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Analysis of Farm Household Preferences in the Management of Invasive Species: The Case of *Miconia* in Hawaii

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Abstract

A major threat to Hawaii's ecosystem is the spread of invasive plant species. One such species is *Miconia calvescens*. Given that this plant was originally introduced to Hawaii by the horticulture industry and has negative effects on agricultural productivity, it is logical to find the farm households' preference for the control of *Miconia*. Using Conjoint Choice Experiment methodology, this study designed a survey to measure farm households' preferences for *Miconia calvescens* control program attributes. Results of the surveys indicate that the farm households are willing to support *Miconia* control programs if they prevent severe soil erosion and loss of biodiversity.

Keywords: *Miconia*, invasive species, Hawaii, farmers, Conjoint Choice Experiment, valuation

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Introduction

As the most isolated oceanic island in the world, Hawaii is naturally vulnerable to biological invasions of non-indigenous species. Due to the isolation, a unique balance has evolved that can easily be disturbed by the introduction of a non-native species. Non-native species can be introduced to Hawaii in two ways, accidental and deliberate. One deliberate introduction of new species to Hawaii is for horticultural purposes. This particular type of introduction accounts for approximately 70% of all documented invasive plant species in Hawaii (DLNR, 2007). The nature of the Hawaii floriculture and nursery industry is such that they are dependent on bringing in and cultivating new plants that are not found in Hawaii. Currently, the floriculture and nursery industry have one of the highest value of agricultural sales, contributing about $100 million to the Hawaiian economy in 2005 which is 20 percent of the revenues of the Hawaii agricultural industry (NASS, 2007). A plant that was introduced to Hawaii by the floriculture and nursery industry is *Miconia calvescens* also known as *Miconia*. *Miconia* was brought into Hawaii in the 1960s as an ornamental plant for its aesthetic value; it was continually cultivated in Hawaii and sold in garden centers and nurseries until 1992 when it was placed on the noxious weeds list of Hawaii (Loope, 1997). Currently, *Miconia* is on the list of the top ten invasive plants or animals of Hawaii. From its initial introduction to the islands as an ornamental plant, *Miconia* through the spread of its seeds made its way from home gardens to surrounding forests. By the time this was discovered the plant had established itself in forests on four Hawaiian Islands namely, Hawaii, Kauai, Oahu and Maui. The tree has proven itself to be highly invasive in Tahiti, which has a very similar environment to that of Hawaii increasing the possibility that what is happening in Tahiti can happen in Hawaii. Studies done in Tahiti have shown that *Miconia* causes soil erosion leading to landslides and directly threatens native species, which can lead to biodiversity loss.

Miconia not only affect the biodiversity of Hawaii, but it is also a direct threat to the productivity of the agricultural and agro-forestry industries. *Miconia* threatens these industries because it causes soil erosion with possibility of landslides. The loss due to soil erosion not only affects the land and watersheds, it has a broad range of effects on an island state from the mountain to the sea. Onsite effects of soil erosion include low soil fertility and reduced agricultural productivity. Studies have shown that loss of topsoil due to soil erosion causes three times the reduction of nutrients and 1.5 to 5 times the reduction of organic matter than the soil that remains behind (Sustainable Table, 2001). In addition, soil erosion causes approximately 3 to 31% decreases in the yield depending on the type of crops (USDA, 2000). As erosion occurs it causes the soil to have a shallower rooting zone, lower available water, and loss of nutrients and organic matter. This leads to farmers having to farm the subsoil, which has poorer tilth and is harder for the plant roots to penetrate which in turn will affect the productivity of the soil. Offsite effects of soil erosion include the runoff from the watersheds. These additional run-offs from the watersheds end up in the streams and rivers (Loope, 1997). These streams and rivers are important to farmers as they depend on them for irrigating their crops. The irrigation ditches, which provide water to the farmers, obtain their water from a system of small streams in the areas where it is suitable for *Miconia* to grow. If the situation with *Miconia* worsens and major erosion occurs there is a possibility that the water in these streams will cease to flow. This will force the farmers to rely on state water supply to irrigate their crops, which will increase their costs considerably. Researchers have estimated that if *Miconia* were to take over the Koolau Mountain Range (one of Oahu's major source of water) it would cost the state between $4.6 billion and $8.5 billion because of the value of the lost recharge to aquifers (Kaiser and Roumasset, 2002).

Furthermore, with the ever-rising costs of energy prices, Hawaii cannot afford to import more inputs or food. As such, there is a need for Hawaii to be competitive to reduce imports and have greater food security. Most of the food Hawaii consumes is imported even though there are abundant arable lands due to the decline of the pineapple and sugar industries. One of the reasons for controlling invasive species is to maintain agricultural productivity and ensure the cost of production does not increase due to soil erosion. Unfortunately, there are not enough resources for complete eradication of all invasive species, despite the cataclysmic economic damages that are inevitable if their invasions are ignored. Current expenditures for control program are not sufficient enough for effective control as their strategy is mainly to destroy the plants. Furthermore, there are different impacts to farms based on the physical and hydrological profile of their locations. Therefore, recognizing the scarcity of resources for management, prioritization becomes an important decision for managers and with the limited resources, control programs have to be optimally designed to address the needs of the farmers. It boils down to a question of which and how many invasive species are chosen for stringent control and which are treated with less vigor. Since this problem will exist as long as there is a scarcity of resources, the best answer is to allocate sufficient resources to the projects where efforts will be answered with more positive results and public support.

Background Information of *Miconia*

Miconia is an invasive tree, which grows to approximately 15 meters tall. The particular species of *Miconia* found in Hawaii is native to Mexico, Guatemala, Belize and Costa Rica. It has tri-nerved leaves that are dark green on the top and purple on the bottom. Full-sized trees (>8 meters tall) can flower 2-3 times a year producing about 2-3 million seeds each time. Production of a large amount of seeds ensures the availability of seeds in the seed bank for re-sprouting when conditions are optimal. In addition, with the large amounts of seeds it sets a foundation for humans, birds and other animals to easily disperse the seeds (Loope, 1997).

Miconia thrives in tropical montane climate regimes. This makes it capable of establishing itself in areas that receive about 1,800-2,000 mm of rain per year. In Tahiti, which has a similar forest habitat to Hawaii, *Miconia* has taken over 65% of the island creating dense mono-specific stands over 25% of the island (Meyer, 1996). Moreover, in Tahiti, 70–100 native plant species, including 35–45 species endemic to French Polynesia, are directly threatened by invasion of *Miconia* into native forests (Medeiros et al, 1997).

Miconia is able to establish itself easily in Hawaii because of the invasive characteristics it has. These characteristics include rapid growth, early maturity, large quantities of fruits and seeds, effective seed dispersal and can reproduce by seed and vegetative growth. Once *Miconia* is established at a certain place it drastically changes the ecosystem and biodiversity of that environment. *Miconia* seeds in the soil seed bank will start to grow if overhead vegetation allows light to penetrate the forest floor. The plant will then continue to grow smothering native forest plants. In addition, *Miconia*'s dense foliage prevents the sunlight from reaching the forest floor causing the destruction of the forest ground cover. This in turns leads to soil erosion and since *Miconia* has a very shallow root system; it is not capable of holding the forest soil (Loope, 1997)

Objectives

The objective of this research is to evaluate the extent of farmers' preference for the control and management programs of *Miconia* so as to provide decision makers with the information to design more effective control programs. The analysis of farmers' preferences is crucial because the losses caused by *Miconia* have primary impact on the watershed, soil erosion and agricultural productivity which immediately affects the farmers. Specifically, this study examines what control program attributes are important to the farm households in Hawaii. This would be indicated by their choice on the different control programs presented to them using the Conjoint Choice Experiment (CCE) methodology. The beauty of CCE is it is able to describe the programs in terms of the program attributes. Then, the respondents would assess which attribute is more important. Based on the preferences of attributes it will be easier to design the programs of interventions. To accomplish this objective, the study performed several tasks, (1) develop a Conjoint Choice Experiment survey, (2) collect primary data from farm households from the four counties in Hawaii (3) analyze the data collected, and (4) interpret the results and make conclusions.

Method

In this study, Conjoint Choice Experiment (CCE) was used to study the farm household's preference for different *Miconia* control program attributes. The following paragraphs summarize past studies using CCE and describe how the design of the CCE for this study took place.

Brief Introduction of Conjoint Choice Experiment (CCE)

The CCE technique was initially developed by Louviere and Woodworth (1983). As an empirical method, CCE originates in the market research and transportation literature (Hensher, 1994), and has only relatively recently been applied to other areas such as the environmental studies discipline. Since the mid-1990s, CCE has been increasingly applied to study various environmental problems. It has been used for valuating environmental amenities such as, recreational moose hunting in Canada (Boxall et. al, 1996, Adamowicz et. al., 1994), woodland caribou habitat enhancement in Canada (Adamowicz et al., 1996), preferences for deer stalking trips in Scotland (Bullock et al., 1998), and remnant vegetation in Queensland (Blamey et. al., 1999).

The CCE technique is based on the idea that any good or program can be described in terms of its attributes, or characteristics, and the levels that these attributes take. In this study's case, a control program for the invasive species *Miconia* can be described in terms of its adverse impacts and cost (which are called "attributes" in CCE context). The potential impacts of not having an effective invasive species control program include loss of biodiversity in terms of native species loss as defined in this study; soil erosion leading to possibility of landslides; and extent of spread which affects the aesthetic beauty of the natural and working landscapes. Using CCE can tell us which attributes are significant determinants of the values farmers' place on *Miconia* control program. This data collected also can be calculated to find out the extent of importance of each attributes given by the farmers.

Reasons for Choosing Conjoint Choice Experiment (CCE)

The study through a survey of farm households in Hawaii in the four counties used a stated preference method to elicit willingness to support *Miconia* control program. A stated preference method is one where the respondent is asked their preference for a good/service or willingness to pay for an environmental asset such as clean air within the context of a hypothetical market. There are generally three types of stated preference methods, 1) Conjoint Analysis, 2) Conjoint Choice Experiment and 3) Contingent Valuation. After extensive literature review on the three types of stated preference methods, Conjoint Choice Experiment was chosen as its advantages far outweighed its disadvantages.

A relatively new concept in environmental valuation, Conjoint Choice Experiment is an evolved form of the more traditional conjoint analysis introduced in the 1980's. It has been used for valuating environmental amenities (Adamowicz et. al., 1994), preferences for different forest landscapes in the UK (Hanley et. al., 2001). While the traditional conjoint analysis presents all the product/program profile choices to respondents at one time, in choice-based conjoint models, respondents typically see a set of two or three profiles at a time which are constructed by varying two or more attribute levels. It then asks the respondent to pick the profile that they would most prefer from that set.

The advantages of using CCE far outweighed the disadvantages after reviewing the literature on the subject. There are two main disadvantages of the method with the first being that the respondents have to repeat similar tasks of choosing between each pair. After the first few repetitions of the task the respondent will "catch on" to what the researchers are trying to do and potentially can give biased answers. The researchers ensured that the problem with respondents "catching on" and giving biased answers was minimized by giving them a fewer number of choice sets to select from which in our study are 12, such that by the time the respondents "catch on" to what is being done the survey will be over. The second disadvantage is that there is no incentive to the respondents to provide accurate responses. Since *Miconia* is a serious and known problem in Hawaii, respondents will be likely to provide accurate responses even with minimal incentives.

The advantages of using CCE show the attractiveness of this particular method. The advantages of this method are: (1) the researchers are able to present program choices with different attribute levels allowing the respondents to answer questions about a sample of events from a universe of possible events; (2) the researchers can also design sets of attributes with different levels which allow for the measurement of tradeoffs that the respondent make in choosing one attribute over another mimicking real world decision making. (3) the survey design is such that the researchers are able to estimate economic values of each attribute by including cost as one of the attributes; (4) the survey tends to be more to the point and shorter in length due to the use of discrete choice answers, reducing the possibility of fatigue and boredom that is often faced with a long list of program profiles to rate in traditional conjoint analysis surveys; and (5) the method allows the researchers to quantify the relative importance of each programs attributes based on the choices the respondents made.

Experimental Design of CCE for *Miconia*

A CCE is designed to allow respondents to choose the program profiles based on their preferences. Each program profile presented to the respondents consists of a combination of different levels of program attribute outcomes such as level of program cost or additional tax burden on the taxpayer, extent of biodiversity loss and soil erosion, and impact on the aesthetic beauty of the natural landscape through the spreading of *Miconia*. Table 1 shows the design stages of a CCE (Green and Wind, 1975, Cattin and Wittink, 1982, Halbrendt et al., 1991).

Table 1: Design Stages for a Conjoint Choice Experiment

Stage	Description
1.Selection of attributes	Selection of relevant attributes of the *Miconia* control program. This is done through expert interviews and literature review. The interviews help to identify the possible environmental impacts (attribute outcomes) associated with the program, as well as the monetary cost of the program.
2.Assignment of attribute levels	After identifying the attributes, the range of each attribute is determined through literature review and expert interviews. The levels should be realistic and span the range over which we expect respondents to have preferences, and/or practically-achievable levels.
3.Choice of experimental design	Statistical design theory is used to combine the levels of the attributes into a number of alternative program profiles to be presented to respondents. Depending on how many choice sets and/or profiles are included in the experiment, one can have either complete or fractional factorial designs. In our case, we have a fractional factorial design to reduce the number of possible combinations of program profiles while allowing for efficient estimation of the effects of the individual attributes ('main effects').
4.Construction of choice sets	The profiles identified by the experimental design are then paired and grouped into choice sets to be presented to respondents.
5.Measurement of preferences	Choice of survey procedure either with face-to-face interviews or mail surveying and survey administration will take place.

The first stage of CCE design involves identifying the relevant attributes of the invasive species control programs. Studies (e.g. Travisi and Nijkam, 2004) have shown that attributes such as program costs, loss of biodiversity, productivity loss, soil and water pollution, effectiveness of control and human health are important factors in invasive species control. However, there is not any study on attributes that are specifically for a *Miconia* control program. In order to come up with the important attributes and their levels on *Miconia* control program, literature reviews heavily based on Tahiti where, *Miconia* is a major problem were conducted. Additionally a panel of *Miconia* experts was formed to solicit information on important control program attributes and information. The experts included scientists, local experts and policy and decision makers, who through their various perspectives helped identified relevant cost and program outcome attributes. Then for each attribute, the range of potential values or level of damage avoidance was identified based on scientific and economic feasibility. This assessment of possible attribute range is used in the second design stage of assigning the levels of each attribute. The four most important attributes selected for the study are (1) cost in terms of additional tax dollars, (2) soil erosion leading to landslides, (3) spread, and (4) loss of biodiversity in terms of native species loss.

Rationale for Choosing the Program Attributes and their Levels

Four attributes are identified as the most important for any *Miconia* control programs. There are three levels for each attribute. The rationale for choosing these attributes is as follows:

Cost

Obviously, program cost in terms of additional tax dollars is included as an attribute of any publicly funded control program. The range of $3-$7 annually per taxpayer is estimated based on expenditure information from Hawaii's Invasive Species Committees' management reports and personal interviews with the staff of the various Invasive Species Committees (Kaiser, 2006, Smith, 2006, Lee, 2006). The levels for program costs assigned for this study are $3, $5, and $7.

Spread

Miconia's characteristics of having rapid growth, producing large amount of seeds, and the dispersion of seeds by birds and other vectors enable it to spread rapidly (Chimera et al., 2000). Meyer and Florence (1996) state that since the introduction of *Miconia* to Tahiti in 1937, over 65% of the island (1,045km^2) has been dominated by *Miconia* in the late 1980s. Thus, preventing and controlling the spread of *Miconia* should be one of the major concerns in Hawaii. In this study, low spread, medium spread, and high spread have been identified as the levels of spread that cover the range of possibility of effectiveness of any control program.

Loss of Biodiversity

Hawaii is reputed by her unique biodiversity, but it is vulnerable to biological invasions of non-indigenous species being an island. In Tahiti, where the climate and ecosystem is very similar as Hawaii, 70-100 native plant species are directly endangered by *Miconia* (Meyer and Florence, 1996). In Society Islands, botanists believe that invasion of *Miconia* causes 60% of the endemic flora to be endangered (Florence, 1996). Using Tahiti case as the reference, the levels of biodiversity loss are 10, 45 and 100 native species loss.

Soil Erosion

Native species forests are being gradually replaced by *Miconia* due to its strong ability of having shade effects on native species growth. The root system of *Miconia* is too shallow to hold the soil. Soil erosion caused by the spread of *Miconia* not only leads to a loss of habitat for native birds and species, but affects the functioning of the watersheds, as well as low soil fertility and reduced agricultural productivity. Moreover, soil erosion affects the run-offs from the watershed which are important irrigation sources to Hawaii farmers. Low soil erosion (no landslides), medium soil erosion (with possibility of landslides), and high soil erosion (severe landslides) are the three levels of soil erosion in the study. Table 2 shows the control program attributes and their levels.

Table 2: *Miconia* Control Program Attributes and Their Levels

Attributes	Levels		
Cost	$3 per year	$5 per year	$7 per year
Spread	Low	Medium	High
Loss of biodiversity	10 native species lost	45 native species lost	100 native species lost
Soil erosion	Low with no landslides	Medium with possibility of landslides	High level with severe landslides

The third and fourth stages of designing the CCE involve choosing and grouping different combinations of attributes and levels to be presented to survey respondents. CCE control program profiles are constructed by selecting one level from each attribute and combining across attributes. In this study, there are four attributes with three levels each, such that the number of possible profiles totaled 3 x 3 x 3 x 3 or 81. A complete factorial design would use all the 81 profiles for the surveying, which is undesirably difficult for respondents to evaluate and make decision from. So instead a fractional factorial design is proposed. A fractional factorial design is a sample of attribute levels selected from a full factorial design without losing information to effectively test the effects of the attributes on respondent's preference. The most commonly used method of constructing fractional factorial design in conjoint measurement is the orthogonal array. Orthogonal arrays build on the Graeco-Latin squares by developing highly fractionated designs in which the scenario profiles are selected so that the independent contributions of all main effects are balanced, assuming negligible interactions (Green and Wind, 1975). Orthogonal array designs are used because they have many desirable properties. First, they allow one to gather data from a large number of profile scenarios using a relatively small number of profile scenarios. Second, from a statistical perspective, orthogonal designs are most efficient. This study constructed 24 different profiles out of 81 based on degrees of freedom requirements to estimate all of the main effects within the orthogonal design (Louviere et. al., 2000). From the constructed 24 profiles, 24 pairs of profiles were randomly assigned and were grouped into 2 sets of 12 pairs. Having only 12 pairs for each respondent to evaluate from ensure the surveying exercise is short and manageable. At the final stage, the experiment is carried out. Each respondent is presented with one choice set of 12 pairs of profiles to make their choices from. The experiment requires respondents to choose one program profile from each pair presented to them. Table 3 shows an example of a pair of program profile scenarios for respondents to choose from.

Table 3: Example of a Pair of Program Profile Scenarios

Attributes	Program A	Program B
Cost	$5 per year	$7 per year
Spread	High	Low
Loss of biodiversity	45 native species	10 native species
Soil erosion	Medium with possibility of landslides	Low with no landslides

Data Collection

Survey Location

Data were collected from four counties of Hawaii (Oahu, Hawaii, Maui and Kauai). Within the four counties, surveys were conducted in both urban and rural areas. A total of 10 locations, including five farmer's markets, one state fair, and four farmer's markets inside shopping centers were chosen for conducting the surveys. Six out of the ten survey locations are in the urban areas, and the rest are in the rural areas.

Sample Population

Respondents from farm households were surveyed from May 16 to August 6, 2006. To ensure having a representative sample, the size of the population sample was determined using sample size calculator (Creative Research Systems, 2003). Accordingly, the minimum sample size needed for statistical analysis at 5% error margin is 96. This study completed 107 surveys. Fourteen percent of the respondents were from Oahu, 32% from Hawaii County, 25% from Maui, and the remaining 29% from Kauai. The percentage of the respondents from Oahu County is lower because it is a big urban center with about 80% of Hawaii population living in this county. Also Oahu has larger and fewer farms. Hawaii County has a higher percentage of surveys completed because the majority of farms are located there. Table 4 shows the socio-demographic profile of the respondents and where Census data is available compared them to the Hawaiian farm population. The population of male farmers of Hawaii is 80% over 20% female farmers whereas in the study about 46 % respondents were female versus 54 % male. The gender distribution of the respondents does not match the demographic characteristics of Hawaii farmers because the sample population was selected from adult members of farm households instead of only farmers. The average age of the respondents is somewhat similar with the average age of Hawaii farmers. Forty-four percent of the respondents have annual household income ranges from $10,000-$50,000. In comparison to other income categories, the percentage of respondents making more than $100,000 or less than $10,000 annual household income is much lower than the other income categories (16.7 % and 12.5% respectively). Majority of the respondents (56%) have high school or some college education.

Table 4: Socio-demographic Profile of Survey Respondents

	Descriptions	Hawaii Farmers * (%)	Survey Respondents (%)
Gender	Female	20.0	45.8
	Male	80.0	54.2
Average Age		56.5	49.0
Income	<$10k		12.5
	$10K to $50K		43.8
	$50K to $100K		27.0
	> $100K		16.7
Education	High School and less		28.8
	Some college		27.0
	College graduate and above		44.2

* NASS. 2002. *Census of Agriculture Hawaii State and County Profile*

Survey Instrument

The questionnaire consisted of two sections. Section one is the set of 12 pairs of program profiles for respondents to choose from. Section two consists of questions regarding the socio-demographic and economic background of the respondents such as age, income, education and other characteristics. Section one data provides the attribute-specific preferences. The data is analyzed using conditional logit regression model software developed by Sawtooth Software, Inc.

Survey Technique

Data were collected using a face-to-face survey technique. In our experiment, some attributes require relatively large amount of verbal and visual explanations. For example, the aesthetic value people attach to the landscape change due to the extent of the spread is better elicited with the aid of photographs. While conducting the survey, the interviewers showed pictures of the *Miconia* plant, landscape covered with *Miconia*, and landslides due to *Miconia.* Compared to other forms of survey technique, using face-to-face technique, the interviewer can motivate the respondent to keep going if her/his interest flags, thus, a face-to-face survey technique avoids the problem of self-selection bias. Brief description of *Miconia* and its potential impacts were read to every respondent regardless of their knowledge of *Miconia* to establish a minimal level of knowledge of *Miconia* prior to completing the survey. Then each respondent was given 12 pairs of programs profiles with differing levels of attributes and asked to choose one from each pair. The response rate of the survey is 70%.

Analysis of CCE Data

CCE is closely linked with random utility theory. Random utility theory derives from Luce (1959) and McFadden (1973), and is based around an alternative theory of choice that is used to derive conventional demand curves. Suppose that we can represent a person's preferences by the following utility function, U:

$$U = U(X_1 \ldots Xm; Z_1 \ldots Zn) \qquad (1)$$

where, utility for this individual depends on the levels of X_a , where a $\in\{1,\ldots m\}$, marketed goods and services consumed, and on Z_b, where b $\in\{1,\ldots n\}$, environmental goods. Now it may well be that some X_a and Z_b are unobservable to the researcher, or are observable only with an error. One way of representing this situation is to break down the conventional utility function U (.) into two parts: one deterministic and observable, V (.), and an error part, e (.). This means we can re-write equation (2) as:

$$U = U(X_1 \ldots Xm; Z_1 \ldots Zn) = V(\mathbf{X}) + e(\mathbf{X}, \mathbf{Z}) \qquad (2)$$

where, the bold letters represent vectors. This is the simplest representation of what lies behind random utility theory.

In choosing the most preferable programs in the choice set, the respondent is assumed to compare the maximum utility s/he could get with the pair of programs such as the example shown in Table 3, and then select the program that gives her/him the highest utility.

Given that there is an error part of the utility function, the analysis becomes one of probabilistic choice. The probability that any particular respondent (call them person *k*) prefers program *A* in the choices to any alternative program *B*, can be expressed as the probability that the utility associated with option *A* exceeds that associated with all other options, as stated in equation (3):

$$P[(V_{kA}+e_{kA})>(V_{kB}+e_{kB})]=P[(V_{kA}+V_{kB})>(e_{kB}-e_{kA})] \qquad (3)$$

where, P(.) is the probability function.

This says that respondent k will choose program A over program B if the difference in the deterministic parts of their utilities exceeds the difference in the error parts.

In order to derive an explicit expression for this probability, it is necessary to know the distribution of the error terms (e). A typical assumption is that they are independently and identically distributed with an extreme-value (Gumbel) distribution. The Gumbel is similar to the normal distribution in shape, but the mathematics associated with it is much more tractable. Its distribution is given by:

$$P(e \le t) = F(t) = \exp(-\exp(-t)) \qquad (4)$$

The above distribution of the error term implies that the probability of a particular program A being chosen can be expressed in terms of the logistic distribution (McFadden, 1973). This specification is known as the conditional logit model:

$$P(U_{kA}>U_{kB})=\frac{\exp(V_{kA})}{\sum_{j}\exp(V_{kj})} \qquad (5)$$

where, j is all the program options.

This study will use the conditional logit model to estimate the attribute parameters and we use the conventional maximum likelihood procedures with the respective log-likelihood functions stated in equation (6) below, where y_{kj} is an indicator variable which takes an unity value if respondent k chose option j and zero otherwise.

$$\log L=\sum_{k=1}\sum_{j=1}y_{kj}\log\left[\frac{\exp(V_{kj})}{\sum_{j=1}\exp(V_{kj})}\right] \qquad (6)$$

The empirical model is usually specified as being linear-in-parameters. If X is a vector of independent variables upon which utility is assumed to depend, and if β is a vector of parameters, this gives:

$$P(chooseA) = \frac{\exp(\beta' X_{kA})}{\sum_j \exp(\beta' X_{kj})} \quad (7)$$

The estimated coefficients can be used to derive the relative importance or preference of the respondents toward each attribute.

Results

Conjoint Model Specification and Estimation

The conjoint preference model specified in equation 8 is used to estimate the importance of *Miconia* control program attributes from respondents' stated preferences through their choice of programs. Conjoint Choice Experiment assumes that each respondent makes one's choices to maximize utilities, which can be measured by their choice preference probability (P). This study assumes P is a function of program cost (C = \$3, 5, 7), extent of spread (S_L-Low, S_M-Medium and S_H-High), loss of biodiversity (B = 10, 45, 100 native species lost), and extent of soil erosion (E_L-Low, E_M-Medium, E_H- High). The model is specified in equation 8 below:

$$P(A) = f(C, S, B, E) \quad (8)$$

where:

P (A) = Probability of choosing program A. Each program is represented by a combination of values taken in attributes of C, S, B, and E
C = Cost, taking values of \$3, \$5, or \$7
S = S_L-Low Spread, S_M-Medium Spread, or S_H-High Spread,
B = Biodiversity Loss in terms of native species, taking values of 10, 45 or 100,
E = E_L-Low Soil Erosion with no landslides,
E_M-Medium Soil Erosion with possible landslides,
or E_H-High Soil Erosion with severe landslides.

Qualitative attributes generally are presented by 'part-worth' or dummy variable specification in marketing studies (Halbrendt et al. 1995). In this case, the attributes that are qualitative (Spread and Soil Erosion), the study used effects-coding specification rather than dummy variable specification so as to better explain the attribute levels' influence on the probability of choosing a particular program. Cost and biodiversity attributes are treated as continuous variables.

Results of the model parameters estimated by logit regression using the Sawtooth Inc. software are reported in Table 5. The Chi-Square value (257.92) shows that the estimated model goodness of fit is significant. Estimated parameter for control program cost is not significant indicating the program costs which ranged from $3 to $7 per year are not a major determining factor in the choice of a particular *Miconia* control program. For the spread parameters, the signs of the parameters are as expected and significant at the 0.05, and 0.01 levels for medium and high spread, respectively. The signs of the low and medium spread variables came out to be positive as expected. Such positive signs can be interpreted that particularly for medium spreads being significant contribute to choice of control programs at those attribute levels. On the other hand, the significant and negative sign for the high spread variable indicates that farmers will be less likely to choose a program that does not mitigate the high level of spread. For the biodiversity parameter, biodiversity loss in terms of native species lost is significant at the 0.01 level and has the expected sign. The significant and negative sign for the biodiversity loss variable indicates that farmers will be less likely to choose programs with increasing native species loss. Finally, the estimated parameters for soil erosion have the expected signs and are significant at the 0.01 and .001 levels for low and high soil erosion, respectively. The significant and positive sign for the low soil erosion variable shows that farmers are more likely to choose control program that result in low soil erosion with no landslides. On the other hand, the significant and negative sign for the high soil erosion variable shows that farmers definitively will be less likely to accept programs that have high soil erosion with possibility of severe landslide. An analysis of interaction between soil erosion and biodiversity, soil erosion and spread, biodiversity loss and spread, and biodiversity loss and soil erosion variables was also conducted. Results indicated that interaction between these attributes was not significant.

Table 5: Conjoint Model Estimated Parameters

Variables	ß Estimate	t Ratio
C	0.105	1.71
S_L	0.201	1.76
S_M	0.124	2.14*
S_H	-0.325	-2.80**
B	-0.008	-3.65**
E_L	0.354	2.98**
E_M	0.042	0.06
E_H	-0.397	-3.90***
Obs.=107		
Chi Sq. = 257.92		

*Significant at the 0.05 level
**Significant at the 0.01 level
***Significant at the 0.001 level

Relative Importance (RI) of Miconia Control Program Attributes

Program managers and decision makers have an interest to know which features of their control program are more important to farmers who might be affected by *Miconia*. Calculating the relative importance (RI) of different program attributes is a way to examine the farmer's preference. In this case, the RI of the four program attributes, cost, spread, biodiversity loss, and soil erosion, are examined. The formula for estimating the RI is detailed in the article by Halbrendt, Wang, Fraiz and O'Dierno (1995). Denote i as an attribute, and the relative importance of attribute (RI_i) is measured by the ratio of the range of utility change estimates of different levels of the attribute i (UR_i) over the sum of such ranges for all attributes of the product $\Sigma\ UR_i$:

$$RI_i = 100 \times \frac{UR_i}{\sum_{j=1}^{n} UR_j} \qquad (9)$$

where, RI_i is the relative importance of attribute *i*, UR_i is the utility range of attribute i.

The RI estimation results suggest that cost is least important in the respondent's choice of control programs (17.58%). The two equally important attributes to farmers are biodiversity loss (29.16%) and soil erosion (31.30%) followed by the extent of spread of *Miconia* (21.96%). Results show that farmers prefer control programs that emphasize more on protecting biodiversity loss and preventing soil erosion. According to previous studies, these two attributes, if realized have shown to have negative effects on environment and agricultural productivity. Based on this result, the researchers suggest that when designing program for the management of *Miconia* in Hawaii, decision makers and program managers need to place more weight on methods that control soil erosion followed by biodiversity loss. The results of the RIs of the control program attributes are presented in Table 6.

Table 6: Estimated Relative Importance (RI) of *Miconia* Control Program Attributes

Program Attributes	Relative Importance (Percent)
Cost	17.58
Spread	21.96
Biodiversity Loss	29.16
Soil Erosion	31.30

Most Preferred Control Program

Since budget priorities for each invasive species might change through time, it is important to know if there is a choice of economically feasible control programs what percent of the farmers will choose a particular program. This will help or guide the designing of the most desirable control program. In Table 7, four feasible control programs are presented. Of the four feasible programs within the price range of $0 to $7 per taxpayer, about 43% of the farmers preferred program 3 which is $5, medium spread, 45 native species lost and low soil erosion. Approximately 35% of the farmers chose program 4, 17% chose program 2 and hardly any acceptance of program 1 which is no cost and assuming no control measures taken. The results show that when there is a choice, farmers will choose a program with a lower cost which results in low soil erosion at the expense of some native species lost and some spread. Furthermore, the majority of the farmers do not accept doing nothing to control *Miconia*.

Table 7: Farmer's Preference for Hypothetical Control Programs

Control Program	Cost	Spread	Biodiversity Loss	Soil Erosion	Farmer Preference (Percent)
1	$0	High	100 species	High	4.98
2	$3	Medium	100 species	Medium	16.60
3	$5	Medium	45 species	Low	42.93
4	$7	Low	10 species	Low	35.49

Valuation of Program Attributes using Expenditure Equivalent Index (EEI)

Aside from the relative importance of program attributes, trade-offs between the attributes are examined. What is interesting to know is if the level of one control program attribute changes, then by how much would an average farmer be willing to pay to leave her/him indifferent between the before and after scenarios? For example, if biodiversity loss is changed from 10 species to 45 species, how much the farmer is willing and able to pay, keeping utility constant? Based on equation (10) and a set of assumptions of utility functions such as separability, Payson developed an expenditure-equivalent index (EEI) of quality change:

where, β_i is the estimated parameter for the ith attribute, dc_i is the change in the ith attribute level, γ is the estimated parameter for willingness to pay, and p is the base cost level.

$$EEI_j = 1 - \frac{\sum_{i=1}^{k} \beta_i dc_i}{\gamma\, p} \qquad (10)$$

EEI can be interpreted as the proportional change in willingness to pay with respect to the change in control program attribute level, which is necessary for the respondents to be indifferent with a reference or base control program profile.

Table 8: Estimated Expenditure Equivalent Index (EEI)

Cost	Spread	Biodiversity Loss	Soil Erosion	EEI
	High	0	High	2.09
	High	10	High	1.98
	High	45	High	1.60
$7	High	100	High	1.00
	Spread	**Biodiversity Loss**	**Soil Erosion**	**EEI**
	Low	100	High	1.72
	Medium	100	High	1.27
$7	High	100	High	1.00
	Spread	**Biodiversity Loss**	**Soil Erosion**	**EEI**
	High	100	Low	2.03
	High	100	Medium	1.60
$7	High	100	High	1.00

For the baseline control program profile, this study uses the profile with the possible lowest preference. For this study, the baseline profile of $7, high spread, 100 native species lost and high erosion is assumed to be the least preferred by the respondents. The EEI for the baseline profile is equal to one since the second term in equation (10) equals zero. To get an idea of farmers' willingness to pay for reducing biodiversity loss, erosion loss and spread using the stated baseline profile, the study uses equation (10) to estimate the EEIs for each of the program attributes while holding the remaining attributes and their levels constant. The results are presented in Table 8. The EEIs for biodiversity loss to avoid losing 100, 90, and 55 native species are 2.09, 1.98 and 1.60, respectively. In other words, farmers are willing to pay 2.09 times more than $7 which is equivalent to $14.63 so as not to lose 100 native species. Similarly, they are willing to pay 1.98 times more than $7 not to lose 90 species which is equivalent to $13.86 and 1.60 times more than $7 not to lose 55 species which is equivalent to $11.2. The EEI for spread to avoid medium and high spread of *Miconia* are 1.27 and 1.72 respectively. This implies that farmers are willing to pay 1.72 times more than $7 which is equal to $12.04 so as to avoid high spread. Similarly, they are willing to pay 1.27 times more than $7 which is about $8.89 to avoid medium spread. In addition, the EEI for soil erosion are 2.03 and 1.60 to avoid high and medium soil erosion respectively. The farmers are willing to pay about $14.21 and $11.20 for avoiding high and medium soil erosion. These monetary amounts are in addition to the current expenditure per capita on controlling *Miconia* as the survey asked the respondents to choose profiles with costs being stated as extra tax dollars.

Conclusion and Implications

This study sets out to examine what aspects of *Miconia* control program attributes that farmers would rate as important as stated by their choices of the different control programs using Conjoint Choice Experiment methodology. Results show that the cost of the control program (willing to pay the given range of costs) is not as important when compared with the rest of the program attributes. In terms of how respondents weigh in on the attributes' relative importance, two program outcome attributes stand out: soil erosion and loss of biodiversity. Together they added up to over 60% of the weights placed by respondents when choosing preferred control programs. This study sets a range of $3 to $7 for program cost of controlling *Miconia* after reviewing current expenditure information on *Miconia* in Hawaii. Obviously, from the farmers' stand point the range of the dollar amount used for this study alone has lesser significant influence on program choice.

More important attribute outcomes of significance to the farmers are preventing soil erosion and loss of native species. One can see why soil erosion causing landslides is particularly perceived as undesirable, as the Hawaiian Islands are made up of many mountains due to how the land mass was created with many farmers currently living or working on or near the mountains. It can also be interpreted that farmers are more concerned about the reduced soil fertility and low farm productivity caused by the soil erosion. Major crops grown near the slopes of the mountains in Hawaii are pineapple, coffee, avocado, banana, papaya, macadamia nut, ginger roots, taro, floriculture nursery, maize and sugarcane. These crops particularly would be impacted due to soil erosion caused by *Miconia.* Furthermore, these industries are primary contributors to the agricultural revenue of Hawaii which together contributed a substantial percentage of the total farm receipt of Hawaii (USDA, 2006). Studies have shown that soil erosion can reduce agricultural productivity by 3-31 percent in the U.S. depending on the location and crops. If *Miconia* is not controlled, one can deduce that there would be substantial economic loss due to soil erosion on the above mentioned crops in Hawaii.

Current management programs fall short of completely eradicating *Miconia* with the main management strategy of applying the chemical Garlon-4 and manually removing *Miconia*. There are some educational programs for enhancing public's awareness about the process of spread, its effect on biodiversity loss and soil erosion in addition to the existing chemical and manual control programs. The educational programs will help the general public to recognize *Miconia* as an invasive plant and would therefore encourage the public to destroy it from their surroundings. Previously, *Miconia* was introduced as an ornamental plant by the floricultural industry and now has evolved as an invasive species. Therefore, to prevent this from happening again, targeted programs for nursery growers for not introducing potential species which will turn into invasive species should be developed. Progress has been made to minimize deliberate introduction and propagation of potentially invasive plants in recent years. The University of Hawaii has developed a Hawaii Weed Risk Assessment (H-WRA) program whose purpose is to assess the invasive potential of plant species. Furthermore, the nursery industry itself realizing that there are adverse effects from introducing invasive species has taken the initiative to develop a code of conduct for a list of invasive plant species that nursery growers should not be propagating and selling. This is a very positive step in the right direction to minimize nurseries from unknowingly propagating and selling invasive plants.

Recent expenditure shows that the state of Hawaii spends about $1.7 million dollars on three of the most *Miconia* infested islands (Hawaii County: $465,000 for 50,000 ha, Oahu: $286,117 for 411 ha, and Maui: $954,000 for 12,500 ha) which is equivalent to about $2 per person for controlling *Miconia* (based on the size of the Hawaii population above 18 years old). This study shows that most farmers are willing to support control program expenditures higher than current expenditures of $2 per taxpayer. This suggests that government agencies should spend more funds to effectively control or eradicate *Miconia* in Hawaii. The plan might include more educational programs and possibly research program on finding a biological control of *Miconia*. The important implication of this study is providing decision makers the information that the farmers are willing to support spending for *Miconia* control programs if they are effective in preventing severe landslides and huge loss of native species.

References

Adamowicz, W., J.J Louviere, & M. Williams 1994. Combining Revealed and Stated Preference Methods for Valuing Environmental Amenities. *Journal of Environmental Economics and Management* 26:271-292.

Adamowicz, W., J. Swait , P. Boxall, J.J. Louviere, & M. Williams. 1996. Perceptions versus Objective Measurement of Environmental Valuation. *Journal of Environmental Economics and Management* 32:65-84.

Blamey, R., J. Bennett, J. Louviere, M. Morrison, & J. Rolfe. 1999. The Use of Policy Labels in Environmental Choice Modeling Studies. Canberra: University of New South Wales.

Boxall, Peter C., W. L. Adamowicz, J. Swait, M. Williams, & J. Louviere. 1996. A Comparison of Stated Preference Methods for Environmental Valuation. *Ecological Economics* 18:243-253.

Bullock, C.H., D.A. Elston, & N.A. Chalmers. 1998. An Application of Economic Choice Experiments to a Traditional Land Use: Deer Hunting and Landscape Change in the Scottish Highlands. *Journal of Environmental Management* 52 (4):335-351.

Cattin, P., & D.R. Wittink. 1982. Commercial Use of Conjoint Analysis. *Journal of Marketing* 46 (Summer):44-53.

Chan-Halbrendt, C.K., J. Yun, H. Keung, T. Lin, & C. Ferguson. 2006. Guangzhou Buyers Preference for Premium Hawaiian Grown Product Gift Baskets. *International Food and Agribusiness Management Review* 9 (4): 45-59.

Chimera, C.G, A.C. Medeiros, L.L. Loope, & R.H. Hobdy. 2000. Status of Management and Control Efforts for the Invasive Alien Tree *Miconia calvescens* DC. (Melastomataceae) in Hana, East Maui.

Creative Research Systems. 2006. *The Survey System: Sample Size Calculator.* 2003 [cited May 2006]. Available from http://www.surveysystem.com/sscalc.htm

DLNR. 2007. *How Do Most Invasive Species Arrive in Hawaii?* [cited March 26 2007]. Available from http://www.state.hi.us/dlnr/dofaw/hortweeds/#howdomostinvasivespeciesarrive.

Florence, J. 1996. Statut IUCN des Plants Vasculaires Endémiques de Polynésie Française et Recommendations de Protection. . Papeete: Délégation à l'Environment

Green, P.E., & Y. Wind. 1975. New Ways to Measure Consumers' Judgements. *Harvard Business Review* (July-August):89-108.

Halbrendt, C.K., F.F. Wirth, & G.F. Vaughn. 1991. Conjoint Analysis of the Mid-Atlantic Food-Fish Market for Farm Raised Hybrid Striped Bass. *Southern Journal of Agricultural Economics* 23:155-164.

Halbrendt, C.K., Q. Wang, C. Fraiz, L. O'Dierno. 1995. Marketing Problems and Opportunities in Mid-Atlantic Seafood Retailing. *American Journal of Agricultural Economics* 77 (5, Proceedings Issue (Dec):1313-1318.

Hanley, N., S. Mourato, & R.E. Wright. 2001. Choice Modelling Approaches: A Superior Alternative for Environmental Valuation? *Journal of Economic Surveys* 15 (3):435-462.

Hensher, D.A. 1994. Stated Preference Analysis of Travel Choices: the State of Practice. *Transportation* 21:107-133.

Kaiser, Brooke. 2006. Economic Impacts of Non-indigenous Species: *Miconia* and the Hawaiian Economy. *Euphytica* 148:135-150.

Kaiser, Brooke & J. Roumasset 2002. "Valuing Indirect Ecosystem Services: The Case of Tropical Watersheds." *Environment and Development Economics* 7(4): 701-714.

Lee, Donna. 2006. *Miconia* Costs. Email communications.

Loope, Lloyd. *HNIS Report for Miconia calvescens*. Hawaii Ecosystems at Risk 1997 [cited November 2, 2006. Available from http://www.hear.org/*Miconia*InHawaii/.

Louviere, J.J., & G.G. Woodworth 1983. Design and Analysis of Simulated Consumer Choice or Allocation Experiments: An Approach Based on Aggregated Data. *Journal of Marketing Research* 20:350-367.

Louviere, J.J., D.A. Hensher, & J.D. Swait. 2000. *State Choice Methods: Analysis and Application*: Cambridge University Press.

Luce, R. 1959. *Individual Choice Behavior*. New York: Wiley.

McFadden, D. 1973. Conditional Logit Analysis of Qualitative Choice Behavior. In *Frontiers in Econometrics*, edited by P. Zarembka: Academic Press.

Medeiros, A.C., L.L. Loope, P. Conant. 1997. Status, Ecology, and Management of the Invasive Plant, *Miconia calvescens* DC (Melastomataceae) in the Hawaiian Islands. *Bishop Museum Occasional Papers* 48:23-36.

Meyer, Jean Yves, J. Florence. 1996. Tahiti's Naive Flora Endangered by the Invasion of *Miconia calvescens* DC. *Journal of Biogeography* 23 (Nov., 1996):775-781.

NASS. 2007. *Statistics of Hawaii Agriculture* 2005 [cited March 22, 2007]. Available from http://www.nass.usda.gov/hi/stats/t_of_c.htm.

NASS. 2002. *Census of Agriculture Hawaii State and County Profile* [cited May 15, 2007] Available from http://www.nass.usda.gov/census/census02/profiles/hi/index.htm

Payson, Steven. 1994. *Quality measurement in economics : New Perspectives on the Evolution of Goods and Services*. Aldershot, England ; Brookfield, Vt.: Elgar.

Smith, Ryan. 2006. Historical Program Costs. Honolulu, October 12, 2006.

Stevens, T.H., P. Belkner, D. Dennis, D. Kittredge, C. Willis. 2000. Comparison of Contingent Valuation and Conjoint Analysis in Ecosystem Management. *Ecological Economics* 32:63-74.

Sustainable Table. 2007. *Sustainable Table 2001* [cited March 22 2007]. Available from http://www.sustainabletable.org/.

Travisi, C. M., & P. Nijkamp. 2004. "Willingness to Pay for Agricultural Environmental Safety." *Tinbergen Institute Discussion Papers.* No. 04-070/3.

US Census Bureau. 2007. *2005 American Community Survey* 2005 [cited February 17 2007]. Available from http://factfinder.census.gov/servlet/ADPTable?_bm=y&-geo_id=04000US15&-qr_name=ACS_2005_EST_G00_DP3&-gc_url=null&-ds_name=&-_lang=en&-redoLog=false

