Perhaps no other person has been so prominently identified with the conservation movement than Gifford Pinchot, but there are many others such as John Muir and Rachel Carson who have contributed to the emergence of this field.

In 1972, Meadows, et al, (commonly referred to as the Club of Rome) revived the Malthusian perspective in their classic text on the sustainability of industrialized society, The Limits to Growth. Both Mathus and the Club of Rome were concerned with finite resources and the relationships between population growth and the use of natural resources. The UN Rio Conference of 1992 can be seen as an extension of these arguments, leading to the formation of initiatives focused on sustainability such as Agenda 21. Two different types of contributions arose. First, there was the inclusion of welfare consideration, that is, the plight of poor people and the related concerns of underdevelopment. Second, there was an attempt to broaden the identification of indicators. Since then, there has been both expansion of what the underlying concept of sustainable development should include as well as widening of the number of different applications of sustainable development.

The Limits to Growth, and concerns about sustainability gave rise to a renewed emphasis among mainstream economists, including Dasupta and Heal (1979), Stiglitz (1974), and Solow (1974, 1986, 1993). Neoclassical models of economic growth were extended to consider the role of non-renewable resources. This work focuses, to some extent, on intergenerational equity and the optimal rate of extraction of exhaustible resources. Of course certain resources became depleted and the finite character of some resources such as forests became apparent. A distinction was made between renewable and non-renewable resources and within renewable resources between fast renewing resources (such as fish) or more slow renewing resources (forests). Issues regarding the overuse of common property resources, the so-called "tragedy of the commons" (Hardin, 1968) and public goods are also addressed with economic analysis. Concern also emerged about the externalities such as air or water pollution that resulted from industrial development. Quotas or other use agreements covering natural resources were developed as well as taxes to cover some of the costs associated with pollution. Economic theories were also developed to identify the optimal use of natural resources. Hotelling (1931), for example, developed a theory based on the market rate of interest, the extraction costs, tax rates, change in the stock of reserves, and the availability of a "backstop" technology. He devised a "switching point" theory in which firms or industries would optimally switch to a different resource input.

The recognition of the finite nature of certain resources led to the early definitions of sustainability. An early definition of sustainability was that "development should meet the needs of present generations without compromising the ability of future generations to meet their own needs." This notion of sustainable development grew out of a 1987 World Commission on Environment and Development Report, entitled "Our Common Future." It is often referred to as the Brundtland Report, after the chair of the committee that was commissioned to prepare it. The basic idea behind the Brundtland Report was that development should be concerned not just with attaining maximum economic growth, but also should be concerned with achieving fairness, both between individuals and groups in the current society (intra-generational) but also across generations (intergenerational equity).

1.2. International Perspectives

Many different countries have launched sustainable development initiatives. The interest in sustainability is not only in countries like Benin, Bhutan, and Costa Rica (van Vuuren and Smeets, 2000), but also in other countries with natural resources such as Brazil (Costa Neto, 2000), Thailand (Nijkamp and Vreeker, 2000), Turkey (Evrendilek and Doygun, 2000), Spain (Garciaruiz and Lasanta, 1996), India (Kartik, 1992) and China (Sardownik and Jaccard, 2001). There has long been a connection between sustainability and international development (ADB, 1990; Dasgupta and Maler, 1991; Kartik, 1992; and Hecht, 1999). The literature focuses not just on the individual country experiences, but also the extent to which social conditions have improved in these environments. Clearly, a range of different perspectives have developed. Pearce (1990) and more recently, Hecht (1999) have summarized the developing country perspectives which can be contrasted with the EU perspective (Baker, et. Al, 1997), the Canadian perspective (Colgen, 1997), Germany (Renn and Goble, 1996), and Sweden and the USA (Vail and Hultkrantz, 2000). In developing countries, the concerns focus much more on poverty alleviation and addressing short-term societal needs as well as protecting resources for the future. In developing countries there are typically significant issues related to sanitation, health and safety concerns, pollution, and the need for institutional as well as regulatory reform. International organizations such as the World Bank (2002), the World Tourism Organization (1998, 2000, 2002) have been deeply involved in not just defining sustainable development, but also identifying models of good practice, and helping to formulate both international agreements as well as country or region specific policies. Clearly larger issues such as international trade and political considerations arise within the context of the international sustainability debates.

1.3. Economic Development Perspectives

Numerous authors have recognized the interrelationships between economic development and the environment. Indeed, Goodland and Ledoc (1987) as well as Collard , et. al. (1988) have tried to find a connection between neoclassical economics and the principles of sustainable development. Their approach is similar to the work of MacNeil, et. al. (1991) and others who describe the “interdependence of the world economy and the earth’s ecology.” May and Motta (1996) go even further by promoting “strategies for pricing the planet.” These valuations have not been without controversy (Costanza, 1991). These perspectives are closely related to the notion of “economics of conservation” (Tisdell, 1988, 1991). Part of this view involves recognizing the environment as a “commodity” (Vatn, 2000). Indeed, Oates and others (1992) have written on the “economics of the environment.” The theoretical development has focused attention on concerns such as pollution or externalities (Drazen and Azariadis, 1990), valuation considerations (Daly and Townsend, 1992), measurement issues (Freeman, 1993), techniques of measuring costs and benefits (Pines, 1998), material flows (Hinterberger, 1997), competitiveness (Sonntag, 2000), job creation (Sneddon, 2000), subsidies (van Beers and van den Bergh, 2001), the role of innovation (McCulloch, et. al., 1996), business linkages (DeSimone, 1997; Hecht, 1999; Davidson, 2000). Those involved in sustainable development often refer to a “triple bottom line” in which economy, environment, and society all experience measurable gains.

It has often been said that the fundamental question that most economists focus on has to do with the allocation of scarce resources. Increasingly, land, water, and other natural resources are viewed as scarce. Resources need to be allocated not just across different economic sectors, but also across various locations and across time, as the well-being of future generations may depend on the resources passed on to them by earlier generations. Resource allocation is no doubt influenced by both how rapidly the particular resource is consumed as well as by the extent to which the resource can be renewed. Some resources are non-renewable. Once they are used up, they will not be available. Renewable resources can be relatively fast in terms of their rate of renewal (fish), or may be slower in terms of the time it takes to renew them (forests). There are some resources, such as solar energy which might be thought of as "continuous" resources because they are expected to long into the future.

1.4. Conservation and Resource Management

The literature on conversation and resource management includes not just arguments regarding the need to conserve assets for future generations, but also focuses on economic arguments for population control (Columbo, 2001 and Rajeswar, 2000). It is, therefore, not surprising to see that the relationship between resource management and development has been long recognized by UNESCO and other development agencies (Young, 1992). Conservation and resource management have focused both on specific types of resources and more generally on arguments for their prudent management. It also covers topics such as the need to conserve water resources (Daibes, 2000) Marchisio, 2000 and Sophocleous, 2000) in a variety of different settings. Wiggering (1997) has also helped to establish a linkage between geology and economic growth, aspects of which affect agricultural potential (Gong and Lin, 2000), rural systems (Midmore and Whittaker, 2000). The relationship between air, water, and soil and sustainability (Jickling, 2000), can be seen in terms of wildlife conservation issues (Lemly, et. al., 2000), open space concerns (Smith, et. al., 2000), forest management (Varma, et. al., 2000), including the management of mangroves (Ronnback and Primavera, 2000). These perspectives have also been applied to fisheries (Salmi, et. al., 2000) and shellfish management (Wefering, 2000). Economic actions can can also have an impact on biodiversity (Muller and Tisdell, 2000). Clearly, there are more complexities associated with resource management that involve consideration of not just economic factors, but also recognition of other systems (Ratter, 1996). Some of these systems are very complex (Tainter, 2000), leading some to argue for the need to recognize the relationship between sustainable development and "deep ecology" (Naess, 1997).

1.5. Scientific Perspectives

Science has much to contribute to the debates on sustainable development. Merkel (1998) has described the role of science in addressing important issues related to sustainability. Some have argued, moreover, that there is a "science of sustainability" (Costanza, 1991; Dodds, 1997). Others have maintained that sustainability can be seen in terms of evolutionary theory (Van den Bergh and Gowdy, 2000). MacNeil (1990) has argued for a scientific basis for developing strategies for sustainable development, although others such as Jorgensen (2002) have pointed out the difficulties of combining ecosystem and economic rules. There are "differing perspectives between ecologists and economists" (Tisdell, 1998). Part of the answer to resolving these differences may entail a clearer definition of indicators for sustainability (Harger and Meyer, 1996). There are numerous data analysis concerns (Hardi and DeSouza, 2000). Recent developments in information technologies may also contribute to a deeper understanding of sustainable development, particularly with respect to issues such as habitat and species loss (McLaren, 2000).

1.6. Issues Related to Data and Measurement

Hardi and DeSouza (2000) have identified data issues and analytical concerns related to sustainable development. Some of these are related to measurement issues (Freedman, 1993), particularly when different systems (economic, environmental, physical, etc.) are brought together. The data issues are complicated by uncertainties associated with measuring environmental change and the multiplicity of factors associated with sustainable development (Levy, et. al. 2000). An underlying concern with sustainable development studies has been the determination of an objective function (Friend, 1996). The issue of scale and measuring sustainable development has also been discussed (Terry, 1996). The need to clearly define indicators using scientific measurements has also been discussed across a wide variety of disciplines (Harger and Meyer, 1996). Custance and Hiller (1998) have summarized some of the statistical issues associated with sustainable development. Davis and Cahill (2000) provide a useful summary of the overall impacts of the tourism industry which include not just the transportation impacts, but also tourist activities at the destination, and various impacts associated with suppliers and consumption activities. Some recent efforts involve linking sustainable development and environmental impact assessment (Devuyst, 2000), and developing an ecosystem typology (Evredilek and Doygun, 2000) to allow for measurement of change over time. Briassolis (2000) has developed useful framework for evaluating the environmental impacts of tourism. Williams (1994) has also developed a similar framework. A popular approach involves putting sustainable development into a cost-benefit framework (Pines, 1998). But there is, especially with sustainable development, difficulties associated with defining and measuring benefits and costs, let alone the larger challenge of measuring progress (Pearce and Hamilton, 1996). Often, by focusing on a particular economic activity, such as agriculture (Pannel and Glenn, 2000), a framework for assessment can be devised. At issue, is the balancing of social and environmental factors (Hediger, 2000) and quantifying the interactions between economy and ecology (Hofkes, 1996). Another approach focuses on a specific geographic area or region (Belousova (2000). Hoffman (2000) has attempted bring together these spatial, social, economic and environmental factors for New York City. Certainly there is reason to relate these concerns, impacts, and methodologies to ongoing efforts to develop an urban systems approach (Baccinni, 1997). Another strategy involves determining threshold levels of pollution or impact and relating these to their social or economic consequences (Neumeyer, 2000). A variety of different methodologies have been proposed, utilizing for example scenario analysis (Nijkamp and Vrecker, 1988), as well as various simulation models that focus on land use change (Read, 1997), policy formulations (Bossel, 2000), using GIS (geographic information systems) technology (Cassel Gintz and Petschel Held, 2000), and the availability of new data such as hyperspectral imagery (Aspinall, 2002). There have been recent efforts to develop new methodologies and techniques for integrating spatial data, GIS technologies, remote sensing, in order to both capture environmental change as well as patterns in the environment. See for example Reynolds (2002) recent work on ecological patterning.

Kandelaars (2000), moreover, has developed a dynamic tourism simulation model that incorporates environmental, economic, government, and demographic data in Mexico.

In reviewing the literature on data and measurement related to sustainable development, there are a number of approaches which would appear to hold some promise. These include the use of cost-benefit analysis techniques, carrying capacity models, ecological footprints, and more advanced techniques.

Cost-benefit models. Cost-benefit analyses often focus on minimizing short-run average costs, or maximizing net social benefits. In the context of tourism, the efforts have often focused on determining the level of tourism which can be provided at the lowest per unit cost, then identifying the optimal flow of visitors such that marginal social benefits are equal to marginal social costs. There are often complexities associated with evaluation of cost and benefits as well as operational concerns such as specification of the geographical area and time period. Because of the inherent difficulties in measuring social costs and benefits, Johnson and Thomas (1996) suggest evaluating the current level of visitor flow, and then asking whether a change from the current level would move towards or away from a social optimum. Using this approach, the positive and negative consequences associated with differential levels of visitors over time can be estimated.

There are complexities associated with defining and measuring benefits of environmental goods. Indeed, it may be useful to distinguish between use and non-use benefits, between direct and indirect benefits, and finally between market and non-market benefits. In terms of benefit analysis, those goods or commodities derived from nature or from an ecosystem that can be directly bought and sold and consumed and thus can be priced, are, in some ways easier to handle than those in which the measurement of benefits is more difficult. Non-market benefits might include recreational opportunities, aesthetic benefits, wildlife or scenery viewing. In addition to the non-market benefits, there are also examples of indirect benefits that arise within the context of environmental resources and ecosystems. These indirect benefits do not directly provide goods or opportunities to consumers. Instead, they may support off-site ecological resources or maintain biological or biochemical processes that are required for life. Wetlands and other natural areas provide recharge for groundwater. Forests can sequester carbon, anchor soils, and provide habitats for various species. Measuring and accounting for these benefits, especially within a benefit-cost framework is difficult. Finally, there are also non-use benefits that may involve, for example, existence values, stewardship, bequest values, and other altruistic values. Species protection or the desire pass environmental benefits on to future generations are examples of a non-use benefit.

When markets for environmental goods and services exist, it is possible to example the relationships between prices and quantities. However, in the absence of such markets, it is necessary to use a variety of different techniques for determining benefit values. There are two general approaches: 1) revealed preferences; and 2) stated preferences. Revealed preferences are based on actual choices made by individuals. These include recreational demand models, focusing on either the discrete choice of destinations or looking at the willingness to pay (WTP) for travel to locations (Freeman, 1993). There are series of different hedonic price models (Rosen, 1974; Palmquist, 1991, 1988) in which the preferences among consumers for various environmental goods and services are revealed. Yet another approach to revealing preferences focuses on the willingness to pay to avert a particular state. Common among these is the cost of illness approach which involves determining the willingness to pay to avoid illness associated with contaminated water or other health risks (Rice, et. al., 1985; Cooper and Rice, 1976). The stated preference methods place values on environmental goods based on hypothetical choices typically through the use of a survey or questionnaire. Hanemann (1991) and Carson (2000) describe various approaches to contingent valuation (CV) or conjoint analysis (CA) or contingent ranking (CR) methods, which basically reveal the willingness to pay for certain environmental goods and services.

Carrying Capacity. Johnson and Thomas (1996) surveyed different approaches to measuring tourism carrying capacity. One approach emphasizes physical limits, that is the capacity of a production system to "supply tourism services or the capacity of an area to absorb tourists." This approach builds on the earlier work done by the U.S. Army Corps of Engineers (1998) in the Florida Keys, where an environmental carrying capacity model was developed. The U.S. EPA (2002) has also developed a method to quantify environmental indicators associated with key leisure activities in the U.S. Much work has been done on energy impacts associated with tourism (see Beck3n, et. al., 2000; Marbek, 1997; Tabatchnaia-Tamirisa, et. al. , 1997;) Another different way of measuring carrying capacity is to investigate perceptual limits. These can be thought of as psychological or experiential limits: "based on the tolerance of visitors by host populations" (Johnson and Thomas, 1996). There have been many surveys of resident attitudes towards tourism (Allen, et. al. 1988; Belise, 1980; Brougham and Butler, 1981; Caneday and Ziegler, 1991; Crandall, 1994; Kearlsley, Mitchell, and Dacrou, 1999; Lio, Sheldon and Var, 1987; Liu and Var, 1986; Long and Allen, 1990; McCool, 1994; Milman and Pizam, 1988; Murphy, 1981; Pearce, 1980; Pizam, 1978; Ross, 1992; Rothman, 1978; and Pizam, 1978). Pearce (1980) studied the acceptance of foreign tourists by host communities. A similar view is advanced by Mathieson and Wall (1982) involves establishment of the "maximum number of people without unacceptable decline in the quality of the experience gained by visitors." Sheldon and Abenoja (2001) focused on a mature destination (Waikiki). An increase in visitors can often lead to a deterioration of the quality of experience in recreational settings (Stankey and McCool, 1984). O'Reilly (1986) puts it in a slightly different way, that is, the "the ability to absorb tourist functions without squeezing out desirable local activities." This is similar to the notion of a "social tourism carrying capacity" (Saveriades, 2000). Coccossis (2000), Cocossis and Parpairis (1996, 1995) have written much about carrying capacity in tourism, both in general and in relation to heritage tourism sites.

Ecological footprint. The ecological footprint technique is designed to measure human impacts on local and global ecosystems. Wackernagel and Rees (1996) developed the first version of this technique, but it has been applied and used in many different settings. See a summary of country level analyses (Benin, Bhutan, Costa Rica, and the Netherlands) in Van Vuuren and Smeeds (2000). Rapport (2000) uses the technique for assessing ecosystem health. Ferng (2002) uses it to examine energy issues. The so-called "footprint" of a given population (household, neighborhood, city, region, or nation) is defined as "the total area of ecologically productive land and water used to produce all the resources (food, fuel, fiber) consumed and to assimilate all the wastes generated by that population." Resources are used from all over the world. The production process generates waste, pollution, and other byproducts. The footprint can be thought of as a sum of these ecological areas wherever that land and water may be located. The ecological footprint of a particular city is that sum total of the area of productive land outside that is appropriated for its resource consumption and waste assimilation. There is a finite area of ecologically productive land and water on the Earth. The amount of ecologically productive land available globally at today's current population is estimated to be approximately 5 acres per person. The ecological footprint of the average American is approximately 25 acres. The ecological footprint method uses accounting procedures to convert the use of resources and the generation of waste by a particular community to equivalent land areas. The consumption of food, energy, the use of various transportation systems, the consumption of goods and services as well as the resultant generation of waste all affect the calculation of the ecological footprint. Each factor is measured in specific units such as weight, miles traveled, or dollar spent) and standard multipliers are used to calculate the acres needed for food production, fuel generation, and resource use. The area is totaled to give the ecological footprint. Additional information on the ecological footprint methodology and its various applications can be found at: http://www.rprogress.org/programs/sustainability/ef/

Input-Output Analysis. Input-output analysis shows how resources flow through complex economic systems using an accounting matrix called an input-output (IO) table. Primary resources, including labor and other value added are used in the production of goods and services. Intermediate good production is accounted for through the use of an unit input coefficient, is defined as the quantity of intermediate commodity used in the production of another commodity. The matrix is balanced, in the sense that the supply of all goods is accounted for in terms of intermediate and final demand. Production or consumption associated with environmental impacts (eg, pollution) or natural resource depletion (water use, energy use) can analysed in terms of direct (through demand) or indirect (through use of intermediates) effects. For example, the visitor use of water is captured by direct expenditures on water as well as the indirect uses of water through the consumption of hotel and restaurant services which require water as an input.

Traditional Input-Output analysis relies on a Leontief assumption that unit input coefficients are fixed. Often, it is assumed that prices are fixed as well. This implies that the impacts are short-term and do not adequately capture the importance of resource scarity, the substitutability of primary and intermediate inputs, and the possibility of factor scarcities.

1.7. Politics and Sustainable Development

It is clear that many of the underlying philosophical debates and methodological differences can not be seen independent of the political and social context of development, growth, and change. As Barrett (1996) has pointed out, there are really fundamental issues regarding fairness and responsibility for stewardship. Some of this entails debates regarding the usury debates on the moral economy (Rogers, 2000), particularly when issues regarding livelihood, wealth, and the use of scarce natural resources are involved. Campbell (1996) has put this in the context of green cities versus growing cities. At the heart of these debates involve questions of ethics when balancing development objectives against the protection of the environment (Engel and Engel, 1990). This has long been debated in terms of the ethics of zero population growth (Meyercord, 2001). Barrett and Graddy (2000) put this, interestingly enough, in terms of freedom, growth, and the environment. Part of the problem also involves defining equity, or how to best optimize it. Stymne and Jackson (2000) write about intra-generational equity. Howarth and Norgaard (1990) focus on intergenerational concerns. The issue focuses on questions about how to best value the future (Heal, 1998) but also how to best measure an improvement in social welfare. A Rawlsian framework (Langhelle, 2000), in which the least well off see an improvement, might be particularly relevant to sustainable development.

There is a tendency to rely upon legal systems (Boer, 2000) to help resolve some of these conflicts. Meiners and Morriss (2000) rely upon interpretations of common law as a basis for resolving these conflicts. Others envision some kind of governance structure or system of councils (Boyer, 2000) to help in the decision-making processes.

It is interesting to note, moreover, that there are different cultural perspectives and traditional knowledge that should be considered. Erickson and Goudy (2000) examine this within the context of Pacific Islands and Costa Neto (2000) focuses the debate on a fishing community in Brazil. Mauro and Hardison (2000) put the traditional knowledge and concerns of indigenous and local communities within the broader context of international debates and policy initiatives. Loomis (2000) argues for the rights of indigenous populations to self-determine their futures. Certainly this question of how to integrate traditional knowledge into a world wide system of economic development raises broader questions related to cultural theory (Roe, 1996). Larger questions loom, such as the relationship between world peace and global sustainability (Cairns, 2000), tensions and relationships between the developed and developing world (Adams, 1992), and other aspects of collective action and social movements (Piccolomini, 1996) related to sustainable development.

1.8. Policy Planning Perspectives

There is a strong connection between policy planning and sustainable development. McDonald (1996) has written an interesting article arguing that planning can be thought of as a form of sustainable development. There has long been a connection between preservation, conservation, and planning (Strange, 1997). Chavez and Browder (1998) have summarized some of the factors associated with infrastructure planning and its relationship to environmental quality. Baccini's work (1997) focuses on a view of the city as a living organism, with a metabolism, supported by an underlying urban system, not too different from the earlier work by Patrick Geddes and others. Indeed, as David Satterthwaite (1997) has so persuasively argued, cities can also contribute to sustainability as well as being sustainable themselves. Grossman (2000) has argued that the advent of the information society can affect both the urban landscape and create new opportunities for sustainable design. Shaw and Kidd (1996) have developed a series of planning principles to guide the implementation of sustainable development programs. Campbell (1996) has also explored the connections between urban planning and sustainable cities. This has also been treated at the neighborhood scale by Barton (2000). Clearly the pattern of urban form influences transportation and energy use (Sadownik and Jaccard, 2001). Analyzing land use and land cover types provides a direct link between urban planning and environmental conditions (Pauleit and Duhme, 2000). Indeed, there has not been enough attention paid to the connection between sustainability and planning. Berke and Conroy (2000) were able to compile and review some thirty different comprehensive plans in terms of content related to sustainable development. Certainly, as Bruff and Wood (2000) have pointed out, there is need to make sense of the perspective of “politicians and professions” when it comes to sustainable development policies in local planning. Meppen's notion of a “discursive community” speaks to the general question as to how knowledge and concern for the environment and development get translated and formulated into coherent policy actions.

1.9. Sustainable Tourism

The definition of "sustainable tourism" is derived from the more general definition of "sustainable development" which as pointed out earlier, arose out of the World Commission on Environment and Development Report (1987), otherwise known as the Brundtland Report. Vail and Hultkrantz (2000) have extended that of definition to include activities that, individually and in aggregate, "function within ecological carrying capacities while contributing to durable economic prosperity and to social, civic and cultural vitality in host regions." It is interesting to note that Mowforth and Munt (1998) further extend this idea of economic sustainability to mean "a level of economic gain from the activity sufficient either to cover the cost of any special measures taken to cater for the tourist and to mitigate the effects of the tourist's presence or to offer an income appropriate to the inconvenience caused to the local community visited." Another related approach involves establishing limits to acceptable change. This idea has been advanced by Stankey, et. al. (1985) and McCool (1994) and has been applied in a variety of different settings including regional tourism planning (Ahn, Lee, and Shafer, 2002) and managing the Great Barrier Reef (Shafter and Inglis, 2000).

It is interesting to note that sustainability, then, would appear to have two different implications. One emphasizes "economic sustainability" while the other focuses more upon "environmental sustainability." Indeed, McKercher (1993) as well as Garrod and Fyall (1998) reach similar conclusions about the meaning of sustainability, referring to a "development-oriented approach, supported by the tourism industry" and an "ecological perspective" that is more consistent with the conservation movement.

The increased availability of data on tourism and travel such as that furnished by the U.S. Travel Data Center (2000) has led to a wide array of different techniques for estimating the impacts of tourism. Kottke (1988), for example, used linear programming techniques to estimate the economic impacts of tourism growth, maximizing gross tourism income subject to constraints such as land and labor. Various states including South Carolina and Hawaii (World Travel and Tourism Council, 1996, 1998, 2001) have also made use of the tourism satellite accounts. Using input-output data from national and regional accounts as well as from state databases (see for more detail, U.S. Department of Commerce, 1992), there have been a variety of different multiplier models that have estimated the impact of tourism on various economies. See Briassolis (1991) for a discussion of methodological issues related to input-output analysis. Others who have utilized this technique include (Delos Santos, et. Al, 1983; Heng and Low, 1990; Jackson, et. Al. 1990, Johnson and Moore, 1993, Lin and Sung, 1983; Pomeroy, Uysal, and Lamberte, 1988, Schafer, 1985). Khan, et. Al. (1990) estimated the tourism multiplier effects for Singapore. Song and Ahn (1983) calculated them for Korea. Mamente (1999) looked at regional economic issues associated with tourism in Italy. Summary (1987) focused on tourism' contributions to Kenya. Schafer (1985) used input-output analysis to measure the impact of tourist expenditures in Hawaii. Liu (1986) estimated did so for Hawaii. Liu and Var (1984) estimated the multipliers for Turkey. They also calculated the differential multipliers for various parts of the visitor industry (Liu and Var, 1982), as did Milne (1987). Wanhill, (1988) examines various multipliers under capacity constraints. Pomery, Uysal, and Lamberte (1988) focused on coastal tourism and recreation. Tabatchnaia, et. al. (1997) used input-output analysis to estimate energy demands for tourists in Hawaii. The availability of both regional input-output data and software packages such as RIMS (U.S. Department of Commerce, 1992), or IMPLAN (Douglas and Harpman, 1995; Stynes and Propst, 1996)

1.10. Conclusion

Based on this comprehensive review of the literature, the researchers have determined that there is a need to develop a common and systematic approach that integrates environmental and economic models in the analysis of tourism impacts. Input-output analysis, for example, captures first-order effects associated with increases in visitor demands on an economy. However, it is important to capture feedback mechanisms associated with the use of natural resources and labor, through price and other effects. Thus, the analysis will involve the development of more advanced methods such as a computable general equilibrium (CGE) modeling. Such an approach, while data and computationally intensive is no doubt the appropriate framework for both assessing the impacts of various development scenarios, but also, perhaps more importantly, it provides an approach to consider various policy approaches. The starting point involves the allocation of resources and the resultant interrelationships for an entire economy with all its diverse components (households, firms, and government). Potential alternatives can be modeled as economic changes that move from one state of equilibrium to another. The difference in the old state, vis-à-vis the new one, moreover, can be measured in terms of the changes in prices, quantities consumed and produced, employment, profits, and other economic quantities. As such, equilibrium models can be used to characterize the net welfare changes for each affect group in the model.

Some work has been done in this area including (Adam and Parmeter, 1995). Cooper and Wilson (2001) have incorporated CGE modeling with tourism satellite accounts in the UK, in order to model the effects of various shocks on industrial sectors, GDP, and employment. Zhou, et. al., (1997) have compared CGE and input-output models for Hawaii. Alavalapati and Wiktor (2000) have developed a model using a CGE framework to estimate environmental damage resulting from tourism. Our analysis will extend this work by also incorporating within a CGE model, scientific and spatial models of the environment.

REFERENCES

Adam, Philip D and Brian R. Parmenter, 1995, An Applied General Equilibrium Analysis of the Economic Effects of Tourism in a Quite Small, Quite Open Economy, *Applied Economics* 27, 985-994.

Adams, William M., 1992, Green Development: Environment and Sustainability in the Third World (New York: Routledge).

Ahn, Bum Yong, BongKoo Lee, and C. Scott Shafer, 2002, Operationalizing Sustainability in Regional Tourism Planning: An Application of the Limits of Acceptable Change Framework, *Tourism Management* 23, 1-15.

Alavalapati, Janaki R.R. and Wiktor L. Adamowicz, 2000, Tourism Impact Modeling for Resource Extraction Regions, *Annals of Tourism Research* 27(1), 188-202.

Alcock, R., 1997, Consumption and sustainable development, *Science* 276(5319): 1632-1633.

Allen, L., P. Long, R. Perdue, and S. Kielelbach, 1988, The Impact of Tourism Development on Resident's Perceptions of Community Life, *Journal of Travel Research* 27 (Summer), 16-21.

Annan, K.A., 2000, Sustaining the earth in the new millennium: The UN secretary-general speaks out, *Environment* 42(8), 20-30.

Arrow, K. J. and A. C. Fisher, 1974, Environmental Preservation, Uncertainty, and Irreversibility. Quarterly Journal of Economics, 88(1), 1-8.

Asian Development Bank, 1990, Economic Policies for Sustainable Development (Manila, Philippines: Asian Development Bank).

Aspinall, R., 2002, Use of logistic regression for validation of maps of the spatial distribution of vegetation species derived from high resolution hyperspectral remotely sensed data, Ecological Modeling, 157, 301-312.

Atkin, J., A. Cobb, et al., 1997, "Sustainable Development." Scientific American 277(2): 8-8.

Atkinson, G. and K. Hamilton, 1996, Accounting for progress: Indicators for sustainable development. Environment 38(7): 16.

Baccini, P. (1997). "A city's metabolism: Towards the sustainable development of urban systems." Journal of Urban Technology 4(2): 27-39.

Baker, S., M. Kousis, et al. (1997). The theory and practice of sustainable development in EU perspective - Introduction. Politics of Sustainable Devel: 1-40.

Barbier, E. B. and A. Markandya, "The Conditions for Achieving Environmentally Sustainable Development" European Economic Review, Vol. 34, No. 2-3 (May, 1990): 659-69.

Barbier, Edward B., Economics, Natural-Resource Scarcity and Development: Conventional and Alternative Views (London, UK: Earthscan, 1989).

Barrett, C. B. (1996). "Fairness, stewardship and sustainable development." Ecological Economics 19(1): 11-17.

Barrett, S and K. Graddy, "Freedom, Growth and the Environment" Vol. 5, No. 4 (2000): 433-456.

Barton, H. Sustainable Communities: The Potential for Eco-Neighborhoods. (London, UK: Earthscan, 2000).

Baumol, W. J. and W. E. Oates, The Theory of Environmental Policy (Cambridge, England: Cambridge University Press, 1988).

Becker, J., "Examples of sustainable development efforts in Costa Rica" International Journal of Sustainable Development and World Ecology Vol. 5, No. 3 (1998): 172-181.

Becker, J., "Sustainable development assessment for local land uses" International Journal of Sustainable Development and World Ecology Vol. 5, No. 1 (1998): 59-69.

Becken, Susanne, Chris Frampton, David Simmons, 2001, Energy Consumption Patterns in the Accommodation Sector – the New Zealand Case, Ecological Economics, 39, 371-386.

Belisle, F., D. Hoy, 1980, The Perceived Impacts of Tourism by Residents, A Case Study of Santa Marta, Colombia, Annals of Tourism Research, 7(1), 84-100

Belousova, A.P., "A concept of forming a structure of ecological indicators and indexes for regions sustainable development" Environmental Geology Vol. 39, No. 11 (2000): 1227-1236.

Bergstrom, J., J. Stoll, J. Titre, and V. Wright, 1990, Economic Value of Wetlands-Based Recration, Ecological Economics, 2(2), 129-148.

Berke, P.R. and M.M. Conroy, "Are we planning for sustainable development? An evaluation of 30 comprehensive plans" Journal of the American Planning Association Vol. 66, No. 1 (2000): 21-33.

Binswanger, M. (2001). "Technological progress and sustainable development: what about the rebound effect?" Ecol Econ 36(1): 119-132.

Boer, B., "Sustainability law for the new millennium and the role of environmental legal education" Water Air and Soil Pollution Vol. 123, No. 1-4 (2000): 447-465.

Bossel, H., "Policy assessment and simulation of actor orientation for sustainable development" Ecological Economics Vol. 35, No. 3 (2000): 337-355.

Bostedt, Goran and Leif Mattsson, 1995, The Value of Forests for Tourism in Sweden, Annals of Tourism Research, 22, 671-680.

Boyd, Stephen W. and Bulter Richard W., 1996, Managing Ecotourism: an Opportunity Spectrum Approach, Tourism Management, 17(8), 557-566.

Boyer, B., "Institutional mechanisms for sustainable development: a look at national councils for sustainable development in Asia" Global Environmental Change - Human and Policy Dimensions Vol. 10, No. 2 (2000): 157-160.

Briassoulis, H., 1991, Methodological Issues: Tourism Input-Output Analysis, Annals of Tourism Research, 18, 485-494.

Briassoulis, Helen, 2000, Environmental Impacts of Tourism: A Framework for Analysis and Evaluation, in H. Briassoulis and J.V.D. Straaten (Eds), Tourism and the Environment, Regional Economic, Cultural and Policy Issues, Revised Second Edition, Boston: Kluwer Academic Publishers.

Brougham, J. E. and R.W. Butler, 1981, A Segmentation Analysis of Residents' Attitudes to the Social Impact of Tourism, Annals of Tourism Research, 8(4), 568-587.

Bruff, G.E. and A.P. Wood, "Making sense of sustainable development: politicians, professionals, and policies in local planning" Environment and Planning C - Government and Policy Vol. 18, No. 5 (2000): 593-607.

Butler, R W and L. A. Waldbrook, 1991, A New Planning Tool: the Tourism Opportunity Spectrum, Journal of Tourism Studies, 2(1), 1-14.

Button, Kenneth, Transport, the Environment and Economic Policy (Cheltenham, UK: Edward Elgar Publishing, 1992).

Cairns, J. (1997). "Sustainability, ecosystem services, and health." International Journal of Sustainable Development and World Ecology 4(3): 153-165.

Cairns, J., "The role of ecotoxicology in the protection and accumulation of natural capital" Ecotoxicology Vol. 9, No. 3 (2000): 151-155.

Cairns, J., "World peace and global sustainability" International Journal of Sustainable Development and World Ecology Vol. 7, No. 1 (2000): 1-11.

Campbell, S. (1996). "Green cities, growing cities, just cities? Urban planning and the contradictions of sustainable development." Journal of the American Planning Association 62(3): 296-312.

Caneday, L., and J. Zeiger, 1991, The Social, Economic and Environmental Costs of Tourism to a Gaming Community as Perceived by its Residents, Journal of Travel Research, 30 (Fall), 45-49.

CasselGintz, M. and G. PetschelHeld, "GIS-based assessment of the threat to world forests by patterns of non-sustainable civilisation nature interaction" Journal of Environmental Management Vol. 59, No. 4 (2000): 279-298.

Chevas, J.P., J. Stoll, and C. Sellar, 1989, On the Commodity Time Value of Travel Time in Recreational Activities, Applied Economics, 21, 711-722.

Chavez, R.G. and J. Browder, "Infrastructure planning and sustainable development" Journal of Urban Planning and Development - ASCE Vol. 124, No. 3 (1998): 133-135.

Chichilnisky, G. (1997). "What is sustainable development?" Land Economics 73(4): 467-491.

Clark, W. C. (1996). "Sustainable development redux." Environment 38(4): COV2.

Coccossis, Harry N., 2000, Tourism and the Environment: Some Observations on the Concept of Carrying Capacity, in H. Briassoulis and J.V.D. Straaten (Eds), Tourism and the Environment, Regional Economic, Cultural and Policy Issues, Revised Second Edition, Boston: Kluwer Academic Publishers.

Coccossis, Harry N. and A. Parpairis, 1996, Tourism and Carrying Capacity in Coastal Areas, in G.K. Priestley and H. Coccossis (Eds), Sustainable Tourism, CAB International, Wallingford.

Coccossis, Harry N. and A. Parpairis, 1995, Assessing in Interaction between Heritage, Environment, and Tourism: Mykonos, in H. Coccossis and P. Nijkamp (Eds), Sustainable Tourism Development, Avebury, London.

Colgan, C. S. (1997). ""Sustainable development" and economic development policy: Lessons from Canada." Economic Development Quarterly 11(2): 123-137.

Collard, David, et al., Economics, Growth and Sustainable Environments (London: Macmillan, 1988).

Colombo, U., "The Club of Rome and sustainable development" Futures Vol. 33, No. 1 (2001): 7-11.

Common, M. and C. Perrings, "Toward an Ecological Economics of Sustainability" Ecological Economics Vol. 6, No. 1 (1992): 7-34.

Cooper, Adrian and Alan Wilson, 2001, Extending the Relevance of TSA Research for the UK: General Equilibrium and Spillover Analysis, Oxford: Oxford Economic Forecasting Ltd.

Copeland, Brian R., 1991, Tourism, Welfare and De-industralization in a Small Open Economy, Economica, 58, 515-529.

Costa Neto, E.M., "Sustainable development and traditional knowledge: A case study in a Brazilian artisanal fishermen's community" Sustainable Development Vol. 8, No. 2 (2000): 89-95.

Costanza, Robert, Ecological Economics: The Science and Management of Sustainability (New York, NY: Columbia University Press, 1991).

Crandall Louise, 1994, The Social Impact of Tourism on Developing Regions and its Mansurement, in J.R. Brent Ritchie and Charles R. Goeldner (Eds), Travel, Tourism, and Hospitality Research, Second Edition, New York: John Wiley and Sons Inc.

Cropper, M. and A. M. Freeman (1991) Environmental Health Effects. In J. Braden and C. Kolstad, eds., Measuring the Demand for Environmental Quality. Amsterdam. Elsevier Science Publishers.

Cropper, Maureen L. and Wallace E. Oates, "Environmental Economics: A Survey" Journal of Economic Literature, Vol. 30, No. 2 (June, 1992): 675-740.

Custance, J. and H. Hillier, "Statistical issues in developing indicators of sustainable development" Journal of the Royal Statistical Society Series A - Statistics in Society Vol. 161(1998): 281-290.

Daibes, F., "Towards sustainable development in the water sector: a perspective from Palestine" Water Science and Technology Vol. 42, No. 1-2 (2000): 81-86.

Daly, Herman E. and Kenneth E. Townsend, ed. Valuing the Earth: Economics, Ecology, Ethics (Cambridge, MA: MIT Press, 1992).

Dasgupta, Partha and Geoffrey M. Heal, 1979, Economic Theory and Exhaustible Resources, Cambridge: Cambridge Univeristy Press.

Dasgupta, Partha and Karl-Goran Maler, "The Environment and Emerging Development Issues" in S. Fischer, et. al. ed. Proceedings of the World Bank Annual Conference on Development Economics 1990, (Washington: The World Bank, 1991): 101-132.

Davidson, J., "Sustainable development: Business as usual or a new way of living?" Environmental Ethics Vol. 22, No. 1 (2000): 25-42.

Davies, Terry and Sarah Cahill, 2000, Environmental Implications of the Tourism Industry, Washington, DC: Resources for the Future, Discussion Paper 00-14.

Degraaf, H. J., C. J. M. Musters, et al. (1996). "Sustainable development: Looking for new strategies." Ecological Economics 16(3): 205-216.

Delos Santos, Jaime S., Evangeline M. Ortiz, Emmelyn Huang, and Francisco Secretario, 1983, Philippines, in T.Lin and E.A. Pye (Eds), Tourism in Asia: The Economic Impact, Singapore: Singapore University Press.

Desimone, L. D. (1997). Eco-Efficiency: The Business Link to Sustainable Development. Cambridge, MA, MIT Press.

Devuyst, D., "Linking impact assessment and sustainable development at the local level: The introduction of sustainability assessment systems" Sustainable Development Vol. 8, No. 2 (2000): 67-78.

Dodds, S. (1997). "Towards a 'science of sustainability': Improving the way ecological economics understands human well-being." Ecological Economics 23(2): 95-111.

Douglas, A.J. and D.A. Harpman, 1995, Estimating Recreation Employment Effects with IMPLAN for the Glen Canyon Dam Region, Journal of Environmental Management, 44, 233-247.

Drazen, A. and C. Azariadis, "Threshold Externalities in Economic Development" Quarterly Journal of Economics, (May, 1990): 501-26.

Elkington, John and Jonathan Shopley, Cleaning Up: U. S. Waste Management Technology and Third World Development (Washington: World Resources Institute, 1989).

Endress, L. and J. Roumasset, "Golden Rules for Sustainable ResourceManagement," Economic Record, v. 70, n. 210 (1994): 267-277.

Engel, J. Ronald and Joan Gibb Engel, Ethics of Environment and Development: Global Challenge and International Response (Tucson: Univerity of Arizona Press, 1990).

Erickson, J.D. and J.M. Gowdy, "Resource use, institutions, and sustainability: A tale of two Pacific Island cultures" Land Economics Vol. 76, No. 3 (2000): 345-354.

Evrendilek, F. and H. Doygun, "Assessing major ecosystem types and the challenge of sustainability in Turkey" Environmental Management Vol. 26, No. 5 (2000): 479-489.

Farrow, S. "Environmental Equity and Sustainability: Rejecting the Kaldor Hicks Criteria" Ecological Economics, Vol. 27, No. 2 (1998): 183-188.

Faucheux, S. and I. Nicolai, "Environmental technological change and governance in sustainable development policy" Ecological Economics Vol. 27, No. 3 (1998): 243-256.

Ferng, Jiun-Jiun (2002) “Toward a scenario analysis for energy footprints” Ecological Economics 40. 53-69.

Filho, W. L. (1996). Putting Principles into Practices: Sustainable Tourism in Small Island States. In L. Briguglio, B. Archer, J. Jafari & G. Wall (Eds.), *Sustainable Tourism in Islands & Small States: Issues and Policies* (pp. 61-68). London, England: Pinter.

Fletcher, J.E., 1989, Input-Output Analysis and Tourism Impact Studies, Annals of Tourism Research, 16, 514-529.

Frazier, J. G. (1997). "Sustainable development: modern elixir or sack dress?" Environmental Conservation 24(2): 182-193.

Freeman, A. Myrick III, (1993) The Measurement of Environmental and Resource Values .Washington, DC: Resources for the Future, Inc.

Friend, A. M. (1996). "Sustainable development indicators: Exploring the objective function." Chemosphere 33(9): 1865-1887.

Frechtling, Douglas C., 1994, Assessing the Economic Impacts of Travel and Tourism – Measuring Economic Benefits, in J.R. Brent Ritchie and Charles R. Goeldner (Eds), Travel, Tourism, and Hospitality Research, Second Edition, New York: John Wiley and Sons Inc.

Fyall, A and B Garrod, 1997, Sustainable Tourism: Towards a Methodology for Implementing the Concept, in M.J. Stabler, Tourism and Sustainability, Principles to Practice, 51-68, Oxon: CAB International.

Garciaruiz, J. M., T. Lasanta, et al. (1996). "Land-use changes and sustainable development in mountain areas: A case study in the Spanish Pyrenees." Landscape Ecology 11(5): 267-277.

Garrod, B. and A. Fyall. (1998) “Beyond the Rhetoric of Sustainable Tourism” Tourism Management. Vol. 19. No. 3. pp. 199-212.

Ghai, Dharam, ed. Grassroots Environmental Action: People's Particpation in Sustainable Development (London: Routledge, 1992).

Gibbs, D., "Regional development agencies and sustainable development" Regional Studies Vol. 32, No. 4 (1998): 365-368.

Gibbs, D.C., et al., "'Struggling with sustainability': weak and strong interpretations of sustainable development within local authority policy" Environment and Planning A Vol. 30, No. 8 (1998): 1351-1365.

Gilbert, A. (1996). "Criteria for sustainability in the development of indicators for sustainable development." Chemosphere 33(9): 1739-1748.

Girard, L.F., "The institutional dimension of urban sustainable development" International Journal of Environment and Pollution Vol. 10, No. 1 (1998): 163-176.

Goldin, Ian and L. Alan Winters, ed. The Economics of Sustainable Development (Cambridge, UK: Cambridge University Press, 1995).

Gong, J.H. and H. Lin, "Sustainable development for agricultural region in China: case studies" Forest Ecology and Management Vol. 128, No. 1-2 (2000): 27-38.

Goodland, Robert and G. Ledoc, "Neoclassical Economics and Principles of Sustainable Development" Ecological Modeling, Vol. 38(1987).

Gowdy, J. W. and C. N. McDaniel (1999). "The Physical Destruction of Nauru: An Example of Weak Sustainability." Land Economics 75(2): 333-38.

Graham, R P Nilsen, and R J Payne, 1988, Visitor Management in Canadian National Parks, Tourism Management, 9(1), 44-62.

Grossmann, W.D., "Realising sustainable development with the information society - the holistic Double Gain-Link approach" Landscape and Urban Planning Vol. 50, No. 1-3 (2000): 179-193.

Gudmundsson, H. and M. Hojer (1996). "Sustainable development principles and their implications for transport." Ecological Economics 19(3): 269-282.

Hanemann, W. M. (1994) Valuing the Environment Through Contingent Valuation. Journal of Economic Perspectives. 8 (4): 19-43.

Hardin, Garrett, 1968, The Tragedy of the Commons, Science, 162.

Hardi, P. and J.A. DeSouzaHuletey, "Issues in analyzing data and indicators for sustainable development" Ecological Modelling Vol. 130, No. 1-3 (2000): 59-65.

Harger, J. R. E. and F. M. Meyer (1996). "Definition of indicators for environmentally sustainable development." Chemosphere 33(9): 1749-1775.

Harrison, D. (1996). Sustainability and Tourism: Reflections from a Muddy Pool. In L. Briguglio, B. Archer, J. Jafari & G. Wall (Eds.), *Sustainable Tourism in Islands & Small States: Issues and Policies* (pp. 69-89). London, England: Pinter.

Harrison, Neil E., Constructing Sustainable Development (Albany, NY: State University of New York Press, 2000).

Heal, G.,Valuing the Future: Economic Theory and Sustainability, Columbia U.Press, 1998.

Heang, K. B. (1997). Sustainable development: A Southeast Asian perspective. Environmental Sustainability: 67-83.

Heaton, George, et al., Transforming Technology: An Agenda for Environmentally Sustainable Growth in the Twenty-First Century (Washington: World Resources Institute, 1991).

Hecht, A. D. (1999). "The Triad of Sustainable Development: Promoting Sustainable Development in Developing Countries." The Journal of Environment and Development 8(2).

Hediger, W., "Sustainable development and social welfare" Ecological Economics Vol. 32, No. 3 (2000): 481-492.

Heng, T.M. and L. Low, 1990, Economic Impact of Tourism in Singapore, Annals of Tourism Research, 17, 246-269.

Hinterberger, F., F. Luks, et al. (1997). "Material flows vs. natural capital - What makes an economy sustainable?" Ecological Economics 23(1): 1-14.

Hoffman, J., "The roots index: Exploring indices as measures of local sustainable development, New York City: 1990-95" Social Indicators Research Vol. 52, No. 2 (2000): 95-134.

Hofkes, M. W. (1996). "Modeling sustainable development: An economy-ecology integrated model." Economic Modeling 13(3): 333-353.

Holley, M., "Sustainable development in Central America: Translating regional environmental accords into domestic enforcement action" Ecology Law Quarterly Vol. 25, No. 1 (1998): 89-119.

Holmberg, Johan, ed. Making Development Sustainable: Redefining Institutions, Policy and Economics (Washington, DC: Island Press, 1992).

Hotelling, Harold, 1931, The Economics of Exhaustible Resources, Journal of Political Economy, 39, 137-175.

Howarth, R. B. and R. B. Norgaard, "Intergenerational Resource Rights: Efficiency and Social Optimality" Land Economics, Vol. 66, No. 1 (February, 1990): 1-11.

Hunter, Colin “Sustainable Tourism as an Adaptive Paradigm” Annals of Tourism Research. Vol 24. No. 4. 1997. 850-867.

Hunter, Colin and Howard Green. Tourism and the Environment: A Sustainable Relationship? New York: Rutledge. 1995.

IyerRaniga, U. and G. Treloar, "A context for participation in sustainable development" Environmental Management Vol. 26, No. 4 (2000): 349-361.

Jackson, Scoot R., Daniel J. Stynes, Dennis B. Propst, and Eric L. Siverts, 1990, Economic Impact Analysis as a Tool in Recreation Program Evaluation, Instructional Report R-92-1, Department of the Army, Waterways Experiment Station, Vicksburg, MS.

Jickling, B., "A future for sustainability?" Water Air and Soil Pollution Vol. 123, No. 1-4 (2000): 467-476.

Johnson, F. R., W. H. Desvousges, L. L. Wood, and E. Fries (1994) Conjoint Analysis of Environmental Preferences: Conceptual, Econometric, and Practical Considerations. Paper presented at American Agricultural Economic Association Meetings. San Diego.

Johnson, P., & Thomas, B. (1996). Tourism Capacity: A Critique. In L. Briguglio, B. Archer, J. Jafari & G. Wall (Eds.), *Sustainable Tourism in Islands & Small States: Issues and Policies* (pp. 118-136). London, England: Pinter.

Johnson, Rebecca .L. and Eric Moore, 1993, Tourism Impact Estimation, Annals of Tourism Research, 20, 279-288.

Jorgensen, S. “Explanation of ecological rules and observation of ecosystem theory and ecological models.” Ecological Modeling. 158. (2002) pp. 241-248.

Kandelaars, Petrica, (2000), A Dynamic Simulation Study of Tourism and Environment in the Yucatan Peninsula in Mexico, in H. Briassoulis and J.V.D. Straaten (Eds), Tourism and the Environment, Regional Economic, Cultural and Policy Issues, Revised Second Edition, Boston: Kluwer Academic Publishers.

Kartik, C. Roy, et al., ed. Economic Development and Environment: A Case Study of India (Oxford, UK: Oxford University Press, 1992).

Kearsley, W., R. Mitchell, and W. Dacrou, 1999, Sustainable Tourism Project Delphi Report, Centre for Tourism, Unviersity of Otago, Dunedin, NZ.

Khan, H., C.F. Seng, and W.K.Cheong, 1990, Tourism Multiplier Effects on Singapore, Annals of Tourism Research, 17, 408-418.

Kottke, Marvin, 1988, Estimating Economic Impacts of Tourism, Annals of Tourism Research, 15, 122-133.

Krautkramer, Jeffrey A. and Raymond G. Batina, "On Sustainability and Intergenerational Transfers with a Renewable Resource" Land Economics Vol. 75, No. 2 (1999): 167-84.

Kulik, Omno and Harmen Verbruggen, In Search of Indicators of Sustainable Development (Hingam, MA: Kluwer academic Publishers, 1991).

Langhelle, O., "Sustainable development and social justice: Expanding the rawlsian framework of global justice" Environmental Values Vol. 9, No. 3 (2000): 295-323.

Langhelle, O., "Sustainable development: Exploring the ethics of Our Common Future" International Political Science Review Vol. 20, No. 2 (1999): 129-149.

Lee, Coong-Ki, 1997, Valuation of Nature-Based Tourism Resources Using Dichotomous Choice Contingent Valuation Method, 18(8), 587-591.

Lemly, A.D., et al., "Irrigated agriculture and wildlife conservation: Conflict on a global scale" Environmental Management Vol. 25, No. 5 (2000): 485-512.

Levy, J.K., et al., "Using environmental indicators to quantify the robustness of policy alternatives to uncertainty" Ecological Modeling Vol. 130, No. 1-3 (2000): 79-86.

Lewis, T.L., "Media representations of "sustainable development" - Sustaining the status quo?" Science Communication Vol. 21, No. 3 (2000): 244-273.

Li, C.Z. and K.G. Lofgren, "Renewable resources and economic sustainability: A dynamic analysis with heterogeneous time preferences" Journal of Environmental Economics and Management Vol. 40, No. 3 (2000): 236-250.

Lin, Tzong-biau and Yun-Wing Sung, 1983, Hong Kong, in T.Lin and E.A. Pye (Eds), Tourism in Asia: The Economic Impact, Singapore: Singapore University Press.

Lindberg, K. and R.L. Johnson, 1997, The Economic Value of Tourism's Social Impacts, Annals of Tourism Research, 24, 90-116.

Liu, Juanita C., 1986, Relative Economic Contributions of Visitor Groups in Hawaii, Journal of Travel Research, 26, 2-9.

Liu, Juanita C., and Turgut Var, 1984, Tourism-income Multipliers for Turkey, Tourism Management, 5(4), 280-287.

Liu, Juanita C., and Turgut Var, 1986, Resident Attitudes Toward Tourism Impacts in Hawaii, Annals of Tourism Research, 13(2), 193-214.

Liu, Juanita C. and Turgut Var, 1982, Differential Multipliers for the Accommodation Sector, Tourism Management, 3(3), 177-187.

Liu, Juanita C., Pauline J. Sheldon, and Turgut Var, 1987, Resident Perception of the Environmental Impacts of Tourism, Annals of Tourism Research, 14, 17-37.

Loomis, L and A R Graefe, 1992, Overview of NPCA's Visitor Impact Management Process, paper presented at the IVth World Congress on Parks and Protected Areas, Caracas, Venezuela.

Long, P., R. Perdue, and L. Allen, 1990, Rural Resident Tourism Perceptions and Attitudes by Commodity Level of Tourism, Journal of Travel Research, 28(Winter), 3-9.

Loomis, T.M., "Indigenous populations and sustainable development: Building on indigenous approaches to holistic, self-determined development" World Development Vol. 28, No. 5 (2000): 893-910.

MacNeill, Jim, "Strategies for Sustainable Development," Scientific American Vol. 261, No. 3, (September 1, 1990): 154-165.

MacNeill, Jim, et al., Beyond Interdependence: The Meeting of the World's Economy and the Earth's Ecology (New York: Oxford University Press, 1991).

Malthus, Thomas R., 1798, An Essay on the Principle of Population as it Affects the Future Improvement of Society. (New York: Norton Press, 1976).

Manente, Mara, 1999, Regional and Inter-Regional Economic Impacts of Tourism Consumption: Methodology and the Case of Italy, Tourism Economics, 5(4), 425-436.

Marbek Resource Consultants and Policy Research International, 1997, Energy Efficiency and Tourism: Focus on the Caribbean, a Discussion Paper prepared for the Roundtable on Energy Efficiency – Tourism Sector, Kingston, Jamaica.

Marchisio, S., "Sustainable management of water resources and international law" Water Science and Technology Vol. 42, No. 1-2 (2000): 241-247.

Markandya, Anil and Julie Richardson, ed. The Earthscan Reader in Environmental Economics (London, UK: Earthscan Publications Ltd., 1992).

Mathieson, A., & Wall, G. (1982). *Tourism: Economic, Physical and Social Impacts.* Harlow: Longman.

Matthee, M. and D. Vermersch, "Are the precautionary principle and the international trade of genetically modified organisms reconcilable?" Journal of Agricultural & Environmental Ethics Vol. 12, No. 1 (2000): 59-70.

Mauro, F. and P.D. Hardison, "Traditional knowledge of indigenous and local communities: International debate and policy initiatives" Ecological Applications Vol. 10, No. 5 (2000): 1263-1269.

May, P. and R. S. d. Motta, Eds. (1996). Pricing the Planet: Economic Analysis for Sustainable Development. New York, Columbia University Press.

McCool, Stephen F., 1994, Planning for Sustainable Nature Dependent Tourism Development: The Limits of Acceptable Change System, 19(2), 51-55.

McCool, Stephen F. and Steven R. Martin, 1994, Community Attachment and Attitudes Toward Tourism Development, Journal of Travel Research, 32, 29-34.

Mcculloch, A., J. Moxen, et al. (1996). "Sustainable development and innovation: Bringing in the Scottish voluntary environmental sector." Regional Studies 30(3): 305-310.

Mcdonald, G. T. (1996). "Planning as sustainable development." Journal of Planning Education and Research 15(3): 225-236.

McLaren, J.S., "Future renewable resource needs: will genomics help?" Journal of Chemical Technology and Biotechnology Vol. 75, No. 10 (2000): 927-932.

McKercher, B. (1993) "The unrecognized threat to tourism: can tourism survive sustainability." Tourism Management. April. Pp. 131-136.

Meadowcroft, J. (1997). "Planning, democracy and the challenge of sustainable development." International Political Science Review 18(2): 167-189.

Meadowcroft, J., "Sustainable development: a new(Ish) idea for a new century?" Political Studies Vol. 48, No. 2 (2000): 370-387.

Meadows, D. H., D.L. Meadows, J. Randers, and W. W. Beharans, 1972, The Limits to Growth. Universe Books. New York.

Mega, V. (1996). "Our city, our future: Towards sustainable development in European cities." Environment and Urbanization 8(1): 133-154.

Meiners, R. E. and A. P. Morriss, Eds. (2000). The Common Law and the Environment: Rethinking the Statutory Basis for Modern Environmental Law. Lanham, MD, Rowman & Littlefield.

Meppem, T. and R. Gill, "Planning for sustainability as a learning concept" Ecological Economics Vol. 26, No. 2 (1998): 121-137.

Meppem, T., "The discursive community: evolving institutional structures for planning sustainability" Ecological Economics Vol. 34, No. 1 (2000): 47-61.

Merkel, A., "The role of science in sustainable development" Science Vol. 281, No. 5375 (1998): 336-337.

Meyercord, K. (2001) The Ethics of Zero Growth (Avaialable from Zero Growth, P. O. Box 23924, Pleasant Hill, CA 94523)

Midmore, P. and J. Whittaker, "Economics for sustainable rural systems" Ecological Economics Vol. 35, No. 2 (2000): 173-189.

Milman, Ady, and Abraham Pizam, 1988, Social Impacts of Tourism on Central Florida, Annals of Tourism Research, 15(2), 191-204.

Milne, S.S., 1987, Differential Multipliers, Annals of Tourism Research, 14(4), 499-515.

Moffatt, I., "Ecological footprints and sustainable development" Ecological Economics Vol. 32, No. 3 (2000): 359-362.

Mowforth, M., & Munt, I. (1998). *Tourism and Sustainability*. London: Routledge.

Muller, F., et al., "Indicating ecosystem integrity - theoretical concepts and environmental requirements" Ecological Modelling Vol. 130, No. 1-3 (2000): 13-23.

Muller, F.G. and C. Tisdell, "Biodiversity, conservation and sustainable development. Principles and practices with Asian examples (Vol 34, pg 156, 2000)" Ecological Economics Vol. 35, No. 2 (2000): 305.

Munda, G. (1997). "Environmental economics, ecological economics, and the concept of sustainable development." Environmental Values 6(2): 213-233.

Murphy, Peter, 1981, Community Attitudes to Tourism, International Journal of Tourism Management, (September), 189-195.

Naess, A. (1997). Sustainable development and the deep ecology movement. Politics of Sustainable Development: 61-71.

Neumayer, E., "On the methodology of ISEW, GPI and related measures: some constructive suggestions and some doubt on the 'threshold' hypothesis" Ecological Economics Vol. 34, No. 3 (2000): 347-361.

Nijkamp, Peter. and R. Vreeker, "Sustainability assessment of development scenarios: methodology and application to Thailand" Ecological Economics Vol. 33, No. 1 (2000): 7-27.

Nijkamp, Peter and Frits Soeteman, "Ecologically Sustainable Development: Key Issues for Strategic Environmental Management" International Journal of Social Economics, Vol. 15, No. 3-4 (1988): 88-102.

Oates, Wallace, ed., The Economics of the Environment (Cheltenham, UK: Edward Elgar Publishing, 1992).

Opschoor, J. B. and S. M. Jongma (1996). "Bretton Woods Intervention Programmes and Sustainable Development." Environment and Development Economics 1(2): 183-202.

O'Reilly, A. (1986). Tourism Carrying Capacity: Concepts and Issues. *Tourism Management, 7*, 254-258.

Palmer Jones, R. and C. Jackson (1997). "Work intensity, gender and sustainable development." Food Policy 22(1): 39-62.

Palmquist, R. B. (1988) Welfare Measurement for Environmental Improvements Using the Hedonic Price Model: The Case of Nonparametric Marginal Prices. Journal of Environmental Economics and Management. 15. 297-312.

Palmquist, R. B. (1991) Hedonic Methods. In. J. Braden and C. Kolstad, ed., Measuring the Demand for Environmental Quality. Amsterdam. The Netherlands. Elsevier Science Publishing.

Panayotou, Theodore, Green Markets: The Economics of Sustainable Development (San Francisco: ICS Press, 1993).

Pannell, D.J. and N.A. Glenn, "A framework for the economic evaluation and selection of sustainability indicators in agriculture" Ecological Economics Vol. 33, No. 1 (2000): 135-149.

Parris, T. M. (1996). "Comparative international indicators of sustainable development." Environment 38(4): 3.

Pauleit, S. and F. Duhme, "Assessing the environmental performance of land cover types for urban planning" Landscape and Urban Planning Vol. 52, No. 1 (2000): 1-20.

Pearce, D. and G. Atkinson (1998). "The Concept of Sustainable Development: An Evaluation of Its Usefulness Ten Years After Bruntland." Swiss Journal of Economic Statistics 134(3): 251-69.

Pearce, D., K. A. Hamilton, et al. (1996). "Measuring Sustainable Development: Progress on Indicators." Environmental and Development Economics 1(1): 85-102.

Pearce, David and et.al., Sustainable Development: Economics and Environment in the Third World (Cheltenham, England: Edward Elgar Publishers Ltd., 1990).

Pearce, David W. and Jeremy J. Warford, World Without End: Economics, Environment, and Sustainable Development (Washington, DC: Oxford University Press for the World Bank, 1993).

Pearce, David, "Economics, Equity and Sustainable Development" Futures(UK), Vol. 20, No. 6 (December, 1988): 598-605.

Pearce, J.A., 1980, Host Community Acceptance of Foreign Tourists, Annals of Tourism Research, 7(2), 224-233.

Pezzey, John, Sustainable Development Concepts: An Economic Analysis, Report No. Paper No. 2 (World Bank Environment Department, 1992).

Piccolomini, M. (1996). Sustainable development, collective action, and new social movements. Research in Social Movements,. 19: 183-208.

Pires, C. P. (1998). "A Note on "Environmental Sustianability and Cost-Benefit Analysis"." Environment and Planning A. 30(11): 2069-73.

Pizam, A., 1978, Tourism's Impacts: The Social Costs to the Destination Community as Perceived by its Residents, Journal of Travel Research, 16(Spring), 8-12.

Pomeroy, R.S., M. Uysal, and A. Lamberte, 1988, An Input-Output Analysis of South Carolina's Economy: With Special Reference to Coastal Tourism and Recreation, Leisure Science, 19, 281-288

Rajeswar, J., "Population perspectives and sustainable development" Sustainable Development Vol. 8, No. 3 (2000): 135-141.

Randers, J., "From limits to growth to sustainable development or SD (Sustainable development) in a SD (System dynamics) perspective" System Dynamics Review Vol. 16, No. 3 (2000): 213-224.

Rangan, H. (1997). "Indian environmentalism and the question of the state: problems and prospects for sustainable development." Environment and Planning A 29(12): 2129-2143.

Rapport, D.J., "Ecological footprints and ecosystem health: complementary approaches to a sustainable future" Ecological Economics Vol. 32, No. 3 (2000): 367-370.

Ratter, B. M. W. (1996). "Complex resource management - Requirements for sustainable development on small Caribbean islands." Geographische Zeitschrift 84(2): 114-124.

Rawat, A. (1996). "Technological change and environmental management in industry." International Journal of Environment and Pollution 6(2-3): 172-184.

Read, P. (1997). "Food, fuel, fibre and faces to feed. Simulation studies of land use change for sustainable development in the 21st century." Ecological Economics 23(2): 81-93.

Redclift, M. (1997). Postscript - Sustainable development in the twenty-first century: the beginning of history? Politics of Sustainable Devel: 259-268.

Redclift, Michael, Sustainable Development: Exploring the Contradictions (London, UK: Methuen, 1987.).

Renn, O. and R. Goble (1996). "A regional concept of qualitative growth and sustainability - Support for a case study in the German State of Baden-Wurttemberg." International Journal of Sustainable Development and World Ecology 3(4): 1-22.

Rennings, K. and H. Wiggering (1997). "Steps towards indicators of sustainable development: Linking economic and ecological concepts." Ecological Economics 20(1): 25-36.

Reynolds, C.S. “Ecological pattern and ecosystem theory” Ecological Modelling. 158. (2002) pp. 181-200.

Rice, D. P., T.A. Hodgson, and A. N. Kopstein, (1985) The Economic Cost of Illness: A Replication and Update. Health Care Financing Review. 39. 61-81.

Robert, K. H., H. Daly, et al. (1997). "A compass for sustainable development." International Journal of Sustainable Development and World Ecology 4(2): 79-92.

Roe, E. M. (1996). "Sustainable development and cultural theory." International Journal of Sustainable Development and World Ecology 3(2): 1-14.

Rogers, R.A., "The usury debate, the sustainability debate, and the call for a moral economy" Ecological Economics Vol. 35, No. 2 (2000): 157-171.

Ronnback, P. and J.H. Primavera, "Illuminating the need for ecological knowledge in economic valuation of mangroves under different management regimes - a critique" Ecological Economics Vol. 35, No. 2 (2000): 135-141.

Rosen, S. (1974). Hedonic Prices and Implicit Markets: Product Differentiation in Perfect Competition. Journal of Political Economy. 82 (1). Pp. 34-55.

Ross, Glenn F., 1992, Resident Perception of the Impact of Tourism on an Australian City, Journal of Travel Research, 30(3), 13-17.

Rothman, R., 1978, Residents and Transients: Community Reaction to Seasonal Visitors, Journal of Travel Research, 16(Winter), 8-13.

Roumasset, J. and L. Endress, "The Yin and Yang of Sustainable Development: A Case for Win-Win Environmentalism," Journal of the Asia-Pacific Economy, v. 1, n. 2 (1996): 185-194.

Rydin, Y. (1997). Policy networks, local discourses and the implementation of sustainable development. Politics of Sustainable Devel: 152-174.

Sabljic, A., "IUPAC and UNESCO efforts towards sustainable development" Environmental Science and Pollution Research Vol. 7, No. 4 (2000): 185-187.

Sadownik, B. and M. Jaccard, "Sustainable energy and urban form in China: the relevance of community energy management" Energy Policy Vol. 29, No. 1 (2001): 55-65.

Salmi, P., et al., "Finnish lake fisheries and conservation of biodiversity: coexistence or conflict?" Fisheries Management and Ecology Vol. 7, No. 1-2 (2000): 127-138.

Sanne, C., "Dealing with environmental savings in a dynamical economy - how to stop chasing your tail in the pursuit of sustainability" Energy Policy Vol. 28, No. 6-7 (2000): 487-495.

Satterthwaite, D. (1997). "Sustainable cities or cities that contribute to sustainable development?" Urban Studies 34(10): 1667-1691.

Saveriades, Alexis, 2000, Establishing the Social Tourism Carrying Capacity for the Tourist Resorts of the East Coast of the Republic of Cyprus, Tourism Management, 21, 147-156.

Schaffer, William A., 1985, Using Input-Output Analysis to Measure the Impact of Tourist Expenditures: The Case of Hawaii, in D.B. Propst (Compiler), Assessing the Economic Impacts of Recreation and Tourism, Asheville, N.C.: Southeastern Forest Experiment Station.

Shafer, C. Scott and Graeme J. Inglis, 2000, Influence of Social, Biophysical, and Managerial Conditions on Tourism Experiences within the Great Barrier Reef World Heritage Area, Environmental Management, 26(1), 73-87.

Shaw, D. and S. Kidd (1996). "Planning sustainable development: Principles and implementation." Journal of Planning Education and Research 15(3): 237-241.

Shearlock, C., et al., "Regional sustainable development: Are the new regional development agencies armed with the information they require?" Sustainable Development Vol. 8, No. 2 (2000): 79-88.

Shelby, B. and Herberlein, T.A., 1986, A Conceptual Framework for Carrying Capacity Determination, Leisure Sciences, 6(4), 433-451.

Sheldon, Pauline J., and Teresa Abenoja, 2001, Resident Attitudes in a Mature Destination: The Case of Waikiki, Tourism Management, 22, 435-443.

Sheldon, Pauline J., and Turgut Var, 1984, Resident Attitudes to Tourism in North Wales, Tourism Management, 5(1), 40-48.

Slee, W H Farr, and P Snowdon, 1997, Sustainable Tourism and the Local Economy, in M.J. Stabler, Tourism and Sustainability, Principles to Practice, 69-87, Oxon: CAB International.

Smith, V. K, C. Poulos, and H. Kim. "Treating open space as an urban amenity." Resource and Energy Economics. Vol. 24. (2000): 107-129.

Sneddon, C.S., "'Sustainability' in ecological economics, ecology and livelihoods: a review" Progress in Human Geography Vol. 24, No. 4 (2000): 521-549.

Song, Byung-Nak and Choong-Yong Ahn, 1983, Korea, in T.Lin and E.A. Pye (Eds), Tourism in Asia: The Economic Impact, Singapore: Singapore University Press.

Sonntag, V., "Sustainability - in light of competitiveness" Ecological Economics Vol. 34, No. 1 (2000): 101-113.

Sophocleous, M., "From safe yield to sustainable development of water resources - the Kansas experience" Journal of Hydrology Vol. 235, No. 1-2 (2000): 27-43.

Solow, Robert M., 1974, Intergenerational Equity and Exhaustible Resources, Review of Economic Studies Symposium, 29-45.

Solow, Robert M., 1986, On the Intergenerational Allocation of Natural Resources, Scandinavian Journal of Economics, 88, 141-49.

Solow, Robert M., 1993, An Almost Practical Step toward Sustainability, Resources Policy, 19(3), 162-72.

Stabler, M.J. Tourism and Sustainability. Principles to Practice. New York. CAB. 1997.

Stankey, G.H., D.N. Cole, R.C. Lucas, M.E. Petersen, and S.S. Frissell, 1985, The Limits of Acceptable (LAC) System for Wilderness Planning, USDA Forest Service General Technical Report INT-176, Utah: Intermountain Research Station Ogden.

Stankey, G. H. and S. F. McCool, 1984, Carrying Capacity in Recreational Settings: Evolution, Appraisal, and Application, Leisure Science, 6(4), 453-473

Stern, P. C. and T. Dietz (1997). "Consumption and sustainable development." Science 276(5319): 1631-1632.

Sterner, Thomas, ed. Economic Policies for Sustainable Development (Boston: Kluwer Academic Publishers, 1994).

Stiglitz, Joseph, 1974, Growth with Exhaustible Natural Resources: Efficient and Optimal Growth Paths, Review of Economic Studies, 41, 123-37.

Stokke, Olav, ed. Sustainable Development (London, UK: Frank Cass/EADI, 1991).

Straaten, Jan ven der, 2000, The Economic Value of Nature, in H. Briassoulis and J.V.D. Straaten (Eds), Tourism and the Environment, Regional Economic, Cultural and Policy Issues, Revised Second Edition, Boston: Kluwer Academic Publishers.

Strange, I. (1997). "Planning for change, conserving the past: towards sustainable development policy in historic cities?" Cities 14(4): 227-233.

Stymne, S. and T. Jackson, "Intra-generational equity and sustainable welfare: a time series analysis for the UK and Sweden" Ecological Economics Vol. 33, No. 2 (2000): 219-236.

Stynes, D.J. and D.B. Propst, 1996, MI-REC Manual Version 3.0. East Lansing, MI: Department of Park, Recreation and Tourism Resources, Michigan State University.

Stynes, D.J. and D.B. Propst, 1992, A System for Estimating Local Economic Impacts of Recreation and Tourism, in S. Reiling (Ed), Measuring Tourism Impacts at the Community Level, Maine Agr. Expmt. Sta. Misc. Report #374.

Summary, R.M., 1987, Tourism's Contribution to the Economy of Kenya, Annuals of Tourism Research, 14, 531-540.

Sun, J.W., "Dematerialization and sustainable development" Sustainable Development Vol. 8, No. 3 (2000): 142-145.

Tabatchnaia-Tamirisa, Natalia, Matthew K. Loke, PingSun Leung, and Ken A. Tucker, 1997, Energy and Tourism in Hawaii, Annals of Tourism Research, 24(2), 390-401.

Tainter, J.A., "Problem solving: Complexity, history, sustainability" Population and Environment Vol. 22, No. 1 (2000): 3-41.

Tait, J. and D. Morris, "Sustainable development of agricultural systems: competing objectives and critical limits" Futures Vol. 32, No. 3-4 (2000): 247-260.

Terry, A. K. (1996). "A sustainable world: Defining and measuring sustainable development, by T.C. Trzyna." Geography 81(351 Part 2): 184-185.

Thomas, D. S. K. and O. J. Furuseth (1997). "The realities of incorporating sustainable development into local-level planning: a case study of Davidson, North Carolina." Cities 14(4): 219-226.

Thomason, P., J. Crompton, and D. Kamp, 1979, A Study of the Attitudes of Impacted Groups within a Host Community Toward Prolonged Stay Tourist Visitors, Journal of Travel Research, 17(Winter), 2-6.

Tietenberg, T. H., Environmental and Natural Resource Economics 5th ed (Reading, MA: Addison Wesley, 2000).

Tietenberg, Tom, Environmental Economics and Policy 3rd ed ed (Reading, MA: Addison Wesley, 2000).

Tilbury, D., "Challenges to sustainable development in Hong Kong" Geography Vol. 83, No. 361 (1998): 367-372.

Tisdell, C., "Sustainable Development: Differing Perspectives of Ecologists and Economists, and Relevance to LDCs" World Development, Vol. 16, No. 3 (March, 1988): 373-383.

Tisdell, C., Economics of Environmental Conservation (Amsterdam: Elsevier Science Publishers, 1991).

Tisdell, Clem, Environmental Economics (Aldershot, UK: Edward Elgar Publishers, 1993)

Turner, R. Kerry, Sustainable Environmental Management: Principles and Practice (Boulder, CO: Westview Press, 1988).

U.S. Army Corps of Engineers, 1998, Florida Keys Carrying Capacity Study.

U.S. Dept. of Commerce, Bureau of Economic Analysis, 1992, Regional Multipliers: A User Handbook for Regional Input-Output Modeling System (RIMS II), Second Edition, Washington, D.C., U.S. Gov't Printing Office.

U.S. Dept. of Interior, National Park Service, 1990, The Money Generation Model, Denver, CO: Office of Social Science, Socio-Economic Studies Division.

U.S. Environmental Protection Agency, Office of Policy, Economics, and Innovation, 2000, A Method to Quantify Environmental Indicators of Selected Leisure Activities in the United States. Prepared by Abt Associates Inc

U.S. Travel data Center, 2002, Impact of Travel on State Economies 2000, Washington, D.C

Vail, D. and L. Hultkrantz, "Property rights and sustainable nature tourism: adaptation and mal-adaptation in Dalarna (Sweden) and Maine (USA)" Ecological Economics Vol. 35, No. 2 (2000): 223-242.

van Beers, C. and J. C. J. M. van den Bergh. (2001). "Perserverance of Perverse Subsidies and Their Impact on Trade and Environment." Ecological Economics 36(3): 475-86.

van den Bergh, J. C. J. M. and J. M. Gowdy. "Evolutionary Theories Environmental and Resource Economics: Approaches and Applications." Environmental Resource Econonomics vol. 17, No.1 (2000): 37-57.

Van Geldrop, J. and C. Withagen, "Natural capital and sustainability" Ecological Economics Vol. 32, No. 3 (2000): 445-455.

Van Jaarsveld, A. S. (1996). "Towards a co-evolutionary framework for implementing sustainable development." International Journal of Sustainable Development and World Ecology 3(2): 15-37.

Van Langenhove, L. and R. Berloznik, "Introduction: Technology assessment and forecasting for sustainable development" Technological Forecasting and Social Change Vol. 58, No. 1-2 (1998): 1-4.

Van Vuuren, D.P. and E.M.W. Smeets, "Ecological footprints of Benin, Bhutan, Costa Rica and the Netherlands" Ecological Economics Vol. 34, No. 1 (2000): 115-130.

Var, Turgut, K.W. Kendall, and Enis Tarakcioglu, 1985, Resident Attitudes towards Tourists in a Turkish Resort Town, Annals of Tourism Research, 12(4), 652-658.

Var, Turgut and J. Quayson, 1985, The Multiplier Impact of Tourism in the Okanagan, Annals of Tourism Research, 12, 497-514.

Vargas, C. M. (2000). "Community development and micro-enterprises: Fostering sustainable development." Sustainable Development 8(1): 11-26.

Vargas, C.M., "Community development and micro-enterprises: Fostering sustainable development" Sustainable Development Vol. 8, No. 1 (2000): 11-26.

Vargas, C.M., "Sustainable development education: Averting or mitigating cultural collision" International Journal of Educational Development Vol. 20, No. 5 (2000): 377-396.

Varma, V.K., et al., "Decision support system for the sustainable forest management" Forest Ecology and Management Vol. 128, No. 1-2 (2000): 49-55.

Vatn, A. "The Environment as a Commodity." Environment Values Vol. 9, No.4 (2000): 493-509.

Von Weizsacker, Ernst U., Ecological Tax Reform: A Policy Proposal for Sustainable Development (London, UK: Zed Books, 1992).

Wackernagel, M and W. E,. Rees, (1996)Our Ecological Footprint: Reducing Human Impact on the Earth. New Society Publishers, Gabriola Island, BC

Wagner, John E., 1997, Estimating the Economic Impacts of Tourism, Annals of Tourism Research, 24(3), 592-608.

Wall, G. (1997). "Is ecotourism sustainable?" Environmental Management 21(4): 483-491.

Wallner, H. P., M. Narodoslawsky, et al. (1996). "Islands of sustainability: A bottom-up approach towards sustainable development." Environment and Planning A 28(10): 1763-1778.

Walz, R., "Development of environmental indicator systems: Experiences from Germany" Environmental Management Vol. 25, No. 6 (2000): 613-623.

Wanhill, Stephen R.C., 1988, Tourism Multipliers under Capacity Constraints, Service Industries Journal, 8, 137-142.

Warnell, Gary, 1986, Feasibility Analysis in Tourism, Extension Bulletin E-1992, East Lansing, MI: Michigan State University Cooperative Extension Service

Wefering, F.M., et al., "Using the AMOEBA approach to measure progress toward ecosystem sustainability within a shellfish restoration project in North Carolina" Ecological Modeling Vol. 130, No. 1-3 (2000): 157-166.

Westing, A. H. (1996). "Core values for sustainable development." Environmental Conservation 23(3): 218-225.

Westlake, K. (1997). "Sustainable landfill - Possibility or pipe-dream?" Waste Management & Research 15(5): 453-461.

Wiggering, H. and K. Rennings (1997). "Sustainability indicators: Geology meets economy." Environmental Geology 32(1): 71-78.

Williams, Peter W., 1994, Frameworks for Assessing Tourism's Environmental Impacts, in J.R. Brent Ritchie and Charles R. Goeldner (Eds), Travel, Tourism, and Hospitality Research, Second Edition, New York: John Wiley and Sons Inc.

World Bank, Sustainable Development in a Dynamic World. World Development Report. New York. Oxford University Press. 2003

World Commission on Environment and Development. (1987). *Our Common Future. (The Brundtland Report).* Oxford: Oxford University Press.

World Tourism Organization, Guide for Local Authorities on Developing Sustainable Tourism. Madrid. WTO. 1998.

World Tourism Organization, Sustainable Development: A Compilation of Good Practices. Madrid. WTO. 2000.

World Tourism Organization, Tourism and Poverty Alleviation. Madrid. WTO. 2002.

World Travel and Tourism Council, 2001, South Carolina, the Impact of Travel and Tourism on Jobs and the Economy, London: WTTC.

World Travel and Tourism Council, 1998, WTTC Hawaii Tourism Report, 1998: How Travel and tourism Affects Hawaii's Economy, London: WTTC.

World Travel and Tourism Council, 1996, State of Hawaii Travel Tourism; A New Economic Perspective, London: WTTC.

Woodward, R.T., "Sustainability as intergenerational fairness: Efficiency, uncertainty, and numerical methods" American Journal of Agricultural Economics Vol. 82, No. 3 (2000): 581-593.

World Resources Institute, Directory of Country Environmental Studies (Washington: World Resources Institute, 1990).

Wright, D. W. (1996). "Infrastructure planning and sustainable development." Journal of Urban Planning and Development - ASCE 122(4): 111-117.

Young, M. D., Sustainable Investment and Resource Use: Equity, Environmental Integrity and Economic Efficiency (Paris: UNESCO and The Parthenon Publishing Group, 1992).

Young, S. (1997). Community-based partnerships and sustainable development - A third force in the social economy. Politics of Sustainable Devel: 217-236.

Yu, D. W., T. Hendrickson, et al. (1997). "Ecotourism and conservation in Amazonian Peru: short-term and long-term challenges." Environmental Conservation 24(2): 130-138.

Zhou, Deying, John F. Yanagida, Ujjayant Chakravorty, PingSun Leung, 1997, Estimating Economic Impacts from Tourism, Annals of Tourism Research, 24

APPENDIX 2. ECONOMIC AND ENVIRONMENTAL DATA SOURCES

This appendix contains a description of data sources for the Hawaii Computable General Equilibrium (CGE) model. The model requires both economic data and data on infrastructure and natural resources. The Hawaii CGE Model is based on a Social Accounting Matrix and a variety of policy, taste, and technology parameters. Intermediate demand, final demand, and value added relationships is largely defined by the 1997 Input-Output (IO) table for the State of Hawaii, which distinguishes ten production sectors and six sources of final demand. The IO table is supplemented with data on the usage of water, wastewater, energy, and petroleum, as well as the generation of solid waste and pollutants that are associated with economic activity. Additional information is compiled on the labor force and on tourism.

There are a number of key assumptions built into our modeling approach. Comprehensive statewide data are utilized to build the baseline economic model. The simulations produced using the Computable General Equilibrium (CGE) model is run at the level of the entire state, including all sectors and all counties. The economic and environmental impacts produced at the statewide level are then distributed to the counties and to the sub-county level. Another approach would have been build the data from the "bottom-up," meaning that county level or community or neighborhood level data might have been used to build the model of the relationships between the economy and the environment. Unfortunately, detailed, consistent data for all of the needed elements in our model were not available. Also, there is value in developing these methods and tools using available statewide data. While at some point in the future, a "bottom-up" approach may be utilized and there are efforts to develop county and sub-county level economic input-output tables, at present, these data sources have not been adequately refined to allow for the type of modeling and analysis conducted in this study.

The appendix is organized as follows. Section 1 provides an overview of Hawaii's industrial structure, the visitor industry, and other aspects of the economy. Also presented is the industrial aggregation of the model based on the NAICS industrial codes. Section 3 documents the data sources of infrastructure services and petroleum products demand by industry and final demand sectors and describes the methods of distributing the original data, which are usually grouped into several broad categories, into 40 industry sectors that matches the industry classification in the Economic and Environmental Assessment Modeling Study. Section 4 describes the methodology of calculating emissions from petroleum products use and shows the emissions by the 40 industry sectors.

Table 1. Structure of Output and Production, condensed

Industry	Output	Inter-industry demand	Imports	Compensation of employees	Proprietor income	Other value added	Jobs
Total	$58.7 bil	$14.4 bil	$5.7 bil	$21.6 bil	$2.1 bil	$14.9 bil	742,231
Agriculture	1.4%	1.9%	1.4%	1.3%	1.8%	1.0%	2.9%
Construction	6.0%	7.9%	11.1%	5.8%	11.6%	1.7%	4.5%
Manufacturing	5.8%	5.9%	28.8%	2.4%	2.2%	2.4%	2.4%
Air Transportation	3.5%	4.8%	5.3%	2.4%	0.3%	3.5%	1.4%
Transportation	2.6%	4.5%	4.0%	1.7%	1.2%	1.8%	1.9%
Entertainment	1.4%	1.8%	1.8%	1.4%	3.0%	0.8%	2.7%
Golf	0.4%	0.6%	0.3%	0.4%	0.0%	0.2%	0.5%
Accommodations	21.2%	21.3%	6.3%	7.8%	19.3%	46.7%	9.5%
Restaurants	3.9%	5.5%	5.2%	3.7%	2.0%	2.3%	6.8%
Trade	10.4%	9.9%	8.2%	11.1%	9.6%	10.9%	14.9%
Services	25.8%	30.3%	23.4%	27.2%	48.9%	17.3%	29.8%
Utilities	2.9%	4.1%	2.5%	1.6%	0.1%	4.1%	0.8%
Government	14.6%	1.5%	1.4%	33.2%	0.0%	7.3%	22.0%

Source: *The Hawaii Input-Output Study, 1997 Benchmark Report*, Department of Business, Economic Development, and Tourism, State of Hawaii, March 2002 (updated August 2003).

Table 2. Structure of Output and Production --40 sectors

Industry	Output	Inter-industry demand	Imports	Compensation of employees	Proprietor income	Other value added	Jobs
Total	$58.7 bil	$14.4 bil	$5.7 bil	$21.6 bil	$2.1 bil	$14.9 bil	742,231
Crops	0.7%	0.9%	0.5%	0.7%	0.4%	0.6%	1.3%
Animal	0.4%	0.5%	0.7%	0.3%	0.4%	0.2%	0.6%
Commercial fishing	0.1%	0.2%	0.1%	0.1%	0.4%	0.1%	0.3%
Landscaping services	0.3%	0.3%	0.1%	0.3%	0.5%	0.1%	0.6%
Construction	6.0%	7.9%	11.1%	5.8%	11.6%	1.7%	4.5%
Food processing	1.8%	3.3%	4.1%	0.9%	0.1%	1.0%	0.9%
Clothing	0.4%	0.4%	1.3%	0.3%	0.3%	0.1%	0.5%
Chemical	0.1%	0.1%	0.2%	0.1%	0.0%	0.2%	0.1%
Petroleum	2.4%	0.8%	19.9%	0.2%	0.0%	0.8%	0.1%
Other manufacturing	1.1%	1.3%	3.3%	0.9%	1.7%	0.4%	0.9%
Air transportation	3.5%	4.8%	5.3%	2.4%	0.3%	3.5%	1.4%
Trucking	0.5%	0.8%	0.2%	0.5%	0.1%	0.3%	0.4%
Water transportation	0.9%	1.7%	2.5%	0.3%	0.2%	0.4%	0.2%
Ground transportation	0.2%	0.2%	0.4%	0.2%	0.8%	0.1%	0.5%
Automobile rental	0.7%	1.2%	0.5%	0.3%	0.1%	0.8%	0.4%
Parking lots	0.2%	0.4%	0.2%	0.1%	0.0%	0.1%	0.2%
Transit	0.2%	0.2%	0.1%	0.3%	0.0%	0.0%	0.2%
Performing arts	0.3%	0.4%	0.1%	0.2%	2.0%	0.1%	0.8%
Amusement	0.3%	0.3%	0.6%	0.2%	0.2%	0.2%	0.3%
Recreation	0.3%	0.4%	0.2%	0.2%	0.7%	0.1%	0.6%
Museums historical	0.1%	0.2%	0.2%	0.2%	0.0%	0.0%	0.3%
Sightseeing transport	0.5%	0.6%	0.6%	0.6%	0.1%	0.3%	0.7%

Table 2. Structure of Output and Production -- 40 sectors (continued)

Industry	Output	Inter-industry demand	Imports	Compensation of employees	Proprietor income	Other value added	Jobs
Golf courses	0.4%	0.6%	0.3%	0.4%	0.0%	0.2%	0.5%
Hotels	5.9%	7.6%	3.4%	5.9%	1.7%	5.7%	5.6%
Real estate rental	15.4%	13.7%	2.9%	1.8%	17.6%	41.0%	3.9%
Restaurants	3.9%	5.5%	5.2%	3.7%	2.0%	2.3%	6.8%
Wholesale trade	3.3%	2.7%	2.8%	3.5%	1.3%	4.1%	3.1%
Retail trade	7.1%	7.2%	5.4%	7.6%	8.3%	6.8%	11.8%
Information	3.3%	3.1%	5.8%	2.3%	1.4%	4.2%	1.7%
Professional	11.2%	13.1%	8.1%	10.4%	27.7%	9.4%	12.6%
Travel reservations	0.8%	0.9%	0.7%	0.8%	1.5%	0.6%	1.0%
Education private	0.8%	0.9%	0.1%	1.4%	0.7%	0.1%	1.9%
Health services	6.6%	8.0%	5.8%	8.6%	11.6%	1.7%	7.1%
Laundry	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%	0.3%
Other services	3.0%	4.2%	2.8%	3.3%	6.0%	1.1%	5.1%
Electricity	2.0%	3.1%	1.9%	0.8%	0.0%	2.9%	0.3%
Propane gas	0.1%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%
Waste mngmt private	0.3%	0.6%	0.2%	0.2%	0.1%	0.3%	0.2%
Water sewer	0.5%	0.4%	0.4%	0.4%	0.0%	0.8%	0.3%
Other government	14.6%	1.5%	1.4%	33.2%	0.0%	7.3%	22.0%

Source: *The Hawaii Input-Output Study, 1997 Benchmark Report*, Department of Business, Economic Development, and Tourism, State of Hawaii, March 2002 (updated August 2003).

2.1. Hawaii Industry, Visitor, and Resident Economic Data

This section provides a descriptive overview of Hawaii's economy and the visitor industry. Included is a description of the industry structure, the role of the visitor industry, a comparison of visitor and resident expenditures, and a summary of key factors influencing tourism industry growth.

Table 1, Structure of Output and Production reveals that in terms of total state output ($58.7 billion), the largest sectors include accommodations (21.2%), services (25.8%), government (14.6%), trade (10.4%), construction (6%), and manufacturing (5.8%). Interestingly enough, agriculture and entertainment comprise similar shares of the economy, each amounting to about 1.4% of total output. The accommodations sector is so large, in part because it also includes real estate rental. Key infrastructure sectors, represented by transportation (2.6%) and utilities (2.9%) are also important to the economy. The table also includes figures for inter-industry demand ($14.4 billion) and imports ($5.7 billion). In terms of the wage bill (compensation of employees), 27.2% is in services, with the next largest sector being trade (11.1%). Proprietor's income ($2.1 billion) is about one-tenth the volume of the compensation of employees ($21.6 billion). Services account for nearly half (48.9%) of total proprietor's income. Other value added including depreciation of capital accounts generates income of $14.9 billion with accommodations industries accounting for a disproportionate share (46.7 %) of demand.

The job count reflects the state's heavy reliance on services, trade, accommodations, and government, which together comprise 76.2% of the total job count.

Table 2 contains more detail as the information is organized according to 40 sectors which were aggregated into the 13 contained in Table 1. With a forty sector view of the economy, the largest contributors to output include real estate rental (15.4%), government (14.6%), professional services (11.2%), retail trade (7.1%), health services (6.6%), and hotels (5.9%). The table also contains information on inter-industry demand and imports. Business make significant purchases of goods and services such as real estate rental (13.7%), professional services (13.1%), health services (8.0%), construction (7.9%), hotels (7.6%), retail trade (7.2%), and air transport (4.8%). The sectors most heavily dependent on imports include petroleum, construction, and professional services. In terms of the compensation of employees, the largest sectors include professional services, retail trade, and health services. Notably, government amounts to almost one-third (33.2%) of the total wage bill in the state. On the other hand, in terms of proprietor income, the key sectors include professional services (27.7%), real estate rental (17.6%), construction (11.6%), health services (11.6%), and other services (6.0%). More than half of the total other value added is concentrated in two sectors – real estate rental and professional services. With a forty sector view of the job count, the big sectors include government (22.0%), professional services (12.6%), retail trade (11.8%), health services (7.1%) and other services (5.1%).

Together, these two tables paint a picture of Hawaii which illustrates the importance of both the services sector in general and tourism in particular. Government is also a disproportionately large part of the state's economy measured in terms of share of output, compensation of employees, and job count. Agriculture represents only 1.4% of total output. Manufacturing comprises only 5.8% of total output. Proprietor income is heavily concentrated in services, construction, accommodations and trade. These tables describe how income and wealth are generated in the state.

Table 3 is a condensed input-output (I-O) transactions table for Hawaii. This table shows both inter-industry transactions and final demand. Generally speaking, the rows in an I-O table correspond to producers (sellers) while the columns refer to purchasers. The inter-industry transactions show the intermediate sales and purchases of goods and services among producers within an economy. Final demand typically consists of the sales of commodities and services by each industry to households and other consumers (e.g. government, investors, exports, etc.). I-O tables also reflect payments to the factors of production which includes not just land, labor and capital owners, but also tax payments to government or interest payments on loans. The I-O model uses an accounting framework in which the total receipts of sellers must balance off against the total expenditures of buyers. In this manner, total output (sales) equals total input (purchases) for each sector in the economy. In this condensed format, it is possible to determine the major categories of purchases of goods and services by key economic sectors. For example, the agricultural sector makes \$83.8 million of agricultural purchases and \$52.2 million worth of manufacturing goods. This sector also purchases approximately \$12.6 million in utility services, a relatively small amount in comparison to accommodations

($277.7 million), services ($198 million). Employee compensation accounts for $286.3 million of total agricultural output ($823.5 million). Note too that the table also reports on proprietor's income, business taxes, and capital costs. In comparison, accommodations sector which includes both hotels and real estate rentals, makes large purchases of services ($1,334.0 million), utilities ($277.7 million) and construction services ($183.8 million). Restaurants, on the other hand, make large purchases of manufacturing goods and services, accommodations, retail and wholesale trade, and other services. From a seller or producer perspective, the key sectors for agriculture include manufacturing ($204.5 million), accommodations ($87.8 million) and restaurants ($41.9 million). Government makes large purchases of services ($63.4 million), utilities ($46.5 million), construction ($20.1 million), air transport ($17.8 million), and trade ($14.6 million). Table 3 also provides a glimpse at final demand, allowing the comparison between household and visitor purchases in the economy. Not surprisingly, household purchases are dominated by expenditures on services (($7.8 billion), real estate rental ($5.4 billion), and trade ($3.0 billion). Visitor spending, on the other hand, is dominated by expenditures on hotels and condominium rentals ($3.5 billion), air travel ($1.6 billion), and restaurant meals ($1.1 billion). Comparing total intermediate purchases, households spend approximately $20 billion annually, compared to $9.5 billion annually by visitors. Note too that while households spend $595 million on utilities, the visitor purchases of utilities are indirect, through the consumption of other goods and services. The table also reveals information on inventories, private investment and exports, as well as reporting on the purchases of other final demanders (state and local government, federal military and non-military transactions). Hence, this table provides a comprehensive overview of not just the structure of the economy but also the principal flows of goods and services through their purchases and sales by key sectors and final demanders.

Table 3. 1997 Condensed Input Output Transactions Table for Hawaii, $ million

Industry	Agri-culture	Constr-uction	Manuf-acturing	Air Trans-port	Trans-port	Enter-tainmt	Golf	Accom-moda-tions	Rest-aurant	Trade	Services	Utilities	Govern-ment
Agriculture	83.8	12.6	204.5	0.0	1.0	2.5	1.5	87.8	41.9	6.0	16.2	0.1	3.1
Construction	4.9	21.4	31.2	0.8	5.5	5.1	2.3	183.8	12.4	11.5	44.8	28.0	20.1
Manufacturing	52.2	202.5	176.9	252.9	63.5	28.0	3.6	65.5	164.2	53.2	120.3	347.5	16.9
Air Transport	4.7	0.9	2.0	15.2	1.4	1.2	0.6	8.4	4.0	11.7	34.2	4.9	17.8
Transportation	8.8	43.4	47.1	11.0	66.0	9.5	1.5	28.1	12.2	28.2	76.7	14.4	11.5
Entertainment	0.0	0.0	0.0	0.0	0.0	26.6	0.1	12.2	5.8	0.0	5.9	0.0	0.0
Golf	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Accommodations	23.9	72.6	46.5	33.8	82.8	58.8	36.4	874.8	210.0	555.5	1297.4	17.8	20.1
Restaurants	1.1	3.0	8.8	19.4	4.8	2.0	0.6	20.6	8.5	6.6	41.4	3.0	1.1
Trade	42.1	366.5	132.6	38.9	59.4	22.1	3.6	145.1	121.1	102.3	256.6	34.8	14.6
Services	32.1	396.5	150.0	218.4	275.9	78.4	18.3	1344.0	114.7	453.2	2201.7	82.9	63.4
Utilities	12.6	17.3	48.4	9.4	18.5	19.2	11.4	277.7	73.1	60.3	198.5	32.8	46.5
Government	0.6	2.9	3.1	86.4	71.0	6.1	1.1	25.7	24.2	132.5	76.0	30.2	2.5
Total intermediate input	266.7	1139.6	851.2	686.2	649.8	259.4	80.8	3073.8	792.1	1421.1	4369.7	596.5	217.7
Imports	81.2	635.1	1647.9	305.5	229.4	101.8	19.7	362.7	295.7	469.8	1339.0	143.6	81.0
Employee compensation	286.3	1247.6	516.6	527.0	371.1	299.7	93.1	1676.7	806.6	2401.6	5879.7	345.6	7174.8
Proprietor's income	37.3	242.5	45.2	6.6	25.5	62.4	0.0	402.9	42.6	200.7	1021.2	1.2	0.0
Indirect bus. taxes	39.6	154.3	27.7	110.6	74.0	39.3	9.6	986.1	96.9	910.1	581.5	129.8	0.0
Other capital costs	112.3	105.2	327.9	408.3	193.9	81.6	26.6	5973.4	240.8	715.3	1990.0	474.3	1092.4
Output	823.5	3524.3	3416.4	2044.1	1543.5	844.2	229.8	12475.7	2274.7	6118.5	15181.0	1691.0	8565.8
Wage and salary jobs	11,496	24,977	15,100	10,196	11,984	13,447	3,574	52,525	48,982	89,035	16,5002	5,917	163,310
Proprietor jobs	9,700	8,387	2,944	132	2,129	6,548		17,774	1,528	21,485	5,6015	45	
Total Jobs	21,196	33,364	18,044	10,328	14,113	19,995	3,574	70,300	50,509	110,520	22,1017	5,962	163,310

Source: *The Hawaii Input-Output Study, 1997 Benchmark Report*, Department of Business, Economic Development, and Tourism, State of Hawaii, March 2002 (updated August 2003).

Table 3. 1997 Condensed Input Output Transactions Table for Hawaii, $ million (continued)

Industry	Industry demand	Household Expenditures	Visitor Expenditures	Change in inventories	Gross private investment	Exports
Agriculture	461.1	122.0	18.4	5.2	0.0	189.9
Construction	371.8	0.0	0.0	0.0	1846.0	0.0
Manufacturing	1547.0	683.0	296.2	14.8	53.4	660.9
Air Transport	107.2	337.9	1555.2	0.0	7.5	15.5
Transportation	358.4	406.3	536.3	0.0	53.1	77.1
Entertainment	50.6	207.3	569.4	0.0	0.0	16.7
Golf	0.0	88.5	141.3	0.0	0.0	0.0
Accommodations	3330.4	5381.3	3487.1	0.0	46.2	153.5
Restaurants	121.1	1017.1	1126.2	0.0	0.0	5.0
Trade	1339.7	2998.3	1278.0	8.6	327.4	71.8
Services	5429.5	7832.2	439.8	0.0	121.4	812.2
Utilities	825.4	595.3	0.0	0.0	0.0	0.0
Government	462.4	264.9	45.6	0.0	0.0	43.0
Total Demand	14404.4	19934.2	9493.4	28.5	2455.1	2045.7
Imports	5712.4	5027.8	1437.6	34.3	982.7	468.0
Employee compensation	21626.2					
Proprietor's income	2088.0					
Indirect bus. taxes	3159.5					
Other capital costs	11742.0					
Output	58732.5	24962.0	10931.0	62.8	3437.9	2513.8
Wage and salary jobs	615,545					
Proprietor jobs	126,686					
Total Jobs	742,231					

Source: *The Hawaii Input-Output Study, 1997 Benchmark Report*, Department of Business, Economic Development, and Tourism, State of Hawaii, March 2002 (updated August 2003).

Table 3. 1997 Condensed Input Output Transactions Table for Hawaii, $ million (continued)

Industry	State and local gov't investment	State and local gov't consumption	Federal military consumption	Federal military investment	Federal civilian consumption	Federal civilian investment	Output
Agriculture	0.0	14.5	12.1	0.0	0.3	0.0	823.5
Construction	791.8	67.2	189.7	215.3	30.5	11.9	3,524.3
Manufacturing	0.0	88.0	68.7	0.3	4.1	0.0	3,416.4
Air Transport	1.0	15.4	3.5	0.2	0.7	0.0	2,044.1
Transportation	4.8	92.1	12.8	1.6	0.7	0.4	1,543.5
Entertainment	0.0	0.0	0.2	0.0	0.0	0.0	844.2
Golf	0.0	0.0	0.0	0.0	0.0	0.0	229.8
Accommodations	10.0	56.6	3.7	0.0	6.8	0.0	12,475.7
Restaurants	0.0	0.0	5.1	0.0	0.4	0.0	2,274.7
Trade	32.9	46.0	12.9	2.5	0.1	0.5	6,118.5
Services	5.8	230.0	258.6	9.4	41.4	0.7	15,181.0
Utilities	0.0	131.4	132.0	0.0	6.7	0.0	1,691.0
Government	0.0	3209.7	4173.4	0.0	366.8	0.0	8,565.8
Total Demand	846.2	3951.0	4872.7	229.3	458.4	13.5	58,732.5
Imports	74.5	162.3	198.9	66.7	20.2	3.3	14,188.8
Employee compensation							21,626.2
Proprietor's income							2,088.0
Indirect bus. taxes							3,159.5
Other capital costs							11,742.0
Output	920.7	4113.4	5071.6	296.0	478.6	16.7	111,537.0

Source: *The Hawaii Input-Output Study, 1997 Benchmark Report*, Department of Business, Economic Development, and Tourism, State of Hawaii, March 2002 (updated August 2003).

Table 4. Indirect Business Taxes by Industry

Industry	Collections ($ million)	Ad Valorem equivalent
Crops	22.2	5.6%
Animal	9.3	4.4%
Commercial fishing	1.1	1.6%
Landscaping services	7.0	4.7%
Construction and mining	154.3	4.4%
Food processing	11.7	1.1%
Clothing manufacturing	1.3	0.6%
Chemical manufacturing	0.6	0.8%
Petroleum manufacturing	4.0	0.3%
Other manufacturing	10.1	1.5%
Air transportation	110.6	5.4%
Trucking	15.6	5.6%
Water transportation	5.6	1.1%
Ground transportation	6.3	4.9%
Automobile rental	41.0	10.4%
Parking lots	5.5	5.1%
Transit		0.0%
Performing arts	7.2	4.6%
Amusement	6.6	4.2%
Recreation	7.6	5.1%
Museums historical	3.5	4.5%
Sightseeing transport	14.5	4.8%
Golf courses	9.6	4.2%
Hotels	336.2	9.7%
Real estate rental	650.0	7.2%
Restaurants	96.9	4.3%
Wholesale trade	393.5	20.3%
Retail trade	516.7	12.4%
Information	90.1	4.6%
Finance business professional	268.7	4.1%
Travel reservations	22.8	5.0%
Education private	18.2	3.8%
Health services	106.0	2.7%
Laundry	4.6	4.7%
Other services	71.0	4.0%
Electricity	117.5	10.1%
Propane gas	4.0	7.7%
Waste management private	8.3	4.4%
Water sewer		0.0%
Other government		0.0%
Total	3,159.5	5.4%

Source: *The Hawaii Input-Output Study, 1997 Benchmark Report*, Department of Business, Economic Development, and Tourism, State of Hawaii, March 2002 (updated August 2003).

No description of the economy would be complete without some discussion of the taxes paid by various sectors. Especially in Hawaii, where government is such a significant part of the economy, the estimation of tax burdens is likely to be of interest. The ad valorem equivalent rates are presented in Table 4, and range from a low of 0.3% for petroleum manufacturing to a high of 20.3% for wholesale trade. Notably retail trade is approximately 12.4%, electricity is approximately 10%, automobile rental is approximately 10.4%, and hotels are at 9.7%. The overall estimated rate is 5.4%.

Table 5 shows a more detailed comparison of visitor and household spending. Generally the same patterns as identified in Table 3 emerge. For visitors, the big spending categories include hotels, air transport, restaurants, and retail trade, while households spend proportionately more on real estate rental, health services, retail trade, and professional services. Quite clearly, there is a difference in terms of the spending patterns of residents versus visitors. While visitors spend much more on amusement parks than residents, residents outspend visitors on performing arts by almost 2 to 1. Interestingly, the spending on historical museums by residents is almost identical to that of visitors, approximately $38.5 million, annually. Visitors spend almost 10 times as much as residents on rental cars. Residents, however spend much more than visitors on parking lots and transit services, yet sightseeing transportation is dominated by visitors. As noted earlier, residents make direct purchases of electricity, propane gas, waste management, water and sewer services, while visitors purchase these services indirectly through the purchase of other goods and services.

Table 6 contains a comparison of spending by U.S., Japanese, and other visitors. Note that of the $10.7 billion in total expenditures, $7.2 billion is by U.S. visitors while Japanese visitor spending amounts to $2.2 billion. All others account for only $1.3 billion in spending. Several observations can be made from the data. First the general patterns of spending by U.S. and other visitors are similar, while that of Japanese visitors is quite different. Japanese visitors spend proportionately less on air transport, less on accommodations, but much more on retail and wholesale trade. Their purchase of imported goods is also much higher. Table 7, which contains spending according to the forty sector view of the economy, reveals some further differences. U.S. and other visitors spend proportionately more on rental cars than the visitors from Japan. Japanese spend almost double the volume in retail purchases than other (non-U.S.) visitors.

Table 8 provides a description of the 131 sectors contained in the Input Output Study, 1997 Benchmark Report of DBEDT, released on March 2002 and available on the DBEDT website. Table 8 also provides a concordance from the 131 sectors to the 40 sectors that were identified by the consultants as important in analyzing economic and environmental impacts of tourism growth. For presentation purposes, a thirteen sector description of economic sectors is also utilized.

Table 5. Household and Visitor Expenditures for Hawaii

Industry	Output ($ million)	(%)	Household Expenditures ($ million)	(%)	Visitor Expenditures ($ million)	(%)
Crops	393.9	0.7%	56.2	0.2%	15.8	0.1%
Animal	212.0	0.4%	41.8	0.2%	1.3	0.0%
Commercial fishing	69.7	0.1%	24.0	0.1%	1.4	0.0%
Landscaping services	147.8	0.3%		0.0%		0.0%
Construction	3,524.3	6.0%		0.0%		0.0%
Food processing	1,054.5	1.8%	419.5	1.7%	52.3	0.5%
Clothing	209.4	0.4%	39.8	0.2%	18.8	0.2%
Chemical	73.9	0.1%		0.0%		0.0%
Petroleum	1,419.3	2.4%	187.8	0.8%	208.4	1.9%
Other manufacturing	659.4	1.1%	35.9	0.1%	16.6	0.2%
Air transportation	2,044.1	3.5%	337.9	1.4%	1,555.2	14.2%
Trucking	279.0	0.5%	98.0	0.4%	18.3	0.2%
Water transportation	522.8	0.9%	133.1	0.5%	116.2	1.1%
Ground transportation	128.9	0.2%	34.6	0.1%	76.2	0.7%
Automobile rental	393.3	0.7%	32.5	0.1%	314.8	2.9%
Parking lots	109.4	0.2%	77.2	0.3%	10.4	0.1%
Transit	110.0	0.2%	30.9	0.1%	0.4	0.0%
Performing arts	155.6	0.3%	62.2	0.2%	31.1	0.3%
Amusement	157.1	0.3%	27.6	0.1%	129.5	1.2%
Recreation	150.7	0.3%	63.7	0.3%	84.7	0.8%
Museums historical	77.2	0.1%	38.5	0.2%	38.6	0.4%
Sightseeing transport	303.7	0.5%	15.2	0.1%	285.5	2.6%
Golf courses	229.8	0.4%	88.5	0.4%	141.3	1.3%
Hotels	3,456.4	5.9%	170.0	0.7%	3,247.4	29.7%
Real estate rental	9,019.3	15.4%	5,211.4	20.9%	239.7	2.2%
Restaurants	2,274.7	3.9%	1,017.1	4.1%	1,126.2	10.3%
Wholesale trade	1,939.0	3.3%	686.6	2.8%	190.3	1.7%
Retail trade	4,179.5	7.1%	2,311.7	9.3%	1,087.7	10.0%
Information	1,940.3	3.3%	776.9	3.1%	33.4	0.3%
Professional	6,578.0	11.2%	2,047.2	8.2%	72.3	0.7%
Travel reservations	456.8	0.8%	148.8	0.6%	191.2	1.7%
Education private	477.5	0.8%	307.9	1.2%	7.0	0.1%
Health services	3,859.3	6.6%	3,642.6	14.6%	83.3	0.8%
Laundry	97.7	0.2%	60.0	0.2%	12.7	0.1%
Other services	1,771.5	3.0%	848.7	3.4%	39.9	0.4%
Electricity	1,169.1	2.0%	394.6	1.6%		0.0%
Propane gas	51.2	0.1%	12.8	0.1%		0.0%
Waste mngmt private	190.4	0.3%	5.7	0.0%		0.0%
Water sewer	280.3	0.5%	182.2	0.7%		0.0%
Other government	8,565.8	14.6%	264.9	1.1%	45.6	0.4%
Imports		0.0%	5027.8	20.1%	1437.6	13.2%
Total	58,732.5	100.0%	24,962.0	100.0%	10,931.0	100.0%

Source: *The Hawaii Input-Output Study, 1997 Benchmark Report*, Department of Business, Economic Development, and Tourism, State of Hawaii, March 2002 (updated August 2003).

Table 6. Visitor Expenditures by Major Market (condensed)

Industry	US	Japan	Others	Total
Total ($ million)	7,189.8	2,212.8	1,336.4	10,739.0
Agriculture	0.2%	0.2%	0.2%	0.2%
Construction	0.0%	0.0%	0.0%	0.0%
Manufacturing	0.9%	1.2%	0.9%	1.0%
Air Transportation	16.6%	7.1%	15.6%	14.5%
Transportation	5.0%	3.6%	7.1%	5.0%
Entertainment	4.6%	5.7%	8.4%	5.3%
Golf	1.6%	0.7%	1.1%	1.3%
Accommodations	33.4%	27.5%	35.4%	32.5%
Restaurants	11.4%	9.5%	7.3%	10.5%
Trade	11.3%	16.1%	8.2%	11.9%
Services	4.5%	3.0%	3.5%	4.1%
Utilities	0.0%	0.0%	0.0%	0.0%
Government	0.5%	0.4%	0.2%	0.4%
Imports	10.0%	25.1%	12.1%	13.4%

Source: DBEDT – READ Division.

Table 7. Visitor Expenditures by Major Market

Industry	US	Japan	Others	Total
Total ($ million)	7,189.8	2,212.8	1,336.4	10,739.0
Crops	0.2%	0.1%	0.1%	0.1%
Animal	0.0%	0.0%	0.0%	0.0%
Commercial fishing	0.0%	0.0%	0.0%	0.0%
Landscaping services	0.0%	0.0%	0.0%	0.0%
Construction and mining	0.0%	0.0%	0.0%	0.0%
Food processing	0.5%	0.4%	0.5%	0.5%
Clothing manufacturing	0.2%	0.2%	0.2%	0.2%
Chemical manufacturing	0.0%	0.0%	0.0%	0.0%
Petroleum manufacturing	0.1%	0.3%	0.1%	0.2%
Other manufacturing	0.1%	0.3%	0.1%	0.2%
Air transportation	16.6%	7.1%	15.6%	14.5%
Trucking	0.2%	0.1%	0.2%	0.2%
Water transportation	0.6%	1.8%	2.6%	1.1%
Ground transportation	0.4%	1.2%	1.7%	0.7%
Automobile rental	3.7%	0.5%	2.6%	2.9%
Parking lots	0.1%	0.0%	0.1%	0.1%
Transit	0.0%	0.0%	0.0%	0.0%
Performing arts	0.3%	0.1%	0.2%	0.3%
Amusement	1.4%	0.6%	1.0%	1.2%
Recreation	0.9%	0.4%	0.6%	0.8%
Museums historical	0.4%	0.2%	0.3%	0.4%
Sightseeing transport	1.5%	4.4%	6.3%	2.7%
Golf courses	1.6%	0.7%	1.1%	1.3%
Hotels	31.1%	25.6%	33.1%	30.2%
Real estate rental	2.3%	1.9%	2.3%	2.2%
Restaurants	11.4%	9.5%	7.3%	10.5%
Wholesale trade	1.3%	3.3%	1.6%	1.8%
Retail trade	10.0%	12.8%	6.6%	10.1%
Information	0.4%	0.2%	0.2%	0.3%
Finance business professional	0.7%	0.6%	0.4%	0.7%
Travel reservations	2.0%	0.8%	2.1%	1.8%
Education private	0.0%	0.2%	0.1%	0.1%
Health services	0.9%	0.7%	0.4%	0.8%
Laundry	0.1%	0.1%	0.1%	0.1%
Other services	0.4%	0.3%	0.2%	0.4%
Electricity	0.0%	0.0%	0.0%	0.0%
Propane gas	0.0%	0.0%	0.0%	0.0%
Waste management private	0.0%	0.0%	0.0%	0.0%
Water sewer	0.0%	0.0%	0.0%	0.0%
Other government	0.5%	0.4%	0.2%	0.4%
Imports	10.0%	25.1%	12.1%	13.4%

Source: DBEDT – READ Division.

Table 8. Industry Concordance based on NAICS Codes

	Sector	NAICS Industry Code		40 Sector		13 Sector
1	Sugarcane	11193	1	Crops	1	Agriculture
2	Vegetables	1112	1		1	
3	Macadamia nuts	111335.111336	1		1	
4	Pineapples	part of 111339	1		1	
5	Other fruits	11131-4, part of 111339	1		1	
6	Coffee	part of 111339	1		1	
7	Greenhouse, nursery	1114	1		1	
8	Dairy cattle	11212	2	Animal	1	
9	Poultry and eggs	1123	2		1	
10	Cattle Ranching	11211.11213	2		1	
11	Hog and pig farming	1122	2		1	
12	Misc. livestock	1124.1129	2		1	
13	Aquaculture	1125, part of 111998	2		1	
14	Other agricultural	113, 1111, 1119 except 11193 and part of 111998	2		1	
15	Commercial fishing	114	3	Fishing	1	
16	Support for agriculture	115, 54194, 81291	2		1	
17	Landscape services	54132, 56173	4	Landscaping	1	
18	Mining	21	5	Construction	2	Construction
19	Single family housing construction	part of 23	5		2	
20	Multiple family housing construction	part of 23	5		2	
21	Commercial building construction	part of 23	5		2	
22	Hotel construction	part of 23	5		2	
23	Road construction	part of 23	5		2	
24	Other construction	part of 23	5		2	
25	Maintenance and repair	part of 23	5		2	
26	Fruit and vegetable manufacturing	3114	6	Food processing	3	Manufacturing
27	Sugar manufacturing	31131	6		3	
28	Confectionery manufacturing	3113 except 31131	6		3	
29	Meat manufacturing	3116	6		3	
30	Dairy manufacturing	3115	6		3	
31	Bakeries manufacturing	3118	6		3	
32	Beverage manufacturing	312	6		3	
33	Snack food manufacturing	31191	6		3	
34	Coffee and tea manufacturing	31192	6		3	
35	Other food manufacturing	3111, 3112, 3117, 31193-9	6		3	
36	Apparel manufacturing	313-315	7	Clothing	3	
37	Wood manufacturing	321	8	Other manuf.	3	
38	Furniture manufacturing	337	8		3	
39	Paper manufacturing	322	8		3	
40	Printing	323	8		3	
41	Chemical manufacturing	325	9	Chemical	3	
42	Petroleum manufacturing	324	10	Petroleum	3	
43	Rubber & plastic manuf.	326	8		3	
44	Non-metallic mineral manuf.	327	8		3	

Table 8. Industry Concordance based on NAICS Codes (continued)

	Sector	NAICS Industry Code	40 Sector		13 Sector	
45	Metal manufacturing	331,332	8		3	
46	Electrical manufacturing	334-335	8		3	
47	Transport equip. manuf.	336	8		3	
48	Misc. manufacturing	316, 333, 339	8		3	
49	Truck transportation	484	11	Truck transport	4	Transportation
50	Warehousing	493	11		4	
51	Water transportation	483, part of 4885	12	Water transport	4	
52	Air transportation	481, part of 4885	13	Air transport	5	Air transportation
53	Ground passenger transport	485	14	Ground transport	4	
54	Support transportation	488 except 4885	15	Other services	6	Services
55	Couriers	492	15		6	
56	Sightseeing transportation	487	16	Sightseeing	7	Entertainment
57	Publishing	511 except 5112	17	Information	6	
58	Software & information	5112, 514	17		6	
59	Motion picture and sound production	512 except 51213	17		6	
60	Motion picture exhibition	51213	17		6	
61	Radio and TV broadcasting	5131	17		6	
62	Cable TV	5132	17		6	
63	Telecommunications	5133	17		6	
64	Electricity	2211	18	Electricity	8	Utilities
65	Gas production	2212	19	Natural gas	8	
66	Wholesale trade	42	20	Wholesale trade	9	Trade
67	Motor vehicle and parts	441	21	Retail Trade	9	
68	Home furnishing stores	442	21		9	
69	Electronics stores	443	21		9	
70	Building materials & gardening equipment dealers	444	21		9	
71	Food stores	445	21		9	
72	Health & personal care stores	446	21		9	
73	Gas stations	447	21		9	
74	Apparel & accessory stores	448	21		9	
75	Sporting goods, hobby, book, and music stores	451	21		9	
76	Department stores	4521	21		9	
77	Other general merchandise	4529	21		9	
78	Misc. store retailers	453	21		9	
79	Non-store retailers	454	21		9	
80	Banking and credit intermediationr	522	22	Finance business professional	6	
81	Securities and investment	523, 525, 533, 55	22		6	
82	Insurance	524	22		6	
83	Owner-occupied dwellings		23	Real estate rental	10	Accommodations
84	Real estate	531	23		10	
85	Equipment rental	532 except 5321	23		10	
86	Automobile rental	5321	24	Automobile rental	4	
87	Legal services	5411	22		6	
88	Accounting services	5412	22		6	
89	Architectural & engineering	5413 except 54132	22		6	
90	Computer systems design	5415	22		6	
91	Management, scientific, and consulting services	5416	22		6	

Table 8. Industry Concordance based on NAICS Codes (continued)

	Sector	NAICS Industry Code	40 Sector		13 Sector	
92	Research and development	5417	22		6	
93	Advertising	5418	22		6	
94	Photographic services	54192	22		6	
95	Other professional services	5414, 5419 except 54192, 3	22		6	
96	Administrative & facilities support services	5611.5612	22		6	
97	Employment services	5613	22		6	
98	Business support services	5614, 5619	22		6	
99	Travel arrangement & reservation services	5615	25	Travel	6	
100	Investigation & security services	5616	22		6	
101	Services to buildings & dwellings	5617 except 56173	22		6	
102	Waste management & remediation services	2213, 562	26	Waste management	8	
103	Educational services	61	27	Education	6	
104	Doctors and dentists	6211-6213	28	Health services	6	
105	Nursing and residential care facilities	623	28		6	
106	Hospitals	622	28		6	
107	Other medical services	6214-9	28		6	
108	Social assistance	624	28		6	
109	Performing arts	7111, 7113-5	29	Performing arts	7	
110	Amusement services	7112, 713 except 7139	30	Amusement	7	
111	Recreation services	7139 except 71391	31	Recreation	7	
112	Golf courses	71391	32	Golf	11	Golf
113	Museums and historical sites	712	33	Museums	7	
114	Hotels and other lodging	721	34	Hotels	10	
115	Eating and drinking places	722	35	Restaurants	12	Restaurants
116	Dry-cleaning and laundry	8123	36	Laundry	6	
117	Automotive repair services	8111	15		6	
118	Other repair services	8112-8114	15		6	
119	Personal care services	8121	15		6	
120	Death care services	8122	15		6	
121	Parking lots and garages	81293	37	Parking lots	4	
122	Other personal services	8129 except 81291, 3; 814	15		6	
123	Organizations	813	15		6	
124	Other state and local govt enterprises	part of state and local govt	38	Government	13	Government
125	State and local govt enterprises: Water and sewer	part of state and local gov't	39	Water sewer	8	
126	State and local gov't enterprises: Transit	part of state and local gov't	40	Transit	4	
127	Federal govt enterprises: Postal service	part of Federal govt	38		13	
128	Other Federal gov't enterprises	part of Federal gov't	38		13	
129	Federal gov't: Military	part of Federal gov't	38		13	
130	Federal gov't: Civilian	part of Federal gov't	38		13	
131	State and local government	part of state and local gov't	38		13	

Source: *The Hawaii Input-Output Study, 1997 Benchmark Report*, Department of Business, Economic Development, and Tourism, State of Hawaii, March 2002; and authors' concordance.

2.2. Data Sources of Infrastructure Services and Petroleum Products Demand by Industry and Final Demand Sectors

The data for each infrastructure service and petroleum product demand collected from different data sources (usually from the state department) are usually grouped into several broad categories. And the amount of emission is derived from the petroleum products demand. Our first task is to distribute the data into 40 industry sectors, in order to match the 40 industry sectors that are used in our study. These 40 industry sectors are grouped from the 131 industry sectors in the 1997 Hawaii input-output (I-O) table. And the grouping is based on the relevance of the industries to the tourism industry in Hawaii.

2.2.1.1. Water Consumption from Water Departments

Data on water consumption by sector (in gallons) are obtained from Mr. Barry Usagawa from the City and County of Honolulu Board of Water Supply; Mr. Milton Pavao and Mr. Richard Tsunoda from the County of Hawaii Department of Water Supply; Ms. Ellen Kraftsow from the County of Maui Department of Water Supply; and Mr. Gregg Fujikawa from the County of Kauai Department of Water.

Water consumption data are classified into several broad categories like residential, agriculture, industrial, commercial, hotel, and government. The main task is to distribute the water consumption in these broad categories (r_{iB}) into 40 industry sectors (r_{ik}). Table 9 shows the water consumption data in broad categories obtained from City and County of Honolulu Board of Water Supply, the County of Hawaii Department of Water Supply, the County of Maui Department of Water Supply, and the County of Kauai Department of Water.

Table 9. Hawaii Water Consumption by County, 1997 (gallons thousands)

Oahu		Big Island		Maui		Kauai	
Agriculture	1,214,264	Agricultural	531,135	Agriculture	1,309,899	Agriculture	201,692
Commercial	8,152,670	Commercial-Industrial	1,037,852	Industrial	477,891	Industrial	50,423
Mixed Residential and Commercial	832,991	Residential-Commercial	22,757	Commercial	950,182	Commercial	403,383
Hotels, motels, resorts, camps, lodges, dormitories, fraternity and boarding houses	2,072,318	Hotel	745,656	Hotel	942,059	Government	453,806
Industrial complex	1,292,070	Government	751,804	Religious Inst.	74,114	MF/Resort	1,260,573
U.S. Military installation	852,518	Others	104,234	Government	932,070	Single Family	2,672,415
U.S. Non-Military installation	64,423	Apartment-Condo	730,165	Residental	6,790,373		
State	2,339,893	Residential-Agri	104,780				
City	1,285,226	Residential	3,829,831				
Religious installations	199,199						
Residental, Single and Multi-Family	28,418,596						
Total	46,724,167		7,858,214		11,476,588		5,042,293

Sources: City and County of Honolulu Board of Water Supply, the County of Hawaii Department of Water Supply, the County of Maui Department of Water Supply, and the County of Kauai Department of Water.

2.2.1.2. Method of Distributing Water Consumption into 40 Sectors

First, the 40 industries (k) are grouped and matched with these broad categories (B) classified by the water departments.

Second, since each row in the I-O table represents the sales in $million by that particular industry to the 40 industries, the sales by the industry "state and local government enterprises: water and sewer" (W_k) are likely to reflect the water and sewer consumption by the 40 industries. The water consumption by industry within each broad category (r_{iBb}) is calculated by multiplying the "proportion of sales" within each broad category by the "state and local government enterprises: water and sewer" sector in the I-O table ($\frac{W_{Bb}}{W_B}$) with the water consumption data in that particular broad category from the water departments (r_{iB}).

Water use by industry within each broad category (r_{iBb}) can be calculated as:

$$r_{iBb} = r_{iB} * \frac{W_{Bb}}{W_B}$$

where

i = water use,

r_{iB} = water consumption data from the water departments in broad categories B, where B = agriculture, industrial, commercial, hotel, and government, $\sum_B r_{iB} = \sum_k r_{ik}$,

r_{ik} = direct water use by the k^{th} industry sector, k = 1…40,

W_{Bb} = sales by "state and local government enterprises: water and sewer" in the I-O table within the broad categories B where $\sum_b W_{Bb} = W_B$,

W_B = sales by "state and local government enterprises: water and sewer" in the I-O table to the broad categories B where $\sum_B W_B = \sum_k W_k$,

W_k = sales by "state and local government enterprises: water and sewer" in the I-O table to the k^{th} industry sector, k = 1…40.

The direct water consumption by final demand sectors is obtained directly from the record of water departments, under the categories single-family, multi-family, and government.

2.2.1.3. Water Consumption not from Water Departments (Ground and Surface Water)

Since some of the water use are directly pumped from wells and not purchased through the water departments, pumping data from different wells are obtained from Mr. Neal Fujii from the Department of Land and Natural Resources. Each well is specified with a well number and the land use for that particular well is identified and then classified into the 40 industry sectors.

The surface water data is also obtained from Mr. Neal Fujii from the Department of Land and Natural Resources, which include Pioneer Mill (Maui) and Maui Pineapple (Maui). The total surface water consumption in 1997 was equal to 16,387.8 million gallons. It is important to note that there is missing data on the surface water consumption since not all surface water users report their water usage to the Department of Land and Natural Resources. Surface water consumption by domestic, agricultural, industry, and commercial sectors are compiled by the U.S. Geological Survey for every 5 years. The latest records are 1995. In 1995, the total surface water consumption was 483.1 million gallons per day, or 176,331.5 million gallons per year. So the data provided by the Department of Land and Natural Resources for 1997 surface water is only about 9.3% of the estimation by the U.S. Geological Survey in 1995. Due to the missing data problem, surface water consumption is not included in our study.

2.2.1.4. Total Water Consumption

The pumping data are combined with the data from the water departments to obtain the total water consumption.

Table 10 shows the total water consumption by industry and final demand sectors in the State of Hawaii, based on the data from the City and County of Honolulu Board of Water Supply, the County of Hawaii Department of Water Supply, the County of Maui Department of Water Supply, and the County of Kauai Department of Water, and the pumping data from the Department of Land and Natural Resources.

2.2.2. Sewer

Once the water consumption is distributed into the 40 industry sectors and the final demand sectors in the I-O table, sewer consumption by industry is calculated by multiplying the "estimated ratios of water consumption entering wastewater system" with the water consumption by sectors. The "estimated ratios of water consumption entering wastewater system" is obtained from Ms. Alma Takahashi in the County of Maui, Department of Public Works, and Wastewater Reclamation Division.

Table 11 shows the estimated sewer consumption.

Table 10. Hawaii Water Consumption, 1997 (1000 gallons)

Industry	Municipal Water Consumption	Private Pumped Water	Total Water Consumption
Crops	2,089,679	10,744,561	12,834,240
Animal	1,161,559	195,727	1,357,286
Commercial fishing	20,806	-	20,806
Landscaping services	89,726	-	89,726
Construction and mining	134,748	44,309	179,057
Food processing	511,660	-	511,660
Clothing manufacturing	36,012	-	36,012
Chemical manufacturing	32,839	-	32,839
Petroleum manufacturing	195,823	1,116,365	1,312,188
Other manufacturing	138,806	-	138,806
Air transportation	212,969	16,561	229,530
Trucking	86,716	-	86,716
Water transportation	44,838	-	44,838
Ground transportation	110,274	-	110,274
Automobile rental	571,348	-	571,348
Parking lots	149,095	-	149,095
Transit	-	-	-
Performing arts	28,822	177,751	206,573
Amusement	65,204	3,466	68,670
Recreation	106,053	49,741	155,794
Museums historical	30,473	53,370	83,844
Sightseeing transport	-	-	-
Golf courses	162,594	976,370	1,138,964
Hotels	4,162,727	229,843	4,392,570
Real estate rental	4,220,882	-	4,220,882
Restaurants	2,858,428	243,727	3,102,155
Wholesale trade	517,582	-	517,582
Retail trade	-	-	-
Information	276,988	367,920	644,908
Finance business professional	942,443	-	942,443
Travel reservations	34,094	-	34,094
Education private	48,066	425,263	473,329
Health services	1,128,557	115,419	1,243,976
Laundry	160,881	-	160,881
Other services	702,294	156,630	858,924
Electricity	87,847	3,571,867	3,659,714
Natural gas	859	-	859
Waste management private	571	155,833	156,405
Water sewer	76,365	-	76,365
Other government	401,106	-	401,106
Total industry demand	**21,599,734**	**18,644,724**	**40,244,458**
Residents demand	43,299,259	-	43,299,259
Visitors demand	-	-	-
State and local gov't demand	4,280,675	24,952	4,305,626
Federal gov't demand	1,921,594	10,597,648	12,519,242
Exports	-	-	-
Total demand in Hawaii	**71,101,262**	**29,267,323**	**100,368,585**

Sources: City and County of Honolulu Board of Water Supply, the County of Hawaii Department of Water Supply, the County of Maui Department of Water Supply, and the County of Kauai Department of Water; Department of Land and Natural Resources.

Table 11. Hawaii Wastewater Generation by Source, 1997 (1000 gallons)

Industry	State Water Use (1000 gallons)	Wastewater Ratios	State Wastewater (1000 gallons)
Crops	12,834,240	0.00*	-
Animal	1,357,286	0.80*	1,085,829
Commercial fishing	20,806	0.80*	16,645
Landscaping services	89,726	0.80*	71,781
Construction and mining	179,057	0.80	143,246
Food processing	511,660	0.80	409,328
Clothing manufacturing	36,012	0.80	28,810
Chemical manufacturing	32,839	0.80	26,271
Petroleum manufacturing	1,312,188	0.80	1,049,750
Other manufacturing	138,806	0.80	111,045
Air transportation	229,530	0.80	183,624
Trucking	86,716	0.80	69,373
Water transportation	44,838	0.80	35,870
Ground transportation	110,274	0.80	88,219
Automobile rental	571,348	0.80	457,078
Parking lots	149,095	0.80	119,276
Transit	-	0.80	-
Performing arts	206,573	0.80	165,258
Amusement	68,670	0.80	54,936
Recreation	155,794	0.80	124,635
Museums historical	83,844	0.80	67,075
Sightseeing transport	-	0.80	-
Golf courses	1,138,964	0.80	911,171
Hotels	4,392,570	0.80	3,514,056
Real estate rental	4,220,882	0.80	3,376,705
Restaurants	3,102,155	0.80	2,481,724
Wholesale trade	517,582	0.80	414,066
Retail trade	-	0.80	-
Information	644,908	0.80	515,927
Finance business professional	942,443	0.80	753,954
Travel reservations	34,094	0.80	27,275
Education private	473,329	0.80	378,664
Health services	1,243,976	0.80	995,181
Laundry	160,881	0.80	128,705
Other services	858,924	0.80	687,139
Electricity	3,659,714	0.80	2,927,771
Natural gas	859	0.80	687
Waste management private	156,405	0.80	125,124
Water sewer	76,365	0.80	61,092
Other government	401,106	0.80	320,885
Total industry demand	**40,244,458**		**21,928,174**
Residents demand: single family	29,422,746	0.45	13,240,236
Residents demand: multi-family	13,876,512	0.70	9,713,559
Visitors demand	-		-
State and local gov't demand	4,305,626	0.80	3,444,501
Federal gov't demand	12,519,242	0.80	10,015,394
Exports	-		-
Total demand in Hawaii	**100,368,585**		**58,341,864**

State Water Use Sources: City and County of Honolulu Board of Water Supply, the County of Hawaii Department of Water Supply, the County of Maui Department of Water Supply, the County of Kauai Department of Water, and the Department of Land and Natural Resources. Wastewater Ratios (Water entering wastewater system) Source: County of Maui, Department of Public Works, Wastewater Reclamation Division (* not available, by authors' assumption).

2.2.3.1. Electricity and Utility Gas

Data on electricity and utility gas consumption by sectors are obtained from Mr. Steve Alber in the Energy, Resource, and Technology Division of the DBEDT. The data is extracted from the Energy 2020 model, which is the energy forecasting model used by the State of Hawaii.

The data are classified into four broad categories:
for industry sectors they include 1) commercial, including hotel, small and large office, retail, grocery, warehouse, elem/sec schools, college, health, restaurant, misc. buildings; and 2) industrial, including sugar industry, other food/agriculture, oil refineries, steel plant, other industrial, water pumping and sewage; for final demand sectors they include 3) residential (direct resident use); 4) military (direct federal military use); and 5) other streetlight (part of direct state and local government use).

The main task is to distribute the electricity and utility gas use in broad categories (for industry sectors) (r_{iB}) into the 40 industry sectors (r_{ik}).

Tables 12 and 13 show the electricity and utility gas demand in broad categories from the Energy 2020 model, respectively.

Table 12. Hawaii Electricity Use by Category, 1997 (GWh/Year)

	Oahu	Big Island	Maui	Kauai	State
Industrial Electric Sales					
Sugar Industry	-	-	6.05	5.19	11.24
Other Food/Agriculture	126.21	28.13	-	-	154.34
29-Oil Refineries	51.91	-	-	-	51.91
Steel Plant	-	-	-	-	-
Other Industrial	143.24	4.09	13.07	-	160.41
Water Pumping & Sewage	152.60	78.55	81.06	-	312.20
Total	473.96	110.76	100.19	5.19	690.10
Commercial Electric Sales					
Hotel	520.30	106.83	202.90	66.95	896.97
Small Office	358.23	43.33	50.76	45.36	497.68
Large Office	674.80	-	-	-	674.80
Retail	520.31	71.83	124.97	22.41	739.52
Grocery	250.92	54.23	57.57	34.20	396.92
Warehouse	97.44	-	-	-	97.44
Elem/Sec Schools	130.91	29.46	-	-	160.37
Colleges	49.57	-	-	-	49.57
Health	267.34	-	-	-	267.34
Restaurant	288.35	15.76	27.59	8.45	340.14
Misc. Buildings	296.73	59.36	98.51	47.30	501.89
Total	3,454.89	380.80	562.29	224.67	4,622.65
Residential Electric Sales					
Single Family	1,027.95	283.85	234.30	106.90	1,653.00
MF-Single Meter	546.01	39.03	113.87	27.00	725.91
MF-Master Meter	278.32	8.23	-	-	286.56
Total	1,852.29	331.12	348.17	133.90	2,665.47
Military	1,217.70	4.63	-	13.07	1,235.39
Other-Streetlight	41.60	66.87	77.29	1.33	187.10
Total	7,040.43	894.18	1,087.94	378.16	9,400.70

Source: DBEDT, the Energy, Resources, and Technology Division.

Table 13. Hawaii Utility Gas Consumption by Categories, 1997 (tBtu/Year)

	Oahu	Big island	Maui	Kauai	State
Hotel	1.0348	0.086	0.0291	0	1.1499
Small Office	0	0.0054	0.0021	0	0.0075
Large Office	0.0431	0	0	0	0.0431
Retail	0	0.0068	0	0	0.0068
Grocery	0.1216	0.0203	0.0114	0	0.1533
Warehouse	0	0	0	0	0
Elem/Sec Schools	0.0659	0.0055	0	0	0.0714
Colleges	0.1938	0	0	0	0.1938
Health	0.1919	0	0	0	0.1919
Restaurant	0.6853	0.0144	0.0049	0	0.7046
Misc. Buildings	0.1269	0.068	0.0177	0	0.2126
Residental	0.5187	0.0238	0.0089	0.0085	0.5599
Total	2.982	0.2302	0.0741	0.0085	3.2948

Source: DBEDT, the Energy, Resources, and Technology Division.

2.2.3.2. Method of Distributing Electricity and Utility Gas Consumption into 40 Sectors

First, the 40 industries (k) are grouped and matched with the categories in the Energy 2020 model (B).

Second, since each row in the I-O table represents the sales in $million by that particular industry to the 40 industries, the sales by the "electricity" sector (E_k) and "gas production & distribution" (G_k) sector are likely to reflect the electricity and utility gas use by the 40 industries.

The electricity use by industry within each category (r_{iBb}) is calculated by multiplying the "proportion of sales" within each category by the "electricity" sector in the I-O table ($\frac{E_{Bb}}{E_B}$) with the electricity use data in that particular category from the Energy 2020 model ($r_{iB,,}$ i = electricity).

Similarly, the utility gas use by industry within each category is calculated by multiplying the "proportion of sales" within each category by the "gas production & distribution" ($\frac{G_{Bb}}{G_B}$) sector in the I-O table with the utility gas use data in that particular category from the Energy 2020 model ($r_{iB,,}$ i = utility gas).

Electricity use by industry within each broad category (r_{iBb}) can be calculated as:

$$r_{iBb} = r_{iB} * \frac{E_{Bb}}{E_B}$$

where

i = electricity use,

r_{iB} = electricity consumption data from the water departments in broad categories B, where B = commercial, including hotel, small and large office, retail, grocery, warehouse, elem/sec schools, college, health, restaurant, misc. buildings; and industrial, including sugar industry, other food/agriculture, oil refineries, steel plant, other industrial, water pumping and sewage, $\sum_B r_{iB} = \sum_k r_{ik}$,

r_{ik} = direct electricity use by the k^{th} industry sector, $k = 1 \ldots 40$,

E_{Bb} = sales by "electricity" sector in the I-O table within the broad categories B where $\sum_b E_{Bb} = E_B$,

E_B = sales by "electricity" sector in the I-O table to the broad categories B where $\sum_B E_B = \sum_k E_k$,

E_k = sales by "electricity" sector in the I-O table to the k^{th} industry sector, $k = 1 \ldots 40$.

Utility gas use by industry within each broad category (r_{iBb}) can be calculated as:

$$r_{iBb} = r_{iB} * \frac{G_{Bb}}{G_B}$$

where

i = utility gas use,

r_{iB} = electricity consumption data from the water departments in broad categories B, where B = commercial, including hotel, small and large office, retail, grocery, warehouse, elem/sec schools, college, health, restaurant, misc. buildings; and industrial, including sugar industry, other food/agriculture, oil refineries, steel plant, other industrial, water pumping and sewage, $\sum_B r_{iB} = \sum_k r_{ik}$,

r_{ik} = direct utility gas use by the k^{th} industry sector, $k = 1 \ldots 40$,

G_{Bb} = sales by "gas production & distribution" sector in the I-O table within the broad categories B where $\sum_b G_{Bb} = G_B$,

G_B = sales by "gas production & distribution" sector in the I-O table to the broad categories B where $\sum_B G_B = \sum_k G_k$,

G_k = sales by "gas production & distribution" sector in the I-O table to the k^{th} industry sector, $k = 1 \ldots 40$.

2.2.4. Solid Waste Disposal

The solid waste disposal by industry sector is calculated by using:

1) "waste disposal rate for business type" from the California Integrated Waste Management Board, where the business grouping follows SIC classification and the disposal rate is shown in terms of "tons/employees/year";

2) the number of jobs (including wage and salary jobs and proprietor's jobs) from the 1997 I-O table.

Table 14 shows the solid waste disposal by industry sector in terms of lbs/employee/year according to the California Integrated Waste Management Board.

Table 14. Solid Waste Disposal by Industry and Jobs

Industry	Solid Waste Disposal Rate (lbs/employee/year)	Total Number of Jobs
Crops	1,800	9,668
Animal	1,800	4,622
Commercial fishing	1,800	2,149
Landscaping services	1,800	4,757
Construction and mining	5,700	33,364
Food processing	3,200	7,020
Clothing manufacturing	1,800	3,637
Chemical manufacturing	1,800	432
Petroleum manufacturing	1,800	622
Other manufacturing	2,640	6,334
Air transportation	2,000	10,328
Trucking	3,800	3,140
Water transportation	2,600	1,385
Ground transportation	2,600	3,930
Automobile rental	600	2,657
Parking lots	1,800	1,533
Transit	2,600	1,469
Performing arts	1,800	6,286
Amusement	1,800	2,533
Recreation	1,800	4,237
Museums historical	1,800	1,941
Sightseeing transport	2,600	4,998
Golf courses	1,800	3,574
Hotels		41,219
Real estate rental	600	29,081
Restaurants	6,200	50,509
Wholesale trade	1,800	23,146
Retail trade	1,554	87,374
Information	2,886	12,848
Finance business professional	2,271	93,889
Travel reservations	3,400	7,070
Education private	1,600	14,371
Health services	3,000	52,473
Laundry	1,800	2,376
Other services	1,800	37,988
Electricity	600	2,445
Natural gas	600	320
Waste management private	3,400	1,226
Water sewer	600	1,971
Other government	1,100	163,310
Total		742,231

Solid Waste Disposal Rate, Source: California Integrated Waste Management Board. Total Number of Jobs, Source: DBEDT, 1997 I-O table.

For the accommodation sector, the solid waste disposal is calculated by using the number of occupied room in Hawaii and the estimated 4 lbs/room/day solid waste generation rate from hotel/motel from the City of LA Bureau of Solid Waste.
The solid waste generated by residents is calculated by using 12.23 lbs/household/day, according to the California Integrated Waste Management Board and the number of household from the Hawaii data book. And an adjustment (-0.4 lb/household/day) is made to match the total solid waste disposal in Hawaii in 1997 (3,198,245,360 lbs), which is obtained from Mr. Lane Otsu from the Hawaii Department of Health, Office of Solid Waste Management.

Table 15 shows the total infrastructure services consumption by industry and final demand sectors in the State of Hawaii in 1997.

Table 15. Infrastructure Demand by Sector

Industry	Output ($million)	Water (1000 gal)	Sewer (1000 gal)	Electricity (GWh)	Propane (mmBtu)	Solid Waste (lbs)
Hotels	3,456.4	4,392,570	3,514,056	897.0	1,149,900	76,755,614
Real estate rental	9,019.3	4,220,882	3,376,705	378.1	41,395	17,448,355
Restaurants	2,274.7	3,102,155	2,481,724	340.1	704,600	313,157,141
Wholesale trade	1,939.0	517,582	414,066	97.4	-	41,662,660
Retail trade	4,179.5	-	-	1,136.4	153,300	148,040,690
Performing arts	155.6	206,573	165,258	4.5	-	11,314,336
Amusement	157.1	68,670	54,936	30.2	-	4,559,176
Recreation	150.7	155,794	124,635	44.0	11,770	7,626,528
Museums historical	77.2	83,844	67,075	14.1	-	3,493,800
Sightseeing transport	303.7	-	-	8.6	3,874	12,994,737
Golf courses	229.8	1,138,964	911,171	67.4	-	6,432,468
Air transportation	2,044.1	229,530	183,624	37.4	4,775	20,655,454
Trucking	279.0	86,716	69,373	15.7	3,198	11,932,766
Water transportation	522.8	44,838	35,870	19.1	4,616	3,600,255
Ground transportation	128.9	110,274	88,219	3.3	-	10,217,105
Automobile rental	393.3	571,348	457,078	7.0	-	1,593,937
Parking lots	109.4	149,095	119,276	14.8	-	2,759,326
Transit	110.0	-	-	3.3	-	3,819,400
Crops	393.9	12,834,240	-	35.7	-	17,402,579
Animal	212.0	1,357,286	1,085,829	36.3	-	8,319,363
Commercial fishing	69.7	20,806	16,645	-	-	3,868,200
Landscaping services	147.8	89,726	71,781	0.4	-	8,563,307
Construction	3,524.3	179,057	143,246	50.8	-	199,200,245
Food processing	1,054.5	511,660	409,328	331.1	-	22,462,543
Clothing	209.4	36,012	28,810	12.7	-	6,547,007
Chemical	73.9	32,839	26,271	3.8	-	776,951
Petroleum	1,419.3	1,312,188	1,049,750	422.6	-	1,119,600
Other manufacturing	659.4	138,806	111,045	38.9	-	18,558,577
Information	1,940.3	644,908	515,927	38.7	-	37,706,260
Professional services	6,578.0	942,443	753,954	141.9	-	184,041,571
Travel reservations	456.8	34,094	27,275	20.2	-	24,037,723
Education private	477.5	473,329	378,664	28.4	-	22,993,012
Health services	3,859.3	1,243,976	995,181	267.3	191,900	157,420,335
Laundry	97.7	160,881	128,705	12.4	9,205	4,277,472

Table 15. Infrastructure Demand by Sector (continued)

Industry	Output ($million)	Water (1000 gal)	Sewer (1000 gal)	Electricity (GWh)	Propane (mmBtu)	Solid Waste (lbs)
Other services	1,771.5	858,924	687,139	320.0	2,086	59,083,187
Electricity	1,169.1	3,659,714	2,927,771	6.8	-	1,466,728
Waste management	190.4	156,405	125,124	0.5	-	4,169,993
Water sewer	280.3	76,365	61,092	302.6	-	1,182,600
Natural gas	51.2	859	687	2.8	-	191,993
Other government	8,565.8	401,106	320,885	144.5	75,119	6,817,913
Total Industry	**58,732.5**	**40,244,458**	**21,928,174**	**5,337.0**	**2,355,737**	**1,488,270,906**
Resident		43,299,259	22,953,795	2,665	559,900	1,709,974,454
Visitor						
State & Local Gov't		4,305,626	3,444,501	729	359,377	
Federal Gov't		12,519,242	10,015,394	1,278	431,721	
TOTAL DEMAND		**100,368,585**	**58,341,864**	**10,009**	**3,706,734**	**3,198,245,360**

2.2.5.1. Petroleum Products

Data on petroleum products distribution are obtained from Mr. Steve Alber in the Energy, Resources, and Technology Division of the DBEDT, which include highway gasoline and diesel, non-highway gasoline, non-highway diesel, residual fuel, jet fuel and aviation gasoline, and propane. The data shows the sales of petroleum products by industry refiners and distributors to some broad categories.

For highway and non-highway gasoline, categories include civilian service stations, military service stations, vehicle fleets, agriculture, commercial, construction, government, industrial, marine, sold to jobbers, and sold to other fuel distributors. For highway diesel, categories include local highway, transit, tour bus, truck, and buses diesel. For non-highway diesel, categories include electricity generation: IPP, plantation, and utility, federal military, federal other, state and county government, vessel bunkering intra-state, and overseas (bonded and non-bonded). For jet fuel and aviation gasoline, categories include aviation intra-state, oversea (bonded and non-bonded), federal military, and state government. For residual fuel oil, categories include construction, electricity generation: IPP, plantation, and utility, federal military, vessel bunkering intra-state, and overseas (bonded and non-bonded). For propane, categories include industrial, commercial, and residential, and utility.

The main task is to distribute the petroleum products use in these categories (r_{iB}) into the 40 industries in the I-O table (r_{ik}). For some petroleum products, it is easy to match the category with the industry. For example, for jet fuel and aviation gasoline, it is obvious that air transportation would be the main industry; for electricity generation: utility, electricity would be the only industry. But for other categories, distribution according to the sales by the "petroleum manufacturing" sector in the I-O table is used.

Table 16 shows the sales of petroleum products by industry refiners and distributors to some broad categories.

Table 16. Sales of Petroleum Products by Refiners and Distributors in Hawaii, 1997 gallons

		Hawaii	Honolulu	Kauai	Maui	Total
Gasoline	Civilian Service Stations	48,214,110	218,032,290	16,598,316	38,939,880	321,784,596
	Military Service Stations	236,628	22,103,844	187,698	-	22,528,170
	Vehicle Fleets	786,282	1,837,122	-	576,408	3,199,812
	Agriculture	52,752	207,018	51,702	66,150	377,622
	Commercial	178,836	1,435,098	-	306,558	1,920,492
	Construction	6,804	243,264	-	-	250,068
	Government	594,048	4,089,288	-	99,372	4,782,708
	Industrial	-	152,124	-	-	152,124
	Marine	-	41,874	-	-	41,874
	Sold to Jobbers	6,689,172	9,336,432	4,458,468	3,620,862	24,104,934
	Sold to Other Fuel Distributors	5,362,182	6,544,482	921,606	2,189,502	15,017,772
	Adjustment	-	-	1,254,582	7,026,600	8,281,182
Diesel Fuel Oil	Electricity Generation - IPP	95,256	11,701,200	-	-	11,796,456
	Electricity Generation - Plantation	-	-	1,417,206	34,062	1,451,268
	Electricity Generation - Utility	17,173,108	545,076	23,452,073	53,461,386	94,631,643
	Federal - Military	126,966	1,359,036	-	-	1,486,002
	Federal - Other	-	2,100	-	-	2,100
	State Government	278,838	129,990	-	85,680	494,508
	County Government	336	5,673,024	-	-	5,673,360
	Vessel Bunkering Intra-State	-	9,895,116	-	-	9,895,116
	Vessel Bunkering Overseas, Bonded	-	49,397,292	-	-	49,397,292
	Vessel Bunkering Overseas, Non-Bond	-	64,722	-	-	64,722
	Other	4,917,904	46,613,578	5,355,064	1,868,026	58,754,572
	Own Use	51,156	34,272	6,426	3,906	95,760
Highway Diesel	Local Highway	2,034,690	-	-	-	2,034,690
	Transit Diesel	3,746,232	-	-	-	3,746,232
	Tourbus Diesel	250,824	-	-	-	250,824
	Trucks Diesel	11,597,544	928,704	528,990	198,408	13,253,646
	Buses Diesel	-	4,718,616	3,260,166	1,222,788	9,201,570

Table 16. Sales of Petroleum Products by Refiners and Distributors in Hawaii, 1997 gallons (continued)

		Hawaii	Honolulu	Kauai	Maui	Total
Residual Fuel Oil	Construction	-	243,810	-	-	243,810
	Electricity Generation - IPP	-	87,714,690	-	-	87,714,690
	Electricity Generation - Plantation	-	80,346	-	9,554,538	9,634,884
	Electricity Generation - Utility	36,865,206	300,354,139	-	20,056,508	357,275,853
	Federal - Military	-	2,291,184	-	-	2,291,184
	Vessel Bunkering Intra-State	-	5,491,164	-	-	5,491,164
	Vessel Bunkering Overseas, Bonded	-	55,892,046	-	-	55,892,046
	Vessel Bunkering Overseas, Non-Bond	-	20,255,592	-	-	20,255,592
Aviation Gasoline	Aviation Intra-State	186,480	953,694	43,260	162,918	1,346,352
Jet Fuel Kerosene	Aviation Intra-State	11,203,416	102,986,940	1,439,718	19,733,784	135,363,858
	Aviation Overseas, Bonded Fuel	-	373,867,536	-	-	373,867,536
	Aviation Overseas, Non-Bonded Fuel	115,164	216,628,818	-	1,937,502	218,681,484
	Federal - Military	348,180	30,534,000	470,484	-	31,352,664
	State Government	-	-	5,376	-	5,376
	Sold to Jobbers	38,052	-	-	5,082	43,134
Propane - NonUtility	Industrial/Commerical	4,472,381	10,532,201	2,532,140	7,361,414	24,898,136
	Residential	1,584,322	1,223,059	926,889	1,115,463	4,849,733
Propane - Utility		2,475,805	33,692,658	96,047	778,548	37,043,058
Grand Total		159,682,674	1,637,827,439	63,006,211	170,405,345	2,030,921,669

Source: DBEDT, the Energy, Resources, and Technology Division.

2.2.5.2. Method of Distributing Petroleum Products Consumption into 40 Sectors

First, the 40 industries (k) are grouped and matched with the above categories (B).

Second, since each row in the I-O table represents the sales in $million by that particular industry to the 40 industries, the sales by the "petroleum manufacturing" sector (P_k) are likely to reflect the petroleum products use by the 40 industries.

The petroleum products use by industry within each category (r_{iBb}) is calculated by multiplying the "proportion of sales" within each category by the "petroleum manufacturing" sector in the I-O table ($\frac{P_{Bb}}{P_B}$) with the petroleum products sales data in that particular category obtained from the Energy, Resources, and Technology Division of the DBEDT (r_{iB}).

Petroleum products use by industry within each broad category (r_{iBb}) can be calculated as:

$$r_{iBb} = r_{iB} * \frac{P_{Bb}}{P_B}$$

where

i = petroleum products use, including highway gasoline and diesel, non-highway gasoline, non-highway diesel, residual fuel, jet fuel and aviation gasoline, and propane,
r_{iB} = petroleum products use data from the Energy, Resources, and Technology Division of the DBEDT in broad categories B, where
B = vehicle fleets, agriculture, commercial, construction, government, industrial, marine, sold to jobbers, and sold to other fuel distributors for highway and non-highway gasoline;

B = local highway, transit, tour bus, truck, and buses diesel for highway diesel;

B = electricity generation: IPP, plantation, and utility, vessel bunkering intra-state (bonded and non-bonded) for highway and non-highway diesel;

B = aviation intra-state for jet fuel and aviation gasoline;

B = construction, electricity generation: IPP, plantation, and utility, vessel bunkering intra-state for residual fuel oil;

B = industrial, commercial, and residential for propane;
for each petroleum product, $\sum_B r_{iB} = \sum_k r_{ik}$,
r_{ik} = direct petroleum products use by the k^{th} industry sector, $k = 1\ldots 40$,
P_{Bb} = sales by "petroleum manufacturing" sector in the I-O table within the broad categories B where $\sum_b P_{Bb} = P_B$,

P_B = sales by "petroleum manufacturing" sector in the I-O table to the broad categories B where $\sum_B P_B = \sum_k P_k$,

P_k = sales by "petroleum manufacturing" sector in the I-O table to the k^{th} industry sector, k = 1…40.

The direct highway gasoline consumption by residents is from the gasoline sales by civilian service stations and military service stations, and the direct highway gasoline consumption by visitors is from the gasoline sales by civilian service stations. The proportions of sales by civilian service stations to residents versus visitors are approximated by the proportion of sales by the "petroleum manufacturing" sector to residents and visitors in the I-O table.

The direct diesel consumption by state and county government is from the category "state and county government". The direct diesel consumption by federal military is from the categories "federal military", and "federal other".

The direct residual fuel oil consumption by federal military is from the category "federal military".

The direct propane consumption by residents is from the category "residential".

Table 17 shows the petroleum products consumption by industry and final demand sectors in the State of Hawaii in 1997.

Table 17. Petroleum Product Demand, 1997

Industry	Highway Gasoline and Diesel	Non-highway Gasoline	Non-highway Diesel	Jet Fuel and Aviation Gasoline	Residual Fuel Oil	Propane	Total Petroleum Products
Crops	-	746,942	2,604,574	-	-	3,933	3,355,449
Animal	-	111,382	388,388	-	-	8,560	508,331
Commercial fishing	-	41,874	9,895,116	-	-	-	9,936,990
Landscaping services	72,340	-	-	-	-	-	72,340
Construction and mining	4,546,298	-	15,863,262	-	243,810	672,683	21,326,053
Food processing	1,042,704	-	744,575	-	6,195,250	515,130	8,497,659
Clothing manufacturing	192,643	-	-	-	-	-	192,643
Chemical manufacturing	201,564	-	-	-	-	54,157	255,721
Petroleum manufacturing	105,005	-	11,227,779	-	1,719,896	-	13,052,681
Other manufacturing	892,897	-	-	-	-	219,939	1,112,837
Air transportation	-	-	-	341,297,863	-	170,075	341,467,938
Trucking	3,892,064	-	-	-	-	113,922	4,005,986
Water transportation	-	-	-	-	5,491,164	164,407	5,655,571
Ground transportation	4,159,761	-	-	-	-	-	4,159,761
Automobile rental	5,368,765	-	-	-	-	-	5,368,765
Parking lots	253,367	-	-	-	-	-	253,367
Transit	3,746,232	-	-	-	-	-	3,746,232
Performing arts	59,036	-	-	-	-	-	59,036
Amusement	216,423	-	-	-	-	-	216,423
Recreation	197,921	-	-	-	-	419,251	617,172
Museums historical	101,146	-	-	-	-	-	101,146
Sightseeing transport	10,900,986	-	-	-	-	137,984	11,038,970
Golf courses	303,438	-	-	-	-	-	303,438

Table 17. Petroleum Product Demand, 1997 (continued)

Industry	Highway Gasoline and Diesel	Non-highway Gasoline	Non-highway Diesel	Jet Fuel and Aviation Gasoline	Residual Fuel Oil	Propane	Total Petroleum Products
Hotels	2,666,304	-	9,429,435	-	-	8,160,672	20,256,411
Real estate rental	2,956,766	-	-	-	-	3,528,412	6,485,178
Restaurants	1,856,887	-	6,566,916	-	-	6,751,132	15,174,935
Wholesale trade	6,110,586	-	-	-	-	-	6,110,586
Retail trade	6,763,502	-	-	-	-	138,825	6,902,328
Information	834,344	-	2,950,674	-	-	-	3,785,018
Finance business professional	3,252,622	-	8,199,000	-	-	-	11,451,622
Travel reservations	579,005	-	2,047,663	-	-	-	2,626,668
Education private	406,520	-	1,437,666	-	-	-	1,844,186
Health services	3,160,288	-	8,457,242	-	-	1,426,350	13,043,881
Laundry	228,969	-	809,752	-	-	784,575	1,823,295
Other services	2,290,256	-	-	12,084,299	-	74,289	14,448,844
Electricity	-	-	96,002,773	-	446,710,281	-	542,713,054
Natural gas	-	-	-	-	-	37,043,058	37,043,058
Waste management private	2,093,012	-	-	-	-	1,553,838	3,646,850
Water sewer	2,199,573	-	-	-	-	-	2,199,573
Other government	1,745,502	-	961,106	-	-	-	2,706,608
Total industry demand	**73,396,725**	**900,199**	**177,585,921**	**353,382,162**	**460,360,401**	**61,941,194**	**1,127,566,601**
Residents demand	322,678,447				-	4,849,733	327,528,180
Visitors demand	21,634,319				-	-	21,634,319
Change in inventories	8,281,182				-	-	8,281,182
State and local gov't demand	4,037,444		5,206,762	5,376	-	-	9,249,583
Federal gov't demand	-		1,488,102	31,352,664	2,291,184	-	35,131,950
Exports	-		49,462,014	375,920,202	76,147,638	-	501,529,854
Total demand in Hawaii	**430,028,117**	**900,199**	**233,742,799**	**760,660,404**	**538,799,223**	**66,790,927**	**2,030,921,669**

2.3. Emissions from Petroleum Products Use

The methodology of estimating the greenhouse gas emissions is based on the EPA State Workbook (1995). Formulas for calculating the emissions of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) are applied to the petroleum products consumption in the State of Hawaii in 1997.

For CO2 emission calculation, the quantity of petroleum products in terms of millions of Btu is first multiplied with the greenhouse gas emission factor of each petroleum product (Table 18) (e.g. 42.8 for highway gasoline and 44 for highway diesel), and then divided by 2000 to provide the amount of carbon emission in tons. Finally, the amount of carbon emission in tons is converted to CO2 by multiplying an oxidation factor of 0.99 and by 44 tons CO2/12 tons of C to yield tons of CO2 emitted. The each petroleum product, the calculation of its CO2 emission is:

$$CO2_{PP} = PP * (CO_2\text{ Emission Factor}/2000) * 0.99 * (44/12),$$

where

subscript PP = emission from petroleum products, including highway gasoline and diesel, non-highway gasoline, non-highway diesel, residual fuel, jet fuel and aviation gasoline, and propane,

PP = petroleum products in millions of Btu, including highway gasoline and diesel, non-highway gasoline, non-highway diesel, residual fuel, jet fuel and aviation gasoline, and propane.

For CH4 emission calculation, the quantity of petroleum products in terms of millions of Btu is first multiplied with the greenhouse gas emission factor (e.g. 0.0016 for highway gasoline and 0.011 for highway diesel), and then divided by 2000 to provide the amount of CH4 in tons. The each petroleum product, the calculation of its CH4 emission is:

$$CH4_{PP} = PP * (CH_4\text{ Emission Factor}/2000).$$

For N2O emission calculation, the quantity of petroleum products in terms of millions of Btu is first multiplied with the greenhouse gas emission factor (e.g. 0.0015 for highway gasoline and 0.004 for highway diesel), and then divided by 2000 to provide the amount of N2O in tons. The each petroleum product, the calculation of its N2O emission is:

$$N2O_{PP} = PP * (N_2O\text{ Emission Factor}/2000).$$

Tables 18 shows the emission factors and Table 19 show the emissions from petroleum products use by industry and final demand sectors in Hawaii in 1997.

Table 18. Emission Factor for Petroleum Product Use

Petroleum Products	Carbon Dioxide (CO_2)	Methane (CH_4)	Nitrous Oxide (N_2O)
Highway and Non-highway Gasoline	42.8	0.0016	0.0015
Highway Diesel	44	0.011	0.004
Non-highway Gasoline, Marine	42.8	0.011	0.0044
Non-highway Diesel, Agriculture Vehicle	37.8	0.024	0.0044
Non-highway Diesel, Commercial, Industrial, and Military	44	0.009	N/A
Non-highway Diesel, Marine	44	N/A	0.002
Non-highway Diesel, OFS	44	0.0007	N/A
Non-highway Diesel, CT	44	0.0124	N/A
Non-highway Diesel, IC	44	0.009	0.004
Jet Fuel	43.5	0.0044	N/A
Aviation Gasoline	41.6	0.133	0.002
Residual Fuel Oil, Marine	47.4	N/A	0.002
Residual Fuel Oil, Military	47.4	N/A	0.002
Residual Fuel Oil, Construction, Commercial, and Industrial	47	0.0022	N/A
Residual Fuel Oil, OFS	47.4	0.0015	N/A
Residual Fuel Oil, CT	47	0.0124	N/A
Propane, Residential	37.8	0.0021	0.098
Propane, Commercial/Industrial	37.8	0.0025	0.1

Source: EPA State Workbook (1995)

Table 19. Hawaii Emissions from Petroleum Products Use, 1997 (tons)

Industry	Carbon Dioxide (CO2)	Methane (CH4)	Nitrous Oxide (N2O)
Crops	24,348	3.06	0.64
Animal	3,683	0.46	0.13
Commercial fishing	110,003	0.03	1.38
Landscaping services	731	0.02	0.01
Construction and mining	229,038	11.36	3.86
Food processing	101,934	1.09	2.61
Clothing manufacturing	1,945	0.06	0.03
Chemical manufacturing	2,390	0.06	0.29
Petroleum manufacturing	147,339	11.16	0.01
Other manufacturing	10,458	0.28	1.18
Air transportation	3,636,808	111.39	0.97
Trucking	40,050	1.13	1.11
Water transportation	71,793	0.02	1.61
Ground transportation	44,538	2.43	0.95
Automobile rental	54,144	1.50	0.77
Parking lots	2,555	0.07	0.04
Transit	41,493	2.86	1.04
Performing arts	595	0.02	0.01
Amusement	2,183	0.06	0.03
Recreation	4,743	0.11	2.03
Museums historical	1,020	0.03	0.01
Sightseeing transport	117,619	6.37	3.14
Golf courses	3,060	0.08	0.04
Hotels	184,797	7.61	39.35
Real estate rental	52,937	1.25	17.27
Restaurants	135,694	5.42	32.50
Wholesale trade	61,625	1.71	0.88
Retail trade	69,119	1.91	1.63
Information	41,095	2.08	0.12
Finance business professional	123,613	6.03	0.47
Travel reservations	28,519	1.44	0.08
Education private	20,023	1.01	0.06
Health services	134,888	6.33	7.26
Laundry	16,418	0.66	3.78
Other services	152,313	4.59	0.69
Electricity	6,806,709	189.18	11.89
Natural gas	242,705	4.42	176.88
Waste management private	31,289	0.77	7.72
Water sewer	21,371	0.22	0.21
Other government	27,604	0.77	0.16
Total industry	12,803,190	389.06	322.85
Residents	3,166,854	32.77	52.96
Visitors	210,195	2.16	2.03
Change in inventories	80,458	0.83	0.78
State and local gov't	96,953	3.66	0.38
Federal gov't	380,163	10.24	0.34
Exports	5,535,242	111.65	18.26
Total emissions in Hawaii	22,273,055	550.37	397.60

2.4. Concluding Remarks

In this appendix, the data utilized in this study have been described. The purpose of this report is to describe the data used to formulate a baseline model of the interactions between the tourism sector, the state's economy, and the environment. The baseline model is used as a benchmark against which alternative forecasts of population growth and economic change can be compared. In addition, the effects of various policy changes can also be simulated by comparing the results of alternative tourism scenarios to the baseline conditions.

This project has brought together a number of different methods and techniques in order to both estimate the effects of changes in visitor spending and also to devise a pragmatic policy tool for measuring economic and environmental conditions. In addition to a comprehensive model of the state's economy, linkages to infrastructure (water, sewer, electricity, solid waste, fossil fuel use) have also been derived. A spatial allocation model has also been developed to map and analyze the location of economic and environmental changes.

Should additional data become available, future refinements could include the development of county-level input-output matrices and models as well as dynamic simulations of the interactions between counties. At present, however, these data are not available nor of the quality and coverage needed.

Conventionally, an input-output table is accompanied by an import matrix which contains data on the share of goods and services by sector imported into the economy. As the state is highly dependent on imported goods and services, absence of detailed information on imports is problematic.

It is recommended that the state conduct additional household surveys to obtain labor, income, and household expenditure data. At present, the I-O table provides only aggregate level household demand. It would be useful to have a breakdown of spending according to household type to conduct further income distribution and incidence analyses. On the production side, it would be most useful to have labor costs disaggregated into various skill types, separating for example between managerial and other labor categories. Moreover, it was determined that existing spatial databases did not have adequate information on the location of job types throughout the state.

In the process of compiling these data and formulating the economic model of the state, it also became quite apparent that the public sector activities are not adequately accounted for in the I-O tables. Of particular concern and interest are the levels of spending, employment, and activity for public education, parks and recreation services, police and fire, airports, public transit and other important government services. It is recommended that future input-output studies address these data deficiencies.

Also there is a need to furnish more complete, detailed information on the source of indirect business taxes. It would be most useful to distinguish between general excise taxes, transient accommodation taxes, fuel taxes, property taxes, customs duties and other fees rather than treat them as an aggregate sum.

Addressing these data deficiencies would greatly extend the choice of policy instruments that could be analyzed.

2.5. References

The Hawaii Input-Output Study, 1997 Benchmark Report, Department of Business, Economic Development, and Tourism, State of Hawaii, March 2002 (updated August 2003).

U.S. Environmental Protection Agency (USEPA), 1995. State Workbook: Methodologies for Estimating Greenhouse Gas Emissions, Second Edition, EPA 230-B-95-001 (Revised), with corrections published in September 1996. Washington, D.C.: Office of Policy, Planning and Evaluation.

APPENDIX 3.1. COMPUTABLE GENERAL EQUILIBRIUM MODEL

This appendix contains a detailed summary of the methods and tools for modeling both static and dynamic relationships between changes in visitor spending, the overall economy, and the environment.

The Model: Analyzing Changes in Hawaii's Visitor Industry

The Hawaii Sustainable Tourism Economic Assessment **Computable General Equilibrium** Model (CGE) provides a tool for analyzing the economic and environmental impacts of various counter-factual experiments under a variety of conditions. It models the relationship between visitor expenditures, the labor force, industry composition, and growth using an applied general equilibrium model of Hawaii.

Illustrated in this section is a set of resident and visitor growth scenarios. Provided are the impacts on a variety of macroeconomic and average person indicators including visitor and household expenditures, visitor and consumer price indices, compensation of employees, output, and gross state product. The impacts of changes on output and the distribution of production across 40 sectors are examined. Finally, estimates of the change in demand for key infrastructure elements including water, electricity, and solid waste, are provided. The model provides a methods for considering the carrying capacity of a mature tourism destination.

In order to assess the effects of the alternative tourism and labor force growth scenarios, a numerical applied general equilibrium model of Hawaii is developed. A Social Accounting Matrix is assembled which describes the flow of goods, services, and factors through each economy in a baseline year. For each production sector, the purchases of intermediate inputs and primary factors (labor and capital) are provided. Demand in each sector is a combination of intermediate demand and final expenditures by households, government, exporters, and investors. The baseline conditions are derived from a 1997 Input-Output tables comprised of 131 industrial sectors, three factor markets, and 11 agents of final demand, as described in Appendix 2. Summary data are given in Tables 1 and 2. Table 3 provides an overview of initial, or baseline, infrastructure usage by sector. The Social Accounting Matrix is supplemented with additional data on visitor expenditures, population, and infrastructure.

Hawaii is modeled as a small and very open economy, in which visitor expenditures generate a significant share of foreign exchange. Visitors demand a bundle of goods, such as hotel and restaurant services, most of which are not importable. Goods are produced under perfect competition and constant returns to scale using intermediate commodities, imports, labor, and capital. Final demand is generated by households, visitors, various government entities, and exports. Within this context, prices are calibrated to clear markets.

Table 1. Structure of Output and Production in Hawaii

Industry	Output	Inter-industry demand	Imports	Compensation of employees	Proprietor income	Other value added	Jobs
Total	$58.7 bil	$14.4 bil	$5.7 bil	$21.6 bil	$2.1 bil	$14.9 bil	742,231
Agriculture	1.4%	1.9%	1.4%	1.3%	1.8%	1.0%	2.9%
Construction	6.0%	7.9%	11.1%	5.8%	11.6%	1.7%	4.5%
Manufacturing	5.8%	5.9%	28.8%	2.4%	2.2%	2.4%	2.4%
Air Transportation	3.5%	4.8%	5.3%	2.4%	0.3%	3.5%	1.4%
Other transportation	2.6%	4.5%	4.0%	1.7%	1.2%	1.8%	1.9%
Entertainment	1.4%	1.8%	1.8%	1.4%	3.0%	0.8%	2.7%
Golf	0.4%	0.6%	0.3%	0.4%	0.0%	0.2%	0.5%
Hotels	5.9%	7.6%	3.4%	5.9%	1.7%	5.7%	5.6%
Real estate	15.4%	13.7%	2.9%	1.8%	17.6%	41.0%	3.9%
Restaurants	3.9%	5.5%	5.2%	3.7%	2.0%	2.3%	6.8%
Trade	10.4%	9.9%	8.2%	11.1%	9.6%	10.9%	14.9%
Other services	25.8%	30.3%	23.4%	27.2%	48.9%	17.3%	29.8%
Utilities	2.9%	4.1%	2.5%	1.6%	0.1%	4.1%	0.8%
Other government	14.6%	1.5%	1.4%	33.2%	0.0%	7.3%	22.0%

Source: *The Hawaii Input-Output Study*, *1997 Benchmark Report*, Department of Business, Economic Development, and Tourism, State of Hawaii, March 2002 (updated August 2003).

Table 2. Household and Visitor Expenditures in Hawaii

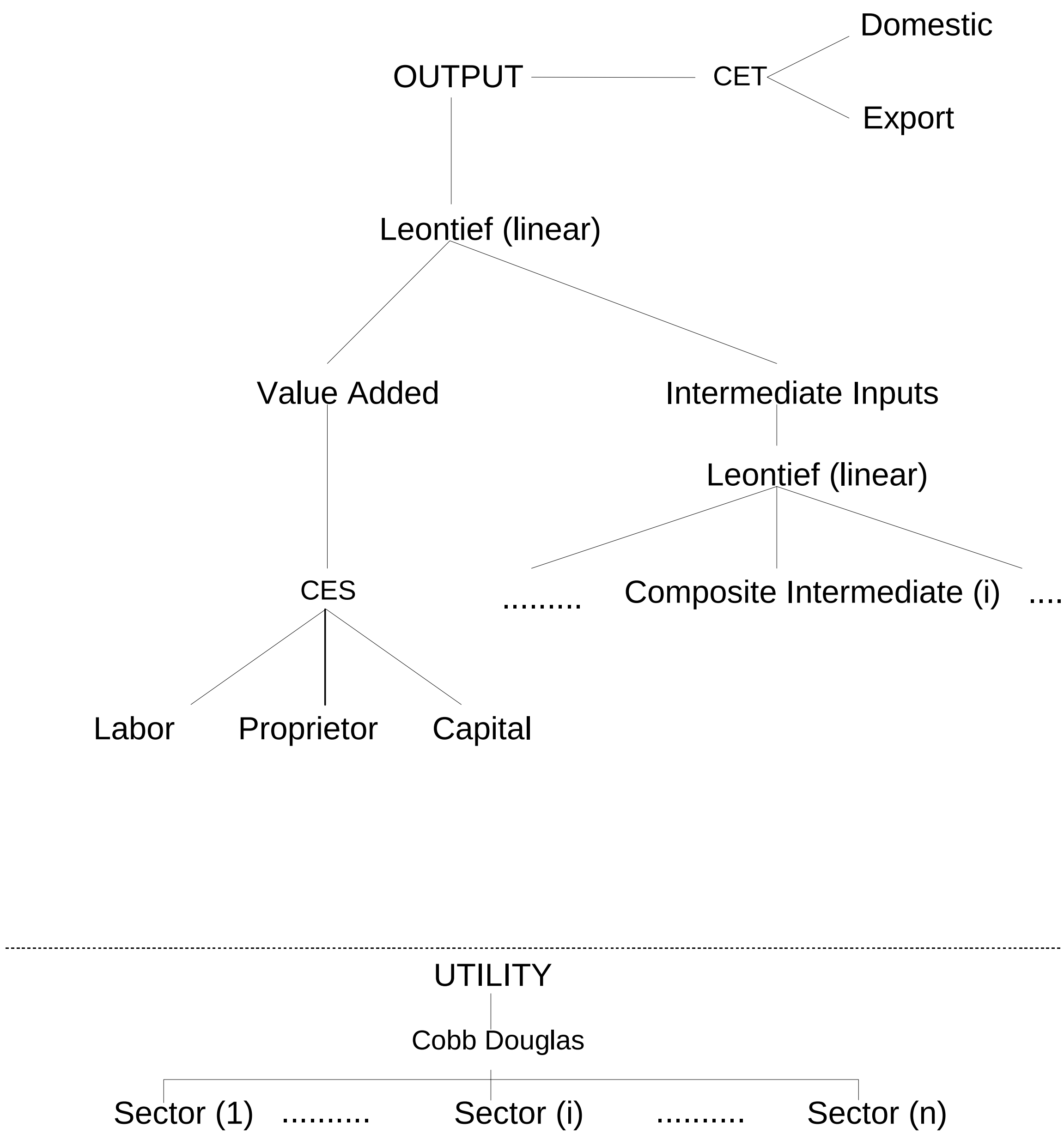
	Household Expenditures		Visitor Expenditures	
Industry	($ million)	(%)	($ million)	(%)
Total	$24,962.0	100.0%	$10,931.0	100.0%
Agriculture	122.0	0.5%	18.4	0.2%
Construction	0.0	0.0%	0.0	0.0%
Manufacturing	683.0	2.7%	296.2	2.7%
Air Transportation	337.9	1.4%	1,555.2	14.2%
Other transportation	406.3	1.6%	536.3	4.9%
Entertainment	207.3	0.8%	569.4	5.2%
Golf	88.5	0.4%	141.3	1.3%
Hotels	170.0	0.7%	3,247.4	29.7%
Real estate	5,211.4	20.9%	239.7	2.2%
Restaurants	1,017.1	4.1%	1,126.2	10.3%
Trade	2,998.3	12.0%	1,278.0	11.7%
Other services	7,832.2	31.4%	439.8	4.0%
Utilities	595.3	2.4%	0.0	0.0%
Other government	264.9	1.1%	45.6	0.4%
Imports	5,027.8	20.1%	1,437.6	13.2%

Source: *The Hawaii Input-Output Study*, *1997 Benchmark Report*, Department of Business, Economic Development, and Tourism, State of Hawaii, March 2002 (updated August 2003).

Table 3. Infrastructure Demand in Hawaii, 1997

	Output ($million)	Water (1000 gal)	Electricity (GWh)	Propane (mmBtu)	Solid Waste (1000 lbs)
Hotels	3,456.4	4,392,570	897.0	1,149,900	76,755
Real estate	9,019.3	4,220,882	378.1	41,395	17,448
Restaurants	2,274.7	3,102,155	340.1	704,600	313,157
Wholesale trade	1,939.0	517,582	97.4	-	41,662
Retail trade	4,179.5	-	1,136.4	153,300	148,040
Performing arts	155.6	206,573	4.5	-	11,314
Amusement	157.1	68,670	30.2	-	4,559
Recreation	150.7	155,794	44.0	11,770	7,626
Museums historical	77.2	83,844	14.1	-	3,493
Sightseeing transport	303.7	-	8.6	3,874	12,994
Golf courses	229.8	1,138,964	67.4	-	6,432
Air transportation	2,044.1	229,530	37.4	4,775	20,655
Trucking	279.0	86,716	15.7	3,198	11,932
Water transportation	522.8	44,838	19.1	4,616	3,600
Ground transportation	128.9	110,274	3.3	-	10,217
Automobile rental	393.3	571,348	7.0	-	1,593
Parking lots	109.4	149,095	14.8	-	2,759
Transit	110.0	-	3.3	-	3,819
Crops	393.9	12,834,240	35.7	-	17,402
Animal	212.0	1,357,286	36.3	-	8,319
Commercial fishing	69.7	20,806	-	-	3,868
Landscaping services	147.8	89,726	0.4	-	8,563
Construction	3,524.3	179,057	50.8	-	199,200
Food processing	1,054.5	511,660	331.1	-	22,462
Clothing	209.4	36,012	12.7	-	6,547
Chemical	73.9	32,839	3.8	-	776
Petroleum	1,419.3	1,312,188	422.6	-	1,119
Other manufacturing	659.4	138,806	38.9	-	18,558
Information	1,940.3	644,908	38.7	-	37,706
Professional services	6,578.0	942,443	141.9	-	184,041
Travel reservations	456.8	34,094	20.2	-	24,037
Education private	477.5	473,329	28.4	-	22,993
Health services	3,859.3	1,243,976	267.3	191,900	157,420
Laundry	97.7	160,881	12.4	9,205	4,277
Other services	1,771.5	858,924	320.0	2,086	59,083
Electricity	1,169.1	3,659,714	6.8	-	1,466
Waste management	190.4	156,405	0.5	-	4,169
Water sewer	280.3	76,365	302.6	-	1,182
Natural gas	51.2	859	2.8	-	191
Other government	8,565.8	401,106	144.5	75,119	6,817
Total Industry	**58,732.5**	**40,244,458**	**5,337.0**	**2,355,737**	**1,488,271**
Resident		43,299,259	2,665	559,900	1,709,974
Visitor					
State & Local Gov't		4,305,626	729	359,377	
Federal Gov't		12,519,242	1,278	431,721	
TOTAL DEMAND		**100,368,585**	**10,009**	**3,706,734**	**3,198,245**

Figure 1. Diagram of Production and Utility Functions



Consumer Behavior

A general diagram of production and utility factors is contained in Figure 1. There are two types of consumers in the economy, residents (r) and visitors (v). This report uses the term "household" and "resident" interchangeably. In the economic literature "consumers" are often referred to as "households." The economy produces n commodities and imports a composite good m. The Cobb-Douglas utility function for the type-h consumer is given by

$$U_h = \prod_i C_{hi}^{b_{hi}} \qquad \sum_i b_{hi} = 1 \quad i = 1, \ldots, n \tag{1}$$

where C_{hi} is consumption and b_{hi} the income expenditure share of i= 1,..,n,m by consumer h = r,v.

Consumer h's demand for domestic tradable goods and imports are assumed to follow a nested utility function, given by the following equation.

$$C_{hi} = [\theta_{Dhi} D_{hi}{}^{(\varepsilon_{him}-1)/\varepsilon_{him}} + \theta_{Mh} M_h{}^{(\varepsilon_{him}-1)/\varepsilon_{him}}]^{\varepsilon_{him}/(\varepsilon_{him}-1)} \tag{1.a}$$

Where ε_{him} is the Armington constant elasticity substitution between tradable good i and imports by consumer h. D_{hi} is sector i demands for domestic (Hawaii) produced and M_h is imported demand by consumer h.

A single representative resident maximizes utility (U_r) subject to the following budget constraint

$$\sum_i p_i C_{ri} = p_L L + P_R R + P_K K + \overline{p}_{fx} BP - T_r \tag{2}$$

where prices p_i represent the market prices for imports and commodities i = 1,..n, m respectively. The resident derives income from factors of production including labor (L), proprietor income (R), and capital (K), where p_L, p_R, p_K are the market price of the respective factors. The resident pays a lump-sum tax (T_r), net of transfer payments, to the state and local government. The resident also receives foreign exchange ($\overline{p}_{fx} B$) from a balance of payment deficit, described below in equation (13).

It is important to note that household income (and thus expenditures) for the representative resident are not equal to labor compensation, as shown in equation 2. Household expenditures ($\sum_i p_i C_{ri}$) may be higher or lower than labor income (p_L L), depending on other sources of income and transfers.

A representative visitor with exogenous income (I_v) maximizes utility (U_v) subject to the budget constraint

$$I_v \equiv I_{v0}(1+\lambda_v) = \sum_i p_i C_{vi} \tag{3}$$

where I_{v0} is the initial visitor expenditure and λ_v serves as an exogenous visitor expenditure shock parameter.

Production and Sales of Goods and Services

Final output (Y_j) in sector j = 1,.., n is produced according to a nested production function comprised of intermediate inputs (Z_{ij}) of commodity i, composite imports (M_j), and value added (V_j). The first level is a Leontief production function

$$Y_j = \min[Z_{1j}/\alpha_{1j},...Z_{nj}/\alpha_{nj},V_j/\alpha_{vj}] \tag{4}$$

where a_{ij}, a_{vj} are unit input coefficients for intermediates and value added respectively.

Importable commodities are assumed to substitute for tradable Hawaii-produced commodities according to the following Armington constant elasticity of substitution production nest.

$$Z_{ij} = [\theta_{Dij} D_{ij}^{(\varepsilon_{ijm}-1)/\varepsilon_{ijm}} + \theta_{Mi} M_i^{(\varepsilon_{ijm}-1)/\varepsilon_{ijm}}]^{\varepsilon_{ijm}/(\varepsilon_{ijm}-1)} \tag{4.a}$$

Where ε_{ijm} is the Armington constant elasticity substitution between tradable good i and imports by producer j. D_{ij} is sector i demands by producer j for domestic (Hawaii) produced and M_i is imported demand in sector i.

A sub-production function describes the substitutability between labor (L_j), capital (K_j), and proprietor income (R_j) in producing real value added (V_j) in each sector j, where σ_j is the constant elasticity of substitution (CES) among value added variables.

$$V_j = [\alpha_{Lj} L_j^{(\sigma_j-1)/\sigma_j} + \alpha_{Kj} K_j^{(\sigma_j-1)/\sigma_j} + \alpha_{Rj} R_j^{(\sigma_j-1)/\sigma_j}]^{\sigma_j/(\sigma_j-1)} \tag{5}$$

Commodity Y_j is differentiated for sale on domestic and international markets, as given by a constant elasticity of transformation (CET) function between domestic (D_j) sales and exports (X_j).

$$Y_j = [\beta_{Dj} D_j^{(\varepsilon_j-1)/\varepsilon_j} + \beta_{Xj} X_j^{(\varepsilon_j-1)/\varepsilon_j}]^{\varepsilon_j/(\varepsilon_j-1)} \tag{6}$$

In this function, ε_j is the elasticity of transformation and β_{Dj}, β_{Xj} are parameter shares.

Government Revenue and Expenditures

Three government agencies procure goods and services in the economy: the state and local government (denoted *SL*), the federal military government (denoted *FM*), and the federal civilian government (denoted *FC*). Each government type purchases domestic commodities (G_{gi}) and imports (G_{gm}) according to a Leontief utility function to assure a constant level of public provision is maintained, where $g = SL, FM, FC$.

The state and local government depends entirely on the economy for the tax base.

$$\sum_i p_i G_{SLi} + p_m G_{SLm} = \sum_i p_i Y_i \tau_i + T_r \tag{7}$$

A primary source of revenue is the State's goods and services tax ($_i$) on the sales (Y_i) of commodity i. The state and local government also impose a variety of taxes, such as property and income taxes, on residents.

The budgets of the federal government agencies are assumed to be completely independent of state economic conditions. In the case of Hawaii, this is a reasonable characterization. Hawaii has unique strategic assets, such as Pearl Harbor. Federal military expenditures, moreover, are determined by factors outside the state, such as international political conditions. As a relatively small state, federal civilian expenditures are not well-correlated with federal taxes paid by Hawaii residents. In the model, federal inflows are assumed to adjust endogenously to assure that federal government objectives are maintained. Thus, the federal public sector budget constraints are given by the following equations

$$\sum_i p_i G_{FMi} + p_m G_{FMm} = I_{FM0}(1+\gamma_{FM}) \equiv I_{FM} \tag{8}$$

$$\sum_i p_i G_{FCi} + p_m G_{FCm} = I_{FC0}(1+\gamma_{FC}) \equiv I_{FC} \tag{9}$$

where the sum on the left-hand side represents the cost of public expenditures. The terms I_{FM0}, I_{FC0} represent initial federal revenue inflows and γ_{FM}, γ_{FC} represent exogenous income multipliers for military and civilian agencies, respectively.

Market Clearing Conditions

Constant returns to scale and perfect competition ensure that the producer price (p_j) equals the marginal cost of output in each sector j. In addition, the State and Local Government collects a general excise tax ($_j$) on sales. This in turn implies that the value of total output equals producer costs, where p_L, p_K, p_R, equal the market price of labor, capital, and proprietor income respectively.

$$p_j Y_j (1+\tau_j) = \sum_{l=1,..,n} p_l Z_{lj} + P_L L_j + p_k K_j + p_R R_j + p_m M_{Yj} \tag{10}$$

The labor force L is identically determined by an initial endowment of $\bar{L}_0$ and an exogenous growth rate γ_L. In equilibrium, labor is fully employed when the quantity of labor supplied equals to that demanded (L_j) across all sectors j = 1, …, n. Note that labor is assumed to be fully mobile across sectors

$$L \equiv \bar{L}_0(1+\gamma_L) = \sum_j L_j \tag{11}$$

Likewise, proprietors (R) and other value added (K) are fully mobile across sectors. Factor supply is determined by initial endowments $\bar{R}_0$, $\bar{K}_0$ and an exogenous growth rate γ_R, λ_K. Given the competitive nature of the model, all factors will be fully employed in equilibrium. The following market clearing conditions hold in the factors markets:

$$R \equiv \bar{R}_0(1+\gamma_R) = \sum_j R_j \tag{12a}$$

$$K \equiv \bar{K}_0(1+\gamma_K) = \sum_j K_j \tag{12b}$$

Sector *j* output, which supplied to the domestic market (D_j), is demanded by consumers $h \in \{r,v\}$, government agencies $g \in \{SL,FC,FM\}$, and industries j = 1,..,*n*.

$$D_j = \sum_h C_{hj} + \sum_g G_{gj} + \sum_l Z_{li} \tag{13}$$

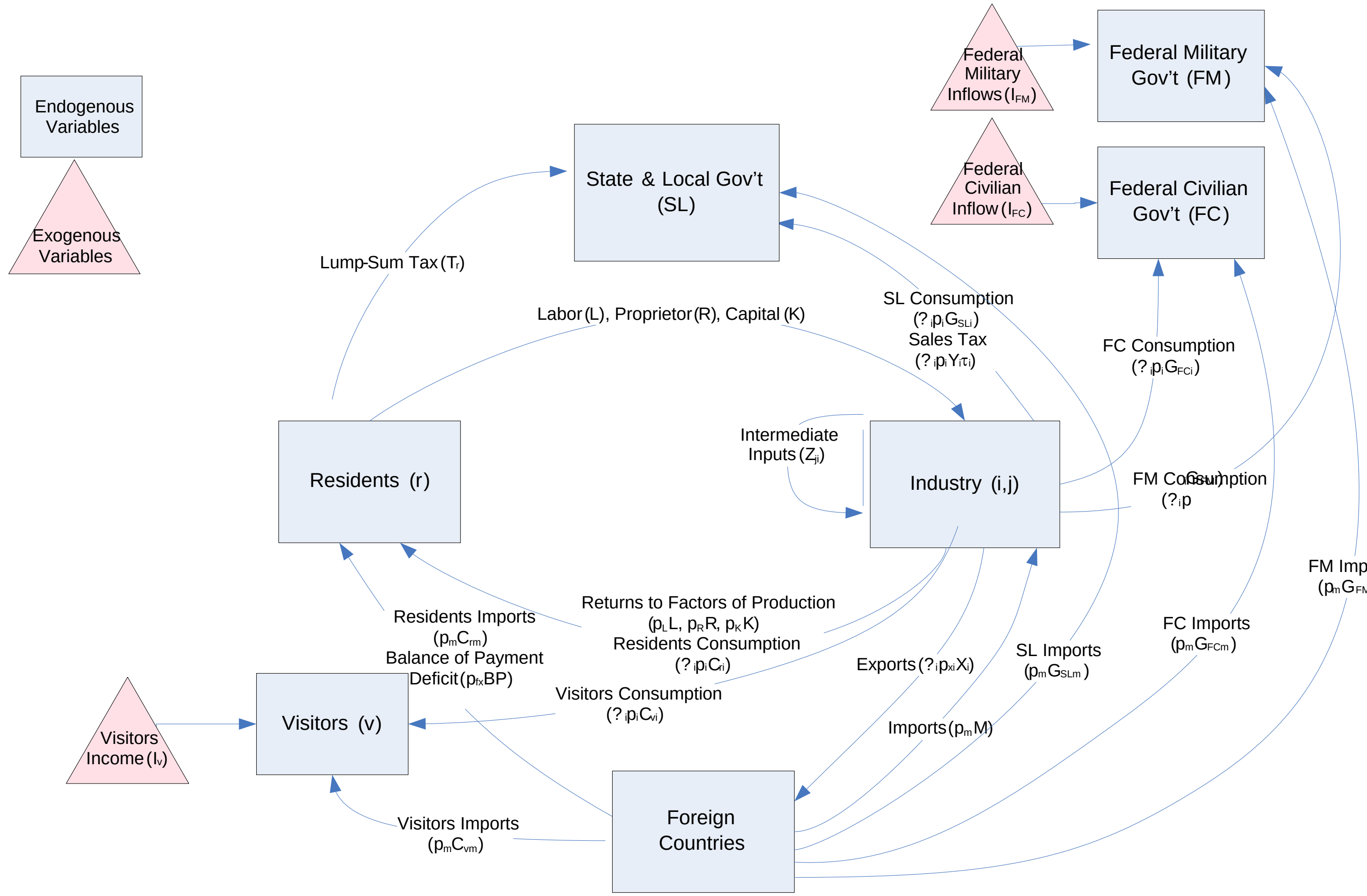
A balance of external payments (*BP*) is maintained under the assumption of a fixed (dollar) exchange rate ($\bar{p}_{fx}$), where $\bar{p}_{fx}$ is the price of foreign exchange, the exchange rate. The quantity of imports (*M*) are thus constrained by the inflow of dollars obtained from visitor expenditures (I_v), federal government expenditures (I_{FM}, I_{FC}), Hawaii exports (X_j), and visitor expenditures. It is assumed that the economy is a small price taker on world markets and thus import and export prices are perfectly inelastic.

$$\bar{p}_{fx} BP = \bar{p}_m M - I_v - I_{FM} - I_{FC} - \sum_j \bar{p}_{xj} X_j \tag{14}$$

A schematic representation of the general equilibrium model of Hawaii's economy is given in Figure 2. Elasticity parameters are given in Table 3. The computable general equilibrium model thus represents a classic Walrasian system. In this particular system, there are 40 commodities markets and three factors markets. Given the convexity of the production and expenditure sets, there exists a unique vector of equilibrium prices at which markets clear (supply is equal to demand). Changes in parameters of the system induce an optimal response on the part of producers and consumers resulting in a new vector of market-clearing equilibrium prices. The model is estimated numerically using the GAMS (General Algebraic Modeling Systems) – MPSGE platform.

Table 3. Elasticity Parameters

Elasticity	Description	Value	Comments
σ^{Ex}	Import Elasticity wrt producers purchase of intermediates	4	
σ^{Im}	Export elasticity wrt domestic price for the sale of producer's goods	-1	Cobb-Douglas Preferences, inverse relationship
σ^{Y}	Income elasticity of demand for local goods and services	1	Cobb-Douglas Preferences
$\sigma_i^{p_j}$	Cross-price elasticity for goods from different industries	1	Cobb-Douglas Preferences
$\sigma_i^{p_i}$	Own-price elasticity for goods and services	-1	Cobb-Douglas Preferences, inverse relationship
$\sigma^{K,L}$	Elasticity of substitution between capital and labor	-1	Cobb-Douglas Preferences, inverse relationship
$\sigma^{Z,V}$	Elasticity of substitution between intermediate industries and value added	0	Leontief Preferences
$\sigma^{Z,M}$	Elasticity of substitution between intermediate industries and composite imports	0	Leontief Preferences



Computable General Equilibrium Model

Substitution of Imports

The CGE model allows for the substitution of imports for tradable Hawaii commodities, both in industrial production as well as in household and visitor expenditures. Tradable sectors of the 131 sector Input Output table are identified, Table 4. The way in which these goods enter into consumption and production has been described earlier.

Table 4: Tradable Commodities

Sector	Sector Number (of 131)
Crops	1-7
Animal	8-14, 16
Commercial fishing	15
Food processing	26-35
Clothing manufacturing	36
Chemical manufacturing	41
Other manufacturing	37-40, 43-48
Information	57-63
Finance, business, professional	80-82, 87-98, 100-101

UHERO LONG-RANGE FORECASTING MODEL FOR HAWAII

This section describes projections for visitor, population, and economic growth. Independent projections were developed by UHERO. A sequential process was used by UHERO to derive visitor spending levels. Visitor arrivals were first estimated on the basis of variables such as the GDP of the origin country, the relative cost of a Hawaii vacation, exchange rates, and supply constraint factors such as the occupancy rate. The length of stay was determined based on ARIMA models that assumed that deviations from recent average length of stay are transitory. Visitor spending was based on the application of daily average person levels of spending, broken into two categories – lodging and all other expenditures.

Population and Employment

Information regarding UHERO estimates used for model inputs such as overall population and job growth, military employment, and Federal civilian government expenditures are contained in Tables 5-8. The model incorporates growth in these factors in their 10-, 20- and 30- year projections. As noted earlier, there are structural adjustments in labor force forecasts based on levels of economic activity. As economic conditions such as visitor spending or Federal expenditures in Hawaii improve, the demand for labor also rises and in-migration increases. Downturns are met with slower growth and out-migration.

Base visitor expenditure growth estimates, as well as low and high visitor expenditure growth, are provided over the thirty year time horizon in Table 5-8. The methodology used by UHERO is described in Appendix 3-4. Projections were developed for visitor arrivals, daily census, and visitor expenditures for various categories of tourists visiting the state and each of the four counties. Table 5 contains actual and projected levels of nominal visitor spending from 1997 to 2030. The baseline projections increase from $10.9 billion (1997) to $28.5 billion (2030) an increase of 160.3%.

On any given day, visitors to Hawaii account for roughly 13 percent of the state's de facto projections for population. In addition to total visitor arrivals, the state's resident population must be considered. Resident population projections were developed using the cohort component method to forecast population by both age and sex, at the County-level, described in Appendix 3-3. This method is used by the US Social Security Administration and the US Census Bureau. The population projections from the UHERO demographic model have been integrated into the UHERO long-range forecasting model to produce a consistent set of visitor expenditure (Table 5) and employment projections for Baseline, Low, and High forecasts to 2030, provided in Table 6. Table 6 shows the UHERO projections for employment over the same period. For the baseline, the total job count goes from 564,137 (1997) to 753,448 (2030) an increase of 33.6%.

Federal Expenditures

UHERO forecasts of growth in federal government expenditures, both military and civilian, as well as capital accumulation, provided in Table 7. Table 7 reveals that the total armed forces stationed in Hawaii is projected (by UHERO) to grow from 44,500 (1997) to 53,300 (2030) while armed forces labor earnings is projected to grow from $1.3 billion to $3.1 billion over the same period. Federal civilian government expenditures are expected to rise from $982.8 million (1997) to over $2.4 billion (2030)

Capital Accumulation

Table 7 also contains the Capital Accumulation Index which is projected to rise from 100 in 1997 to 173 in 2030. The CGE model incorporates annual 'base' projections on employment, visitor expenditures, and federal civilian and military expenditures. The capital accumulation index represents growth in both the capital stock and capital productivity. The capital accumulation index is entered in the market clearing conditions of the model as one of the factor endowments. Thus technological change over time is incorporated into the model through UHERO growth projections of capital productivity.

Table 5. Nominal Visitor Expenditure Projections to 2030

	Low Projection		Base Projection		High Projection	
	$ million	Cum % change from 1997	$ million	Cum % change from 1997	$ million	Cum % change from 1997
1997*	$ 10,931		$ 10,931		$ 10,931	
2003	11,362		11,362		11,362	
2010	13,773	26.0%	14,501	32.7%	15,243	39.4%
2020	17,948	64.2%	20,138	84.2%	22,541	106.2%
2030	23,891	118.6%	28,457	160.3%	33,860	209.8%

Source: UHERO Projections; *actual.

Table 6. Employment Projections to 2030

	Low Projection		Base Projection		High Projection	
	Jobs	Cum % change from 1997	Jobs	Cum % change from 1997	Jobs	Cum % change from 1997
1997*	564,137		564,137		564,137	
2003*	591,800		591,800		591,800	
2010	609,043	8.0%	637,941	13.1%	651,503	15.5%
2020	634,727	12.5%	702,642	24.6%	737,397	30.7%
2030	656,669	16.4%	753,448	33.6%	814,709	44.4%

Source: UHERO Projections; *actual

Table 7. Macroeconomic Projections to 2030

	Total Armed Forces		Armed Forces Labor Earnings		Federal Civilian Government Expenditures		Capital Accum-ulation
	(thous)	Cum % change from 1997	($ thous)	Cum % change from 1997	($ thous)	Cum % change from 1997	Index
1997*	44.5		1,350.7		982.8		100
2010	48.8	9.6%	2,182.1	61.6%	1,535.8	56.3%	120
2020	50.3	13.0%	2,590.1	91.8%	1,955.9	99.0%	147
2030	53.3	19.7%	3,111.6	130.4%	2,437.8	148.0%	173

Source: UHERO Macroeconomic Forecasting Model of Hawaii, *actual

Table 8. Population Projections to 2030

	Low Projection		Base Projection		High Projection	
	Pop.	Cum % change from 1997	Pop.	Cum % change from 1997	Pop.	Cum % change from 1997
2000	1,212,000		1,212,000		1,212,000	
2003	1,232,000		1,232,000		1,232,000	
2010	1,271,000	3.19%	1,319,000	7.11%	1,336,000	8.5%
2020	1,330,000	7.96%	1,420,000	15.26%	1,451,000	17.84%
2030	1,381,000	12.12%	1,488,000	20.81%	1,540,000	25.08%

Source: UHERO Projections

APPENDIX 3.2. ENVIRONMENTAL AND INFRASTRUCTURE ASSESSMENT

In this section, the methodologies for environmental and infrastructure assessment are described. There are three sections. The first describes the environmental assets in Hawaii that should be protected. The second identifies an infrastructure demand model used to assess and evaluate infrastructure needs and capacity in Hawaii. The third section contains a detailed methodology for assessing the nitrogen-carbon cycle in Hawaii. Due to data limitations and because of the complexities associated with multiple systems, the nitrogen cycle is presented as proposed methodology which could be implemented with additional data and resources.

3.2.1. Hawaii's Environmental Resources

In addition to the coastal areas and world renowned beaches, Hawaii has numerous environmental resources. These resources include more endangered species than any other place in the U.S. and a wide mix of environments and habitat, including: wetlands, perennial streams, natural lakes, reservoirs, upland bogs, mangrove swamps, and achialine ponds. From the coastal areas to valleys and plains to the mountains, Hawaii does indeed have a vast array of valuable environmental resources. Long recognized by the Native Hawaiians, there has been increased interest in traditional systems of land management, or "ahupua'a" planning principles. This integration between the natural, cultural, and social environment is no doubt an important aspect of sustainable development.

One strategy for managing Hawaii's important and fragile environmental resources involves the use of mapping and other technologies to identify the critical resources, species, and habitat that should be protected and ensure that new development does not negatively impact these resources.

An example of how this might be achieved is illustrated below. Figure 1 shows the location of perennial streams on the island of Oahu. These streams play an important role in feeding the various wetlands which are shown in Figure 2. The classification system utilized illustrates the standard types of wetlands: estuarine, lacustrine, marine, palustrine, and riverine developed by Cowardin, et. al. (U.S. Fish and Wildlife Services, 1979). Figure 3 shows the location of bird habitat. These are areas which should be protected from development as are the locations where threatened and endangered plants are concentrated (Figure 4). Figure 5 shows the spatial relationship between wetlands and the location of threatened and endangered plants. The strong spatial correlation suggests that an important of preserving habitat involves protecting wetland areas. At the same time, it is important note that there are wetlands in areas where agricultural activities (crop and animal industries) exist (Figure 6). But the spatial analysis reveals that the primary threat to wetlands involves residential development (Figure 7) which is occurring in more locations throughout the state. Therefore, one strategy for protecting habitat, endangered species and other important environmental resources involves restricting development in these sensitive areas. Figure 8 reveals one such attempt. It utilizes a high growth population projection, combined with an urban growth model indicating where the likely development would occur in 2030. Then, development was restricted in the areas adjacent to or containing wetlands, leading to more concentrated development in areas without wetlands.

Clearly, the approach could be refined to address other important issues such as habitat fragmentation as well as the impact of other factors such as infrastructure development on species and habitat loss. And while the analysis was performed on Oahu, a similar approach could be extended to other parts of the state.

The difference between this approach and the general tactic followed in other parts of the study is that here we are starting with the identification of important environmental resources and assets and seeking to protect those areas and resources.

Figure 1. Perennial Streams on Oahu

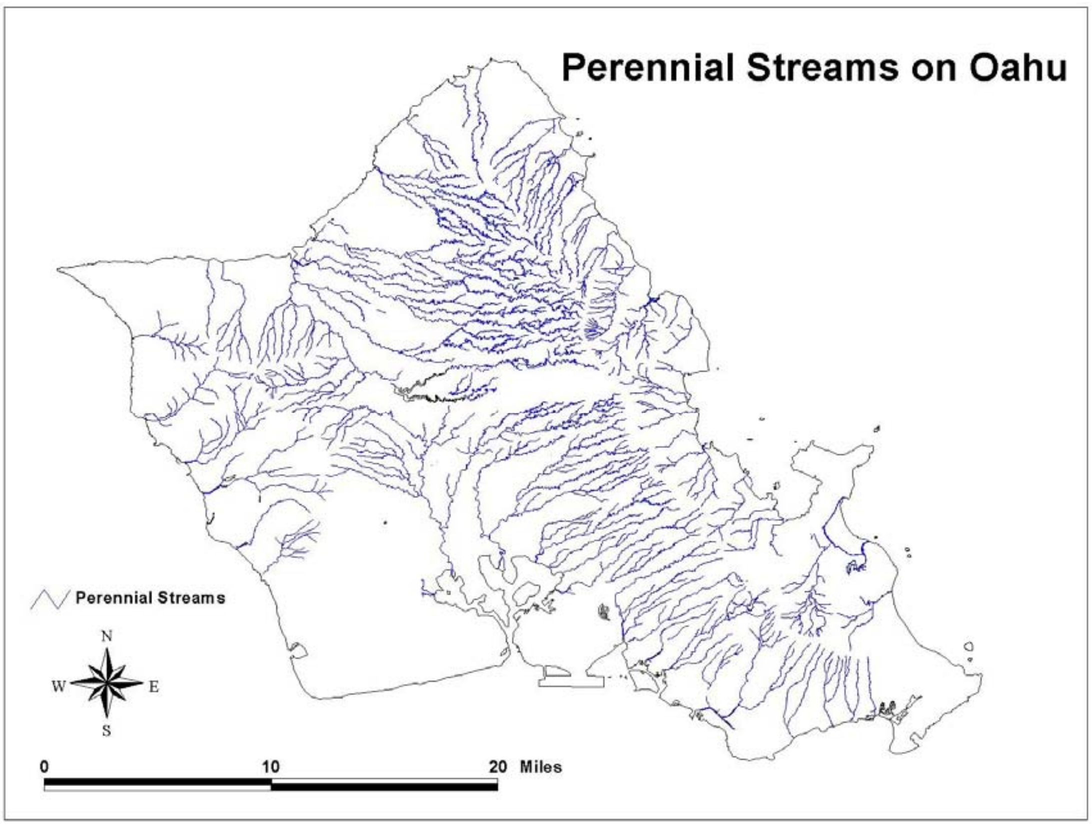


Figure 2. Wetlands on Oahu

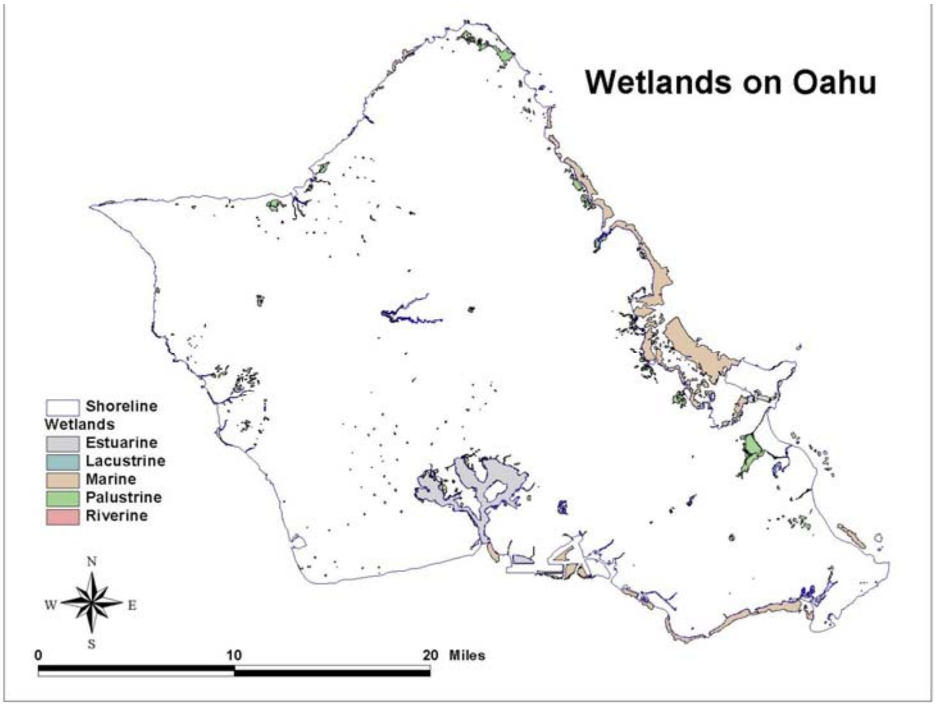


Figure 3. Bird Habitat on Oahu

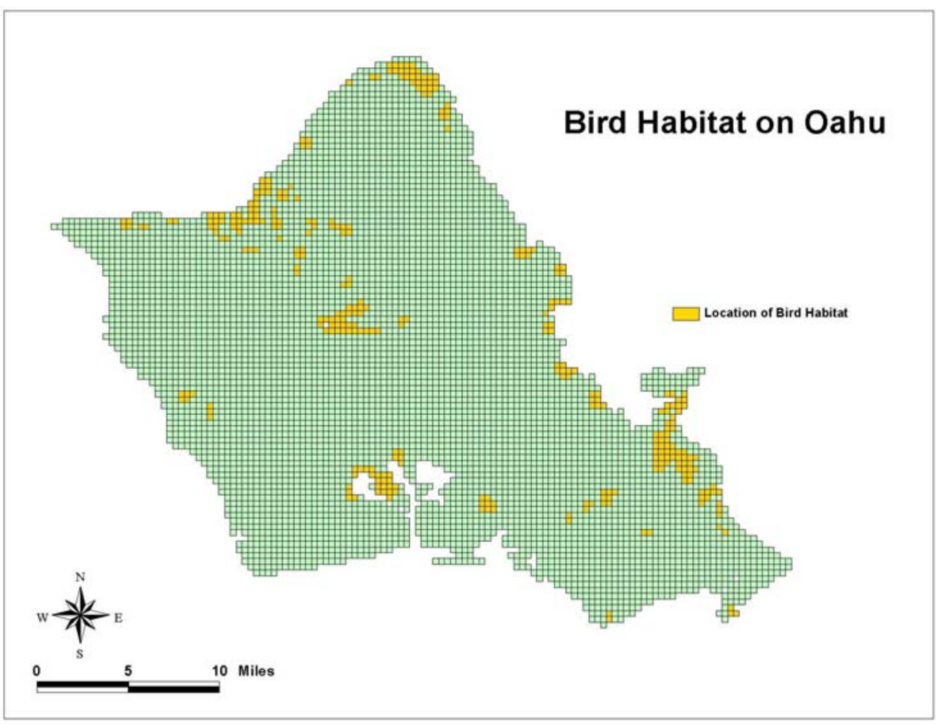


Figure 4: Threatened and Endangered Plant Concentration

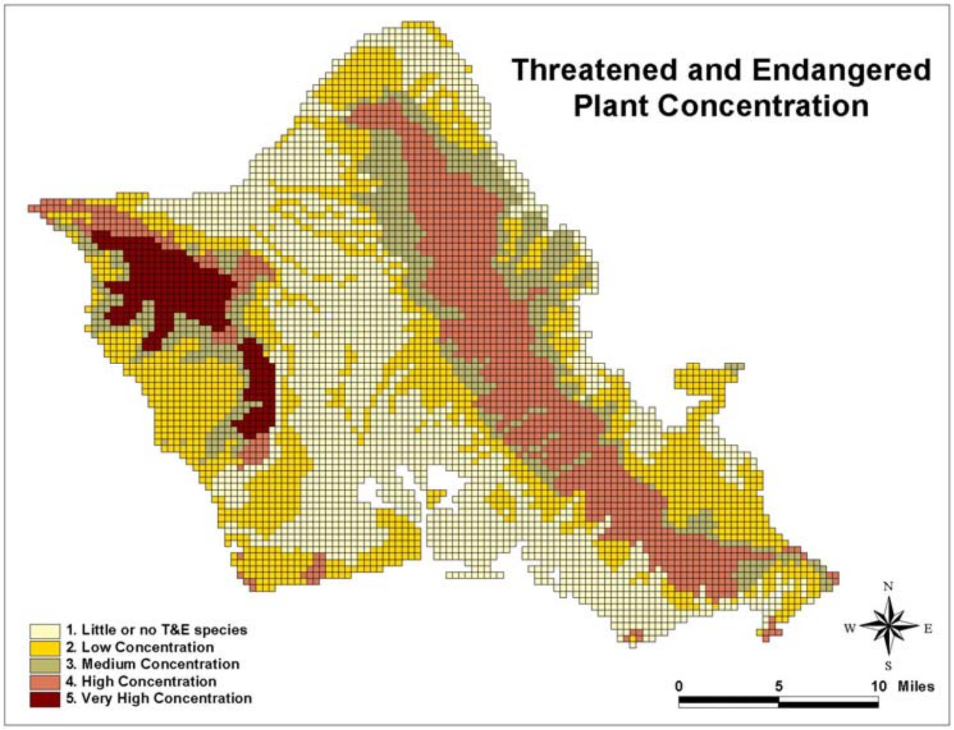


Figure 5. Intersected Areas between Wetlands and Threatened & Endangered Plants on Oahu

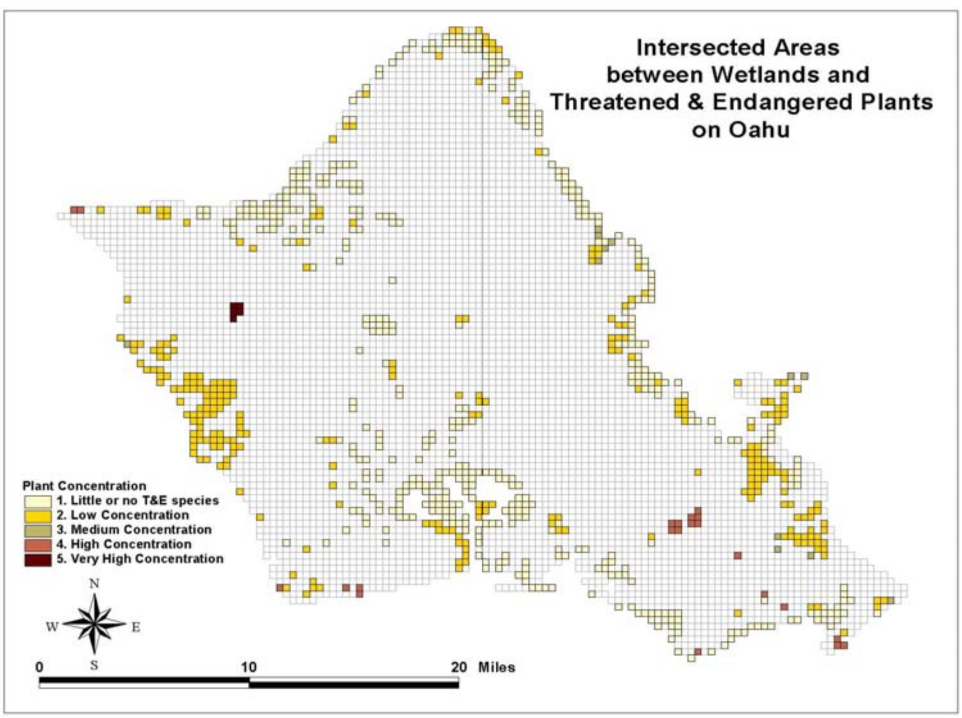


Figure 6. Intersected Area between Wetlands and Crop and Animal Industries on Oahu

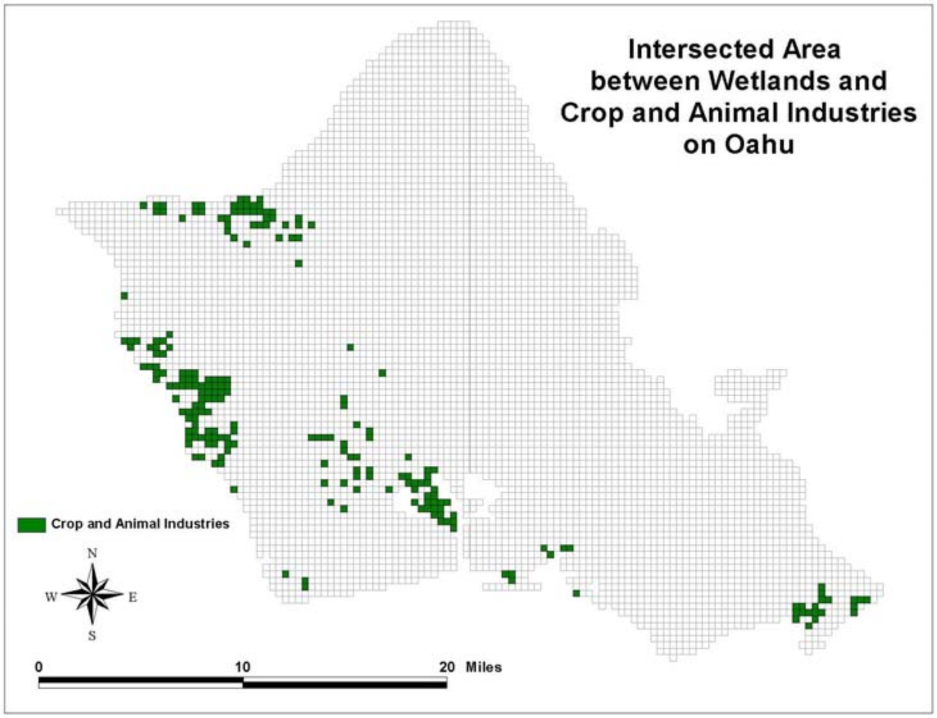


Figure 7. Intersected Area between Wetlands and Residential Activities on Oahu

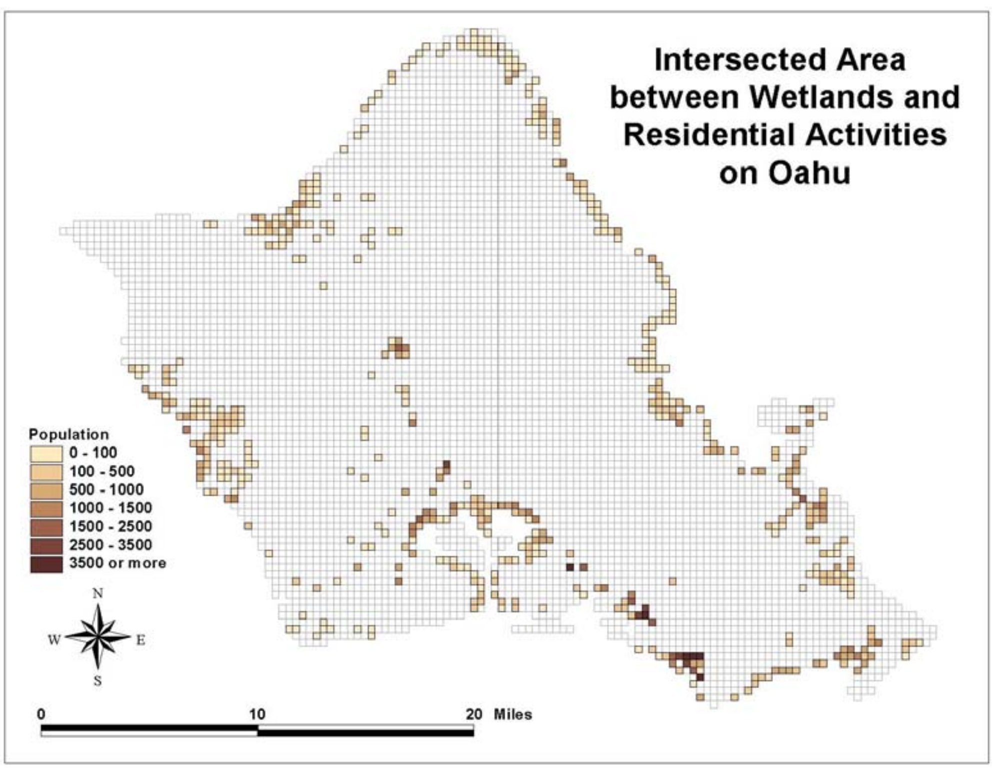
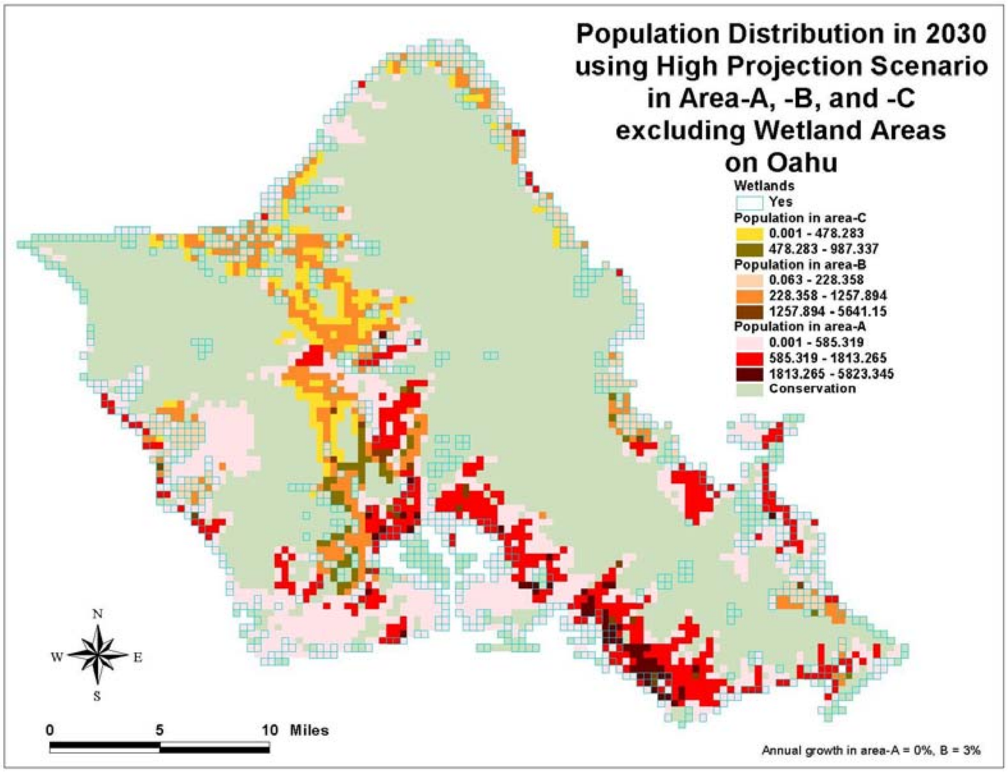


Figure 8. Population Distribution in 2030 using High Projection Scenario in Area-A, -B, and -C excluding Wetland Areas on Oahu



3.2.2. Infrastructure Demand Model

The second part of this appendix describes an infrastructure demand model used along with the CGE Model and other tools. The infrastructure demand model will be used to assess and evaluate a range of infrastructure investment scenarios of interest to State planners. There are limitations on the ability to meet large increases in residential and visitor demand given Hawaii's present physical infrastructure. Environmental damages may also be mitigated by appropriate infrastructure investments. The production functions for the supply of infrastructure services are generally not continuous. As plant-level capacities are met, substantial fixed costs may be required to extend quantity supplied. The methodology identifies resident and visitor components of the demand for infrastructure services. Included is an analysis of water, sewer, solid waste disposal, electricity, natural gas, and petroleum products.

For each resource, the calculation of its indirect use by residents and tourists is based on the 1997 I-O table developed by DBEDT and the direct resource use by different industry sectors. The I-O table shows the inter-industry transactions between 131 sectors, and the expenditures by final users, where two of the final users, namely households, which are represented by personal consumption expenditures (PCEs), and visitors, which are represented by visitor's expenditures are used in the calculation.

The data for each infrastructure services collected from different data sources (usually from the state department) are usually grouped into several broad categories. The first task is to distribute the data into 40 industry sectors, in order to match the 40 industry sectors that are used in our study. Once the original data of infrastructure services are distributed into 40 industry sectors, we can calculate their indirect use by residents and visitors using input-output analysis. The following section describes the methodology of the indirect use calculation.

The total infrastructure use (F_s) can be expressed as follows:

$$F_s = \sum_{j=1}^{40} F_{sj} + \sum_{y} F_{sy} \qquad (1)$$

where

type of infrastructure use *s*, where *s* = water, sewer, electricity, utility gas, solid waste disposal, highway gasoline and diesel, non-highway gasoline, non-highway diesel, residual fuel, jet fuel and aviation gasoline, and propane

F_{sj} = direct infrastructure use *s* by the j^{th} industry sector

F_{sy} = direct infrastructure use *s* by the final demand sector, *y* = residents, visitors, state and local government, federal government, and exports

In order to calculate the indirect infrastructure use by residents and tourists, there are three components.

First is the direct infrastructure intensity for each industry sector (DF_{sj}), which shows the amount of infrastructure required by each industry sector to deliver one dollar's worth of its output:

$$DF_{sj} = \frac{F_{sj}}{Y_j} \qquad (2)$$

where

Y_j = total output of industry sector *i*.

The second component is the 1997 "total requirements matrix" or the Leontief inverse $(I-A)^{-1}_{ji}$, which is a derivation of the 1997 I-O table. Each column in the total requirements matrix represents the direct and indirect impacts on the row industry sectors (*j*) of a $1 change in the column sector's (*i*) final demand. With 40 industry sectors, this is a 40 × 40 matrix.

The multiplication of the direct infrastructure intensity and the total requirements matrix produces the "total infrastructure intensity" for each industry sector (TF_{si}), which shows the total amount of infrastructure required *directly and indirectly* by each industry sector to deliver one dollar's worth of its output.

The total infrastructure intensities for each industry sector TF_{sj} can be calculated as:

$$TF_{si} = DF_{sj} (I - A)^{-1}{}_{ji} \qquad (3)$$

where

$(I\text{-}A)^{-1}_{ji}$ = total requirements matrix or Leontief inverse, which represents the direct and indirect impacts on sector j by \$1 change in final demand of sector i.

The third component are the expenditures by households, which are represented by personal consumption expenditures (PCEs), and the expenditures by visitors, which are represented by visitor's expenditures in the 1997 I-O table. By multiplying the total infrastructure intensities with PCEs and visitor expenditures, it produces the indirect infrastructure use by residents and visitors, respectively.

Indirect infrastructure use by residents or visitors (I_s) can be calculated as:

$$IF_s = TF_{si} C_{hi} \tag{4}$$

where

C_{hi} = Consumption of commodity i by h, $h = r$ (residents), v (visitors)

The calculation of the indirect infrastructure use can be extended to other final demand sectors like state and federal government, and exports. The sum of the indirect infrastructure use by all the final demand sectors is equal to the total infrastructure use by all the industry sectors.

The infrastructure demand methodology provides a powerful for examining and comparing industrial demand as well as the demand by households and residents. This tool can also be used to estimate per day and per capita requirements as well as the aggregate levels of demand.

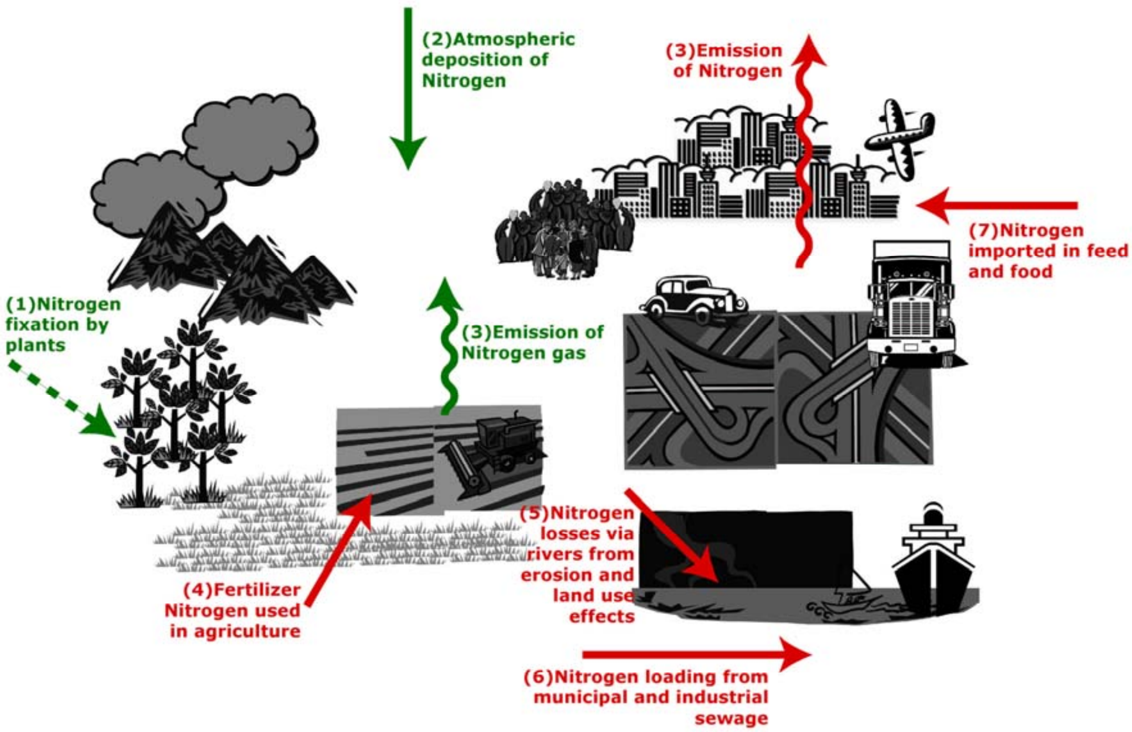
3.2.3. Hawaii Nitrogen-Carbon Cycle Model

A comprehensive review of the sources of data for the construction and characterization of a biophysical model of the nitrogen cycle for the State of Hawaii has been conducted. We have identified the critical components of the nitrogen cycle to include the concentration and mass of nitrogen in the various reservoirs in the atmosphere, on land, in soil water and freshwater reservoirs (lakes, rivers and streams), and in the coastal margin. Additionally, the magnitude and direction of the biological, geochemical, and physical processes that transfer nitrogen between the reservoir masses are also identified as important parameters in the modeling of the nitrogen cycle.

We have compiled data to allow us to develop a tentative nitrogen budget for the pristine state (year 1945). In this initial state, the input of nitrogen from the atmosphere (via wet and dry deposition and biological nitrogen fixation) approximately balances the export of nitrogen via the rivers and streams in the form of runoff and sediment transport. There are no significant effects on the nitrogen cycle from human activities.

The components of the perturbed nitrogen cycle (present year 2000) have also been identified. The perturbations on the contemporary N-cycle are associated with two distinct human activities: (1) the cultivation of sugar cane and pineapple, and (2) the development and urbanization of coastal areas induced by the rapidly increasing population and development of the Visitor Industry **(**see Figure 9). A tentative nitrogen budget for the contemporary state reveals the dominance of anthropogenic input and output fluxes of nitrogen, such as the use of inorganic fertilizer in agriculture, combustion of fossil fuels for power and transportation, import of N-containing food and feed, runoff and sediment transport to the coastal margin, and loading of municipal and industrial sewage effluent.

Figure 9. Schematic of the perturbed (unbalanced) cycle of nitrogen in Hawaii relative to an assumed "balanced state" in 1945.



Transfer fluxes that are heavily influenced by the expanding Visitor Industry are highlighted in red: (3) enhanced emission of nitrogen gases from agricultural fields and burning of fossil fuels; (4) fertilizer nitrogen used in agriculture; (5) enhanced riverine transport of nitrogen in dissolved and organic forms to the coastal margin; (6) increased loading of nitrogen enriched sewage effluent from municipal and industrial sources; and (7) increased importation of food and feed for local consumption. Two other transfer fluxes of nitrogen are affected less strongly by the Visitor Industry (shown in green): (1) uptake of dissolved or atmospheric nitrogen by plants; and (2) deposition of dissolved and particulate nitrogen from the atmosphere.

Methodology

Eight major reservoirs of nitrogen on land (Land Biota, Humus, Inorganic Soil, Soil Water, Groundwater), the coastal zone (Coastal Organic Matter, Coastal Waters, and Coastal Sediments) are represented in the model (see model schematic, figure 10). The reservoirs on land are further subdivided into the major Hawaii land-use categories of agricultural (A), forest (F), non-forest (NF), residential (R) (including municipal infrastructure and buildings), and visitor industry-related (V). The carbon component of each of these reservoirs is also defined in the model to highlight its coupling to nitrogen at the biologically mediated transfer processes of photosynthesis, auto respiration, decay, and burial. Although the population of humans (residential and visitor) is also defined as a stock, it is not the N or C stored in human body mass that is defined as part of the system. Rather, this stock represents the human drivers of change, for example, on land-use, burning of fossil fuels, municipal use of fertilizer, and the transformation of N from food to sewage. Rivers are also described in the model as a conduit for materials transport from land to the coastal ocean but are not defined as a reservoir as it has a relatively short residence time.

The coupling of the nitrogen and carbon cycles is achieved in the model by the average C:N ratios associated with coastal oceanic and terrestrial photosynthesis, autorespiration on land and in coastal oceanic waters, humus formation, and sedimentation of organic matter in the coastal zone. A simplifying assumption is that these biologically mediated coupling processes are generic and apply over many different species and environments within the terrestrial or oceanic domains, and occur with the same global mean elemental ratios that do not change with time, on the annual to decadal time scale.

The photosynthetic production of terrestrial organic matter by plants is represented by the biochemical transformation of atmospheric C and the inorganic nutrient N from the continental soilwater reservoir to organic matter in the terrestrial phytomass reservoir. The terrestrial gross photosynthetic uptake flux of C (CF101 = GPP, moles/yr) is given by the following relationship:

*CFAtm1 = INIT(CFAtm1)*Kphoto*(C_land_biota/INIT(C_land_biota)))*

where Kphoto is a dimensionless parameter that represents the dependence of photosynthetic carbon uptake on other environmental parameters, as defined below. The gross photosynthetic uptake rate of N (NF41) is calculated from GPP by applying the appropriate Redfield-type C:N ratio for terrestrial phytomass uptake.

The factor Kphoto represents the coupling between the C and N through the dependence of GPP on atmospheric CO_2, N concentration in soilwater, and temperature. As such, this factor is analogous to the "biotic growth factor," β, used by other investigators to describe the response of carbon uptake by the phytomass to changing CO_2 concentrations.

*Kphoto = C_atm_kinetics*Nsw_kinetics*ftemp*

Each of the terms on the right hand side of the above equation represents a number of generalized ecological and physiological response relationships rather than empirical results from single literature sources. The f terms, vary with time, making K a time-dependent parameter. The term C_atm_kinetics is the response function to changes in atmospheric CO_2, calculated using a Michaelis-Menten relationship (hyperbolic reaction kinetics). Michaelis-Menten kinetic relationships are also used to describe the response functions of photosynthetic rate to available inorganic nutrient N in the soilwater reservoir.

*C_atm_kinetics = C_atmosphere*RmC/(kC+C_atmosphere)*

*Nsw_kinetics = N_soil_water*RmN/(kN+N_soil_water))*(1/INIT(NF41))*

The Redfield ratio of uptake is assumed to be preserved in the Michaelis-Menten constants Rmax and k. With these definitions of the parameters, the photosynthetic rate tends to a constant value, Rmax/(Flux at t=0), as the nutrient concentration increases indefinitely, and it decreases with declining nutrient concentrations.

The functional dependence of GPP on temperature generally varies considerably among plant taxa, soils, and local climatic conditions. Drawing from the observations of a positive effect of elevated temperature on photosynthesis, the term ftemp is defined as:

ftemp = Q10^((T – INIT(T))/10)

The Q10 function, commonly used in plant ecology and physiology, is the factor by which the rate of photosynthesis increases with a 10°C increase in temperature.

In the model equations listed below, the flux terms are defined as XF_{ij}, where X = N (nitrogen) or C (carbon), the subscripts i = originating reservoir, and j = receiving reservoir; the numbers identifying the reservoirs are listed in the table below. Other subscripts used are: Atm = atmosphere; diss = dissolved; Fert = inorganic fertilizers; inorg = inorganic; LU = land-use; org = organic; Ocn = open ocean; out = outside of defined model boundaries (i.e., external); part = particulate; and Sewage = sewage discharge. Reservoir masses are in units of 10^{12} moles of the element; fluxes are in units of 10^{12} moles of element/yr; rate constants are in units of 1/yr.

Nitrogen-Carbon Cycle Model

Symbol	Reservoir	Description
1	Land Biota	N and C in living organic matter (terrestrial phytomass only, not including humans and other animals)
2	Humus	N and C in reactive fraction of dead organic matter
3	Inorganic Soil	Inorganic N and C in soil
4	Soil Water	Dissolved N and C in soil moisture
5	Groundwater	Dissolved N and C in shallow groundwater
6	Rivers (*not a Reservoir*)	Dissolved, particulate, inorganic and organic N and C in riverine water
7	Coastal water	Dissolved inorganic (bioavailable N) N and C in coastal water
8	Coastal organic matter	Dissolved and particulate organic N and C in coastal water
9	Coastal sediments	Inorganic and organic particulate N and C in coastal sediments
	Sub-Reservoir	
A	Agriculture	N and C in living, non-living, organic, and inorganic forms in Agricultural land
F	Forest	N and C in living, non-living, organic, and inorganic forms in forested land
NF	Non-Forest	N and C in living, non-living, organic, and inorganic forms in land that is not categorized as A, F, or R, including pasture, brush, and fallow land
R	Residential	N and C in living, non-living, organic, and inorganic forms in land used for residential activities
V	Visitor-Industry	N and C in living, non-living, organic, and inorganic forms in land used for visitor activities, including hotels, restaurants, parks, golf courses, etc.

A. Mass Balance equations

N_land_biota(t) = N_land_biota(t – dt) + (NF41 + NFAtm1 – NF12 – NF14_LU – NF1Atm_LU) * dt
N_land_biota_A(t) = N_land_biota_A(t – dt) + (NF41_A + NFAtm1_A – NF12_A – NF14_LU_A – NF1Atm_LU_A) * dt
N_land_biota_F(t) = N_land_biota_F(t – dt) + (NF41_F + NFAtm1_F – NF12_F – NF14_LU_F – NF1Atm_LU_F) * dt
N_land_biota_NF(t) = N_land_biota_NF(t – dt) + (NF41_NF + NFAtm1_NF – NF12_NF – NF14_LU_NF – NF1Atm_LU_NF) * dt
N_land_biota_R(t) = N_land_biota_R(t – dt) + (NF41_R + NFAtm1_R – NF12_R – NF14_LU_R – NF1Atm_LU_R) * dt
N_land_biota_V(t) = N_land_biota_V(t – dt) + (NF41_V + NFAtm1_V – NF12_V – NF14_LU_V – NF1Atm_LU_V) * dt
C_land_biota(t) = C_land_biota(t – dt) + (CFAtm1 – CF12 – CF1Atm_LU – CF1Atm) * dt

N_humus(t) = N_humus(t – dt) + (NF12 – NF24 – NF24_LU – NF26) * dt
N_humus_A(t) = N_humus_A(t – dt) + (NF12_A – NF24_A – NF24_LU_A – NF26_A) * dt
N_humus_F(t) = N_humus_F(t – dt) + (NF12_F – NF24_F – NF24_LU_F – NF26_F) * dt
N_humus_NF(t) = N_humus_NF(t – dt) + (NF12_NF – NF24_NF – NF24_LU_NF – NF26_NF) * dt
N_humus_R(t) = N_humus_R(t – dt) + (NF12_R – NF24_R – NF24_LU_R – NF26_R) * dt
N_humus_V(t) = N_humus_V(t – dt) + (NF12_V – NF24_V – NF24_LU_V – NF26_V) * dt
C_humus(t) = C_humus(t – dt) + (CF12 + CFout2 – CF24 – CF2Atm_LU – CF26 – CF24_weath) * dt

N_inorganic_soil(t) = N_inorganic_soil(t – dt) + (NFout3 – NF34 – NF36) * dt
N_inorganic_soil_A(t) = N_inorganic_soil_A (t – dt) + (NFout3_A – NF34_A – NF36_A) * dt
N_inorganic_soil_F(t) = N_inorganic_soil_F (t – dt) + (NFout3_F – NF34_F – NF36_F) * dt
N_inorganic_soil_NF(t) = N_inorganic_soil_NF (t – dt) + (NFout3_NF – NF34_NF – NF36_NF) * dt
N_inorganic_soil_R(t) = N_inorganic_soil_R (t – dt) + (NFout3_R – NF34_R – NF36_R) * dt
N_inorganic_soil_V(t) = N_inorganic_soil_V (t – dt) + (NFout3_V – NF34_V – NF36_V) * dt
C_inorganic_soil(t) = C_inorganic_soil(t – dt) + (CFout3 – CF34 – CF36) * dt

N_soil_water(t) = N_soil_water(t – dt) + (NF24 + NFAtm4 + NF34 + NF14_LU + NF24_LU + N_emissions4 + NFert_Leach – NF4Atm – NF41 – NF45 – NF46 – NFert6) * dt
N_soil_water_A(t) = N_soil_water_A (t – dt) + (NF24_A + NFAtm4_A + NF34_A + NF14_LU_A + NF24_LU_A + N_emissions4_A + NFert_Leach_A – NF4Atm_A – NF41_A – NF45_A – NF46_A – NFert6_A) * dt
N_soil_water_F(t) = N_soil_water_F (t – dt) + (NF24_F + NFAtm4_F + NF34_F + NF14_LU_F + NF24_LU_F + N_emissions4_F + NFert_Leach_F – NF4Atm_F – NF41_F – NF45_F – NF46_F – NFert6_F) * dt
N_soil_water_NF(t) = N_soil_water_NF (t – dt) + (NF24_NF + NFAtm4_NF + NF34_NF + NF14_LU_NF + NF24_LU_NF + N_emissions4_NF + NFert_Leach_NF – NF4Atm_NF – NF41_NF – NF45_NF – NF46_NF – NFert6_NF) * dt
N_soil_water_R(t) = N_soil_water_R (t – dt) + (NF24_R + NFAtm4_R + NF34_R + NF14_LU_R + NF24_LU_R + N_emissions4_R + NFert_Leach_R – NF4Atm_R – NF41_R – NF45_R – NF46_R – NFert6_R) * dt
N_soil_water_V(t) = N_soil_water_V (t – dt) + (NF24_V + NFAtm4_V + NF34_V + NF14_LU_V + NF24_LU_V + N_emissions4_V + NFert_Leach_V – NF4Atm_V – NF41_V – NF45_V – NF46_V – NFert6_V) * dt
C_soil_water(t) = C_soil_water(t – dt) + (CF24 + CF34 + CF24_weath – CF46 – CF45 – CF4Atm) * dt

N_groundwater(t) = N_groundwater(t – dt) + (NF45 – NF56) * dt
N_groundwater_A(t) = N_groundwater_A (t – dt) + (NF45_A – NF56_A) * dt
N_groundwater_F(t) = N_groundwater_F (t – dt) + (NF45_F – NF56_F) * dt
N_groundwater_NF(t) = N_groundwater_NF (t – dt) + (NF45_NF – NF56_NF) * dt
N_groundwater_R(t) = N_groundwater_R (t – dt) + (NF45_R – NF56_R) * dt
N_groundwater_V(t) = N_groundwater_V (t – dt) + (NF45_V – NF56_V) * dt
C_groundwater(t) = C_groundwater(t – dt) + (CF45 – CF56) * dt

N_coastal_orgMatter(t) = N_coastal_orgMatter(t – dt) + (NF78 + NFAtm8 + NF68_diss + NF68_part + N_Sewage_Input – NF87 – NF89 – NF8Ocn) * dt
C_coastal_orgMatter(t) = C_coastal_orgMatter(t – dt) + (CF78 + CF68_diss + CF68_part + C_Sewage_Input – CF89 – CF87 – NF8Ocn) * dt

N_coastal_waters(t) = N_coastal_waters(t – dt) + (NF87 + NFAtm7 + NF97 + NF67 + N_emissions7 + NFOcn7 – NF78 – NF7Atm) * dt
C_coastal_waters(t) = C_coastal_waters(t – dt) + (CF97_inorg + CF97_org + CF87 + CF67 + CF7Atm7 + CFOcn7 – CF79_inorg – CF78) * dt

N_coast_seds(t) = N_coast_seds(t – dt) + (NF89 + NF69_org + NF69_inorg – NF97 – NF9out – NF9Atm) * dt
C_coast_seds(t) = C_coast_seds(t – dt) + (CF89 + CF79_inorg + CF69_org + CF69_inorg – CF97_inorg – CF97_org – CF9out_org – CF9out_inorg) * dt

B. Flux equations

NFAtm1 = NFAtm1K
NFAtm4 = N_atmosphere*(INIT(NFAtm4)/INIT(N_atmosphere))
NFAtm7 = N_atmosphere*(INIT(NFAtm7)/INIT(N_atmosphere))
NFAtm8 = NFAtm8K
NF12 = N_land_biota*(INIT(NF12)/INIT(N_land_biota))
NF14_LU = CF1Atm_LU/LBio_CN_out
NF24 = N_humus*(INIT(NF24)/INIT(N_humus))*ftemp
NF24_LU = CF2Atm_LU/Humus_CNratio
NF26 = INIT(NF26)*(1+fLU_NPS)
NF34 = N_inorganic_soil*(INIT(NF34)/INIT(N_inorganic_soil))
NF36 = INIT(NF36)*(1+fLU_NPS)
NF41 = N_LBio_Uptake
NF4Atm = N_soil_water*(INIT(NF4Atm)/INIT(N_soil_water))*ftemp
NF45 = N_soil_water*(INIT(NF45)/INIT(N_soil_water))
NF46 = N_soil_water*(INIT(NF46)/INIT(N_soil_water))
NF46 = N_soil_water*(INIT(NF46)/INIT(N_soil_water))
NF56 = N_groundwater*(INIT(NF56)/INIT(N_groundwater))
NF67 = N_rivers*(INIT(NF67)/INIT(N_rivers))
NF68_diss = N_rivers*(INIT(NF68_diss)/INIT(N_rivers))
NF68_part = N_rivers*(INIT(NF68_part)/INIT(N_rivers))
NF69_inorg = N_rivers*(INIT(NF69_inorg)/INIT(N_rivers))
NF69_org = N_rivers*(INIT(NF69_org)/INIT(N_rivers))
NF7Atm = NF87*(INIT(NF7Atm)/INIT(NF87))*ftemp
NF78 = N_CBio_Uptake
NF87 = N_coastal_orgMatter*(INIT(NF87)/INIT(N_coastal_orgMatter))
NF89 = N_coastal_orgMatter*(INIT(NF89)/INIT(N_coastal_orgMatter))
NF9Atm = INIT(NF9Atm)*((NF89+NF69_org)/(INIT(NF89)+INIT(NF69_org)))
NF97 = N_coast_seds*(INIT(NF97)/INIT(N_coast_seds))
NF9out = CN_coast_sed_conv
NFout3 = NFout3K
N_emissions4 = (1 – N_emissions7_f)*NEmissions*z_atm_emiss_sw
N_emissions7 = N_emissions7_f*NEmissions*z_atm_emiss_sw
NFert_Leach = N_Fert*NP_leach_f*z_fert_sw
NFert_Runoff = N_Fert*N_Fert_rnf_f*z_fert_sw
N_Sewage_Input = N_sewage*z_sewage_sw
CFAtm1 = C_LBio_Uptake
CF1Atm = C_land_biota*(INIT(CF1Atm)/INIT(C_land_biota))*ftemp
CF1Atm_LU = LBio_fraction*CLU*z_LU_C_sw
CF12 = C_land_biota*(INIT(CF12)/INIT(C_land_biota))
CF2Atm_LU = (1-LBio_fraction)*CLU*z_LU_C_sw
CF24 = C_humus*(INIT(CF24)/INIT(C_humus))*ftemp
CF24_weath = C_humus*(INIT(CF24_weath)/INIT(C_humus))
CF26 = INIT(CF26)*(1+fLU_C)
CF34 = C_inorganic_soil*(INIT(CF34)/INIT(C_inorganic_soil))

CF36 = INIT(CF36)*(1+fLU_C)
CF4Atm = C_soil_water*(INIT(CF4Atm)/INIT(C_soil_water))*ftemp
CF45 = C_soil_water*(INIT(CF45)/INIT(C_soil_water))
CF46 = C_soil_water*(INIT(CF46)/INIT(C_soil_water))
CF56 = C_groundwater*(INIT(CF56)/INIT(C_groundwater))
CF67 = C_rivers*(INIT(CF67)/INIT(C_rivers))
CF68_diss = C_rivers*(INIT(CF68_diss)/INIT(C_rivers))
CF68_part = C_rivers*(INIT(CF68_part)INIT(C_rivers))
CF69_inorg = C_rivers*(INIT(CF69_inorg)/INIT(C_rivers))
CF69_org = C_rivers*(INIT(CF69_org)/INIT(C_rivers))
CF7Atm7 = if (z_Perturbation_switch>0) then (dCCWat_disst-CWaters_Fluxes) else (C_atmosphere*(INIT(CF7Atm7)/INIT(C_atmosphere)))
CF78 = C_CBio_Uptake
CF79_inorg = C_coastal_waters*(INIT(CF79_inorg)/INIT(C_coastal_waters))
CF87 = C_coastal_orgMatter*(INIT(CF87)/INIT(C_coastal_orgMatter))
CF89 = C_coastal_orgMatter*(INIT(CF89)/INIT(C_coastal_orgMatter))
CF97_inorg = C_coast_seds*(INIT(CF97_inorg)/INIT(C_coast_seds))
CF97_org = C_coast_seds*(INIT(CF97_org)/INIT(C_coast_seds))
CF9out_inorg = C_coast_seds*(INIT(CF9out_inorg)/INIT(C_coast_seds))
CF9out_org = CF9out_orgK
CFossil_Fuel_Input = CFossil_Fuel_ipcc*z_atm_emiss_sw
CFout2 = CFout2K
CFout3 = CFout3K
C_Sewage_Input = C_sewage*z_sewage_sw

C. Other equations

C_atm_kinetics = C_atmosphere*RmC/(kC+C_atmosphere)
C_LBio_Uptake = = if (z_Perturbation_switch>0) then (INIT(CFAtm1)*C_atm_kinetics*Nsw_kinetics*ftemp*(C_land_biota/INIT(C_land_biota))) else (C_land_biota*(INIT(CFAtm1)/INIT(C_land_biota)))
C_river_input = CF46+CFL6+CF56+CF26+CF36
CAtm_ppmv = C_atmosphere*5.647e-3
CN_coast_sed_conv = CF9out_org/Coast_Ocn_Sed_CN_Ratio
Coast_Ocn_Sed_CN_Ratio = CF9out_orgK/NF9outK
Crop_NP_ratio = 20
CWaters_Fluxes = CF67+CF87+CF97_inorg +CF97_org-(CF78+CF79)
d = 4
dCAtm_dt = DERIVN(C_atmosphere,1)
dCCWat_dt = ((INIT(C_coastal_waters)/R0_CAtm0)*(1-((C_atmosphere-INIT(C_atmosphere))*d/R0_CAtm0)))*dCAtm_dt
fLU_C = z_LU_C_sw*fLU
fLU_NPS = z_LU_NPS_sw*fLU
Humus_CNratio = INIT(C_Humus)/INIT(N_Humus)
kC = 45407*RmC
kN = (RmN*INIT(N_soil_water)/INIT(NF41))-INIT(N_soil_water)

LBio_CN_in = INIT(CFAtm1)/INIT(NF41)
LBio_CN_out = INIT(CF12)/INIT(NF12)
N_CBio_kinetics = N_coastal_waters/INIT(N_coastal_waters)
N_Fert_rnf_f = 0.25
N_LBio_Uptake = C_LBio_Uptake/LBio_CN_in
N_river_input = NF46+NF56+NFert_Runoff+NF36+NF26
NF14_LU = LBio_fraction*CLU*z_LU_NPS_sw/LBio_CN_out
NF24_LU = (1-LBio_fraction)*CLU*z_LU_NPS_sw/Humus_CNratio
NP_leach_f = 0.3
Nsw_kinetics = (N_soil_water*RmN/(kN+N_soil_water))*(1/INIT(NF41))
R0_CAtm0 = (Ro*INIT(C_atmosphere))+(d*(C_atmosphere-INIT(C_atmosphere)))
RmC = 1/0.072643
RmN = RmC*INIT(NF41)
Ro = 9
TOC = CF68_diss+CF68_part+CF69_org+C_Sewage_Input
TON = NF68_diss+NF68_part+NF69_org+N_Sewage_Input

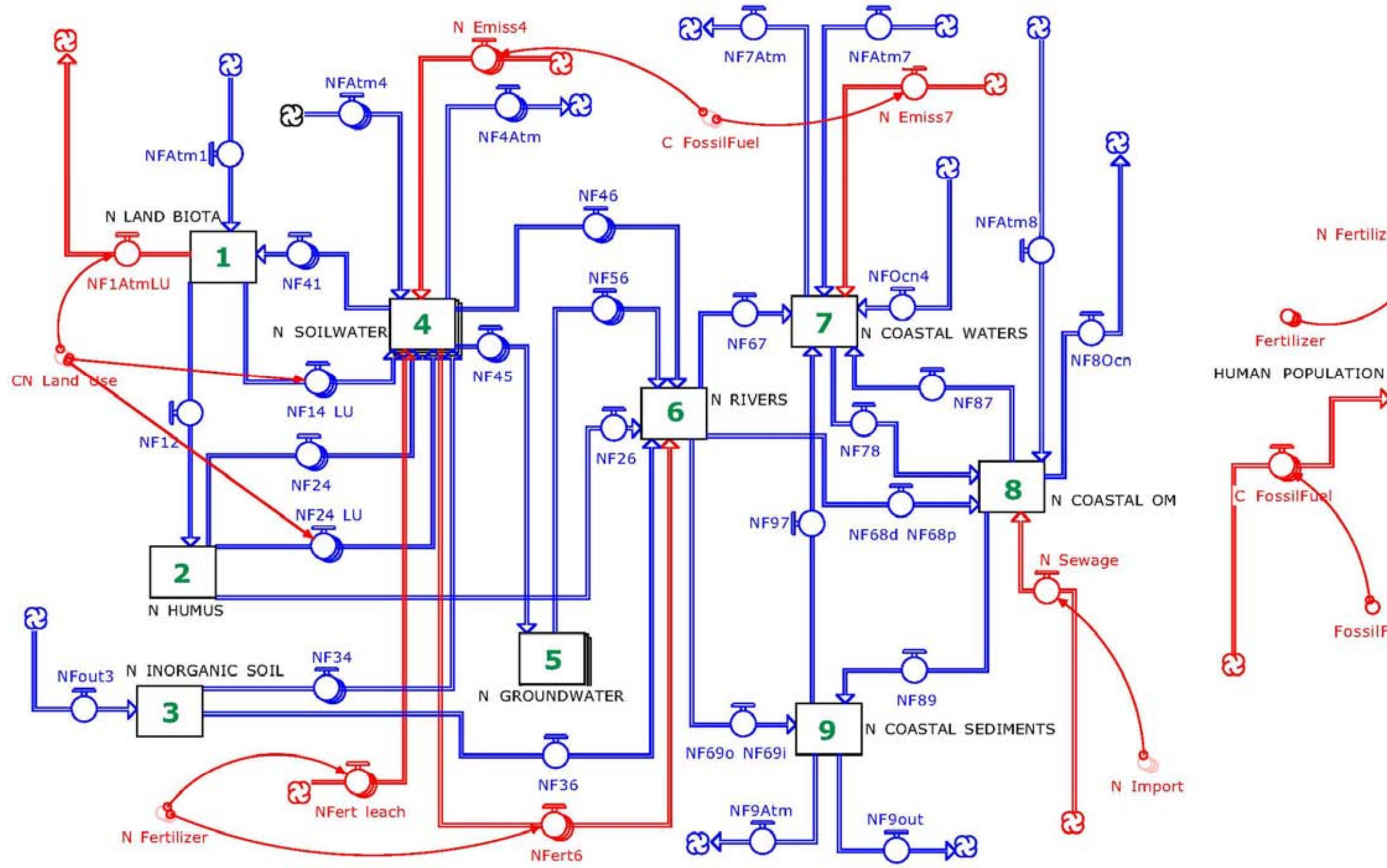
z_atm_emiss_sw = 1
DOCUMENT:
emiss sw=1, CNS emissions perturbation ON
emiss sw=0, CNS emissions perturbation OFF

z_LU_C_sw = if (z_Perturbation_switch=1) or (z_Perturbation_switch=3) or (z_Perturbation_switch=4) then 1 else 0
z_LU_NPS_sw = if (z_Perturbation_switch=1) or (z_Perturbation_switch=3) then 1 else 0

z_Perturbation_switch = 1
DOCUMENT:
0=fert off, LU CNPS off
1=fert on, LU CNPS on
2=fert on, LU CNPS off
3=fert off, LU CNPS on
4=fert on, LU C on, LU NPS off

z_sewage_sw = 1
DOCUMENT:
sewage sw=1, sewage perturbation is ON
sewage sw=0, sewage perturbation is OFF

z_temperature_sw = 1
DOCUMENT:
temp sw>0, temperature effect is ON
temp sw<0, temperature effect is OFF


N Emiss4
NF7Atm
NFAtm7
NFAtm4
NF4Atm
N Emiss7
C FossilFuel
NFAtm1
NF46
NFAtm8
N Fertiliz
N LAND BIOTA
1
NF41
NF1AtmLU
NF56
NFOcn4
N SOILWATER
4
NF67
7
N COASTAL WATERS
NF8Ocn
Fertilizer
HUMAN POPULATION
NF45
CN Land Use
NF14 LU
6
N RIVERS
NF87
NF12
NF26
NF78
NF24
8
N COASTAL OM
C FossilFuel
NF24 LU
NF97
NF68d NF68p
N Sewage
2
N HUMUS
FossilF
NF34
NFout3
N INORGANIC SOIL
5
N GROUNDWATER
3
NF89
9
N COASTAL SEDIMENTS
NF69o NF69i
NF36
N Import
NFert leach
NF9Atm
NF9out
N Fertilizer
NFert6

APPENDIX 3.3. POPULATION PROJECTION MODEL

In this section, the UHERO (University of Hawaii Economic Research Organization) population projection model is described. The basic approach, key parameters, data sources and initial results of the modeling effort are described.

3.3.1. Hawaii's Population, 2000-2030

Hawaii's population is experiencing two important changes that will persist into the foreseeable future – our population is growing and it is aging. According to the most recent Census, Hawaii's population exceeded 1.2 million in 2000, an increase of just over 100 thousand persons during the 1990s. We anticipate continued, but slowing growth. In no decade between now and 2030 do we anticipate an increase in Hawaii's total population by as much as 100,000. The total population for 2030 is projected at 1.38 million – an increase of less than 200,000 over the 2000 population (Table 1).

Table 1. Population Projections, State and County, 2000-2030

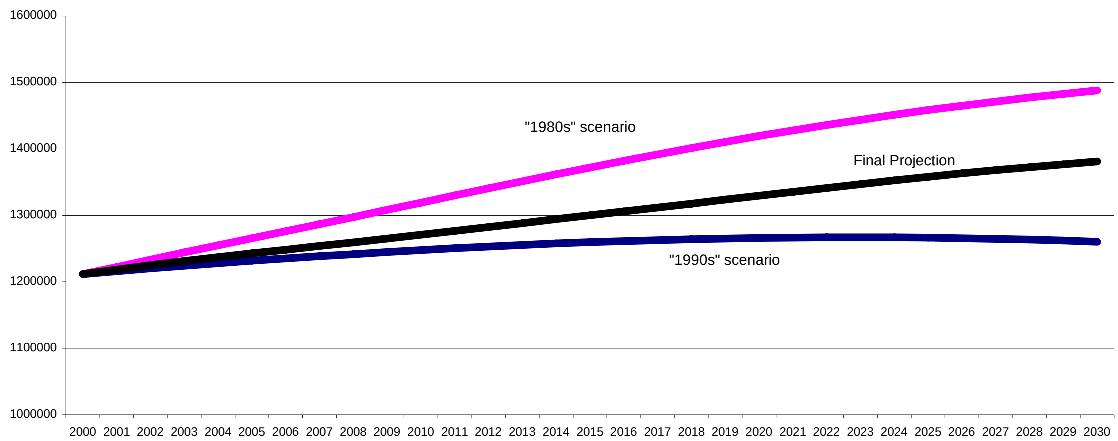
		Counties			
	State of Hawaii	Hawaii	Honolulu	Kauai	Maui
2000	1,211,537	148,677	876,156	58,463	128,241
2005	1,243,076	159,896	885,162	60,256	137,763
2010	1,270,795	167,692	900,368	60,574	142,161
2015	1,300,213	176,071	916,833	61,041	146,267
2020	1,329,532	184,479	933,986	61,448	149,619
2025	1,358,192	193,570	949,902	61,980	152,741
2030	1,380,848	201,975	961,594	62,200	155,079

The projected increase in Hawaii's population reflects a variety of considerations. The first is substantial growth in the US mainland population fueled by substantial international in-migration. The second is improved job growth for Hawaii as compared with the 1990s. The third is a very modest increase in the number of active duty military in Hawaii.

The importance of job growth to demographic change in Hawaii is illustrated by comparing the projection to two other scenarios. The "1980s scenario" shown in Figure 1 is our projection of Hawaii's population with in-migration rates that persisted during that decade – a decade of relatively robust job growth. The "1990s scenario" applies the net migration rates that persisted during the 1990s when job growth was much weaker and the number of active duty military was in decline. As can be seen from Figure 1, the scenario shift from the 1980s to the 1990s produces a smaller population in 2030 by over 200,000 individuals. The final projection falls midway between the two scenarios.

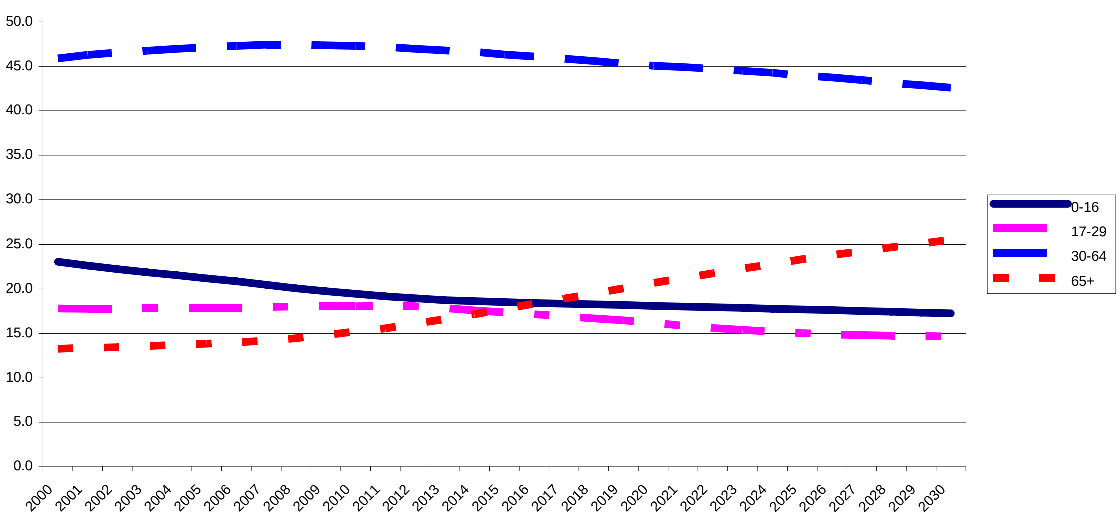
Honolulu County is projected to grow somewhat more slowly than the State, as has been the case in recent decades. The most rapid growth is projected for Hawaii County and then Maui County. Kauai's share of the State population is projected to remain relatively constant between 2000 and 2030.

Figure 1. Population, State of Hawaii, 2000-2030



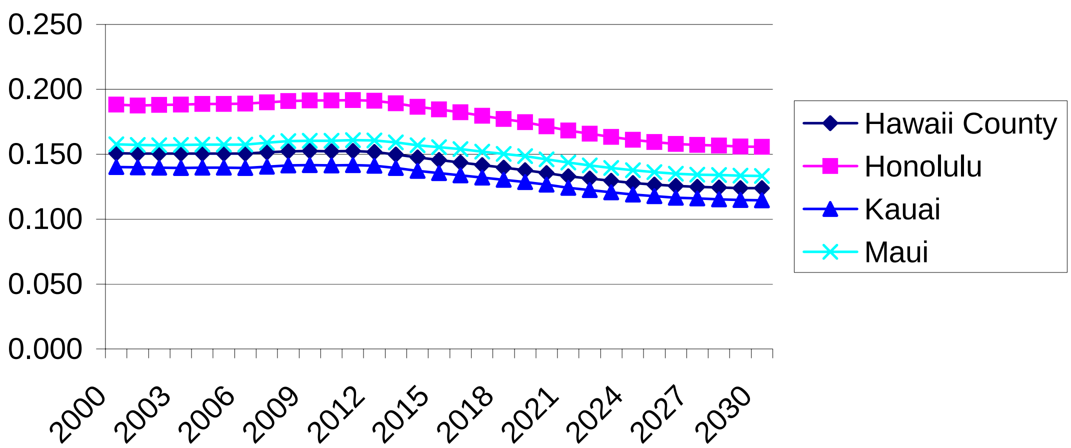
Most of the population increase will be due to increase in the State of Hawaii's senior population – those 65 and older. Between 2000 and 2030, the senior population is projected to more than double, increasing from 161 thousand to 352 thousand (Figure 2). One-quarter of Hawaii's population will be 65 and older by 2030 as compared with 13.3% in 2000. Rapid changes will occur between 2010 and 2030, in part because of improving life expectancy and in part because of the aging of the baby-boom generation.

Figure 2. Age Shares, Hawaii Population, 2000-2030



The changes in age structure that characterize the State population also characterize the county populations. In particular, all counties will experience substantial population aging. Age structure does vary across counties and is projected to persist throughout the next three decades. Maui, for example, has a somewhat younger population than the rest of the State. Only 11.4 percent of its residents are 65 or older. The share of 16-29-year-olds is lower on the neighbor islands than Honolulu County. This group is singled out because it is the age from which new labor force entrants are largely drawn. It is also heavily influenced by the number of active duty military, explaining in part why Honolulu has a larger share of this age group (Figure 3).

Figure 3. Population, Ages 17-29



Projections of males and females in single-year age groups annually from 2000 to 2030 for the State and Counties from 2000-2030 are available. Methodological details are described in "Population Projections: Methodology, Estimation, and Results".

3.3.2. Methodology

This section describes the methodology, estimation, and results for new population projections for the State and Counties of Hawaii. The base year population is drawn from the 2000 Census of Population and the projections extend to 2030. Results are available annually by single years of age from 0 to 85 and older.

The projections employ a new methodology that links demographic change to Hawaii's economic performance relative to the US as a whole.

The population is projected separately for males and females in single-year age groups annually. The model is a variation on the standard cohort-component model. In the cohort-component model, the size of each cohort declines from one period to the next because of deaths to members of the cohort and either declines or increases due to net migration. Thus, the population of a cohort in a period is the population of the same cohort one year earlier multiplied by the proportion surviving and the net migration rate. The population of the youngest cohort is equal to the number born during the previous twelve months less deaths plus net migrants into that cohort. Applying the cohort-component method requires the base year population and forecast values of age-specific fertility rates, the sex ratio at birth, sex- and age-specific survival rates, and sex- and age-specific net migration rates.

The population aged 0 is projected using the standard cohort-component methodology. The number of births is calculated by:

$$B(t) = \sum_{a} f(a,t) Z^{f}(a,t)) \tag{1}$$

where $f(a,t)$ is births per woman aged *a* in year *t* and $Z^{f}(a,t)$ is the female population aged *a* in year *t*. The sex ratio at birth is used to calculate the number of male and female births. The female and male populations aged 0 depends on the survival and net migration rates for the under 1 population. These rates are assumed to be constant over the projection period. This is a reasonable assumption for Hawaii given the low infant mortality rates that characterize the state.

In all other respects, the population projection for the State of Hawaii is conditioned by the population projection for the United States. Following the cohort-component method, the population in any age group is represented by:

$$Z^{H}(a+1,t+1) = s^{H}(a,t) m^{H}(a,t) Z^{H}(a,t) \tag{2}$$

where $s^{H}(a,t)$ is the proportion of the age group surviving one year, $m^{H}(a,t)$ is the net migration rate (a value exceeding 1 indicates net in-migration; a value less than 1 net out-migration), and $Z^{H}(a,t)$ is the population aged *a* in year *t*. For simplicity sake, we do not distinguish males from females in the formula, but the model is applied separately to males and females. The superscript *H* represents Hawaii; the absence of a superscript denotes values for the US.

If we divide both sides of equation (2.2) by $Z^{H}(a,t)$ and take the natural logarithm, we obtain the annual growth rate of the cohort as:

$$z^{H}(a,t) = \ln(s^{H}(a,t) m^{H}(a,t)) \tag{3}$$

The relationship between growth in a Hawaii cohort and a US cohort is given by:

$$z^{H}(a,t) = z(a,t) + \frac{\ln(s^{H}(a,t) m^{H}(a,t))}{\ln(s(a,t) m(a,t))} \tag{4}$$

The rate of growth of a cohort in Hawaii exceeds the rate of growth of the same cohort in the US to the extent that the survival rate and the net migration rate for that cohort exceeds the survival rate and net migration rate for the same cohort for the US population as a whole. The relative survival rate and relative net migration rates in equation (2.4) could be separated into two linear components, but for the present purpose this is unnecessary. The cohort growth rate and cohort population are projected by:

$$z^H(a,t) = z(a,t) + \varphi(a,t), \text{ where}$$
$$\varphi(a,t) = \ln(s^H(a,t)m^H(a,t)) / \ln(s(a,t)m(a,t)), \text{ and} \quad (5)$$
$$Z^H(a+1,t+1) = e^{z^H(a,t)} Z^H(a,t)).$$

The differential cohort growth rates for Hawaii ($\varphi(a)$) reflect several features of Hawaii's demography. During the early young adult ages the values are high reflecting the large influx of active duty military, their dependents, and, depending on economic conditions, job seekers. During the later young adult ages the values typically turn negative as military personnel and their dependents complete their tour of duty and return to the mainland and, depending on economic conditions, other young adults fail to establish themselves in Hawaii and move to the mainland.

The cohort growth rate for Hawaii's older adults also differs from that of those on the mainland. The source is not migration, however, but Hawaii's unusually high life expectancy.

Hawaii's differential growth rates have varied in important ways during the last two decades as documented below. During the 1980s, the differential growth rates were relatively high reflecting favorable economic conditions and mortality conditions. During the 1990s, the differential growth rates dropped substantially reflecting the decline in the number of active duty military based in Hawaii, a poorer job market and, perhaps, a narrowing of Hawaii's life expectancy advantage. In the results section we present two scenarios. The first projects Hawaii's population assuming that the conditions of the 1990s persist into the future, i.e., using the average cohort growth rates for the 1990s. The second projects the population assuming a return to conditions in the 1980s. These alternative scenarios are useful in that they may bracket the possibilities.

The main projection explicitly incorporates the effects of anticipated changes in the number of active duty military and employment conditions in Hawaii relative to the mainland. This is accomplished through analysis of the differential growth of young adults, i.e., those aged 16 to 29. For females we focus on the cumulative experience of those aged 16 to 29 as measured by:

$$D(16,29,t) = \sum_{16}^{29} \varphi(a,t) \quad (6)$$

D(a1,a2,t) can be interpreted as follows. Suppose that a cohort were subject to the differential growth rates observed in year *t* from the time it reached age 16 to the time it reached age 29. *D* would be the percentage increase in the cohort between ages 16 and 30 as compared with the US cohort. However, *D* is period measure that depends only on the current differential growth rates. Or it can be thought of as a synthetic cohort measure.

The estimation model for females is:

$$D(16,29,t) = \beta_0 + \beta_1 w(t) + \varepsilon(t) \qquad (7)$$

where *w(t)* is the ratio of civilian employment in Hawaii relative to civilian employment in the US and $\varepsilon(t)$ is an error term. The projected values of the cohort growth rates for ages 16 to 29 are . *t*)+ *(a)*, where . *t)* is the average difference between the annual growth in period *t* and the base year and $\varphi(a)$ is the cohort growth rate in the base year.

For males we estimate a model identical to the model estimated for females. In addition, we estimate a model of cumulative cohort growth for the 16 to 20 age interval.

$$D(16,20,t) = \psi_0 + \psi_1 MIL(t) + \varepsilon(t) \qquad (8)$$

where $MIL(t)$ is the number of active duty military in Hawaii relative to the population aged 17 to 21. As for females, the individual age cohort growth rates vary in the projection by a constant amount for each age group to produce the predicted cumulative growth.[1]

Employment and military variables are based on UHERO forecasts.

3.3.3. County Projections

In theory the methodology employed for the state projection could be applied to projections for the counties. Several factors mitigate against this, particularly the extent and quality of data. In particular differential cohort growth rates are available only for the 1990s.

The methodology used to construct county projections is a simple but robust method developed by Deming and applied to other population projection methods (McFarland 1975; Mason and Racelis 1992). The method is illustrated with respect to Table 2. From the state projection, the row totals – the populations of each age – are known. From the UHERO model the county share in the total and, hence, the total county populations are known. The problem is to determine the joint county-age distribution of population that is consistent with row and column totals.

Table 2. Projected population for any year in the future

Age	Hawaii	Honolulu	Kauai	Maui	State
0					N0
1					N1
2					N2
:					:
Total	N(Hawaii)	N(Honolulu)	N(Kauai)	N(Maui)	N

[1] For males, variation in the military will produce variation in the growth rates at ages 16 to 20. For ages 21 to 29, growth rates will vary positively with employment growth and negatively with military growth to produce the net predicted cumulative effect over the 16 to 29 age interval.

Deming proposed an iterative method for accomplishing this task. An initial joint distribution is selected. The elements in each row are adjusted proportionately to yield the row totals. Then the elements in each column are adjusted proportionately to yield the column totals. The adjustments are repeated until all column and row totals are equal to the known values within a prescribed tolerance, e.g., 0.1%. The initial joint distribution employed is the joint distribution in the preceding year. For 2001 the actual 2000 distribution is used. For 2002 the projected 2001 distribution is used and so forth. The methodology is reliable to the extent that the current joint distribution reflects the relative attractiveness of each county to the individuals in each age group.

3.3.4. Data and Estimation

Adjustments to Population Estimates

The US Census Bureau produces annual estimates of the US and state populations by sex and single-year of age. The 1990-99 series uses the 1990 census as its basis; the 1980-89 series uses the 1980 census as its basis. The Bureau does not adjust the 1980-89 series to obtain conformity with the 1990 census; hence, the two time series are not consistent with each other or with the results from the 2000 census.

We have constructed an adjusted series for the US and Hawaii for 1980-2000. We have adjusted the 1980-1989 series in the following manner. First, we project the 1990 population based on the 1980-89 trends assuming that the cohort growth rate from 1988-89 persists to 1990, i.e.,

$$\begin{aligned}\hat{N}(a,1990) &= \tilde{N}(a-1,1989)e^{n(a)} \\ n(a) &= \ln \tilde{N}(a,1989) / \tilde{N}(a-1,1988).\end{aligned} \tag{9}$$

Next we will calculate the difference between the average growth rate between the actual and projected 1990 population as:

$$\phi(a) = \ln N(a,1990) / \hat{N}(a,1990). \tag{10}$$

The revised estimate for the 1981-1989 population data are given by:

$$\begin{aligned}&N(a+1,t+1) = N(a,t)e^{n(a,t)+\phi(a)} \text{ where} \\ &n(a,t) = \ln \tilde{N}(a+1,t+1) / \tilde{N}(a,t) \text{ for t=1980-1989} \\ &N(a,1980) = \tilde{N}(a,1980)\end{aligned} \tag{11}$$

Any discontinuity between 1989 and 1990 is essentially distributed evenly across the series holding the populations in 1980 and 1990 constant. The procedure smoothes away any difference in the cohort growth rate between 1988 and 1989.

Adjustment to the data for the 1990s is identical except for one minor difference. The population estimates are as of July 1 whereas the population census is as of October 1, three months later. To account for this difference:

$$\begin{aligned} \hat{N}(a,2000) &= \tilde{N}(a,1999)e^{1.25n(a)} \\ n(a) &= \ln \tilde{N}(a,1999)/\tilde{N}(a,1998). \end{aligned} \tag{12}$$

Then:

$$\phi(a) = (10/10.25)\ln N(a,2000)/\hat{N}(a,2000). \tag{13}$$

The adjusted population values for the 1990s are calculated as in equation

3.3.5. Population Projections: Base Year Population

The population for 2000 is from the 2000 Census of Population. These data have not been adjusted for under- or over-enumeration. The population in five-year age groups is:

Table 3. Population of Hawaii, 2000

Age	Male	Female
0-4	40110	38053
5-9	43739	41241
10-14	42740	40366
15-19	42200	38802
20-24	45709	37700
25-29	44016	39984
30-34	44391	42768
35-39	48760	47175
40-44	47817	47425
45-49	45130	45274
50-54	40523	40052
55-59	29905	30656
60-64	22293	24107
65-69	19503	23344
70-74	18919	23496
75-79	16020	19366
80-84	9626	12763
85+	7270	10294

3.3.6. Population Projections: Fertility Assumptions

Age-specific fertility rates (ASFRs) for Hawaii 1995-2000 are estimated using registered births from the Department of Health and population estimates from the US Census Bureau. The ASFRs and the total fertility rate (TFR) are assumed to remain constant throughout the projection period. ASFRs within five-year age groups are assumed to be identical.

Table 4. ASFRs and TFR, Hawaii, 1995-2000

Age	Births per woman
15-19	0.047
20-24	0.114
25-29	0.110
30-34	0.095
35-39	0.050
40-44	0.012
TFR	2.140

A sex ratio at birth of 1.06 male birth per female birth is used.

3.3.7. Population Projections: Net Growth Differential

The differential rate of cohort growth is estimated using population estimates for Hawaii and the US at single year intervals for 1980 to 2000. The differential is calculated as the mean differential for each age and sex group during the period in question. The values obtained for the 1980s and the 1990s are plotted in Figures 1 and 2. The data in the figures have been smoothed by using a centered moving average for five-year age groups. The analysis and the projections, however, are based on unsmoothed data.

The mean values by single years of age for the 1980s are used to construct one scenario and for the 1990s to construct a second scenario. In the final projection, the survival differential among young adult males is determined by the size of Hawaii's active duty military and the trend in Hawaii's civilian employment relative to the US' civilian unemployment. Based on analysis of the 1980-2000 values, for males:

$$\begin{aligned} D(16,20,t) &= 0.0082MIL(t) + 0.8558 \\ D(16,29,t) &= 1.707l(t) - 0.695. \end{aligned} \tag{14}$$

For females:

$$D(16,29,t) = 1.518l(t) - 0.504. \tag{15}$$

The forecast employment and military variables in these equations are UHERO forecasts to 1923. The values are held constant from 1923 to 1930 at their 1923 levels. Cohort growth rates for all other age groups are held constant at the mean for the 1980-2000 period.

3.3.8. Population Projections: United States

Population projections are projections for the United States prepared by the Social Security Administration. The assumptions underlying the projections are described in detail in US SSA 2002.

Table 5. Assumptions Underlying Projections of US Population

		Sex- Age- Adjusted Death Rates per 100,000			Net Immigration	
	TFR	Total	Under 65	Over 65	Legal	Other
2000	2.1	812.4	238.1	4834.1	637,358	300,000
2010	2.1	759.8	215.1	4574.3	600,000	300,000
2020	2.0	698.1	195.6	4217.3	600,000	300,000
2030	2.0	642.2	178.4	3890.1	600,000	300,000

Detailed projections have not been published, but were provided for this study by the Social Security Administration.

3.3.9. References

Mason, Andrew and Rachel Racelis, 1992. "A Comparison of four methods for projecting households," *International Journal of Forecasting* 8(3) 509-527.

McFarland, David 1975. "Models of marriage formation and fertility," *Social Forces* 54 (1) 66-83.

APPENDIX 3.4. TOURISM EXPENDITURE PROJECTIONS

This section contains a brief discussion of the UHERO (University of Hawaii Economic Research Organization) tourism expenditure projection model. The general approach and key parameters for the model are described. In other sections, modifications and enhancements to this forecasting tool for use with the CGE model have been described.

3.4.1. Modeling Approach

UHERO maintains a quarterly model of the State and County visitor industry. That model is used to produce simulated paths of visitor arrivals, days, and expenditures for US, Japanese and other visitors for each county and the State. The other visitor category is the difference between total visitors and the sum of US and Japanese visitors and consists of Canadian, European, and other Asian visitors by order of importance. UHERO's visitor model is a system of statistically identified equations used to represent the decisions of visitors and the visitor industry.

Visitor arrivals, days, and expenditures serve as the primary measures of visitor demand. Because long time series of high frequency visitor expenditures are not available, the statistical identification of visitor demand begins with the number of visitors arriving in the islands each time period. Visitor arrivals are modeled as an equilibrium relationship between arrivals and small number of causal variables. Causal variables include the real Gross Domestic Product of the origin country, the relative cost of a Hawaii vacation (the ratio of Hawaii room prices and the origin country consumer price index), a separate exchange rate term in the case of non US visitor arrivals, and possibly supply constraint factors such as the occupancy rate.

A typical visitor arrivals equation has the following form:

$$\begin{aligned}\%\Delta V_{l,t} = {} & \sum_{q=1}^{p}\lambda_q \%\Delta V_{l,t-i} + \sum_{q=1}^{p}\eta_q \%\Delta Y_{l,t-i} + \sum_{q=1}^{p}\gamma_q \Delta RP_{l,t-i} + \sum_{q=1}^{p}\xi_q \%\Delta Ex_{l,t-i} + \\ & \sum_{q=1}^{p}\omega_q \Delta Ocup_t + \rho\{V_l - \delta_1 Y_l - \delta_2 RP_l - \delta_3 Ex_l\}_{t-1} + \varepsilon_t \end{aligned} \qquad (1)$$

where V_l is visitor arrivals from country l (where l = US or Japan), Y_l is Real GDP for country l, RP_l is the ratio of the hotel room price as a proxy for the cost of a Hawaii vacation to the consumer price index in country l as a proxy for the cost of goods and services in the home country. *Ocup* is the hotel occupancy rate, and Ex_l is the yen-dollar exchange rate for l = Japan.

The arrivals equation allows for the existence of temporary disequilibrium between causal variables and the number of visitor arrivals represented by the expression in brackets. The adjustment term ( ) estimates the speed of adjustment towards the equilibrium relationship represented by the parameters $_q$ for q = 1, 2, 3. For example, if US arrivals are less than predicted by US income growth and the relative cost of a Hawaii vacation, arrivals would increase over time, eliminating the disequilibrium.

Based on the simulated paths of visitor arrivals, a visitor days path is determined using the assumed path for length of stay. The length of stay assumptions are based on ARMA models which imply that deviations from recent average lengths of stay are transitory. For instance, the recent rise in length of stay by US and Japanese visitors is not assumed to be permanent.

$$Vdays_{l,t} = Vlos_{l,t} \times V_{l,t} \quad (2)$$

Where *Vdays* is total visitor days, and the average daily census is roughly *Vdays/365*.

Visitor expenditures are simulated by applying a daily expenditures projection to the visitor days paths. Specifically, per person per day expenditures are divided into two categories, expenditures on lodging and all other expenditures. The UHERO tourism model provides simulated paths for hotel room rates, and the UHERO state model provides simulated paths for the consumer price inflation. The simulated room rate is used as a measure of the rate of growth of per person per day lodging expenditures, while consumer price inflation is used as a proxy for the rate of nominal growth in non-lodging visitor expenditures. In addition, the model allows for assumed rates of real growth in per person per day expenditures as well as assumed changes in the mix of visitors based on the type of lodging choices the visitors make.

$$c_{v,lodging\,l,t} = c_{v,lodging\,l,t-1} \times (1 + \%\Delta p_{lodging\,t} + \%\Delta c_{v,lodging\,l,t}) \quad (3)$$

Where $c_{v,lodging\,l,t}$ is the per person daily expenditures on lodging, $\%\Delta p_{lodging,t}$ is the rate of growth in the simulated hotel room price, and $\%\Delta c_{v,lodging\,l,t}$ is an assumed real growth in visitor expenditures on lodging (zero by assumption in the baseline). A similar equation is used to simulate the non-lodging per person daily visitor expenditures. In that equation, a simulated Honolulu consumer price index is used instead of the simulated hotel room price.

On the supply side of the visitor market, the UHERO tourism model projects the stock of visitor accommodations and the rental price for accommodations. The supply of visitor accommodations (hotel rooms and condos rented in the tourism market) for each island is modeled as a function of room prices, the demand for accommodations (either visitor arrivals or hotel occupancy), and a distributed lag of the history of the room stock. In addition to the accommodations projections we use assumed paths for cruise berths. The projected cruise berths are used when calculating each island's occupancy rate to account for visitor nights on board cruise ships rather than in hotel rooms.

Room rates are assumed to be identical on all islands. The room rate is modeled as an equilibrium relationship between room prices, total visitor arrivals and the stock of rooms. Like the visitor arrivals equations mentioned above, the room price equation allows for temporary disequilibrium with an adjustment term that pushes room rates back towards their long run equilibrium with the causal variables.

Three scenarios are simulated based on UHERO long-term projections of economic and demographic activity in the United States and Japan. The projections of US and Japan real GDP, Population, Price, Employment and Exchange Rates drive UHERO's baseline, high and low scenarios for visitor arrivals as well as simulations of the Honolulu consumer price index used in the visitor expenditures calculations.

3.4.2. Model Results

Table 1. Visitor Expenditures by Island and Origin Country

	2003	2008	2013	2018	2023	2028	2033
	Total State Visitor Expenditures						
US	6,867,490	8,465,914	9899482.1	11,599,739	13,567,731	15,936,894	18,884,489
JP	1,788,558	3,064,133	3656479.1	4,310,496	5,207,409	6,136,528	7,204,648
Total	10,278,353	13,582,153	15,978,754	18,820,038	22,338,778	26,498,910	31,647,952
US %Δ		4%	3%	3%	3%	3%	3%
JP %Δ		11%	4%	3%	4%	3%	3%
Total %Δ		6%	3%	3%	3%	3%	4%
	Oahu Visitor Expenditures						
US	2,376,125	2,971,647	3,459,754	4,012,643	4,635,502	5,373,930	6,280,176
JP	1,490,811	2,583,773	3,110,807	3,682,249	4,454,629	5,247,935	6,153,659
Total	5,357,747	8,139,193	9,681,369	11,377,141	13,544,759	15,869,799	18,587,495
US %Δ		5%	3%	3%	3%	3%	3%
JP %Δ		12%	4%	3%	4%	3%	3%
Total %Δ		9%	4%	3%	4%	3%	3%
	Hawaii Visitor Expenditures						
US	1,069,631	1,378,995	1,642,003	1,958,682	2,333,358	2,791,913	3,370,473
JP	143,711	211,077	251,913	296,461	356,950	418,578	488,790
Total	1,357,053	1,801,150	2,145,829	2,551,603	3,047,258	3,629,069	4,348,054
US %Δ		5%	4%	4%	4%	4%	4%
JP %Δ		8%	4%	3%	4%	3%	3%
Total %Δ		6%	4%	4%	4%	4%	4%
	Kauai Visitor Expenditures						
US	943,098	1,198,715	1,412,857	1,668,409	1,967,267	2,329,837	2,783,782
JP	19,244	33,957	40,184	46,993	55,978	64,897	74,758
Total	1,127,533	1,443,988	1,712,918	2,034,640	2,417,831	2,886,056	3,474,284
US %Δ		5%	3%	3%	3%	3%	4%
JP %Δ		12%	3%	3%	4%	3%	3%
Total %Δ		5%	3%	4%	4%	4%	4%
	Maui Visitor Expenditures						
US	2,478,637	2,916,557	3,384,868	3,960,004	4,631,603	5,441,214	6,450,058
JP	134,792	235,326	253,575	284,795	339,853	405,119	487,440
Total	3,147,338	3,736,737	4,278,977	4,988,680	5,877,547	6,987,156	8,405,382
US %Δ		3%	3%	3%	3%	3%	3%
JP %Δ		12%	2%	2%	4%	4%	4%
Total %Δ		3%	3%	3%	3%	4%	4%

Source: UHERO, all numbers are in thousands with the exception of the growth rates.

Table 1. Visitor Expenditures on Lodging by Island and Origin Country (continued)

	2003	2008	2013	2018	2023	2028	2033
	State visitor Expenditures on Lodging						
US	2,407,226	3,044,722	3,538,418	4,144,533	4,898,545	5,818,210	7,002,289
JP	485,816	855,237	1,016,810	1,199,281	1,465,471	1,746,895	2,084,219
Total	3,863,719	5,184,361	6,072,770	7,166,174	8,603,953	10,353,646	12,603,740
US %Δ		5%	3%	3%	3%	4%	4%
JP %Δ		12%	4%	3%	4%	4%	4%
Total %Δ		6%	3%	3%	4%	4%	4%
	Oahu Visitor Expenditures on Lodging						
US	743,191	956,774	1,106,567	1,282,240	1,496,868	1,754,815	2,083,561
JP	413,998	739,713	884,404	1,045,868	1,279,269	1,524,927	1,818,278
Total	1,710,010	2,495,977	2,952,416	3,487,004	4,193,651	5,026,191	6,074,029
US %Δ		5%	3%	3%	3%	3%	3%
JP %Δ		12%	4%	3%	4%	4%	4%
Total %Δ		8%	3%	3%	4%	4%	4%
	Hawaii Visitor Expenditures on Lodging						
US	390,241	516,747	611,550	728,885	876,741	1,059,898	1,298,375
JP	48,374	73,064	86,643	101,876	123,907	146,874	174,155
Total	527,019	691,834	824,120	987,063	1,197,706	1,457,268	1,794,334
US %Δ		6%	3%	4%	4%	4%	4%
JP %Δ		9%	3%	3%	4%	3%	3%
Total %Δ		6%	4%	4%	4%	4%	4%
	Kauai Visitor Expenditures on Lodging						
US	332,486	434,286	508,685	600,182	714,697	855,353	1,037,365
JP	1,997	3,660	4,294	5,015	6,057	7,126	8,384
Total	408,373	534,690	631,325	750,471	901,826	1,089,964	1,334,467
US %Δ		5%	3%	3%	4%	4%	4%
JP %Δ		13%	3%	3%	4%	3%	3%
Total %Δ		6%	3%	4%	4%	4%	4%
	Maui Visitor Expenditures on Lodging						
US	941,308	1,136,915	1,311,616	1,533,226	1,810,239	2,148,145	2,582,989
JP	21,448	38,800	41,469	46,523	56,237	67,968	83,403
Total	1,218,318	1,461,861	1,664,909	1,941,637	2,310,770	2,780,224	3,400,911
US %Δ		4%	3%	3%	3%	3%	4%
JP %Δ		13%	1%	2%	4%	4%	4%
Total %Δ		4%	3%	3%	4%	4%	4%

APPENDIX 3.5. SPATIAL ALLOCATION MODEL

In this section, the procedures for spatially allocating economic and environmental data are described. Data from a variety of different sources were used to build the spatial database. The data are more completely described in a separate report entitled, "Spatial Data Codebook" which was submitted as a separate work product.

The principal software used is Arc View 3.2. In addition to the Arc View files, a database was also built in SAS (statistical analysis software) to allow for more detailed statistical analysis and modeling.

Six topics are discussed in this section:

1) Sources of data;
2) Base map construction;
3) Spatial allocation procedures;
4) Analytical concerns;
5) Accuracy and data quality;
6) Locating Economic and Environmental Impacts.

3.5.1. Sources of Data

The principal sources of data for this study come from the State of Hawaii's Input/Output (I-O) Model, and the U.S. Census Bureau's Economic Census of 1997. The purpose of this phase is to allocate information regarding industry output and personal consumption expenditure spatially across the State of Hawaii. The Hawaii Input-Output Study, 1997 Benchmark Report is available at:

http://www.hawaii.gov/dbedt/97io/97io-d.xls.

Output is represented as statewide dollars of goods and services flowing into and out of each industry sector. Industries listed in the 1997 I-O table for Hawaii were identified by NAICS (North American Industry Classification System) codes, identified in the appendix of the following report:

http://www.hawaii.gov/dbedt/97io/97i-o.pdf .

Expenditures in terms of the consumption of resources such as water, fuel, energy, transportation, and land were allocated to each industrial sector (NAICS). Similarly, the demand for various infrastructure services (wastewater, solid waste, etc.) was determined for each sector. The 1997 Economic Census also provides detailed information organized by NAICS codes. Statistics such as the number of establishments (or companies), the number of employees, payroll, and output (sales, receipts, revenue, value of shipments, or value of construction work done) are tabulated. Data are available for states, metropolitan areas (MA's), counties, places with 2,500 or more inhabitants, and ZIP codes. Information on smaller geographic areas is withheld to avoid disclosing information about individual firms. Detailed information about the census data can be found at:

http://www.census.gov/epcd/www/guide.html,

The level of detail for various sectors varies by spatial unit of analysis as shown in Table 1. While there is detailed information for all kinds of firms at the state level, at the smaller spatial units, the coverage becomes less complete.

Table 1. Geographic Areas in the 1997 Economic Census

Sector	States	MA's	Counties	Places 2500+	ZIP Codes
Mining	X				
Utilities	X	X			
Construction	X				
Manufacturing	X	X	X	X	X
Wholesale Trade	X	X	X	X	
Retail Trade	X	X	X	X	X
Transportation and Warehousing	X	X			
Information	X	X	X	X	
Finance and Insurance	X	X			
Real Estate and Rental and Leasing	X	X	X	X	
Professional, Scientific, and Technical Services	X	X	t	t	t
Management of Companies and Enterprises	X				
Administrative and Support and Waste Management and Remediation Services	X	X	X	X	X
Educational Services	X	X	t	t	t
Health Care and Social Assistance	X	X	t	t	t
Arts, Entertainment and Recreation	X	X	t	t	t
Accommodation and Food Services	X	X	X	X	X
Other Services (Except Public Administration)	X	X	t	t	t

"t" indicates data are not available for tax-exempt firms at this level.

Information on the number of establishments and employment levels by zip code for each NAICS codes listed in the 1997 I-O Table was obtained from two major sources: 1998 County Business Pattern, which is available online at:

http://censtats.census.gov/cbpnaic/cbpnaic.shtml

and the 1997 Economic Census, which was extracted from ECON^{97}Z Report Series Disc 3-1 and Disc 3-4. Data obtained from 1998 County Business Pattern were needed for industries that were not available by zip code in 1997 Economic Census data. The following table depicts data for each type of industries available by zip code in 1997 Economic Census and supplemented by 1998 County Business Patterns data.

Table 2. Data Availability for Industries by NAISC Code by Zip Code

Sector	NAISC	1998 County Business Pattern	1997 Economic Census
Forestry, fishing, hunting, and agriculture support	11	X	
Mining	21	X	
Utilities	22	X	
Construction	23	X	
Manufacturing	31-33		X
Wholesale Trade	42	X	
Retail Trade	44-45		X
Transportation and Warehousing	48	X	
Information	51	X	
Finance and Insurance	52	X	
Real Estate and Rental and Leasing	53	X	
Professional, Scientific, and Technical Services	54		t
Management of Companies and Enterprises	55	X	
Administrative and Support and Waste Management and Remediation Services	56	X	X
Educational Services	61		t
Health Care and Social Assistance	62		t
Arts, Entertainment and Recreation	71		t
Accommodation and Food Services	72		X
Other Services (Except Public Administration)	81		t

"t" indicates data are not available for tax-exempt firms at this level.

3.5.2. Base Map Construction

A uniform grid was constructed for the entire state. Each cell is approximately 0.1 mile square (or 0.333 miles x 0.333 miles in size). Because of the large areas on the Big Island, a 1 mile square grid structure was used (10 times larger than the other islands). The decision to build a uniform grid structure was based on an analysis of existing geographic structures. After considering the use of block groups, census tracts, and zip codes, it was concluded that a more uniform, standardized spatial unit of analysis was needed.

Figure 1, Employment by Census Tract illustrates some of the inherent problems with using a non-uniform spatial unit of analysis. The boundaries of the census tracts appear to be somewhat arbitrary in nature. The uneven shapes and sizes also make it difficult to compare areas and places. In Figure 2, the zip code map has been redrawn with a one-mile square overlay grid. In comparing Figure 1 and Figure 2, one can see the advantages of the base maps constructed for this study. Spatial units are more readily compared since they are uniform in size and shape.

3.5.3. Spatial Allocation Procedures

There are three types of spatial information that need to be integrated: 1) points; 2) segments; and 3) zones or polygons. Points are represented by X, Y coordinates or street addresses. They refer to specific locations. Segments are linear features such as roads, sewer lines, boundaries, etc. Zones or polygons refer to parcels, block groups, census tracts, zip codes, and other area-type features. In building the uniform grid base map, there were three procedures used to develop the spatial database:

1) point within a polygon;
2) segment within a polygon;
3) polygon within a polygon.

The first two procedures are straightforward. The third, involving the matching up of various polygons to the grid structure is more complicated. In some instances, smaller spatial units, such as parcels were aggregated up to the 0.1 mile square grid structure. In most instances, the process involved disaggregating a larger spatial unit, such as a zip code or block group or census tract to the small spatial unit (0.1 square grids).

Figure 3 shows a flow chart of the methodology used in allocating industry output and personal expenditures across the state. The I-O model's table represents all industries and economic activity in the state. These were aggregated to the 40 key industries in the state. Using I-O data, a vector of quantities demanded by sector and county were derived and then matched on the basis of employment levels by sector and zip code for the entire state. The procedure essentially involves taking the total levels of output by sector and allocating these shares across the state according to the proportionate share of employment by zip code. Infrastructure services are treated just like any other output sector. Then the total quantities demand by households and visitors are allocated both in terms of direct and indirect purchases of goods and services. The final step involves assigning this information to the grid based structure. The uniform grid thereby allows for comparisons across each island and across the state.

Figure 4, Land Use by Grid Structure, shows the state land use classifications with a 0.1 mile square grid overlay. Using land use information from both the state and the county, as well as information on the location of roadways and other pertinent information and the three spatial allocation procedures, economic activities from the I-O table and the CGE model were located.

3.5.4. Analytical Concerns

There are a number of different analytical concerns. It is important to note that the spatial analysis is based on data and information generated from the input-output tables and the CGE model. As such, in its present form, statewide data are allocated to the county and sub-county levels. Also, it is important to point out that at present; the opportunities for spatial feedback into the model are limited. Changes in land use, changes in the allowable intensity of development, for example, do not feed back into the

CGE model. While the level and nature of development can be changed in terms of parameters in the statewide CGE model, at present, it is not possible to, for example, change the zoning of one parcel and then have this change affect the CGE model. This is a function of the "top-down" nature of the model that was constructed. In the future, however, "bottom-up" approaches may be utilized which better allow for this type of feedback between land use changes and economic output.

Another analytical concern relates to the way in which infrastructure demand was estimated and spatially modeled. As described in Appendix 6, procedures for estimating direct and indirect demand from the expenditure patterns of households and visitors were developed. Infrastructure services were tried just like other goods and services that flow through the state economy. The estimates, therefore, are based not only actual levels of water use or wastewater demand, but rather on the levels of spending for these services either by households (direct consumption) or through the purchase of goods and services by households and visitors from firms (sectors) which consume these infrastructure services (indirect consumption). A related concern is the inability to fully assess infrastructure capacity. While some initial work was done by others (Part I of the Overall Study), the data were not available at the scale and level of analysis for which this model was built.

3.5.5. Accuracy and Data Quality

The spatial databases were built using common mapping standards and various federal, state, and local sources of information. Where possible, the spatial data was reconciled across different databases. Additionally, recent air photographs and other imagery were used to help confirm land uses and activity patterns. However, there are a number of potential sources of error. First, statewide economy data was allocated to the county and sub-county levels using a variety of different spatial analytical techniques. Employment by sector by zip code was the principal basis for allocating economic activity. Second, because not all the sectors in the Hawaii I-O tables matched up neatly against all of the NAISC and census categories, there may have been some misclassification error. This is a common problem which occurs as new categories are often added and other categories are dropped as the overall structure of the economy continues to change, shifting more from a manufacturing and traditional industrial base to one more dominated by service industries. Finally, there are problems resulting from the fact that there have been significant changes since 1997 which is the base year for the input-output data. There have been changes in the structure of the economy. There have been changes in the location of economy activity. There have been changes in the intensity of this activity. Yet these changes may not have been all captured in each of the different databases.

Figure 1. Employment Distribution by 2000 Census Tracts

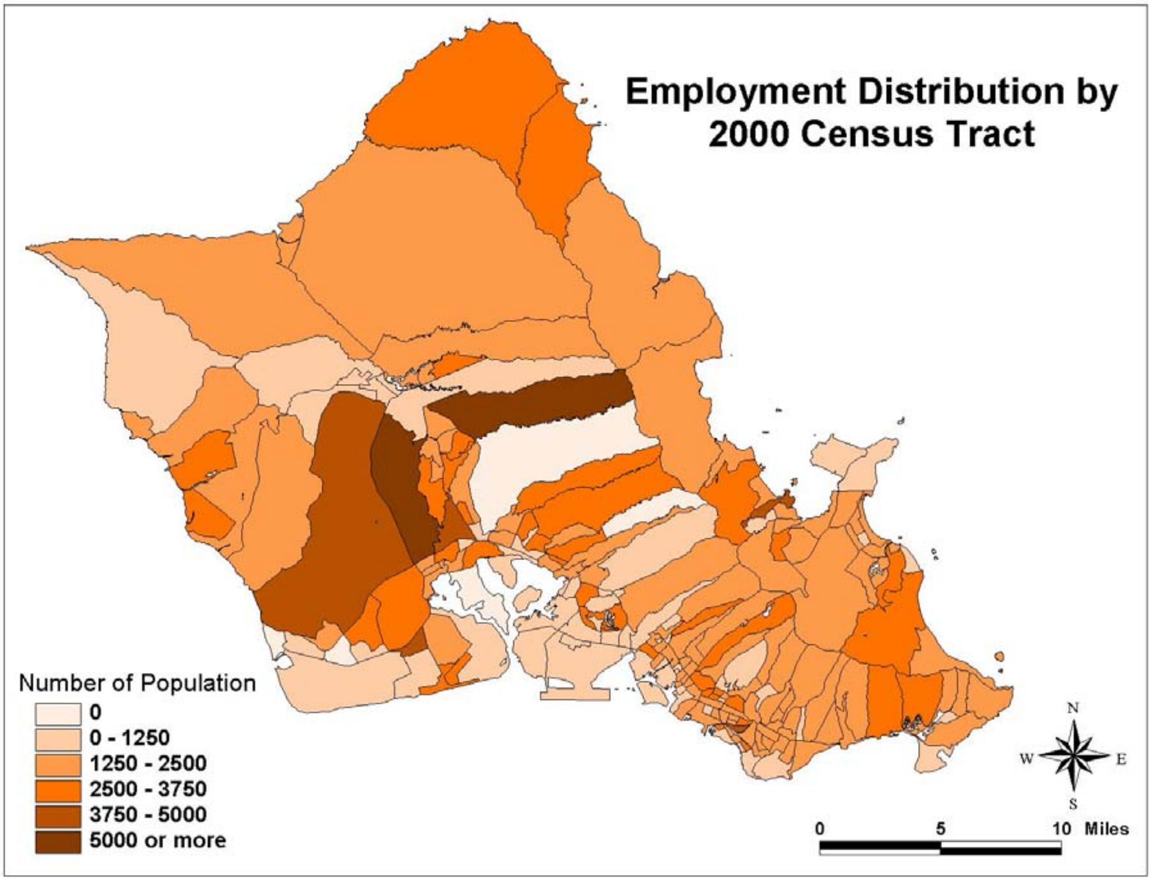


Figure 2. Zip Code Allocation in Oahu by 1-mile Grid Structure

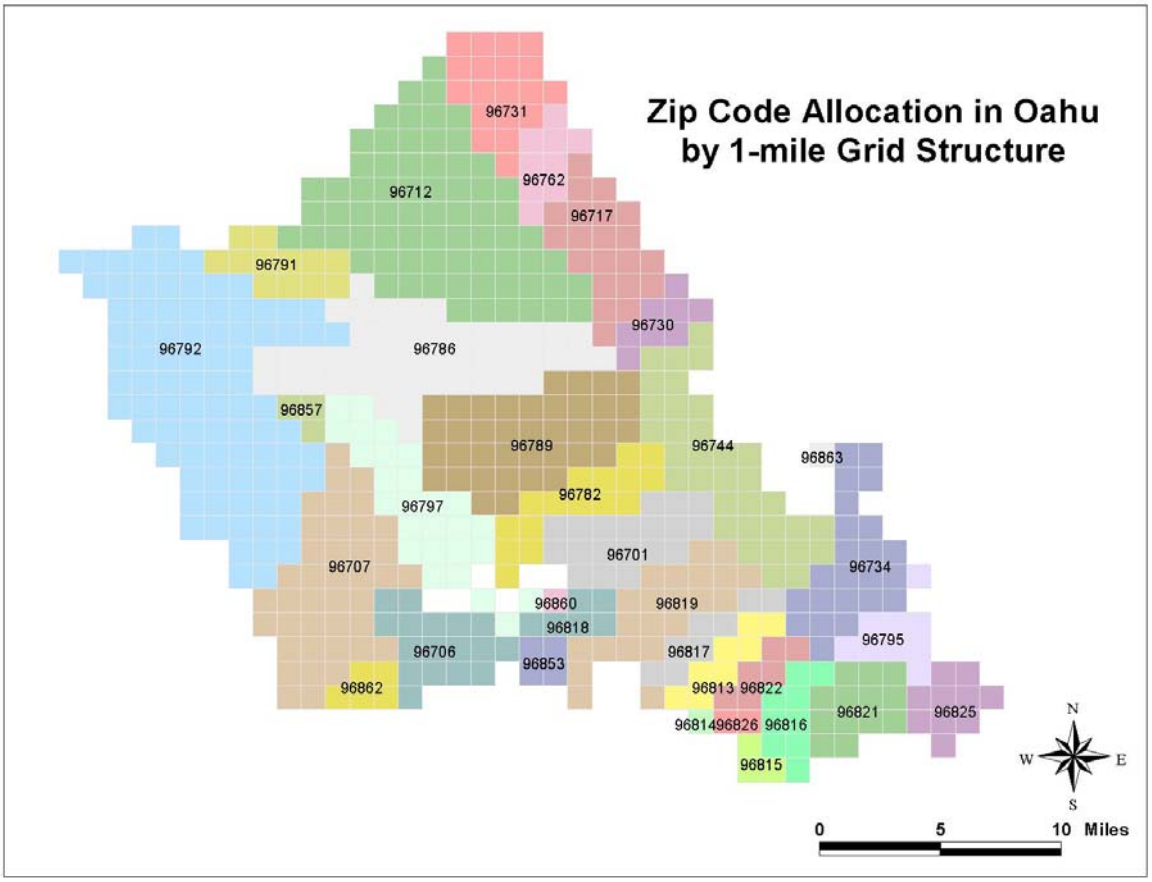


Figure 3. Methodology Flow Chart

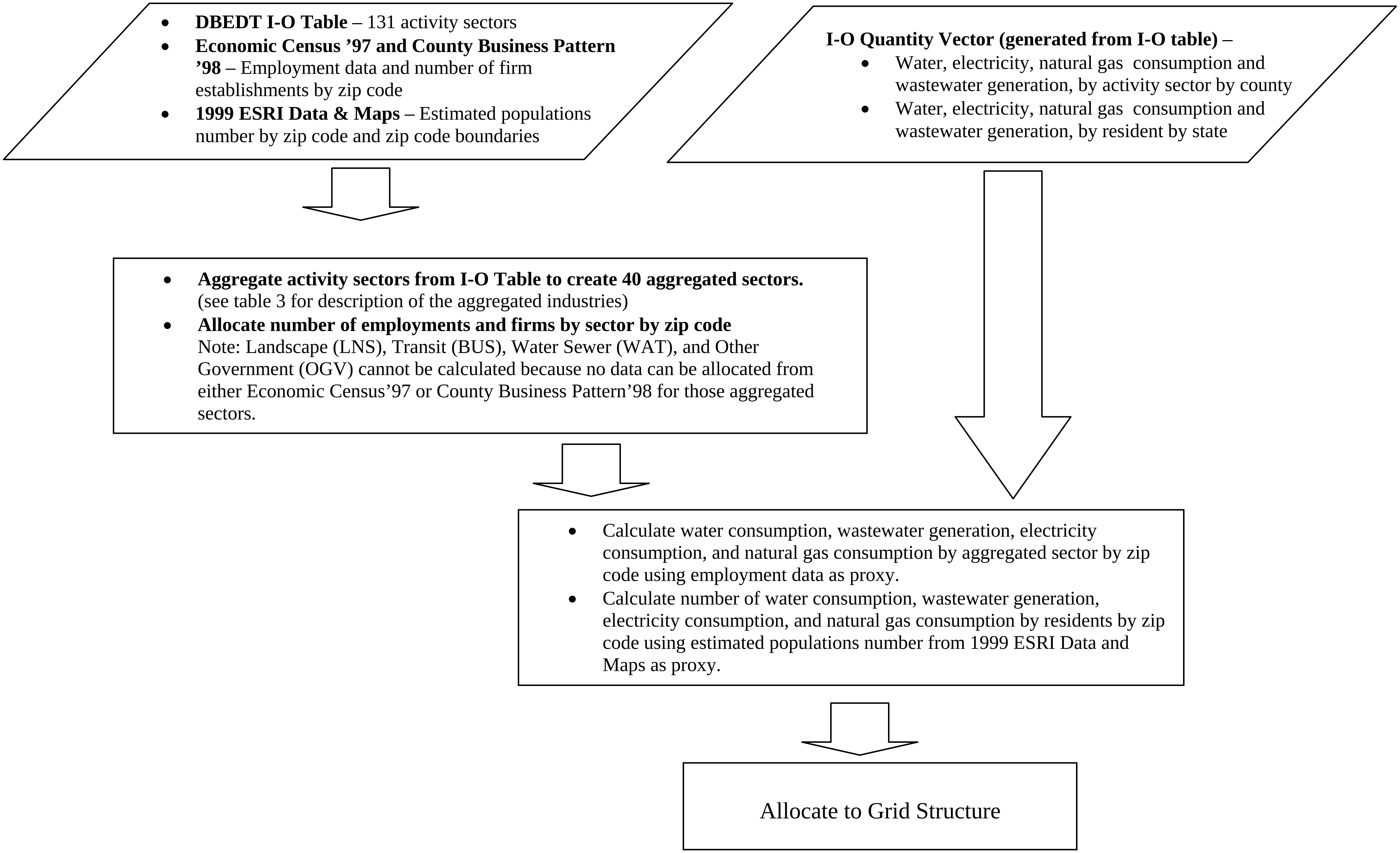
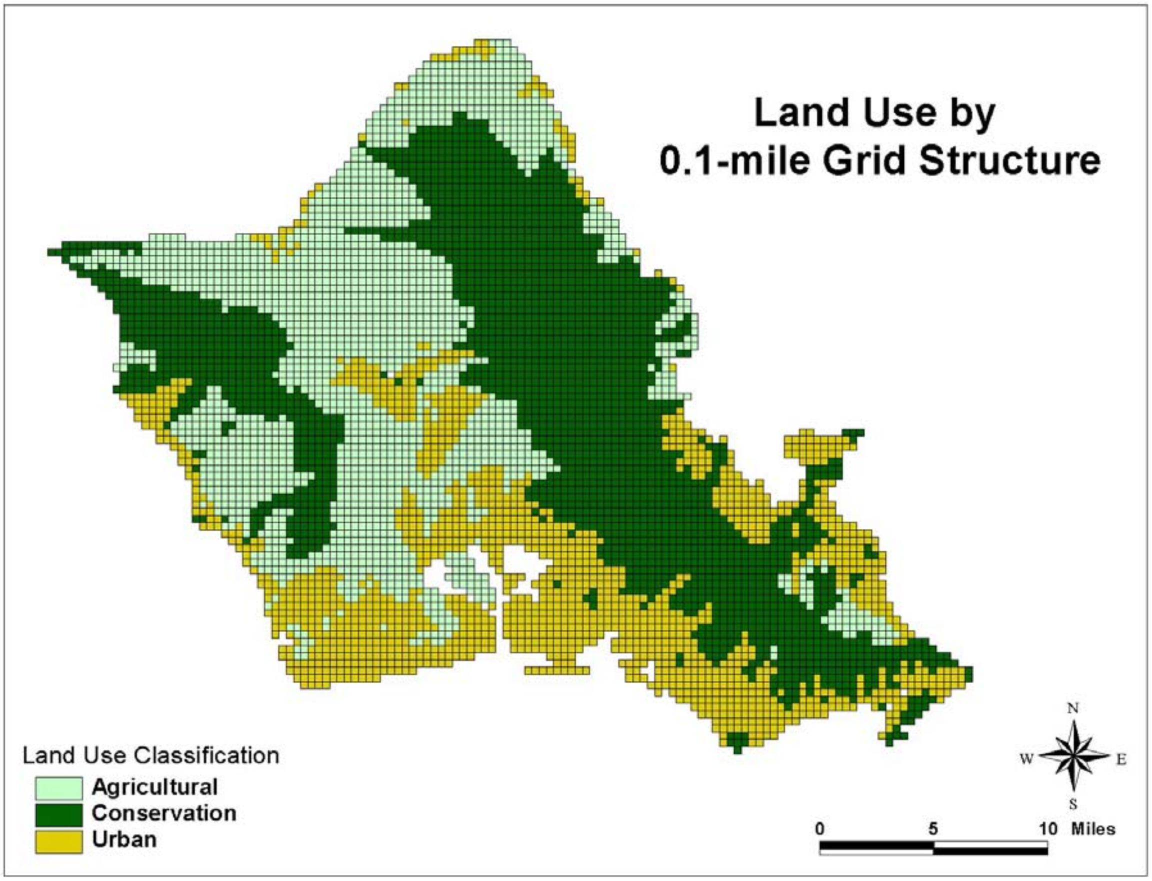


Figure 4. Land Use by 0.1 mile Grid Structure



3.5.6. Locating Economic and Environmental Impacts

The purpose of this section is to describe the location of economic activity and the resulting environmental impacts in terms of water use, energy, and solid waste generation. Using data from the input-output tables, and simulation results from the CGE (Computable General Equilibrium) model, the impacts of two different scenarios are also tested. In one scenario, visitor spending decreases by 25%. In another it increases by 10%. The impact of these economic changes is then modeled in terms of changes in employment across the state. The point of this analysis is to first to demonstrate the extent to which economic activity is spatially concentrated. Then, mapping the location of both industries and the population base, the spatial pattern of demand for infrastructure is also analyzed. These patterns are examined across the state and on each of the islands in Hawaii. The other point of this analysis is to demonstrate how economic and environmental data have been linked and how these data can be used to analyses the location of various changes.

Using GIS (geographic information systems) and various spatial databases, the location of economic activity, resident population, and the cumulative levels of water, energy, solid waste generation, and resource use are depicted. The purpose of this analysis is to show baseline conditions in terms of where economic activity is located and to establish a spatial relationship between economic activity and environmental impact. This information is to be used in conjunction with other findings regarding resident and visitor economic activity and environmental impacts. By creating a uniform, grid cell based representation of economic activity and environmental impact; it is possible to see where activity is concentrated, where the impacts are most likely to be significant and to compare one area to another.

This spatial analysis, therefore, augments the information that is contained in other parts of the report. The maps and displays enable the visual representation of economic activity in terms of the state as whole as well as in terms of various counties, or communities where growth and development has concentrated. The spatial analysis is, thereby important for two different reasons. First, it gives an indication of where the pressure points are currently located in terms of both economic activity and the resulting environmental impacts. Second, it identifies the potential for development in other places. One could compare developed to undeveloped or less developed parts of an island. Or one could compare certain regions in the state (Waikiki, Kona, Lahaina, etc.) in terms of their respective levels of development, their resource use, and their potential for new growth. Also, by identifying the locations of bird habitats and the places where endangered species are concentrated, areas that need protection can also be determined.

After describing the data and methods used in this study, a series of maps organized by county is presented. In addition to mapping economic output, the location of the resident population is also displayed. Maps showing the locations of bird habitat and endangered species are also displayed. The aggregate demand for water, electricity, solid waste by grid cell is also determined. Then, two different economic scenarios are mapped. One involves a 25% decrease in visitor spending. The second involves a 10% increase in visitor spending. The impact of these changes on aggregate employments levels by grid cell are then mapped and analyzed.

RESULTS AND FINDINGS

The spatial analysis is organized in the following manner. The maps are first grouped by county: Honolulu, Maui, Hawaii, and Kauai. Then, for each county, the following maps have been produced:

1) baseline economic output;
2) population distribution;
3) bird habitat;
4) threatened and endangered plants;
5) water consumption;
6) electricity consumption;
7) solid waste generation;
8) 25% decrease in visitor spending (Scenario 1);
9) 10% increase in visitor spending (Scenario 2).

A brief commentary and explanation of each map follows.

Economic and Environmental Impacts: Oahu

Figure 5 shows the baseline output for all industries on Oahu. Economic activity is highly concentrated in a number of key districts: Waikiki, downtown, and in several industrial areas. It is important to note the magnitude of economic activity by grid cell also far exceeds any other part of the state. There are several grid cells which generated more than $329 million to $729 million of output. These are, among the most productive locations, economically speaking, in the state.

The population distribution (Figure 6) is much more dispersed. Population has tended to concentrate along the southern coast of Oahu, although there are notable high concentrations of population in areas such as downtown, Makiki, Salt Lake, and other communities. Not too that Pearl City to East Honolulu corridor is the most heavily developed in terms of residential population.

Figures 7 and 8 show bird habitat and the location of threatened and endangered plant species. Note that most of the areas are located away from where most of the principal economic activity is generated.

Figure 9 shows water consumption by grid cell. The resulting demand for water is clearly a function of both industrial location and residential growth. Similarly, the demand for electricity (Figure 10) is located in both areas where there are high concentrations of population, businesses, and industrial activities.

Figure 11 shows the baseline solid waste generation on Oahu. While the spatial pattern is more dispersed, it is clear that the solid waste generation is function of both the density of commercial and industrial activities and the location of population.

Figure 12 shows the impact of a 25% decrease in visitor spending. Note that employment in some sectors (principally located in Waikiki) decreases significantly, while there are some places that will experience a growth in employment as the economy shifts towards non-visitor related economic activities. Similarly, a 10% increase in visitor spending (Figure 13) will lead to some declines in employment, but also growth in employment in those visitor related economic activities. The spatial impacts are a function of the location of employment.

Economic Activity and Environmental Impacts: Maui

Figures 14 to 22 show the same data for Maui. Note that compared to Oahu, all of the values and the scaling of economic activity and environmental impacts are much lower. The level of concentrated output (Figure 14) is also much lower. The highest producing grid cell on Maui is $235 million, annually.

Figure 15 shows the distribution of population for the County of Maui, including the islands of Maui, Molokai, and Lanai. The most populated grid cell contains 1774 persons.

Figures 16 and 17 show the locations of bird habitat and threatened and endangered species. Many of these locations are in the conservation districts and in other remote areas.

Baseline water consumption is displayed in Figure 18. It reveals that the highest water demand is located in both the more urbanized and developed locations of the county. It shows a similar location pattern to the demand for energy (Figure 19). Figure 20 contains the baseline solid waste generation which is a function of both the location of the resident population and the visitor industry.

Table 21 shows the impact of a 25% decrease in visitor spending on Maui. While some economic sectors will experience a decline in employment, others will experience growth. It is also interesting to note that a 10% increase in visitor spending (Figure 22) results in growth for some regions, but also a decline in others. Those industries directly tied to visitor spending will gain, drawing labor and other factors of production from non-visitor related businesses.

Economic Activity and Environmental Impacts: Hawaii

The data on economic activity and environmental impacts for the Big Island are contained in Figures 23 to 31. Because of the larger areas and distances each of the grid cells represents one square mile, instead of 0.1 square miles. For this reason, the level of economic activity is somewhat higher and also the activity also appears to be somewhat more concentrated. Economic activity (Figure 23) is more heavily concentrated in Kona and in Hilo. Waimea also shows up on this map. Population (Figure 24) is more dispersed.

Figures 25 and 26 show the location of bird habitat and endangered species.

Figure 27 shows baseline water consumption by industries, visitors, and residents on the Big Island. Water demand is clearly a function both industrial development and residential growth. Notably there is much more water use in the eastern part of the island than the western region.

Figure 28 shows the location of electricity demand. It is a function of the location of both the visitor industry and other industries. It bears somewhat of a similar pattern to the generation of solid waste (Figure 29).

Figure 30 shows the impact of a 25% decrease in visitor spending. Notably there are declines in employment on both sides of the island as well as gains in some sectors. A boost in visitor spending (Figure 31) shows growth in some sectors and declines in others. Note that a 10% increase in visitor spending translates in to job losses of ranging from 65 to 85 persons per square mile in some locations.

Economic Activity and Environmental Impacts: Kauai

The final series of maps (Figures 32-40) illustrates the economic and environmental conditions for Kauai. Figure 32 shows output. Output is concentrated in Lihue and to some extent on the south shore. The pattern of population distribution is shown in Figure 33. Population is more dispersed than economic output. Figures 34 and 35 show the location of bird habitat and threatened and endangered species.

Baseline water consumption is shown in Figure 36. It is a function of both economic output and the population distribution. In addition to Lihue and south shore areas, other areas of high demand include Kapaa and districts on the North Shore. Figure 37 shows the demand for electricity. Figure 38 contains a map of the baseline solid waste demand.

Figure 39 contains a representation of the employment impacts of a 25% decrease in visitor spending. While some sectors will lose employment, others will gain. The impact of a 10% increase in visitor spending is displayed in Figure 40.

DISCUSSION

The spatial analysis reveals a number of key findings. There is quite clearly, a concentration of economic activity in key locations. The mapping served to identify these locations, both across the state and from the perspective of individual counties. The pattern of residential location is much more dispersed. Knowing the location and densities of the resident population is important, not just in terms of planning for infrastructure, but also in terms of assessing workforce conditions. As economic changes occur and as various industries expand and decline, the labor requirements will also change. The changes in the labor force will in turn affect the demand for housing, infrastructure (water, sewer, energy, solid waste disposal, etc.).

Like the analysis of the location of output, the mapping of the demand for infrastructure services shows some spatial patterns. Generally, the demand is highest in those areas with the greatest output and the largest number of employees. Offsetting this spatial pattern is the residential demand for water, electricity, and solid waste disposal services.

Mapping together the location of economic activity, population densities, and the resulting demands for infrastructure serves to illustrate the key communities and areas which experience environmental stress. Indeed the mapping exercise has shown to reveal not only the relationship between economic activity and environmental stress, but also the extent to which such tensions are concentrated in key districts, neighborhoods, and regions of the state. A surprisingly large amount of economic activity is concentrated in a relatively small area. The strain on infrastructure systems is also concentrated in key locations. It is in these locations, where the potential overloading of systems can cause increased stress on the environment. The maps and spatial analyses can be used to identify those areas that are particularly in need of environmental monitoring, remediation, and reduction of environmental stress.

A dimension that also can be integrated into this analysis involves the identification of areas or regions that need to be protected. The mapping effort has also included the location of bird habitat and threatened and endangered species. These areas may need additional protection from development.

Another important finding arising from the CGE modeling effort is that while a decrease in visitor spending results in employment losses, it also creates conditions where employment increases in some sectors. Similarly an increase in visitor spending means not just growth across all sectors, but rather that the employment in certain sectors will expand, while it will constrict in others.

While the mapping and spatial analysis can be used to identify key “hot spots” and locations were economic growth will produce increased environmental strain, the analysis also serves to point to one unmistakable pattern: while the economic activity tends to concentrate in selected locations, the real threats to the environment arise out of residential expansion. Call it urbanization, sprawl, or subdivision development. The growth of the resident population creates far more strain on the environment in more locations than does the expansion of industries and businesses.

Figure 5. Baseline Output on Oahu by Industries

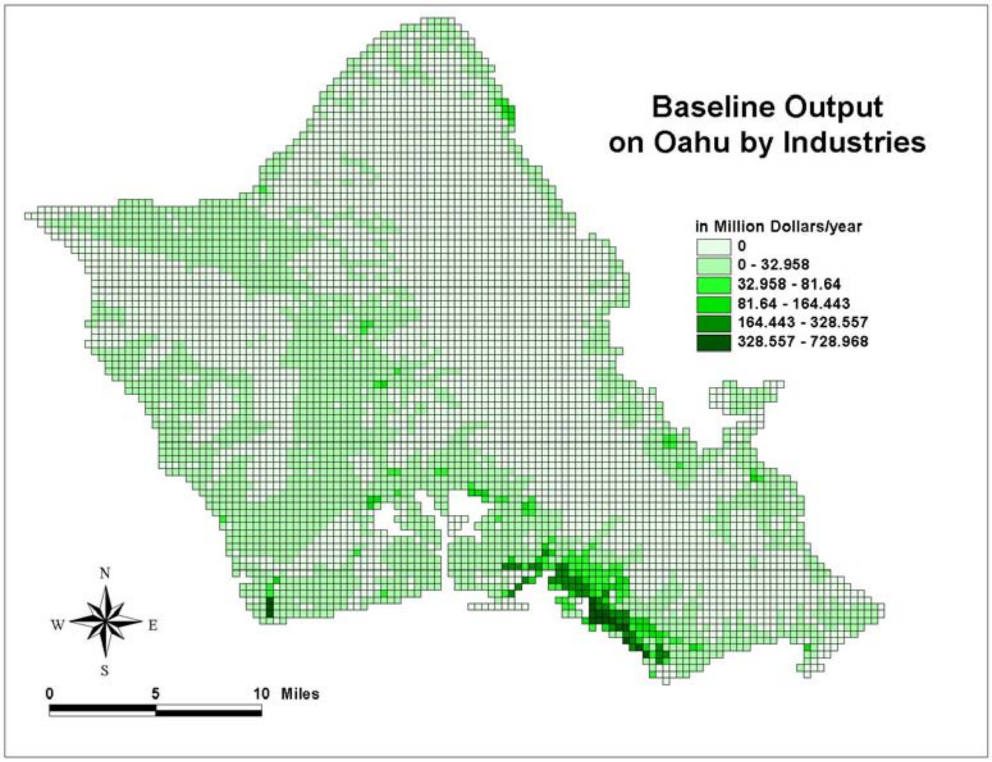


Figure 6. Baseline Population Distribution on Oahu by 0.1 sq-mile Grids

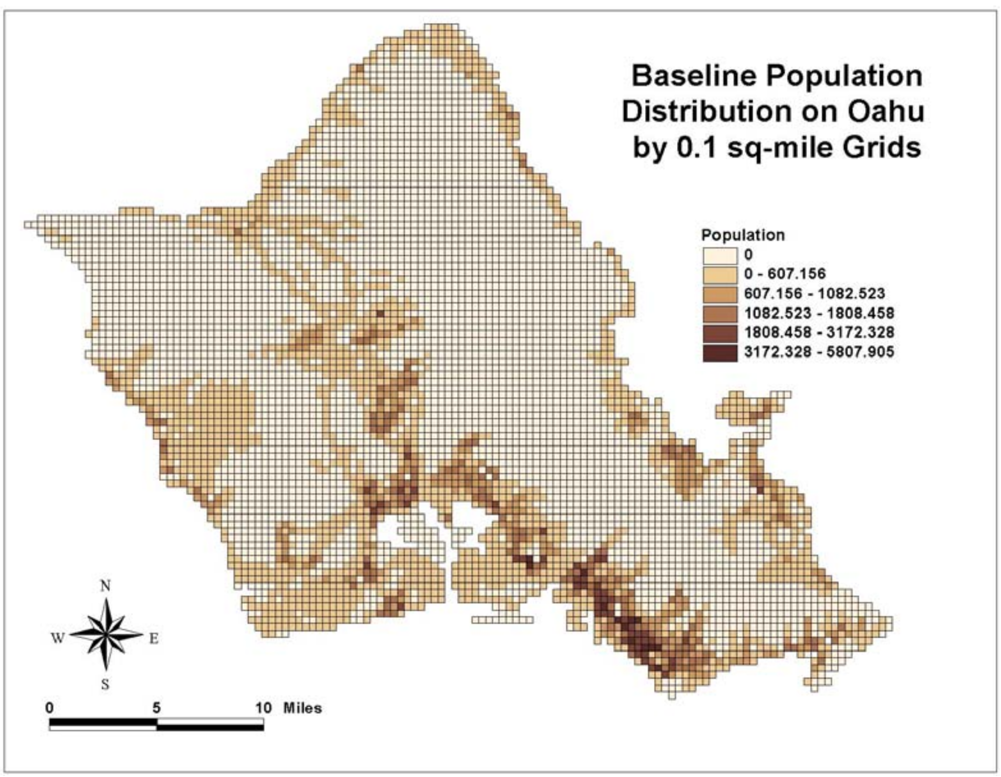


Figure 7. Bird Habitat on Oahu

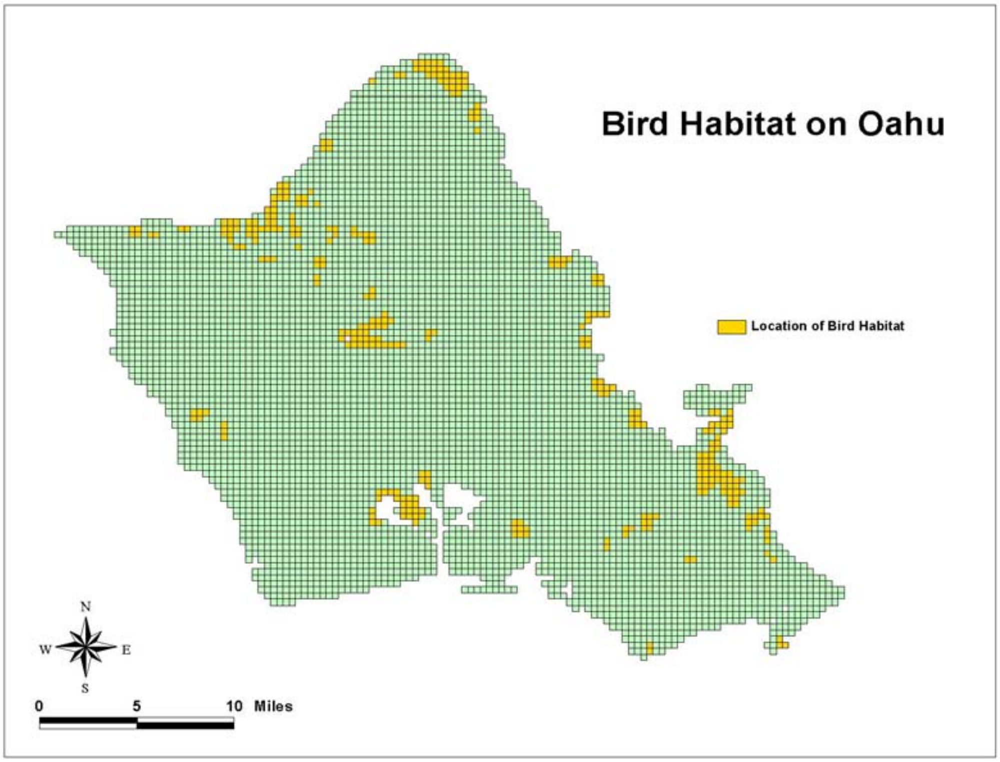


Figure 8. Threatened and Endangered Plant Concentration on Oahu

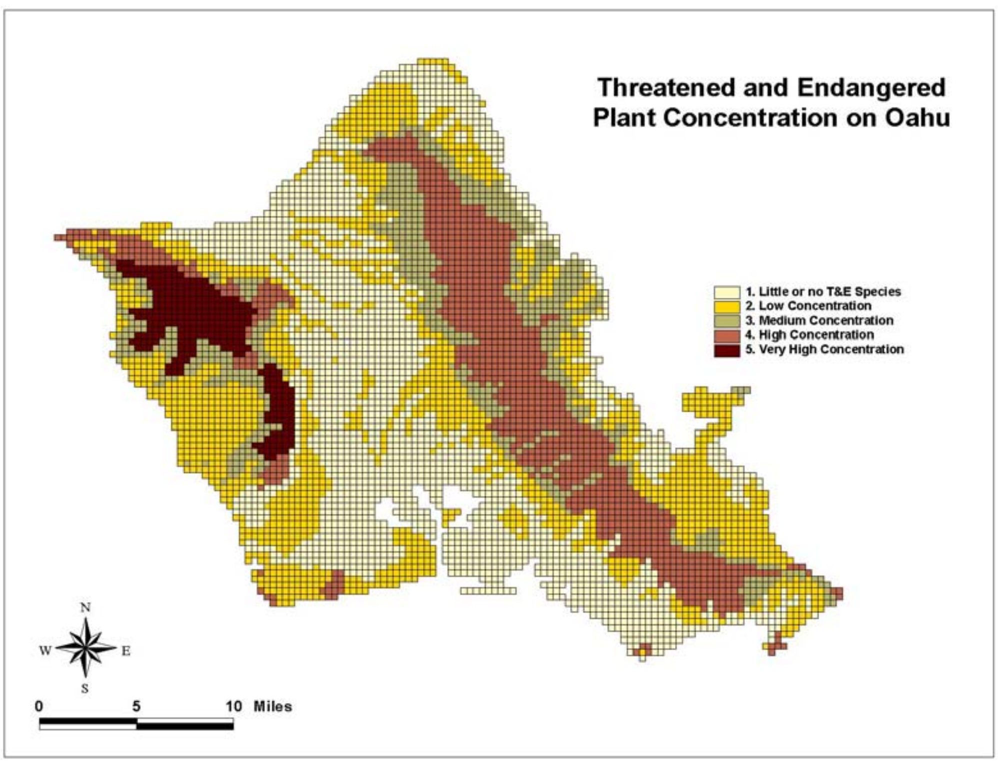


Figure 9. Baseline Water Consumption on Oahu by Industries, Visitors, and Residents

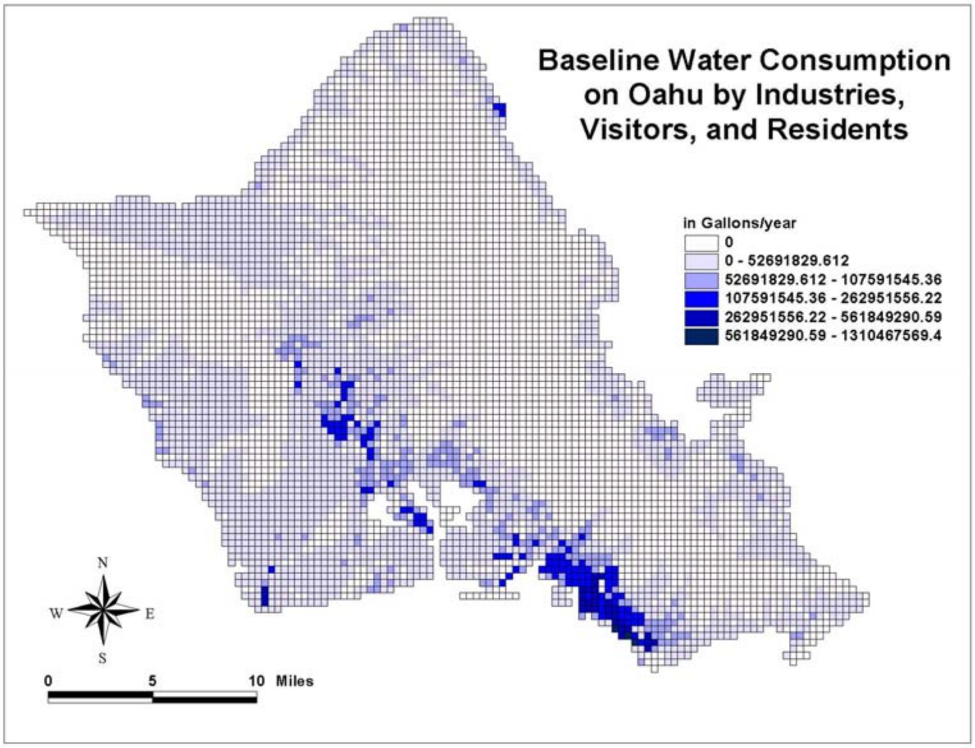


Figure 10. Baseline Electricity Consumption on Oahu by Industries, Visitors, and Residents

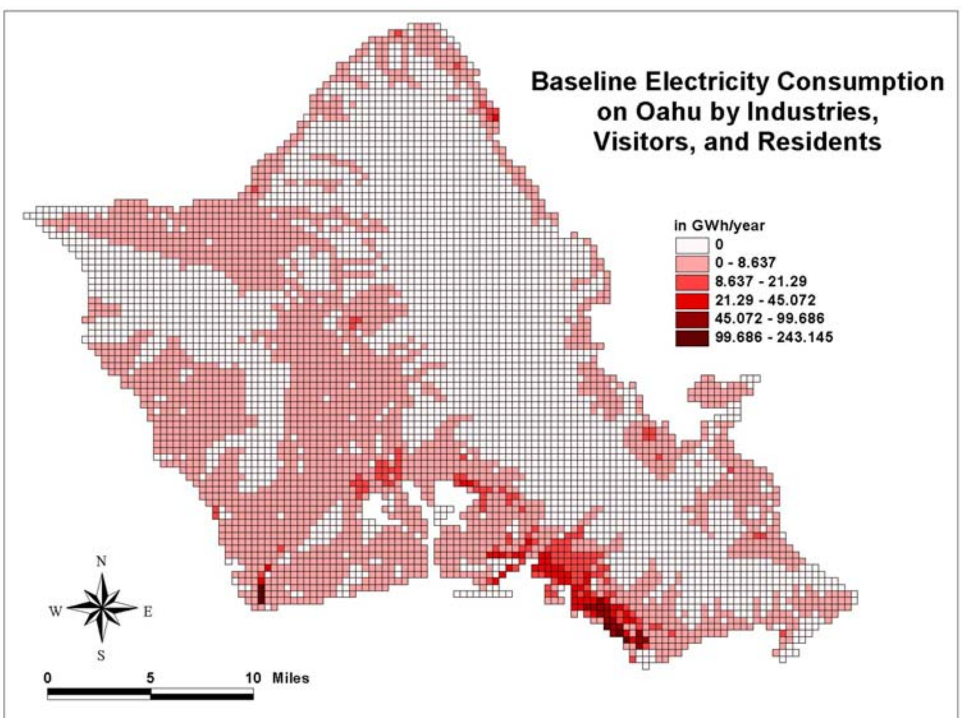


Figure 11. Baseline Solid Waste Generation on Oahu by Industries, Visitors, and Residents

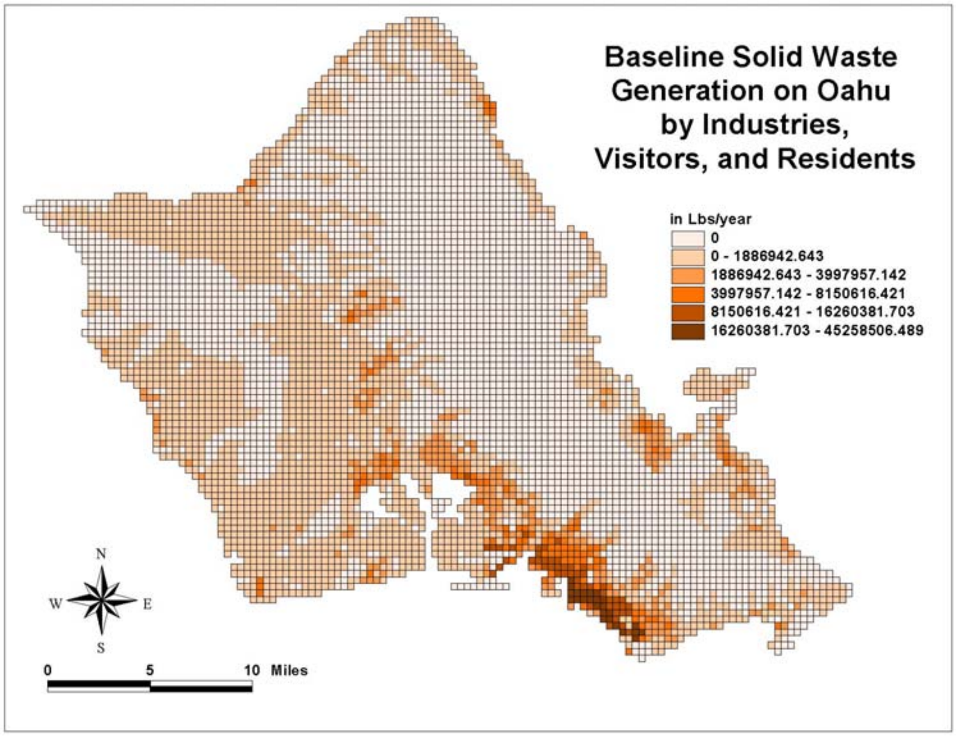


Figure 12. Employment Change on Oahu Based on 25% Decrease in Visitor Expenditure

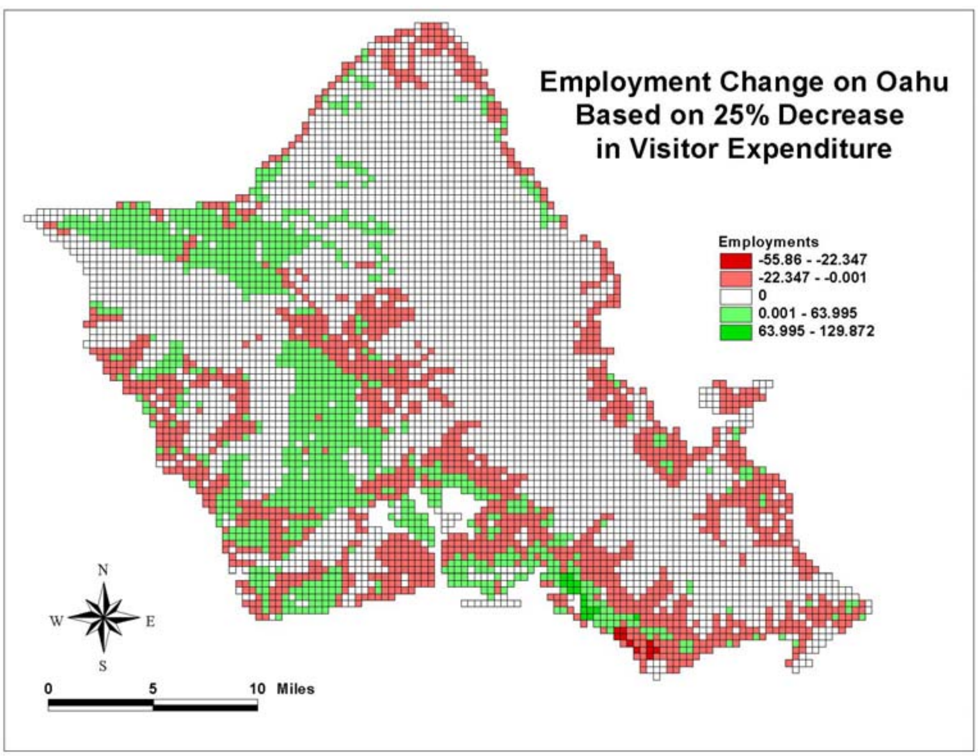


Figure 13. Employment Change on Oahu Based on 10% Increase in Visitor Expenditure

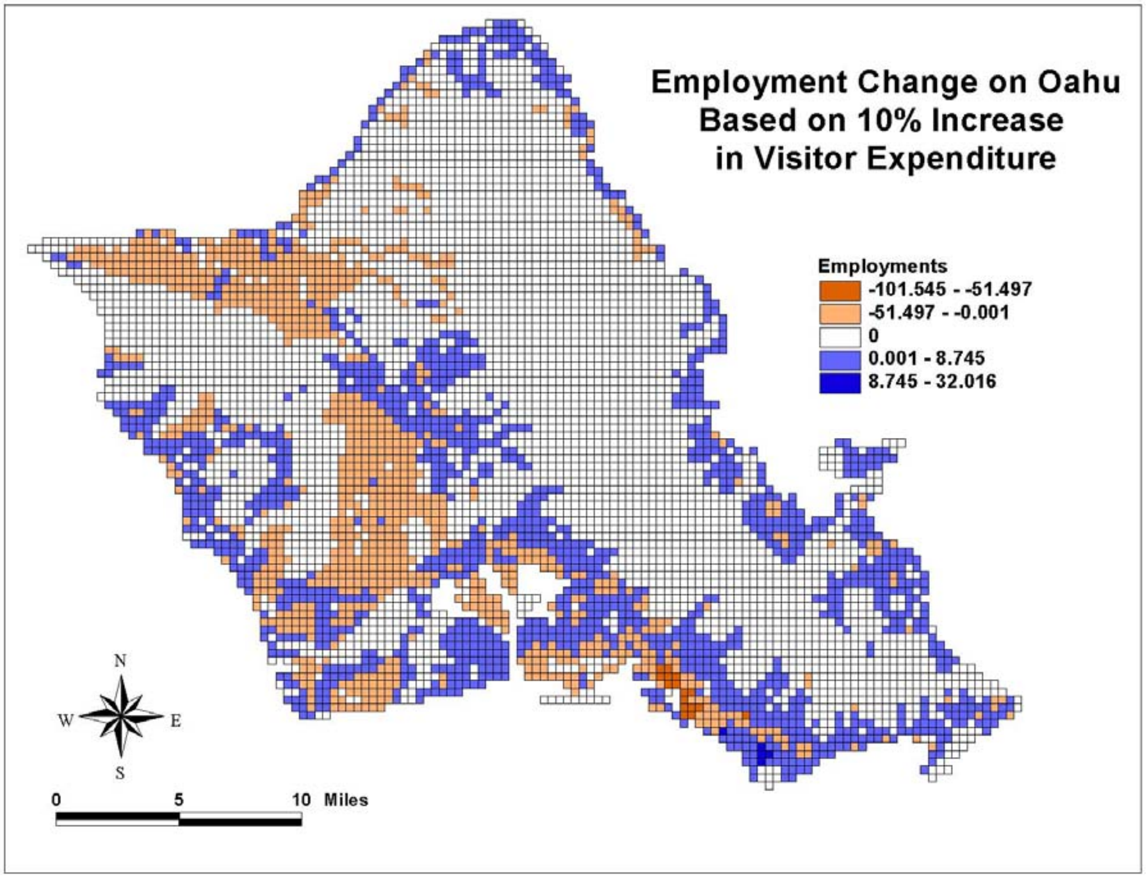


Figure 14. Baseline Output on Maui by Industries

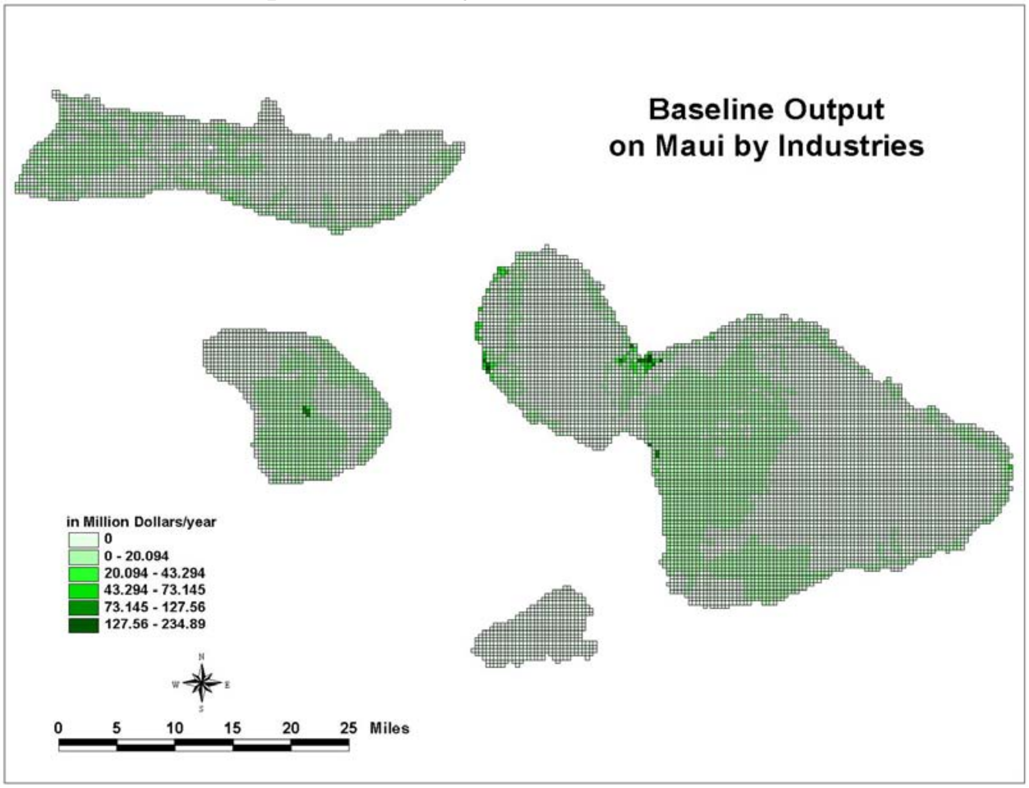


Figure 15. Baseline Population Distribution on Maui by 0.1 sq-mile Grids

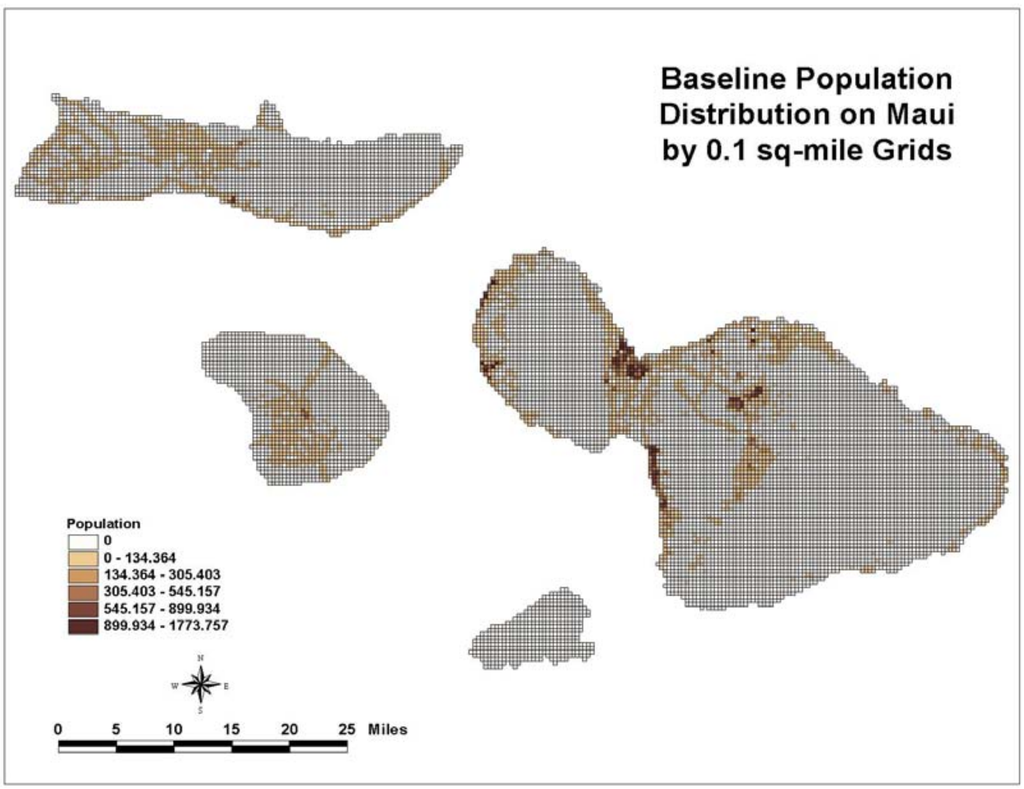


Figure 16. Bird Habitat

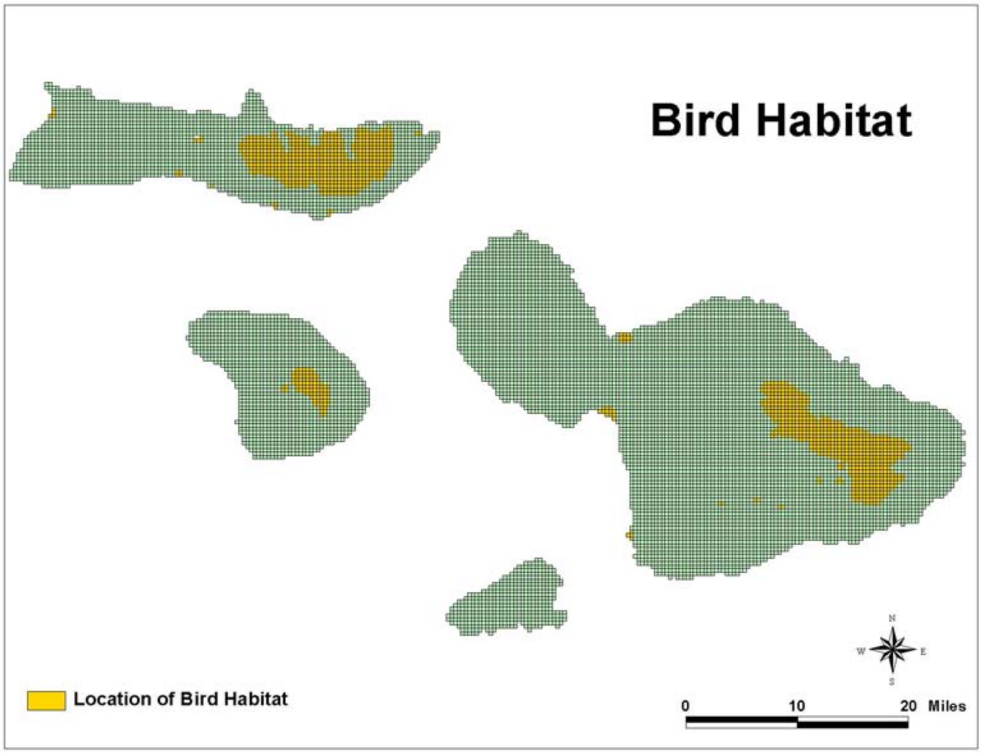


Figure 17. Threatened and Endangered Plant Concentration

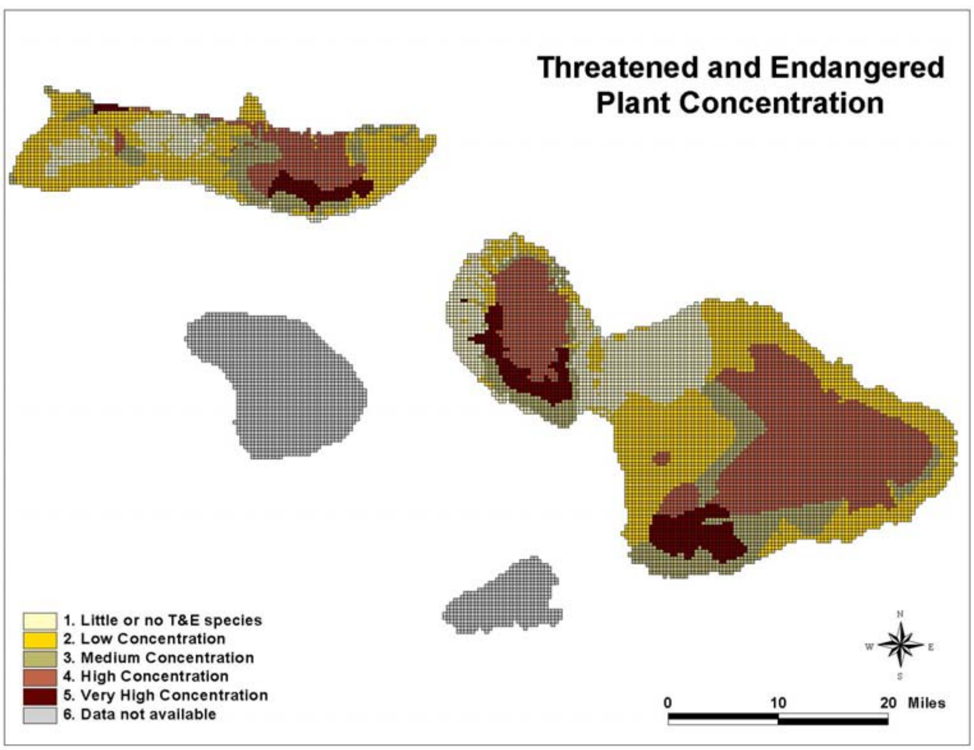


Figure 18. Baseline Water Consumption on Maui by Industries, Visitors, and Residents

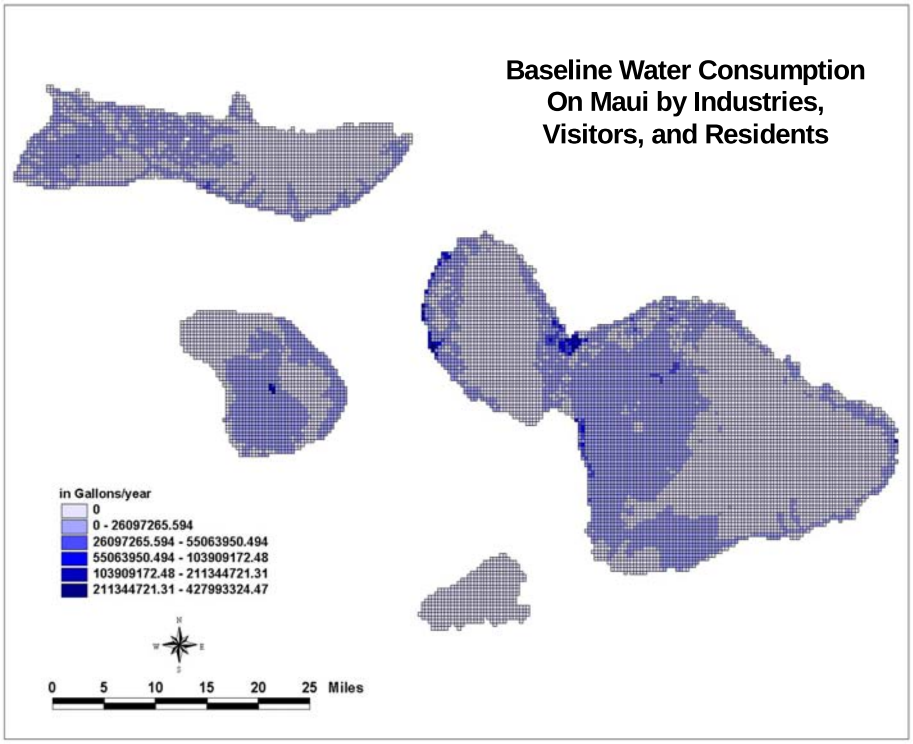


Figure 19. Baseline Electricity Consumption onMaui by Industries, Visitors, and Residents

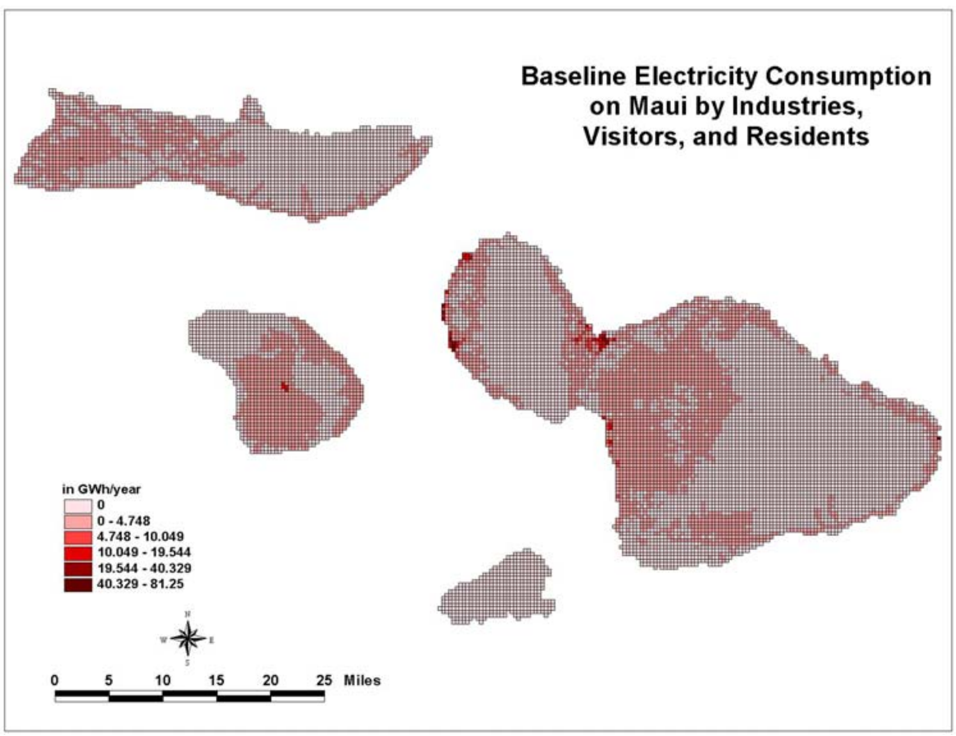


Figure 20. Baseline Solid Waste Generation on Maui by Industries, Visitors, and Residents

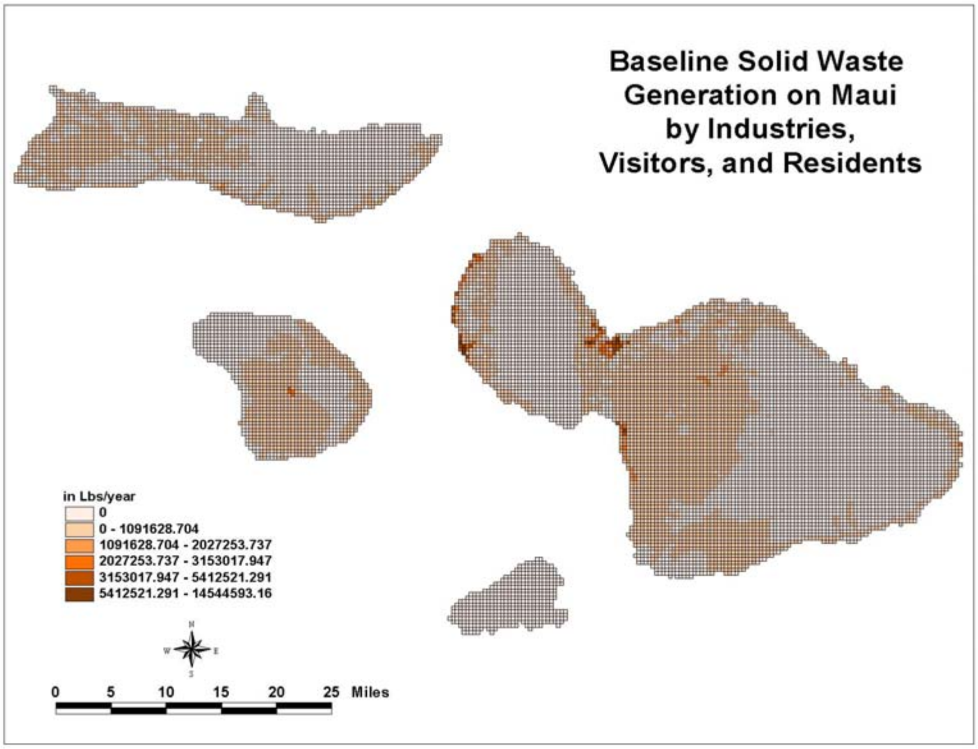


Figure 21. Employment Change on Maui Based on 25% Decrease in Visitor Expenditure

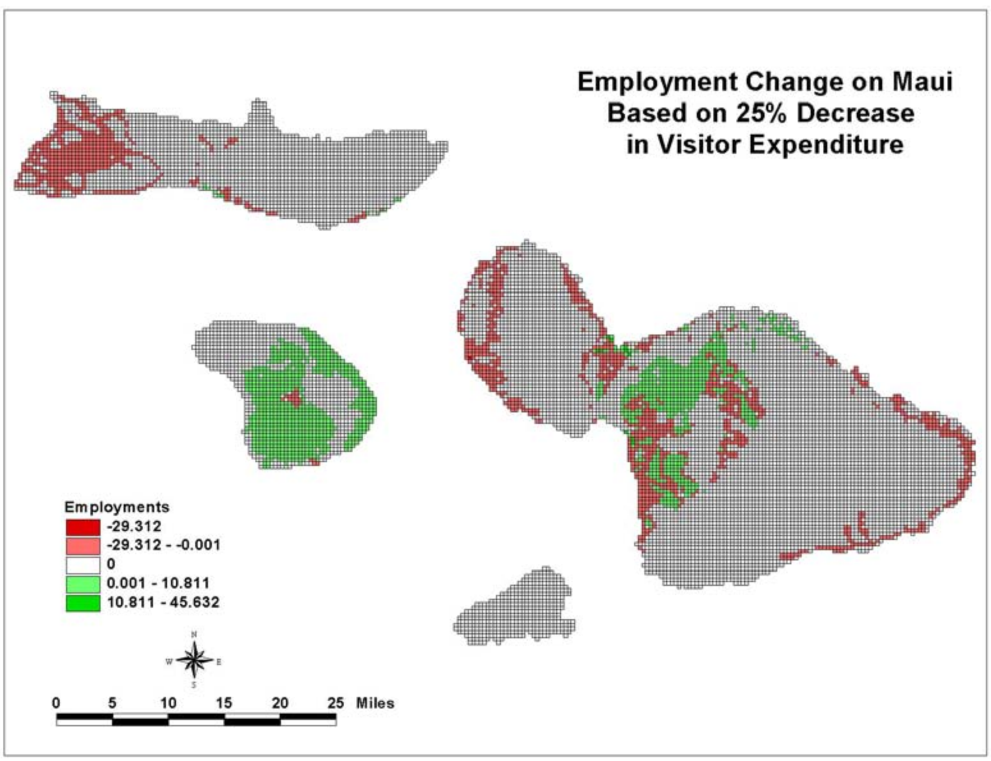


Figure 22. Employment Change on Maui Based on 10% Increase in Visitor Expenditure

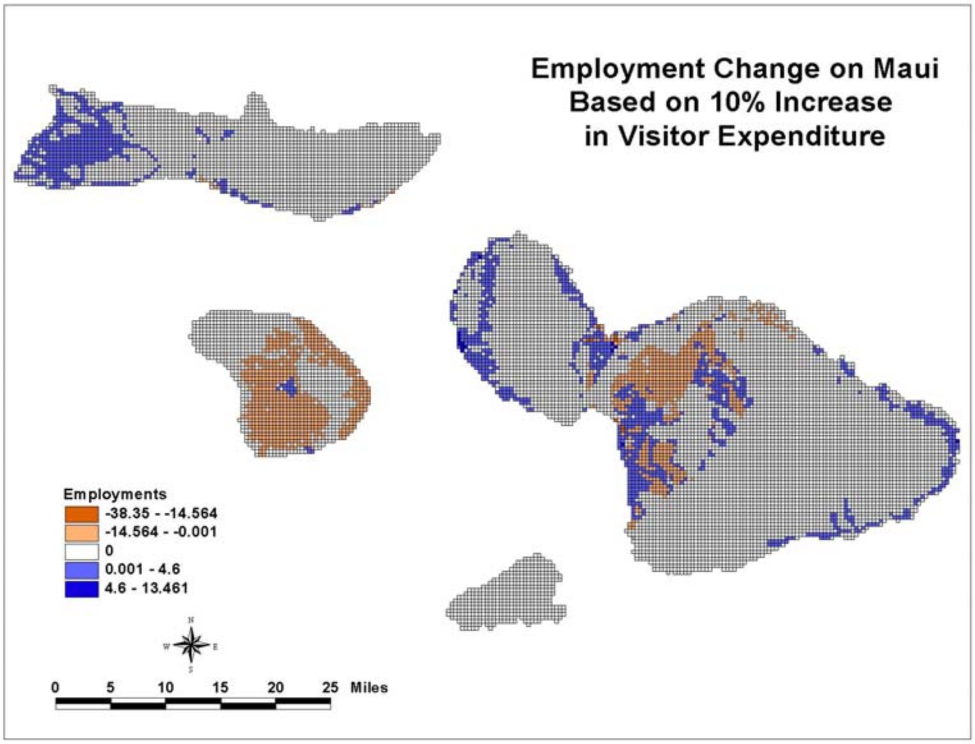


Figure 23. Baseline Output on Hawaii by Industries

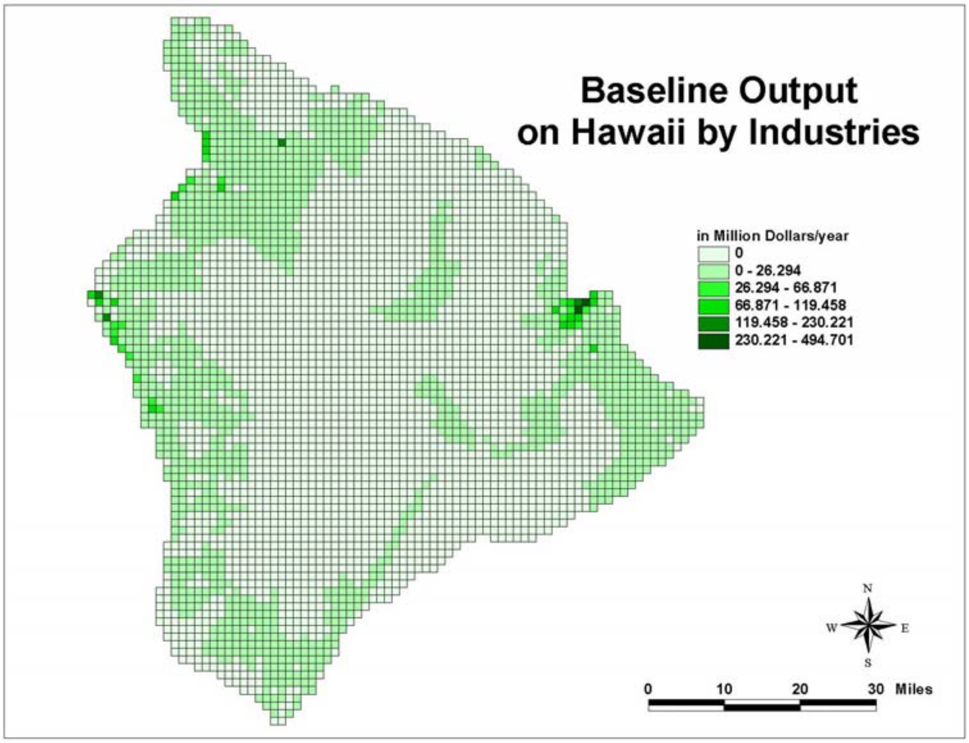


Figure 24. Baseline Population Distribution on Hawaii by 1 sq-mile Grids

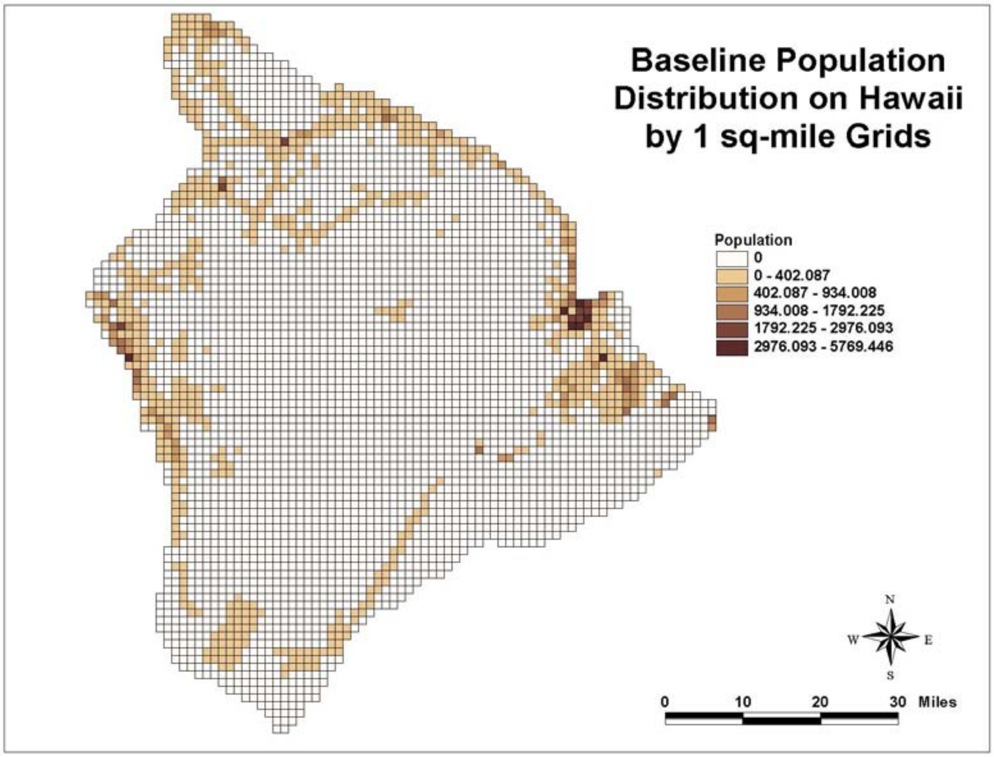


Figure 25. Bird Habitat

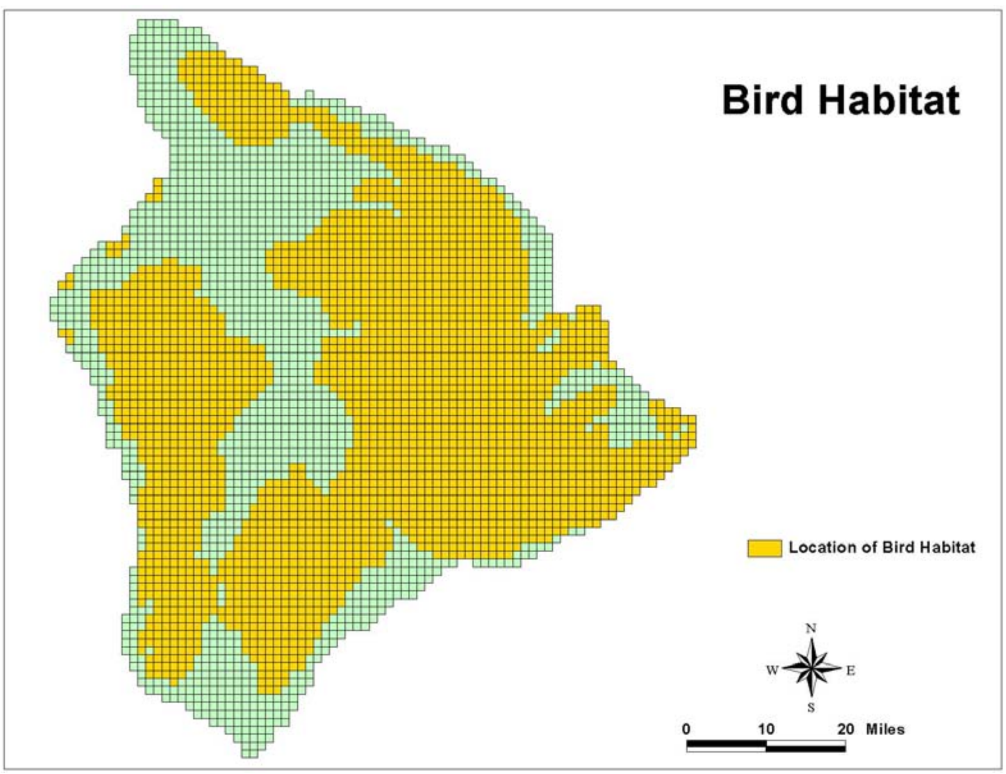


Figure 26. Threatened and Endangered Plant Concentration

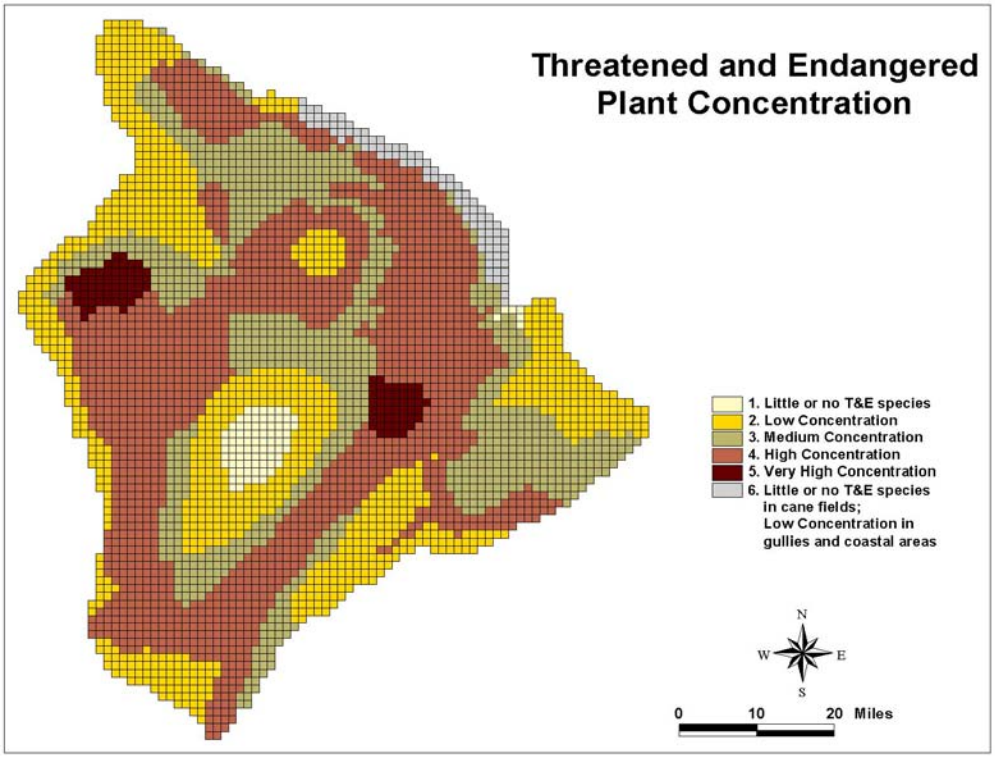


Figure 27. Baseline Water Consumption on Hawaii by Industries, Visitors, and Residents

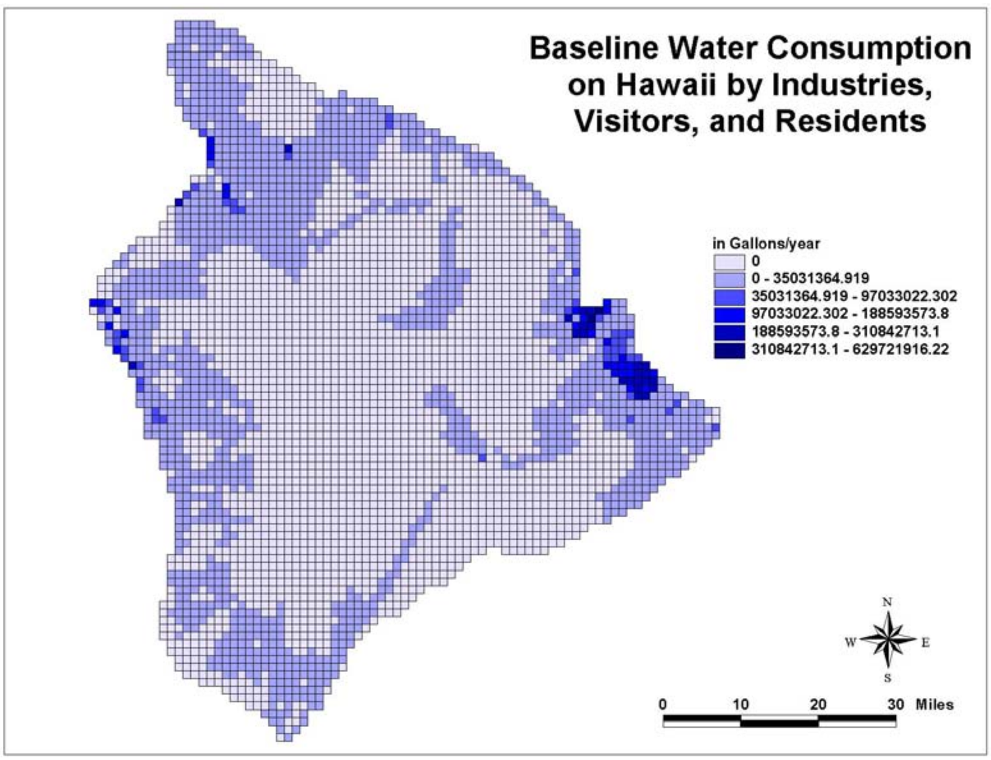


Figure 28. Baseline Electricity Consumption on Hawaii by Industries, Visitors, and Residents

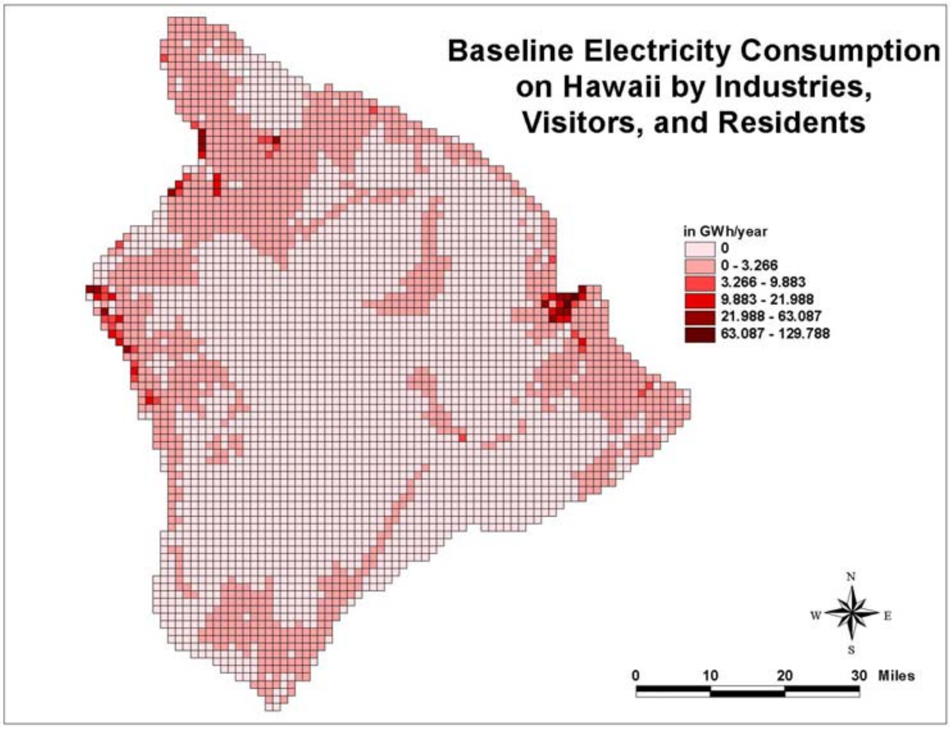


Figure 29. Baseline Solid Waste Generation on Hawaii by Industries, Visitors, and Residents

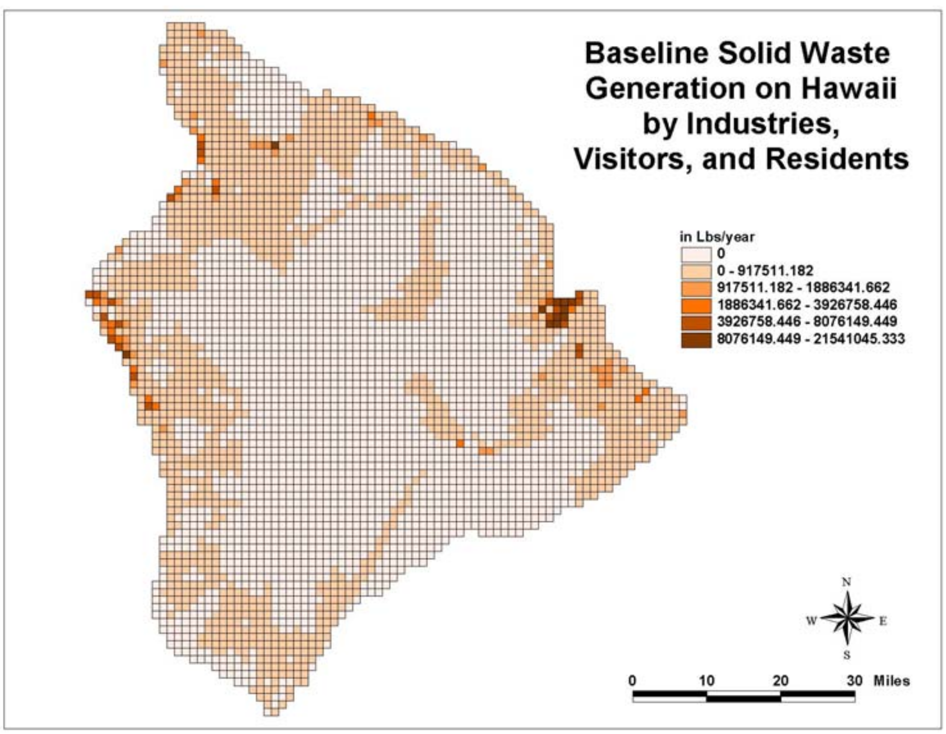


Figure 30. Employment Change on Hawaii Base on 25% Decrease in Visitor Expenditure

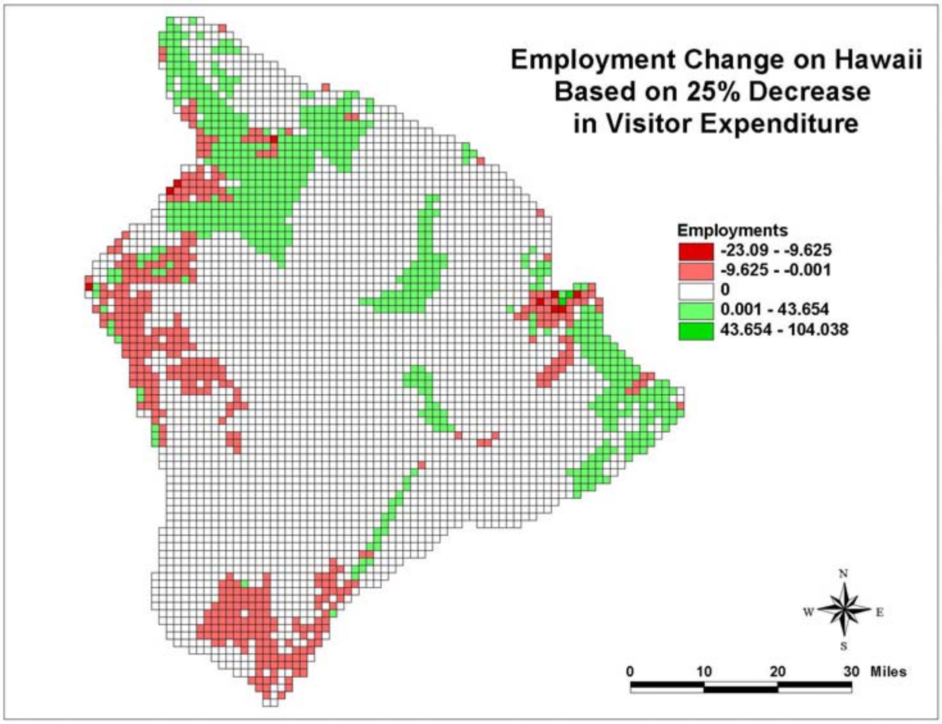


Figure 31. Employment Change on Hawaii Based on 10% Increase in Visitor Expenditure

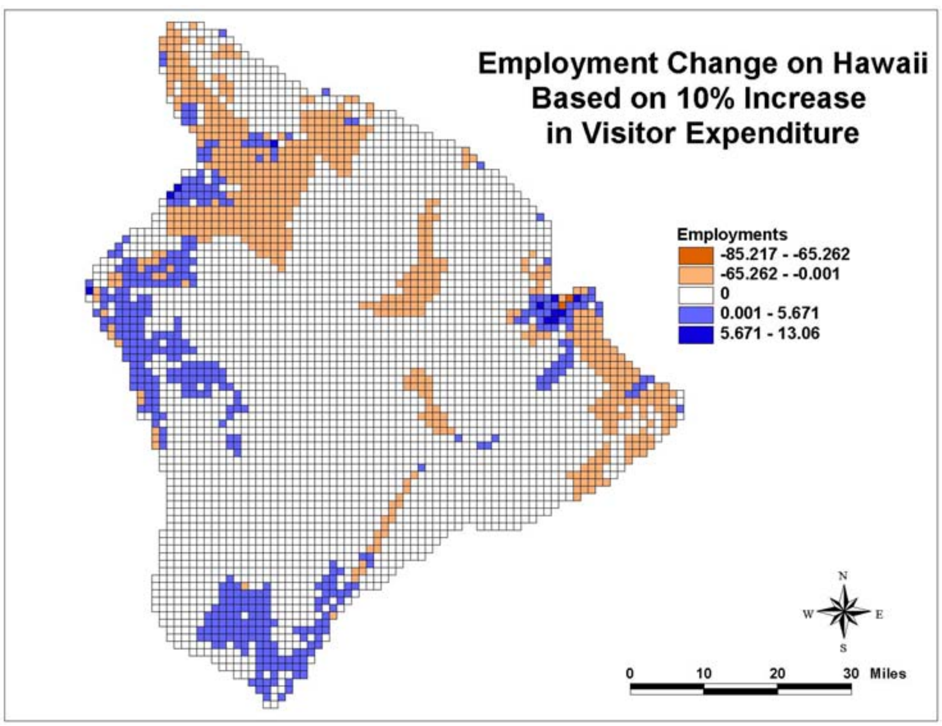


Figure 32. Baseline Output on Kauai by Industries

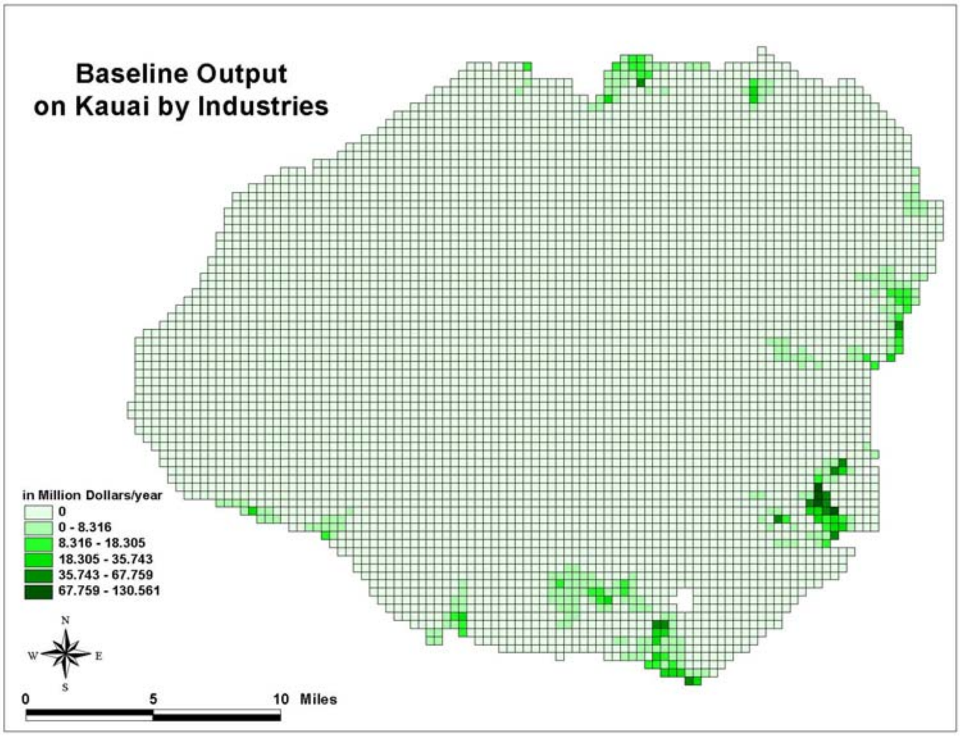


Figure 33. Baseline Population Distribution on Kauai by 0.1 sq-mile Grids

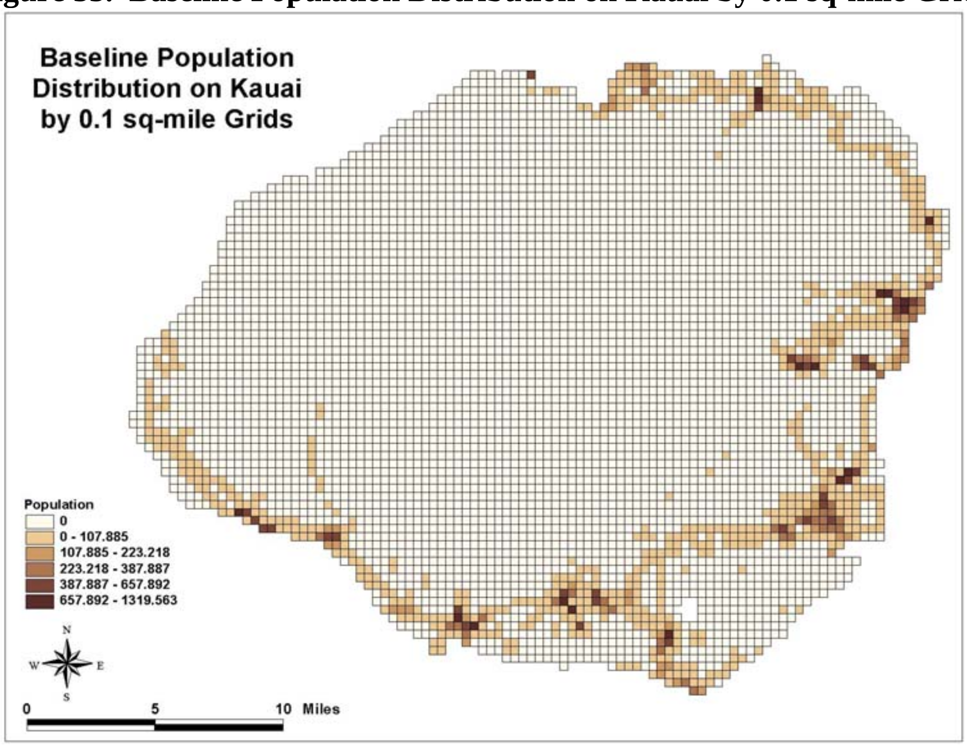


Figure 34. Bird Habitat

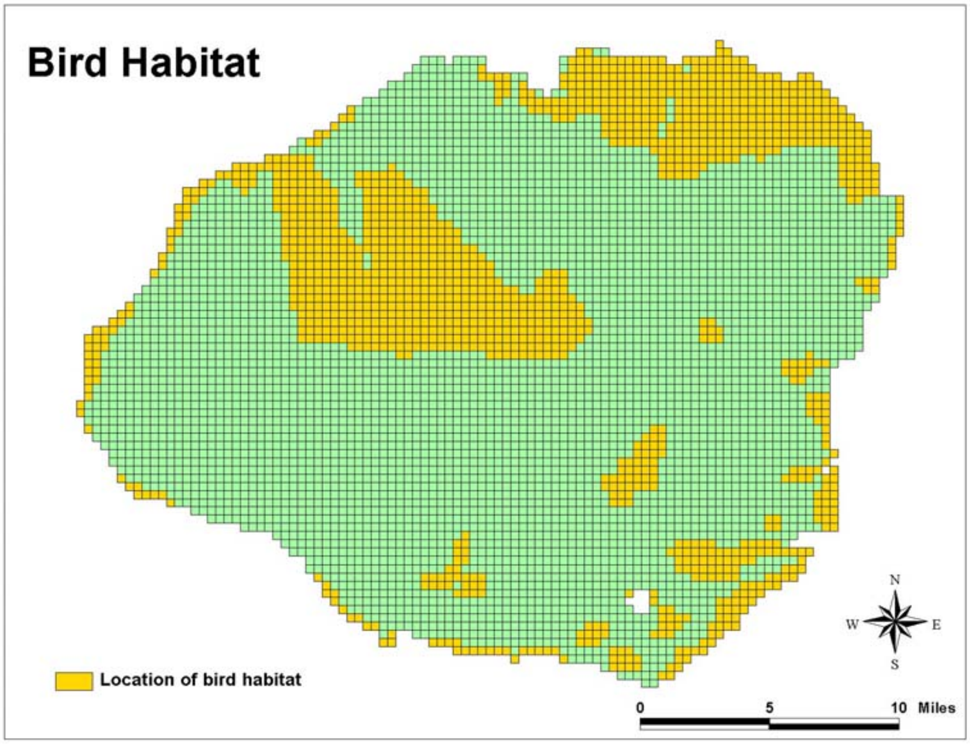


Figure 35. Threatened and Endangered Plant Concentration

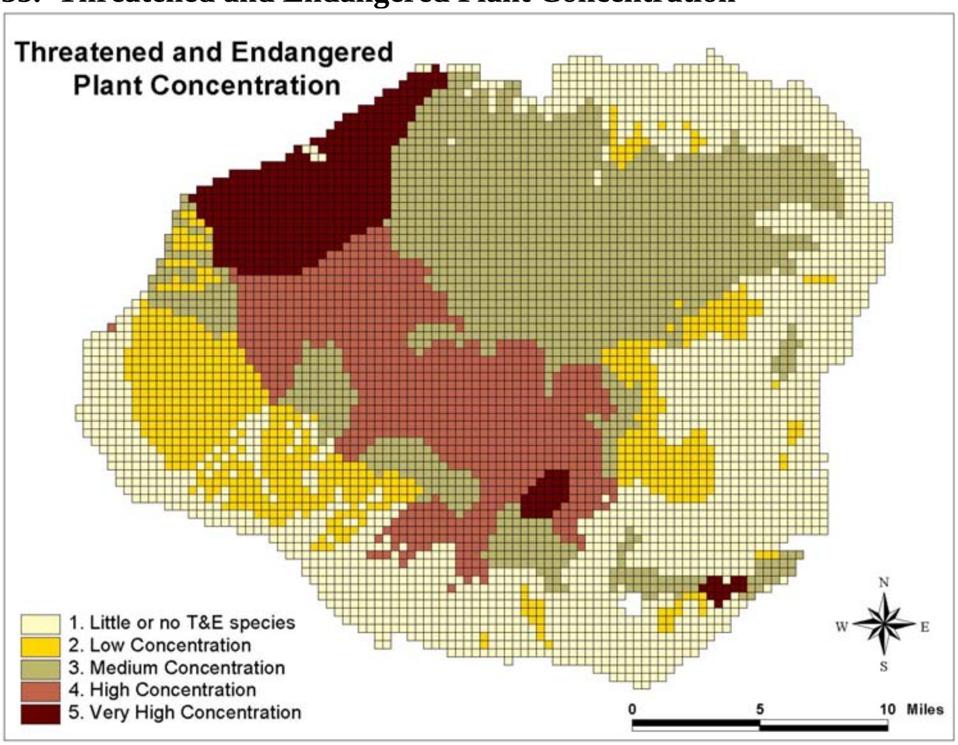


Figure 36. Baseline Water Consumption on Kauai by Industries, Visitors, and Residents

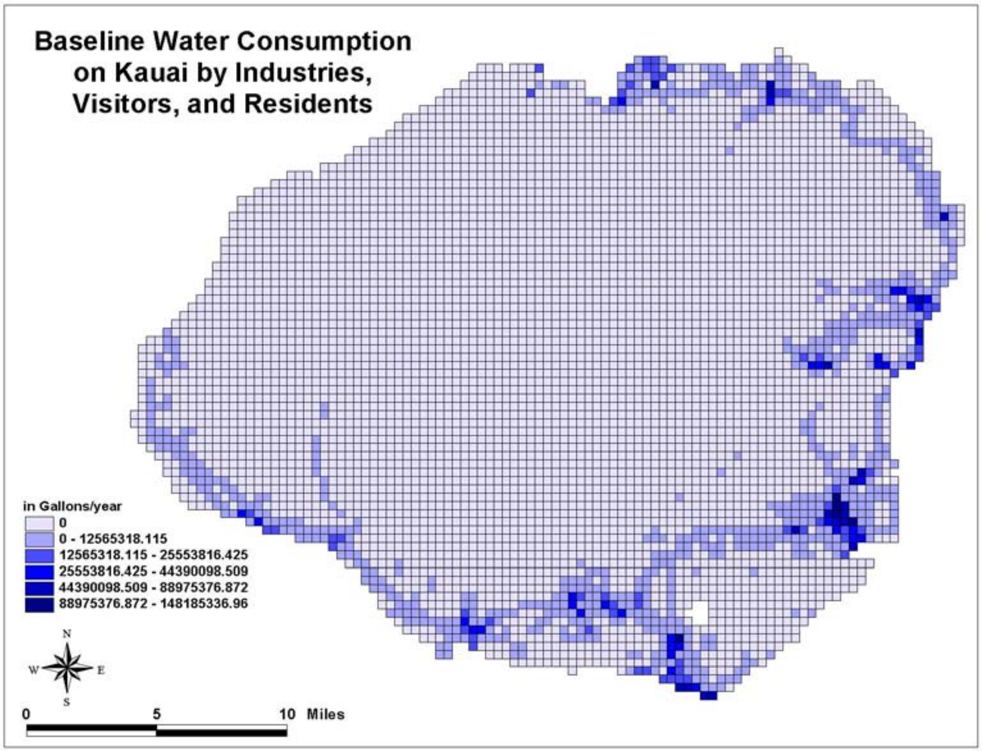


Figure 37. Baseline Electricity Consumption on Kauai by Industries, Visitors, and Residents

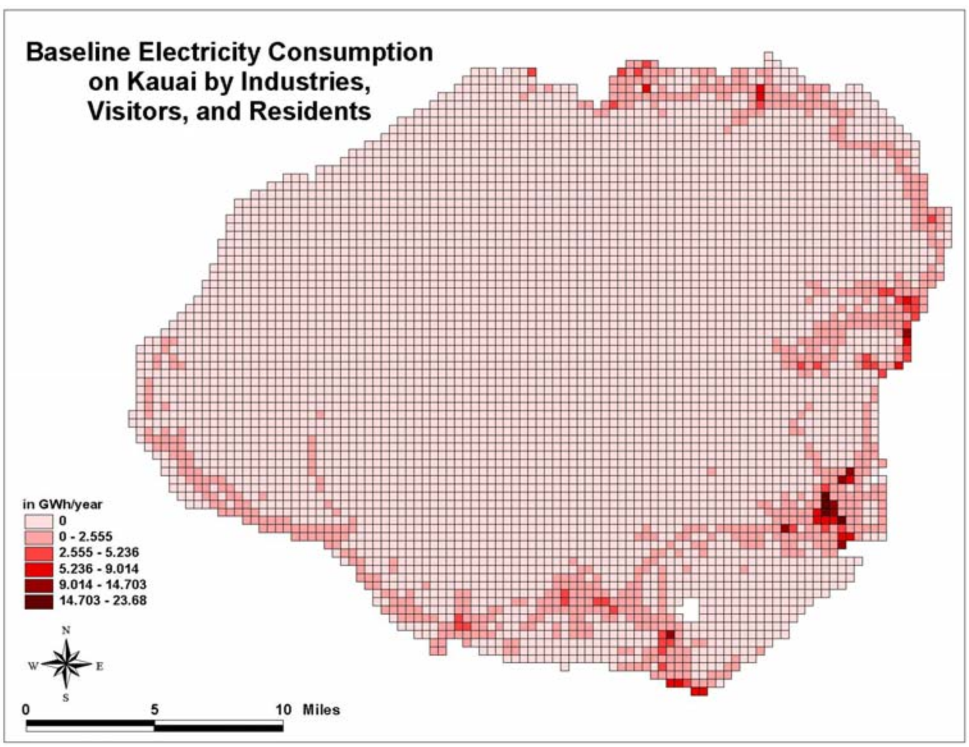


Figure 38. Baseline Solid Waste Generation on Kauai by Industries, Visitors, and Residents

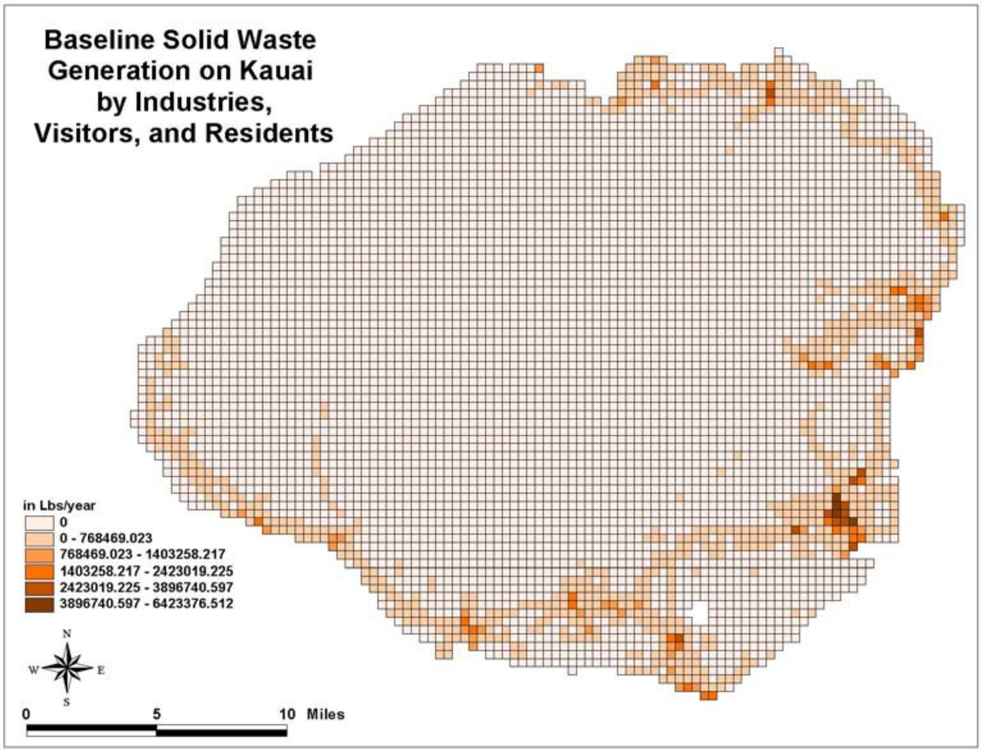


Figure 39. Employment Change on Kauai Based on 25% Decrease in Visitor Expenditure

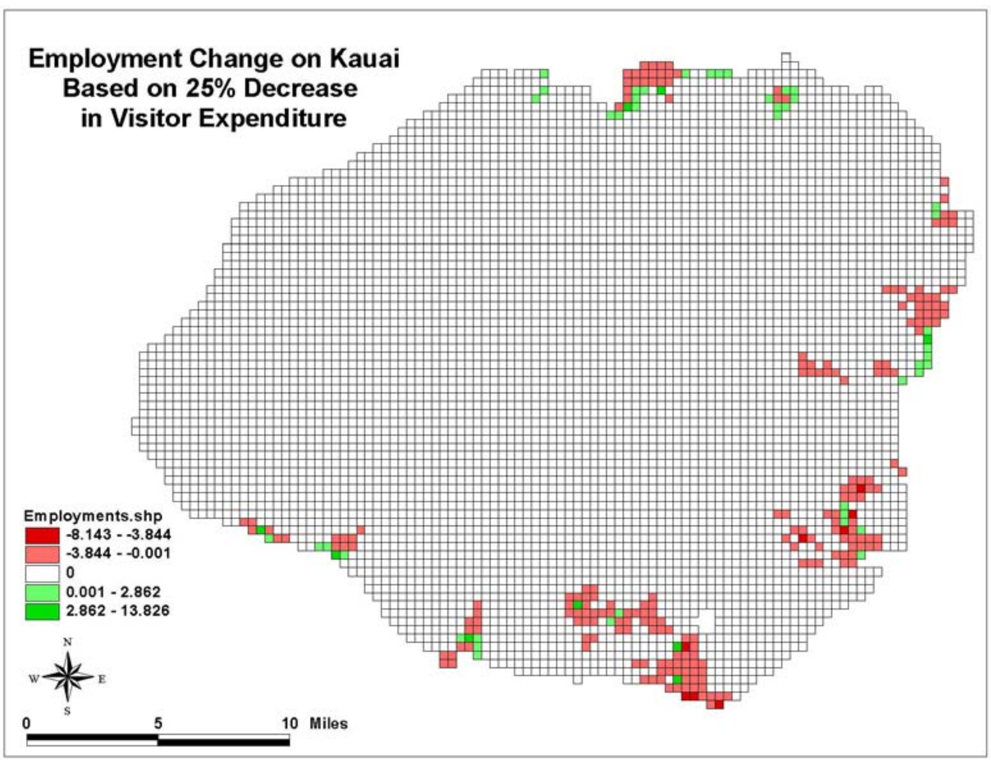
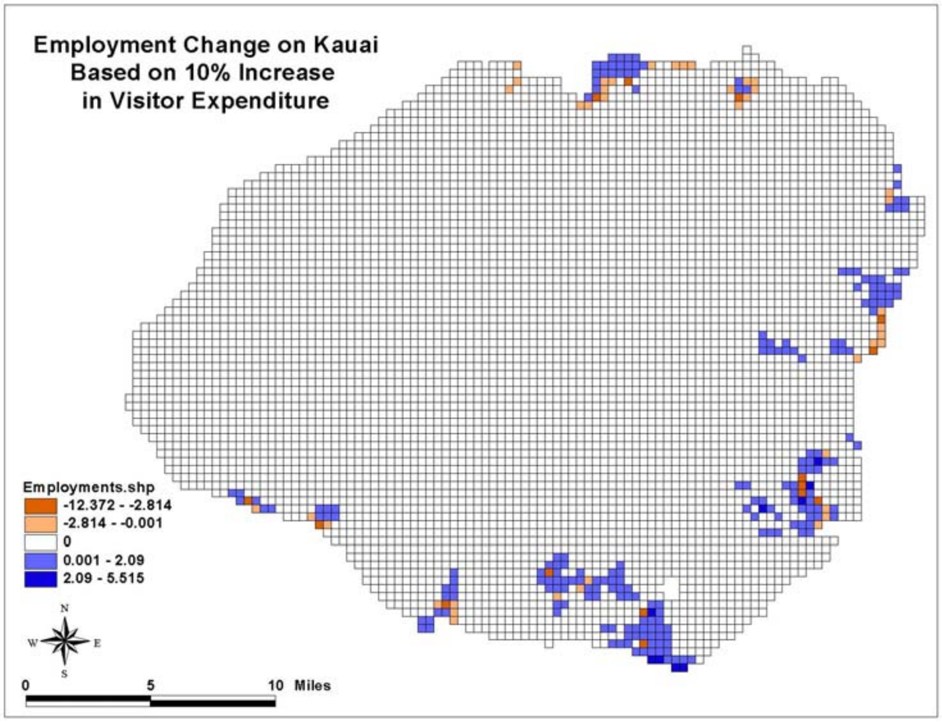


Figure 40. Employment Change on Kauai Based on 10% Increase in Visitor Expenditure



Department of Business, Economic Development & Tourism
P.O. Box 2359
Honolulu, Hawaii 96804
Street Address: 250 South Hotel Street

www2.hawaii.gov/dbedt