4296

# STAKEHOLDERS' LATENT PREFERENCES FOR INVASIVE SPECIES CONTROL PROGRAMS: THE CASE OF CROFTON WEED (*Eupatorium adenophorum*) IN CHUXIONG, YUNNAN, CHINA

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By
Fang Yang

Thesis Committee:

Catherine Chan-Halbrendt, Chairperson
Greg Bruland
Tun Lin

4296

We certify that we have read this thesis and that, in our opinion, it is satisfactory in scope and quality as a thesis for the degree of Master of Science in Natural Resources and Environmental Management.

THESIS COMMITTEE

chair

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## ABSTRACT

Crofton Weed (*Eupatorium adenophorum*) is a severe threat to the environment and economy in China. Controlling Crofton Weed involves several challenges: fluctuating and insufficient funding, difficulty in evaluating environmental goods, and multiple stakeholders with different expectations. This study used conjoint choice experiment (CCE) and interviews to evaluate stakeholder preferences for control programs in Chuxiong, Yunnan, China. Latent class analysis (LCA) was used to examine how social background affects choice behavior. This study reveals that farmers and officials similarly evaluate programs based on all attributes while scientists concentrate on one or two location-specific attributes. Generally, government funding will be most effective with control programs supported by a majority of stakeholders. However, local implementation should modify programs based on socio-demographic data. This study shows that people are willing to pay more than current expenditures to protect environmental resources, and demonstrates that CCE and LCA can be used to evaluate preference differences between socio-demographic background groups.

## TABLE OF CONTENTS

## LIST OF TABLES

Table Page

## LIST OF FIGURES

# CHAPTER 1

# INTRODUCTION

Chapter 1 is divided into three sections. The first section provides general background information on invasive species, problems caused by Crofton Weed (*Eupatorium adenophorum*), current control methods of this weed, and the importance of evaluating stakeholders' preferences for control programs. The second section identifies the overall and specific objectives of this study. In the third section, the structure of this thesis is presented, along with a brief introduction to each chapter.

## 1.1 Background information

The globalization of economic systems has accelerated the spread of species from one part of the world to another through trade, transport, travel, and tourism. While not all non-native species become invasive, those that do, known as invasive species, have caused severe and costly damage. Invasive species are "species whose introduction, establishment and spread into new areas threaten ecosystem, habitats or other species and cause social, economic or environmental harm, or harm to human health" (FAO 2007). Globally, the spread of invasive species has emerged as one of the most serious environmental problems as well as a great threat to economic well being in recent decades (FAO 2007; Mooney and Hobbs 2000).

Although invasive species have gained much attention from scientists and policy makers, understanding the public's needs and stakeholders' preferences for invasive species control programs will provide insight into factors that are crucial for addressing invasive species management issues. The focus of this thesis is to investigate stakeholders' latent preferences[1] for invasive species control programs while using Crofton Weed (*Eupatorium adenophorum*) in Chuxiong, Yunnan, China as a case study. This case study adds an important component to the existing research on understanding stakeholders' values and concerns of Crofton Weed control programs. This component is necessary to ensure that control programs are accepted and supported by the public.

It is common knowledge that invasive species have caused great damages to environmental and social communities. Invasive species can be competitors, predators, pathogens and parasites. They have been found in almost every type of ecosystem and threaten hundreds of native species by changing species diversity, composition, and richness (IUCN 2000). Moreover, invasive species have degraded ecosystems by altering the fire regime, water balance, soil structure, and nutrient cycling (Mack et al. 2000). In effect, invasive species have caused biodiversity loss, vegetation structure alteration, habitat destruction, as well as reduced productivity in agriculture, forestry, fishery, and animal husbandry operations (FAO 2007). Invasive species have also brought severe problems to social welfare and human health. For example, the spread of viral disease in maize crops in the Americas caused damage to human nutrition and

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[1] In this case, latent preferences refer to respondents' preferences affected by their socio-demographic factors.

health in other countries in the 1990s (McMichael and Bouma 2000).

The economic costs of biological invasions are difficult to precisely calculate on a global scale given the fact that it is very challenging to assess biodiversity, ecosystem services, and other indirect values, such as impact of control methods and human diseases (FAO 2007). However, many countries estimate that overall losses as a result of invasive species are approximately one percent of their national GDP (McKenzie et al. 2003). Using a study conducted in six countries (Australia, Brazil, United Kingdom, India, New Zealand, South Africa, and The United States) as a reference, Pimentel et al., (2001) estimated that the worldwide annual economic losses are more than $1.4 trillion USD, including both damage and control costs caused by about 480,000 alien species of plants, animals, and microbes in agriculture and forestry.

Invasive species cause serious environmental problems in China. Qu and Li, (2007) have reported that more than half of the biological invasions listed in the IUCN's "100 of The World's Worst Invasive Alien Species" have been recorded in China, and the total number of invasive species in the entire country has exceeded 400 species. According to their estimation, 11 major invasive species cause at least 57.4 billion CNY[2] in economic losses annually in agriculture and forestry. These economic losses include ecosystem degradation, reduction of forestry and agricultural productivity, and diseases of human beings and livestock (Qu and Li 2007).

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[2] CNY: Chinese National Yuan. 1 USD = 7.3 CNY.

Crofton Weed (*Eupatorium adenophorum*), which is native to Mexico and Costa Rica, is one of the most threatening invasive species in China. It is believed that Crofton Weed was accidently spread from Myanmar into southern Yunnan Province by wind or rivers in the 1930s (Wu, Zhang, and Lu 1984). Since its discovery in 1935 in Yunnan Province, this weed has rapidly spread throughout southwest China (Yao, Zhang, and Liu 2003). In 2003, Crofton Weed was identified as one of the top 16 invasive species of China[3] (EPAC 2003).

Crofton Weed is a fast-growing and highly invasive weed. It invades various habitats, such as barren land, roadsides, riverbanks, farmlands, grasslands, forests, and abandoned plantations (Ma and Bai 2004; Yu, Yu, and Ma 2004; Zhou, Tang, and Zhang 2004). Crofton Weed competes with native species and absorbs enormous water and nutrition to support its rampant expansion (Ma and Bai 2004). In addition, this weed produces an allelopathic toxin that restrains other species growth, including crops, plants, and soil organisms (He and Liu 2003; Liu, Xu, and Ding 2006). As a result, Crofton Weed displaces native species and forms dense monotypic stands.

Crofton Weed not only affects the biodiversity and agriculture, but it is also a serious threat to livestock production. Pollen and the fine hair from the Crofton Weed seeds cause livestock to develop asthma. If the asthma is serious, it may lead to

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[3] The top 16 invasive species of China are : Crofton Weed, Mile-a-minute Weed, Alligator Weed, Ragweed, Darnel Rye-grass, Smooth Cord-grass, Fragrant Eupatorium, Water Hyacinth, Johnson Grass, Banana Moth, Lobdelly Pine Mealybug, Red Turpentine Beetle, Fall Webworm, Giant African Snail, Apple Snail, and Bull Frog.

livestock death (Sun, Lu, and Sang 2004).

There are many concerns about protecting the Yunnan Province from invasive species. This province is located in the south-western China and bordered with Vietnam, Laos, and Myanmar (Figure 1.1 shows the location of Yunnan Province). It is a mountainous province with many climate zones from tropical to temperate. Most land ecosystem types that can be found across of China, exist in the Yunnan Province (Yang, Wang, and Liu 1998).

The biodiversity in Yunnan Province is very abundant. More than 18,000 vascular plant species (51.6% of total species in China) and more than 1,830 vertebrate species (54.8% of total species in China) have been recorded in this province, but, among these species, 151 plant species (42.6% of total species in China) and 243 animal species (72.5% of total species in China) are endangered (Yang et al. 2004).

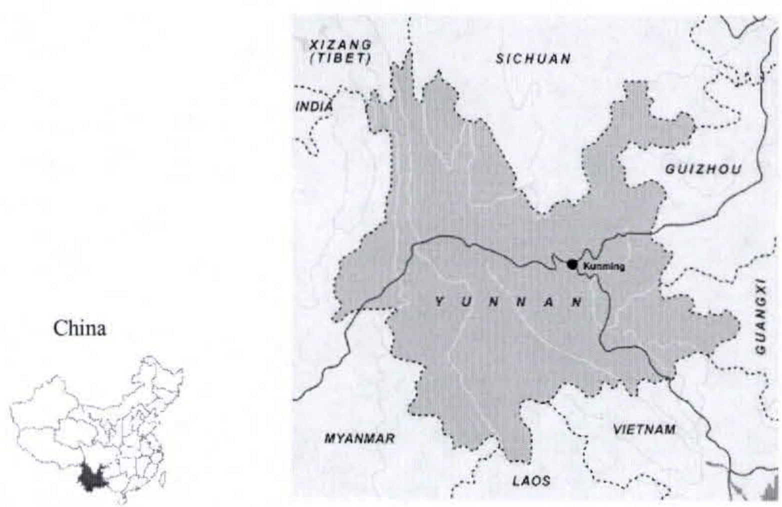


**Figure 1. 1**: Location of Yunnan Province, China

(Source: http://www.infohub.com/Maps/yunnan_map_2135.html)

Yunnan Province is vulnerable to invasive species because of the extensive topography, climate types, and ecosystems that provide a wide range of habitats for invasive species. Seven of the top 16 invasive species of China have been widely found in Yunnan Province (Zhang, Zhang, and Gao 2004). Moreover, the recent opening of frontier trades between Yunnan Province and other bordered countries (Vietnam, Laos, and Myanmar) accelerate the spread of invasive species (Liu 2004).

Invasive species are considered one of the most serious threats to biodiversity worldwide, second only to habitat destruction (FAO 2007). In Yunnan Province, invasive species are gradually destroying the environment and threatening native species. For instance, the infestation of water hyacinth[4], an aquatic invasive species, has dominated Dianchi Lake and has significantly decreased water quality. As a result, the number of native aquatic plants has been reduced from 16 to 3, and the number of aquatic animal species has declined from 68 to 30 (ISTIY 2000; Xu and Lu 2006).

Yunnan Province was the first place reported to be invaded by Crofton Weed. By the end of 1998, Crofton Weed had invaded in 10 prefectures, 24.7 million hectare (67% of the total area in Yunnan Province) (Yao, Zhang, and Liu 2003). Chen (2002) estimated that, in Yunnan Province, wherever Crofton Weed has invaded, annual crop productivity was reduced by more than 20%. It was also reported that 5,015 horses were seriously sick and 3,486 horses died due to asthma caused by Crofton Weed in Yunnan Province in 1979 (Liu 2004).

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[4] Water hyacinth (*Eichhornia crassipes*) is also identified as one of the 16 top invasive species of China.

The importance of controlling Crofton Weed is obvious when looked at from both a biological and economic perspective. Currently, the environmental and economic losses have gradually drawn attention of government agencies and scientific research institutes. During the 1990s, the Yunnan provincial government spent more than 800,000 CNY annually on Crofton Weed control (CCICED 2002). Manual removal and chemical control have been used as the main approaches to controlling Crofton Weed. In addition to the Yunnan's provincial expenditure, Feng (2007) estimated that the Chinese government has spent 8,000,000 CNY for basic research and 3,000,000 CNY for control programs for Crofton Weed.

However, there has been no annual consistent funding for Crofton Weed control in the last decade. Funding has been sporadic and provided on a project-by-project basis, which has become a major hurdle for complete eradicating Crofton Weed in China. Fluctuating and insufficient resources constrain the effectiveness of these control programs. Meanwhile, the weed still spreads at an average rate of 10-50 km per year (Wang and Qin 2004). Therefore, recognizing the scarcity of resources for management, and judging which attributes are considered the most important in an optimal control program becomes a crucial decision for managers.

Decision making processes involving environmental protection should be based on social choices since government environmental management programs are public goods (Kolstad 2005). In recent years, several studies have revealed that both expert and public valuation and concerns are necessary to be incorporated in the management alternatives of natural resources (Linkov et al. 2006; Stern and Fineberg

1996). In this study, therefore, evaluating stakeholders' preferences for Crofton Weed control programs is necessary for allocating optimal resources to projects in which public will support. Hopefully, these efforts will be answered with more positive results.

As the most vulnerable group to Crofton Weed invasion, farmers have been suffering direct and indirect negative impacts caused by Crofton Weed for many years. First, farmers' consumption and household income are mostly dependent on the productivity of food and livestock. Problems caused by Crofton Weed, such as reduction of crop yield, loss of livestock, and decline of natural grassland productivity, decrease farm household income. Secondly, the growth of Crofton Weed leads to the degradation of agricultural land by decreasing soil fertility, such as nitrogen, phosphorus, and potassium (Zhou and Xie 1999). Thus, farmers have to bridge the soil nutrient gap with chemical fertilizer. Extra fertilization further burdens farmers with additional labor and expenditure, in addition to accelerating agricultural land degradation. Third, farmers have implemented several control methods, such as manual removal and chemical control, to eradicate Crofton Weed from their own farmland. These control approaches also require farmers to input extra work and expenditure. Moreover, some herbicides may cause food safety problems.

So far, farmers' participation in Crofton Weed control programs is very limited. Besides manually eradicating Crofton Weed from their own agricultural land, they have rarely participated in the government funded programs, which include active support of fundamental research, program design, and farmer's trials. This shows that the government programs failed to consider farmers' opinions and that they lack an understanding of economic and demographic factors affect farmers' concerns on this issue. However, farmers' opinions and support are necessary for developing and adapting an optimal control program since they personally experience the damage caused by Crofton Weed. Therefore, it seems logical to investigate farmers' preferences for managing Crofton Weed.

Aside from farmers, natural resource management officials are the key to the decision making of Crofton Weed management issues. These officials have been working in government departments, such as forest management bureaus and agricultural management bureaus, for many years. To develop a sustainable resource management strategy, they have vast experience on Crofton Weed control because they review reports on problems caused by this weed, participate in program design trials, and attempted to implement these control programs. However, they personally have not directly experienced the negative impacts caused by this weed. In addition, government officials have perspectives that might be different because of their educational backgrounds and other socio-demographic factors, such as household incomes, age, and occupations, compared to the farmers' profiles.

Regarding Crofton Weed management issues, scientists are also closely aligned with the effectiveness of control programs. Scientists are responsible for basic and applied research on Crofton Weed. They participate in policy discussion and consultation, experiment on various control methods, monitor the results, and implement research on Crofton Weed management issues. Their study results and policy implications significantly affect the adoption of the control programs. However, scientists might also have different views on Crofton Weed control programs since their social-economic background and goals of Crofton Weed control are different from farmers.

In Yunnan Province, more than 71% of the population lives in farm households (YBS 2007). Thus, evaluation of farmers' preferences for Crofton Weed control programs will provide decision makers information on the local people's needs and concerns. This evaluation will enable decision makers to develop a more democratic and informed invasive species management program that is less controversial and will more readily to be adopted. In order to have well designed control programs, differences on preferences of Crofton Weed control programs between farmers, resource management officials and scientists should be considered jointly when evaluating gaps in the current decision making process. This process will also lead to effective allocating of resources to Crofton Weed management and ultimately help decision makers develop more comprehensive management decisions concerning invasive species policy.

## 1.2 Study objectives

The overall objective of this study is to evaluate stakeholders' preferences for Crofton Weed control programs, and provide decision makers with the information to design effective control programs for managing this weed. This study focuses on two objectives. The first objective is to analyze what control program attributes are important to the farm households and other stakeholders (policy decision makers and scientists) in Chuxiong Prefecture, Yunnan Province. This will be indicated by stakeholders' choices of the different control programs with different attributes. The second objective is to further examine what socio-demographic factors influence stakeholders' preferences for control programs. This objective considers age, gender, educational background, annual household income, and occupation.

To achieve the overall objective, the following tasks have been accomplished: (1) Designing a survey using conjoint choice experiment methodology, (2) Collecting primary data from farmers, resource management officials, and scientists from Chuxiong Prefecture, Yunnan Province, China, (3) Analyzing the data using latent class analysis approach, and (4) Interpreting results and provide policy implications for decision-making about Crofton Weed control programs.

### 1.3 Overview of chapters

There are five chapters in this study. Chapter 1 is the introduction of the topic and structure of the thesis. Chapter 1 is also an overview of the study background, including problems caused by invasive species worldwide, Crofton Weed's ecological characteristics, importance of controlling Crofton Weed, and significance of evaluating stakeholders' preferences of Crofton Weed control programs. This chapter ends with discussing objectives of this study, and a review of the structure of this thesis.

Relevant background literature for this study is reviewed in Chapter 2. This chapter consists of three sections. The first section provides information on Crofton Weed's characteristics, problems associated with the weed and current control programs. The second section discusses techniques for valuing environmental goods and services, while the third section is a review of empirical studies related to socio-demographic factors affecting the public's environmental attitudes.

Methods relating to the fieldwork conducted for this thesis research are described in Chapter 3. The primary data was collected via a questionnaire from Chuxiong Prefecture, Yunnan Province, Southwest China, from June to July 2007. Using a research method of conjoint choice experiment with face-to-face interviews, this study developed a survey and interviewed 197 farm households, 50 resource management officials, and 42 scientists.

Chapter 4 focuses on data analysis approach and discussion of results. The method used for data analysis in this study is latent class analysis to explain how individual heterogeneity affects respondents' preferences of control programs. Stakeholders' socio-demographic factors, including gender, age, household income, and occupation, were examined to find out how they relate to an individual's preferences for Crofton Weed control programs. Chapter 4 also calculated the value of parameter estimates of each attribute levels, relative importance (RI) of each attribute, and expenditure equivalent index (EEI) of the environmental resources.

Chapter 5 presented conclusions of this study, and provided policy implications. This chapter mainly focuses on discussion of the optimal control program and the revealed preferences of the stakeholders. Based on the conclusions, this chapter provides policy implications and recommendations for future studies.

# CHAPTER 2

# LITERATURE REVIEW

The literature review below is divided into four sections. The first section is an overview of the biological characteristics of Crofton Weed, problems associated with the weed, and current control programs. The second section is a review of literature on techniques for valuing environmental goods and services, while the third section is a review of factors that affect people's environmental attitudes. Based on the literature review, the last section of this chapter presents hypotheses of this study.

## 2.1 Crofton Weed

### Studies of Crofton Weed

Crofton Weed (*Eupatorium adenophorum*) is a tufted perennial shrub with a shallow root system, green trowel-shaped leaves, white flowers, and numerous, upright, erect, purplish, and woody branching stems (Trounce and Dyason 2003). It is native to Mexico and Costa Rica (Auld 1970; Liu, Xie, and Zhang 1985), and is currently identified as a weed in Australia, New Zealand, the United States (including mainland U.S. and Hawaii), Fiji, the Canary Islands, Jamaica, China, Thailand, Myanmar, Vietnam, Nepal, Pakistan, India, Sri Lanka, Philippines, Malaysia, Singapore, Indonesia, and Papua New Guinea (Auld 1966; Kluge 1991; Lu and Ma 2004; Trounce and Dyason 2003). In China, Crofton Weed has been found widely in the south and southwest regions, such as Yunnan, Sichuan, Chongqing, Xizang (Tibet), Guizhou, and Guangxi province (Lu and Ma 2004).

Crofton Weed is characterized by its great reproductive capacity, enormous dispersal ability, and broad tolerance to various environmental conditions (Sun, Lu, and Sang 2004). These characteristics help to increase the weed's invasive potential. Crofton Weed develops seeds during all its life cycle, including the first 1-2 year juvenile stage, the 3-6 year adolescent stage, the 7-11 year mature stage, and the 12-15 year senescence stage. The majority of seeds are produced in the adolescent stage (Sun, Lu, and Sang 2004). Furthermore, Crofton Weed is characterized by a persistent seed bank which enables seeds to survive in soil for a long period of time (Shen and Liu 2004). One plant can produce 10,000 to 100,000 seeds per year, ensuring the availability of ample seeds to store in the soil seed bank (Zhou and Xie 1999). In addition, the seed is very light (about 0.040 ~0.045 g /1000 seeds) which give them a greater potential to be dispersed over long distances by water, wind, humans, birds and other animals (Zhou and Xie 1999). The seed also have the ability to remain dormant for a long period of time in the soil until optimal conditions are met for germination. Moreover, Crofton Weed can also reproduce asexually. Its roots and stems have the ability to develop aerial roots which can generate new plants (Xiang 1991).

Sunlight is a crucial factor that effects the germination of Crofton Weed, however, its seedlings have strong shading tolerance ability (Lu, Sang, and Ma 2005). Within six months of germination the woody seedling can adapt itself to various environmental conditions, such as cold, drought, or heat (Sun, Lu, and Sang 2004).

Temperature, humidity, and elevation have also been shown to be correlated with the spread of Crofton Weed (Meng, Feng, and Zhou 2003). Papes and Peterson (2003) applied ecological niche models to predict Crofton Weed potential distributional range in China. Their prediction includes central and eastern regions where there have no yet to be any reports of Crofton Weed presence.

Environmental and economic damage caused by Crofton Weed

Crofton Weed is considered a serious threat to biodiversity and agricultural productivity due to its rapid growth once the population has been established. This growth competes with native species and absorbs enormous amount of water and nutrients to support its rampant expansion (Ma and Bai 2004). For example, 210 days after the introduction of Crofton Weed, the fertility of soil was decreased by losing 56% - 96% nitrogen, 46% - 53% phosphorus, and 6% - 33% potassium (Zhou and Xie 1999). Moreover, studies have shown that the amount of water extracted by Crofton Weed inhibits the germination and growth of surrounding crops, plants, and soil organisms, making Crofton Weed highly invasive. As a result, Crofton Weed displaces native species and forms dense monospecific stands. According to He and Liu (2003), the invasion of Crofton Weed reduces crop yields by 5-10%. Once Crofton Weed invaded barren lands, it is able to restrain tree seedling growth as well as the regeneration of other species of grass (Sun, Lu, and Sang 2004). The study conducted by Ma and Bai (2004) reports that once Crofton Weed occupied a natural landscape for a period of three years, the weed took over 85-95% of the open pasture land and reduced grassland output by 70-80%.

Along with its aggressive spread, Crofton Weed has been found to be poisonous to large livestock and human beings. For instance, horses may selectively graze on Crofton Weed (Harper 1979). It has been shown that when horses graze on Crofton Weed for a period of eight weeks, the following symptoms emerged: coughing, acute pulmonary consolidation, heart damage, and in some instances, death (Harper 1979; Wang et al. 2005). In contrast, cattle generally refuse to eat Crofton Weed. The lack of alternative grazing resources due to reduction of natural grassland output can cause the number of cattle to dramatically decline. For example, Tao, Ji, and Liu (2002) has reported that around 3,360 head of large livestock died due to asthma caused by Crofton Weed every year in Liangshan prefecture of Sichuan province. For humans, it has been observed that some people became allergic, asthmatic and suffered from diarrhea after eradicating Crofton Weed in the field (Wang, He, and Ma 1994; Yao, Zhang, and Liu 2003).

Control strategies

Current control programs have both advantages and disadvantages in controlling Crofton Weed. The most popular approaches of Crofton Weed control are manual removal, mechanical removal, chemical control, and biological control. Manual removal is the easiest to implement and was used to eradicate 600 hectares Crofton Weed in Hawaii in 1950s (Bess and Haramoto 1958). In China, manual removal is also a general method farmers use to eradicate Crofton Weed. However, this method is very labor intensive. Labor is generally inexpensive in China, but eradicating Crofton Weed in a large area can still be quite expensive requiring many hours of labors (Liang and Zhang 2004; Sun, Lu, and Sang 2004). Simply eradicating Crofton Weed by hand poses potential threats to human health when workers are exposed to Crofton Weed for extended periods of time (Wang, He, and Ma 1994; Yao, Zhang, and Liu 2003).

Mechanical control using tractors to uproot the weed have also been effective. In Australia, experiments have demonstrated that slashing, followed by a single ripping, reduced the number of surviving plants by 54%, while the number of seedlings decreased by 78% six months after initial treatment (Auld 1969). However, effectiveness of this approach can be affected adversely by a number of reasons. For example, using tractors is impractical in steep mountainous areas and forest regions (Yao, Zhang, and Liu 2003). In addition, mechanical control does not eradicate all Crofton seeds stored in soil. After several weeks of treatment, remaining seeds in the soil enable Crofton Weed to quickly dominate the land once again (Yao, Zhang, and Liu 2003).

Chemical control is another option for Crofton Weed management. This method can kill Crofton Weed plants quickly and effectively. Herbicides such as 2,4-D, 2,4,5-T, chlorate sodium, and glyphosate are commonly used in eradicating Crofton Weed (Auld 1970; Auld 1972; Qiang 1998). However, chemical control can be unsafe for the environment as well as to other species. Many treatments are non-selective and unless the habitats are composed only of Crofton Weed, spraying herbicides may have negative impacts on the environment and non-targeted species (Auld 1972; Yao, Zhang, and Liu 2003). Additionally, some herbicides are not biodegradable so chemicals remain in the soil or groundwater for long periods of time. Thereafter, when people use the land to grow crops, the residual chemicals may enter the food chain and negatively affect the health of humans and livestock. Moreover, some of the herbicides can only clear the plant above the ground, while the subterranean roots still have the ability of regeneration (Sun, Lu, and Sang 2004). Chemical control using herbicides is also relatively expensive, especially when used to control large areas of Crofton Weed.

Another program is biological control, which has been practiced for more than 100 years. The basic principle of biological control is to reduce the population of weeds using their natural enemies. This method is considered inexpensive and effective because, after establishing a population of predator species, host-specific interactions are able to control the weed a longtime (Debach and Rosen 1991). Biological control is also widely experimented for Crofton Weed management. Up until now, two insects, eupatorium gall fly (*Procecidochares utilis* Stone) and a crown-boring insect, *Dihammus argentatus*, and two fungi, *Mycovellosiella eupatoril-odorati* and *Alternaria alternate*, have been identified as the primary control agents of Crofton Weed (Auld 1969; Bess and Haramoto 1959; Dodd 1961; Qiang 1998). In some countries, this method has been highly successful, such as in Hawaii and India (Bess and Haramoto 1959; Julien 1987); but ineffective in areas such as China because only one insect, *Procecidochares utilis* Stone, was used and the quantity of this insect was not enough to control the spread of Crofton Weed (Yao, Zhang, and Liu 2003). Experimental results show that those insects and fungi are able to reduce plant height, plant bud number, photosynthetic rate, chlorophyll content, transpiration rate, total nitrogen and total phosphorus content of Crofton Weed (Sun, Lu, and Sang 2004). However, the impacts of control agents are affecting by environmental conditions and natural enemies in indigenous habitats (Julien 1987). Li et al. (2006) shows that the spread of these control agents generally fall behind the dispersal rate of Crofton Weed. Currently, many scientists are still working on the question of whether these control agents are really host-specific and safe for the environment.

In recent decades, replacement control has been considered as an option of Crofton Weed control programs. Replacement control is based on the idea that replacing the ecologic environment with a fast-growing tree or grass species after Crofton Weed removal can reduce the spread of Crofton Weed (Auld 1970). Previous studies conclude that many species, such as *Trifolium repens*, *Trifolium pretense*, *Pennisetum hydridum*, *Eucalyptus citriodora,* and *Acacia confusa* have potential to overcome Crofton Weed (Sun, Lu, and Sang 2004). Experiments conducted in Yunnan Province reveal that the spread of Crofton Weed can be reduced through decreasing the weed's population density and the weight of fresh plants, but the canopy density of replacement plants must be able to cover over 70% of the plots within a short period of time to be effective (He and Liang. 1988). However, Crofton Weed may still defeat these replacement plants in the long-term. It is observed that in some replacement control experiments, after several years, Crofton Weed was able to occupy the habitats again (He 2006). Therefore, replacement control method has not been convincing.

Crofton Weed control programs have been carried out in Yunnan Province since the 1980s. Almost all control methods have been employed or examined in this area because Yunnan Province is one of the places where Crofton Weed has caused the most damage (Wu, Zhang, and Lu 1984). During the 1990s the Yunnan provincial government spent more than 800,000 CNY (107,000 USD) annually on Crofton Weed control, but the weed still spread at the rate of 10-50 km per year (CCICED 2002; Wang and Qin 2004). Feng (2007) estimated that the Chinese government spent 8,000,000 CNY for research and 3,000,000 CNY for control programs throughout the entire country in recent years. However, there have been few literature or official reports on Crofton Weed control effectiveness assessment[5]. The problem of project-by-project based funding versus annually commitment funding is still the major hurdle for completely eradicating Crofton Weed in China.

## 2.2 Valuating environmental goods and services

While the physical and biological management of Crofton Weed has been well studied, little research has been conducted on the economics of various control strategies. In fact, estimating the value of invasive species control programs is a challenge due to the lack of economic markets for environmental goods and services.

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[5] In the field research, I interviewed some government officials working in either forest or agricultural bureaus, and asked them the specific question about funding for controlling Crofton Weed. They all said that there was no government commitment to funding in the recent decade.

The critical question that arises then is to determine which valuation techniques are appropriate to more responsibly evaluate specific environmental goods and services.

A limited number of environmental goods and services, such as forests for timber, fisheries, and farmland, have been evaluated based on their market values (Bennett 2003). However, a great number of environmental goods and services are non-marketable, such that no observable economic value is available (Pearce and Moran 1994). Economists and researchers have developed three categories of valuation techniques to estimate the economic value of environmental goods and services: market-based techniques, revealed-preference techniques, and stated-preference techniques (Bennett 2003).

Market-based techniques estimate the value of environmental goods and services that can be directly traded in markets, such as fish and timber (Bennett 2003). As conventional goods and services, it is possible to observe market behavior of producers and consumers regarding tradable environmental goods and services. Therefore, economists and researchers can use standard economic techniques to analyze the value of these environmental goods and services (Bennett 2003).

Different from market-based techniques, revealed-preference techniques and stated-preference techniques are generally used for estimating non-marketable environmental goods and services. Revealed-preference techniques are indirect approaches based on observing consumers' behavior in surrogate markets (Asafu-Adjaya 2005). These approaches reveal consumers' demand for environmental goods and services based on the consumption of relevant marketed substitute goods, complementary goods, or other commodities impacted by environmental change. For example, the environmental complementary goods of a recreational site can be an individual's time and travel cost for visiting this site. The primary revealed preference techniques include travel-cost method and hedonic price method (Garrod and Willis 1999). Alternatively, stated-preference techniques directly ask for an individual's preferences based on a set of structured survey questions. These approaches measure the value of environmental goods and services by asking hypothetical scenarios and their valuation. Individuals can be directly asked their willingness-to-pay (WTP) or asked to make tradeoffs between levels of environmental attributes through simulating hypothetical scenarios. Normally, stated-preference techniques are broadly classified into two categories: contingent valuation, such as asking individual's WTP, and conjoint analysis, such as ranking, rating, and conjoint choice experiment (Asafu-Adjaya 2005; Garrod and Willis 1999; National Invasive Species Council (U.S.) 2001).

Invasive species control programs are environmental goods, and there are no surrogate markets for these programs. Thus, stated-preference techniques, either contingent valuation or conjoint analysis, are possible options for estimating the value of invasive species control programs.

Contingent valuation has been used in environmental valuation for years. Instead of discovering how much a particular environmental good is worth, contingent valuation uses survey technique to ask individuals directly how much they would be willing to pay for an environmental good. This method is called "contingent" because it simulates a hypothetic market to obtain value of environmental goods and services (Asafu-Adjaya 2005). For example, contingent valuation may ask respondents a question as "if there were a market for a given invasive species control program, how much would you be willing to pay for it?"

Conjoint analysis methods are relatively new stated-preference techniques for environmental studies. The earlier forms of conjoint analysis are ranking and rating, and the latter evolved form is conjoint choice experiment. Conjoint analysis approaches estimate values of environmental changes in terms of specific environmental goods or services attributes (Garrod and Willis 1999). Lancaster's consumer theory provides a fundamental theory of these methods. Lancaster (1966) stated that all general goods possess characteristics or attributes. Within each attribute, different goods provide various proportions. Consumer utility is based on the varying of attribute levels. Lancaster's consumer theory of general goods can be applied to environmental goods or services. In a simulated market, environmental goods or services can be defined based upon their attributes and their levels.

Price represents a monetary value assigned by individuals and is an attribute to all markets, including simulated markets for environmental goods and services. Prices or costs vary with different combinations of these environmental goods and services attributes. Thus, individuals make purchasing decisions combining prices along with their preferences of changes of environmental goods and scenarios (Garrod and Willis 1999).

There are very few studies on valuation of the social attitudes toward environmental goods, such as invasive species control programs (Halbrendt et al. 2007). However, studies on market goods revealed that two primary categories of attributes significantly affect consumer behavior: search attributes and experience attributes (Nelson 1970). Search attributes, such as price, are those product attributes that are easy to be identified by consumers. Since search attributes are observable, they are crucial factors driving consumers' preferences (Nelson 1970). Experience attributes such as taste and durability are ones that consumers cannot verify until they use the product. Although consumers may pay higher cost than search attributes to obtain experience of these attributes, experience attributes shape consumers' preferences as well because of previous experiences (Ford, Smith, and Swasy 1990). Likewise, it is important to note that search attributes and experience attributes are important characteristics for consumers when they are evaluating the economic value of environmental changes.

## 2.3 Factors affecting people's evaluation of environmental goods and services

Conjoint analysis methodologies have been used to evaluate individual's stated value of environmental goods and services. Specifically, conjoint analysis studies' main feature is to break down the attributes and ask respondents to evaluate their preferences based on tradeoffs between attributes and their levels. Besides preferences, studies have show that socio-demographic characteristics may influence individual respondents' choice behavior.

Previous studies show that people's social background has an influence on public's preferences towards environmental goods and services. Based on reviewing previous studies, Hines, Hungerford, and Tomera (1986) concluded that age, gender, education, and income do not significantly influence the public's behaviors towards environmental issues. However, other studies found significant relationships between these socio-demographic variables and people's environmental concerns.

One of the most popular tested socio-demographic factors that affect people's evaluation for environment issues is age. Previous studies have reported varying results on this factor. Empirical studies reveals a negative relationship between age and people's environmental concerns, even though age relates to individual's experiences of benefits from environmental conservation and costs from environmental disasters. Torgler and Garcia-Valinas (2005) identify that older people expect less benefits from preserving the environment compared to younger persons, and, therefore, older people participate in fewer environmental protection activities. Other studies come to a similar conclusion, but propose different possible reasons. Hornback (1974) argues that one of the possible explanations is social status which is related to age. Older people are more integrated into the current social order and economic system, but most of the solutions to environmental problems challenge the existing social order and economic system. Thus, it is logical to expect older people to be less likely to support environmental reform compare to younger people. Another age hypothesis considers changes in attitudes over time. Howell and Laska (1992) have observed that the number of older people concerned with environmental degradation is increasing over time. They explain that the reason is the access to information, meaning there is more information available in the media, such as radios and televisions. Therefore, the difference in environmental attitudes between older and younger people has decreased.

Gender is another variable that has no conclusive impact on people's environmental attitudes. Although literature shows that there is no gender difference in people's environmental concern and valuation of environmental goods, Passino and Lounsbury (1976) have reported that females are more concerned about environmental quality. In their study, compared to females, males consider job and economic growth are more important than environment quality. This implies that males show less concern for environmental consequences than females. Zelezny, Chua, and Aldrich (2000) provided another analysis. According to socialization theory, females' social role is care-giving. Thus, they are more compassionate, nurturing, cooperative, and helpful than males (Beutel and Marini 1995; Chodorow 1974; Eagly 1987; Gilligan 1982), which might lead them to be more socially responsible and considering the needs of others. Contrarily, McEvoy (1972), Arcury and Christianson (1990), and Cameron and Englin (1997) found females are less likely to be willing to help the environment.

Additionally, the influence of education background on the public's environmental concern has been examined in numerous studies. Education enhances people's capacity for understanding ecosystem functions and human beings' responsibility for environmental protection. From most studies, almost all of them conclude that the higher the education level, the more the public is concerned about environmental problems (Blomquist and Whitehead 1998; Israel and Levinson 2004; Popp 2001; Van Liere and Dunlap 1980).

Income is also an important variable on people's attitudes towards environmental damages. People with low household income are less likely to be concerned about environmental problems because they are struggling to survive, while wealthier people are expected to be willing and able to help with environmental problems since they do not have the economic pressure (Torgler and Garcia-Valinas 2005; Van Liere and Dunlap 1980). Similar to normal goods and services, the demand for environmental goods and services has been found to increase as income increases. For example, wealthier populations usually demand more environmental amenities and fewer environmental damages compared to poorer populations (Franzen 2003). At the highest income level, however, this may reverse. Nelson (1999) reveals that people with very high income traditionally work in businesses where economic development is often valued higher than environmental conservation.

## 2.4 Hypotheses

The primary questions of this study ask which control program attributes are important to stakeholders, including farmers, governmental officials, and scientists. This study hypothesizes that all the control program attributes examined in this study, program cost, spread of Crofton Weed, reduction of grassland productivity, loss of biodiversity, and control methods, are all important attributes when stakeholders are valuing a control program.

However, individuals have different preferences for control program attributes because of their heterogeneity in socio-demographic background. In this study, the individual heterogeneity derives from age, gender, education, household income, and occupation. Therefore, this study's second hypothesis is that these five socio-demographic factors influence individual's preferences for control program attributes. The main differences of individuals' preferences are the significance of each attribute in a particular control program and the relative importance of each attribute (how much influence each attribute has on individuals' choices).

Previous studies provide evidence that Crofton Weed is a highly aggressive invasive species because of its vast reproductive capacity, enormous dispersal ability, and broad tolerance to various environmental conditions. Although several control methods have been tried in the past, such as manual removal, chemical control, biological control, they are not effective due to fluctuating and insufficient monetary resources supplying. Thus, it is crucial to recognize the scarcity of funding for management, and make judgment on which attributes are considered the most important in an optimal control program. However, valuing invasive species control programs is a challenge owing to the lack of economic markets for environmental goods and services. In recent decades, stated preference techniques, such as contingent valuation and conjoint analysis, have been utilized in empirical studies to estimate individual's WTP and preferences for environmental goods and services. Besides the difference in preferences, previous research has also shown that socio-demographic characteristics may influence the level of respondents' attitude towards environmental issues. The four of the most frequent examined factors are age, gender, education, and income.

# CHAPTER 3
# METHOD OF EXPERIMENT DESIGN

The purpose of this thesis is to understand stakeholders' preferences for Crofton Weed control programs in Chuxiong Prefecture, Yunnan Province, Southwest China (see section 3.3.1). In order to accomplish the objectives of the study, the method of conjoint choice experiment (CCE) was used to design the experiment for evaluating preferences for Crofton Weed control program attributes. The CCE design and data collection require the following steps: (1) develop a CCE questionnaire to gather data; and (2) collect the data via face-to-face interviews. The primary data was collected from Chuxiong Prefecture, Yunnan Province, Southwest China, from June to July 2007. In this study, 197 farm households, 50 resource management officials, and 42 scientists/experts completed the survey. The response rate was 99%.

## 3.1 Rationale for choosing conjoint choice experiment (CCE)

As a hypothetical non-marketed environmental goods and services, invasive species control programs cannot use conventional estimation technique to evaluate which factors influence stakeholders' choice of a particular program (Garrod and Willis 1999). In this study, a stated-preference technique, called conjoint choice experiment (CCE), has been employed to estimate stakeholders' preferences for Crofton Weed control programs. CCE is a useful model for evaluating products or programs that feature attributes with multiple levels (Tietenberg 2006).

### 3.1.1 Conjoint choice experiment

Conjoint choice experiment (CCE), which is sometimes called discrete choice experiment or choice based conjoint, was developed from traditional conjoint analysis (CA) methods, which use ranking and rating of program profiles versus choosing among a few profiles. Louviere and Woodworth (1983) initially introduced conjoint choice experiment. CCE is a technique for understanding how people make purchasing decisions amongst alternative designed products defined by multiple attributes (Louviere and Woodworth 1983). Originally, CCE was widely employed in travel behavior studies and marketing behavior research (Hensher 1994; Louviere, Hensher, and Swait 2000). For CCE, products can be defined in terms of attributes with varying levels for each attribute. These attributes are key characteristics that affect consumer's purchasing decisions. In a CCE study, researchers provide respondents a series of choice sets (each choice set includes two or more product profiles with different levels of the attributes) to choose amongst. When respondents choose the preferred product profiles from each choice set, the data collected can then be used to estimate the attribute utility. "Utility" is a numerical concept used to measure respondents' value for an attribute and its levels. A higher utility of an attribute indicates that respondents place more value on that particular attribute, while a lower utility implies less value. With this interpretation, respondents are more likely to purchase a product with a higher aggregate utility product profile (Yong 2004).

Since the mid-1990s, CCE has been increasingly used to evaluate environmental problems, such as wetland restoration in Australia, polluted watershed in Southwest England, and a remnant vegetation in desert upland in Queensland

(Blamey et al. 1999; Garrod and Willis 1999; Morrision, Bennett, and Blamey 1999). Empirical studies show that CCE not only reveals the total economic value of the environmental goods or programs, but also identifies the relative importance of each attribute (Garrod and Willis 1999).

In this study, Crofton Weed control programs are practical hypothetical products (goods). The profiles created by combining the attributes with different values were shown to respondents. These control program attributes include costs, potential damages caused by Crofton Weed if there is no control program, and different types of control methods. Different control program profiles were designed and presented to respondents to measure tradeoffs in the levels of the attributes. WTP more for each attribute enhancement can be calculated if cost is one of the attributes. Furthermore, CCE data can be analyzed to find out the relative importance of each attribute, which implies how much influence, each attribute has on individuals' choices.

3.1.2 Why did this study use conjoint choice experiment?

Two major stated preference methods applied to environmental problem analysis are contingent valuation and conjoint analysis (ranking, rating, and conjoint choice experiment). These two methods have advantages and disadvantages (Halbrendt et al. 2007). However, compared to the other conjoint analysis methods, CCE was considered the most appropriate approach for this study because its advantages far outweighed its disadvantages.

<u>Comparison between contingent valuation and conjoint analysis</u>

Contingent valuation (CV) is historically the most widely used stated preference technique for valuation of non-market goods and services. This technique allows researchers to estimate direct economic values, including non-use or passive-use values, for all kinds of ecosystems and environmental services (Asafu-Adjaya 2005). Moreover, CV can be utilized to calculate an exact dollar amount for environmental goods or services because this method directly asks individuals their maximum WTP to use or accept a given environmental good or service.

However, the disadvantages associated with CV may result in critical measurement errors. The three main errors of CV are: information bias, strategic bias, and non-response bias. They influence the decision to use conjoint analysis (CA) rather than using CV in this study (Asafu-Adjaya 2005; Tietenberg 2006). Table 3.1 presents the comparison of CV and CA in terms of the three biases mentioned above.

**Table 3. 1**: Comparison of contingent valuation and conjoint analysis

| Disadvantages of CV | Corresponding Solutions by CA |
|---|---|
| **Information Bias**: respondents do not understand the topic very well | **Solution**: choice sets are described by attributes and levels instead of requesting WTP for provided scenarios |
| **Strategic Bias**: respondents do not consider their budget constraints so they might overstate their WTP | **Solution**: making a choice from profiles with price as one of the program attributes |
| **Non-response Bias**: respondents are forced to state their value of an environmental scenario | **Solution**: making a choice amongst profiles is easier |

The first disadvantage of CV is information bias. In CV studies, researchers describe to respondents a hypothetical scenario to improve environmental quality, and respondents are expected to state their WTP for the provided scenario. If respondents do not understand the topic or the provided scenarios very well, they may provide biased answer (Tietenberg 2006). Thus, the results of the CV rely heavily on respondents to fully understand the information researchers conveyed. On the other hand, CA methods present respondents a series of choice sets with each set having two to five profiles to choice from. Compared to CV, CA approaches rely less on respondents' perception, but more on defining well the program attributes (Louviere 1994).

The second disadvantage of CV is strategic bias. Respondents often do not consider their budget constraints when giving the dollar amount they are willing to pay because CV studies directly ask respondents' WTP for a given scenario (Tietenberg 2006). CA studies can avoid this problem because respondents are assigned to make a choice from a set of program profiles. Within each profile, price or cost is only one of the attributes. In effect the process of CA studies is more analogous to how consumers purchase in a real market (Asafu-Adjaya 2005).

The third disadvantage of CV is non-response bias. Stating the value of an environmental scenario is harder than making a choice amongst several given profiles that indicate the value (Veisten 2007). If CV creates more difficulties for respondents by forcing them to answer questions than CA, non-response rate in CV studies will be higher than CA studies. As a result, the interviewed sample cannot represent the population because people with particular interests in the research topic are more likely to participate in the survey (Asafu-Adjaya 2005).

Comparison of traditional conjoint analysis (CA) and conjoint choice experiment (CCE)

In recent decades, CA has become a popular method used to evaluate environmental goods and services. CA requires respondents to make tradeoff decisions between the money they are willing to pay and the change in environmental amenities and quality they are willing to obtain.

Traditional CA can be further divided into ranking-based CA and rating-based CA. Ranking-based CA presents respondents with a series of hypothetical environmental scenarios (in experiment design which are called profiles), and respondents' are requested to rank all of these profiles from the least preferred to the most preferred. Rating-based conjoint analysis also provides respondents with a series of hypothetical environmental scenarios, but respondents rate their preferences for these profiles on a rating scale (for example, 10-point scale). For rating, a respondent can assign same ratings for more than one scenario or profiles (Asafu-Adjaya 2005).

CCE is an enhancement of traditional CA methods because CCE provides respondents with two or more environmental scenarios (profiles) to choose from, rather than asking respondents to rank or rate a long series of profiles.

Compared to ranking-based and rating-based CA, CCE has more advantages because it overcomes some of the weakness of CV methods. Table 3. 2 shows the comparison of traditional CV (ranking and rating) and CCE.

**Table 3. 2**: Comparison of traditional conjoint analysis (CA) and conjoint choice experiment (CCE)

| Ranking and Rating | CCE |
|---|---|
| 1. respondent rate or rank all profiles simultaneously causing response fatigue | 1.respondents evaluate only two to five profiles at a time |
| 2. respondent do not have an opportunity to reject given profiles | 2. respondent can choose a "none" response |

Firstly, traditional CA methods provide respondents with all of the profiles at the same time to rank or rate. Thus, these methods have to limit the number of profiles to reduce the potential for respondents' fatigue. In contrast, CCE studies use discrete choice sets, which can shorten the length of surveys without reducing the number of profiles and design efficiency (Halbrendt et al. 2007). Furthermore, CCE usually presents respondents with only two to five profiles to choose at a time which respondents can handle the process easily because it is similar to what they usually do in a real market (SSI 2007).

Secondly, neither the ranking method nor the rating approach provides respondents an opportunity to reject given product profiles. Respondents can only give a lower ranking or rating for the profile they do not accept. These methods are considered unconditional, and respondents' WTP, therefore, is sometimes relatively understated (Asafu-Adjaya 2005). Unlike regular CA, CCE studies usually provide a choice, such as "none, I wouldn't choose any of these." CCE can be used to obtain conditional results of respondents' WTP.

CCE has two main disadvantages. However, a well-designed study can reduce the influence of these disadvantages. The first disadvantage is that CCE requests respondents to repeat choice procedures when making decisions among similar choice sets (each choice set is composed of 2-5 profiles). After too many repetitions, respondents may be able to "catch on" to the research purpose and provide biased answers (Halbrendt et al. 2007). To reduce the possibility of respondents "catching on" to what the researchers are trying to understand, relevant literature has suggest that a typical CCE study is composed of 12-20 choice sets within each survey (SSI 2007). Hence, this study minimized the number of choice sets to 12 per survey.

The second disadvantage is that it is not effective to include a large number of attributes in a full-profile CCE study. Respondents must process several profiles simultaneously before they make decisions. Hence, a large number of attributes will confuse respondents (SSI 2007). To reduce the likelihood of confusion, this study selected five key attributes after extensive literature review and interview with experts. The five key attributes are fundamental characteristics of Crofton Weed control programs. These attributes are also closely related to the impact of Crofton Weed on local people's livelihood, and therefore, respondents are less likely to be confused by the information listed in the profiles.

Overall, CCE's advantages far outweighed its disadvantages. Moreover, a well-designed study can reduce influence of its disadvantages on the results. Thus, CCE was the most reliable method to analyze stakeholders' preferences for Crofton Weed control programs in this study.

### 3.2 Design of conjoint choice experiment (CCE)

Referencing experimental design steps suggested by previous research (Cattin and Wittink 1982; Garrod and Willis 1999; Halbrendt et al. 2007), the CCE design of this study included five stages: identify attributes, determine levels for each attribute, specify an experiment design for choice sets, develop survey questionnaire, and perform a pre-test. Attributes and levels identification were the most challenging part of this study. Five attributes were carefully chosen, and within each attribute, three levels were assigned. This study employed a fractional factorial design to generate 12 choice sets, and each choice set included two full-profiles and a "none" response. The five stages of CCE design are presented in Table 3. 3.

**Table 3. 3**: Conjoint choice experiment (CCE) design stages

| Stage | Design description |
|---|---|
| 1 | Identify key attributes: cost, spread of Crofton Weed, livestock loss, reduction of grassland productivity, and control methods |
| 2 | Determine levels for each attribute: three levels in each attribute |
| 3 | Specify an experiment design for choice sets: a choice set includes two full-profiles and a "none" response |
| 4 | Develop survey questionnaire: seven versions of the questionnaire, and each version has different choice sets of 12 |
| 5 | Perform a pre-test and finalize survey questionnaires |

<u>Stage 1: Identify key attributes</u>

The key attributes for this study had to reflect the main characteristics of Crofton Weed control programs. They also had to be crucial factors that respondents use to evaluate their choice of control programs. Since Crofton Weed control programs are considered to be goods (products), and respondents are considered to be consumers in a hypothetical market, these control programs include both search attributes and experience attributes.

Key attributes for evaluating people's preferences for environmental improvement were carefully chosen based on extensive literature review. In general, the cost of an environmental management program is an important search attribute, and it is also an indispensable factor for measuring the economic value of environmental programs. Experience attributes for environmentally related studies include loss of biodiversity, pollution on water and soil, spread of invasive species, and soil erosion (Halbrendt et al. 2007; Travisi and Nijkamp 2004). In this study, cost of control programs in terms of additional Chinese dollars was identified as the search attribute, and the four experience attributes were chosen based on their close relationship to potential damage caused by Crofton Weed, and local residents' livelihoods (Table 3. 4).

Since this study focused on Crofton Weed control programs, the main experience attribute is the type of control method because it is a fundamental component of every control program. Stakeholders' evaluation of a control method also influences their preferences for that particular control program. The other three experience attributes are the extent of Crofton Weed spread, the extent of natural grassland productivity reduction, and the extent of livestock loss for reasons stated below:

(1) *Spread*: It is a main characteristic of Crofton Weed invasiveness. Since

1935, when researchers identified it as a weed, Crofton Weed had invaded in 10 prefectures, 24.7 million hectare (67% of the total area in Yunnan Province) by the end of 1998 (Yao, Zhang, and Liu 2003). Thus, reducing the spread of Crofton Weed was considered one of the major goals in a control program.

(2) *Native grassland productivity reduction*: Crofton Weed is a highly aggressive invasive species. Once it has invaded a natural landscape, the weed rapidly displaces native species, forms dense monospecific stands, and reduces native grassland output (He and Liu 2003; Ma and Bai 2004). Moreover, native grassland degradation affects agricultural productivity and animal husbandry. Hence, controlling the reduction of native grassland productivity is a necessary component of a Crofton Weed control program.

(3) *Livestock loss*: Crofton Weed is poisonous to large livestock and has caused livestock diseases and deaths (Harper 1979; Wang et al. 2005). Since livestock is very important to farmers' livelihood, preventing the loss of any livestock is a substantial reason for Crofton Weed control.

Stage 2: Determine levels for each attribute

Orme (2006) has provided guidelines for designing attribute levels. He has suggested that appropriate attribute levels have the following characteristics:

(1) levels cover the entire possible range for each attribute;

(2) levels are mutually exclusive within each attribute;

(3) the number of levels within each attribute is equal;

(4) each attribute has less than five levels.

Using Orme's guidelines as a reference, this study determined three levels for each attribute (Table 3. 4). Literature review, focus group analyses, and interviews with experts were the basis for determining realistic and practically-achievable levels of each attribute.

**Table 3. 4**: Crofton Weed control program attributes and their levels

| Attribute | Level 1 | Level 2 | Level 3 |
|---|---|---|---|
| Cost of program | 5 CNY | 10 CNY | 20 CNY |
| Spread of Crofton Weed | 10 km/year | 30 km/year | 50 km/year |
| Livestock loss | 0% | 50% | 100% |
| Grassland productivity reduction | 0% | 35% | 70% |
| Control method | manual | chemical | biological |

*Cost*: Based on literature review and correspondence with experts through emails, the current annual cost of Crofton Weed control is estimated at 0.5 CNY per household (CCICED 2002; Feng 2007; Wang and Qin 2004). This study initially specified the program cost levels as 0.50 CNY, 1.00 CNY, and 1.50 CNY. However, the pre-test results showed that this range was so low that respondents did not consider cost when valuing each control program. Thus, the final cost levels were expanded to 5.00 CNY, 10.00 CNY, and 20.00 CNY based on respondents' WTP in the pre-test[6].

[6] Details about the pre-test will be explained in "Stage 5: Perform a pre-test and finalize survey questionnaire".

*Spread*: Previous studies show that the spread of Crofton Weed is 10-50 km/year. Orme (2006) emphasized the importance of specifying discrete levels with concise statements rather than ranges. In this study, spread levels were set at 10, 30, 50 km/year.

*Livestock loss*: There were no relevant studies that recorded data on farm household livestock loss. The number of livestock loss also varied by households in different areas. Hence, this study used percentage to measure livestock loss. Since one of the focus groups was with farmers, and they were not used to the concept of percentage, this study defined livestock loss levels as "0%, 50%, and100% of the livestock got diseases/dead in the household", meaning the affecting of Crofton Weed on livestock is "no influence", "medium influence", and "severe influence", respectively. In the survey, these levels were stated as "no loss," "half loss," and "total loss", respectively.

*Reduction of native grassland productivity*: Studies have revealed that Crofton Weed caused degradation to native grasslands. Once the weed has occupied a natural landscape for three years, grassland productivity reduced by up to 70-80% (Ma and Bai 2004). Native grassland degradation may be caused by many other reasons, such as natural degradation and human activities, therefore, this study assigned the range from 0% -70% and capped it at 70%, but in the design it was specified at three levels of 0%, 35%, and 70%.

*Control methods*: Current control methods include manual, mechanical, chemical, and biological control. Mechanical control methods are not popular and practical in Yunnan Province because the topography is mountainous. Thus, the three control methods selected were manual control, chemical control, and biological control.

Stage 3: Specify an experimental design for choice sets

One attribute level from each attribute was randomly selected to combine into one control program profile. In this study, there were five attributes, each with three levels. Mathematically, a full factorial design will have $3^5$, or 243, possible unique control program profiles. However, it is impossible to ask respondents to go through all the options and choose the most preferred one. Swait and Adamowicz (2001) have concluded that an experiment with fewer alternatives may be preferable to a complex experimental design in stated preferences studies. Moreover, this study used paper-and-pencil based interviews to collect data rather than computer-based web surveys so many choice options would have been difficult to administer. Therefore, this study used a fractional factorial design to reduce the possible profiles.

This study employed a complete enumeration method, which considers all possible profiles, to construct the fractional factorial design by using Sawtooth Software™. The complete enumeration design carefully conformed to three principles: orthogonality, minimal overlap, and level balance (SSI 2007). In this study, 84 profiles out of 243 were randomly selected. Design testing results (see Appendix A) showed that all main effects equally contribute in selected profiles. That is, these 84 profiles were almost orthogonally assigned to respondents (Green and Wind 1975). Compared to the hypothetical orthogonal design, the relative efficiency of each attribute level in this design was higher than 98%. Design testing results also showed that this design was almost perfectly balanced because each attribute level appeared approximately an equal number of times in the selected profiles.

Every choice set included two full-profiles and a "none" response. Previous literature highly recommends including a "none" option in choice sets for three reasons. First, a "none" option helps to better mimic conventional markets because, as in the real world, consumers can reject products that do not satisfy them; secondly a "none" option can reduce respondents bias because researchers do not force them to accept an profile they do not want; and third, a "none" option makes the data more realistic because respondents provide information on the decrease in demand when they are not satisfied by the control programs in that particular profile (Johnson and Orma 2003). Table 3. 5 shows an example of a program choice set.

**Table 3. 5**: Example of a Program Profile

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 5.00 CNY | 10.00 CNY | I wouldn't |
| Spread | 50km/yr | 30km/yr | choose any |
| Loss of livestock | 100% | 50% | of these |
| Reduction of grassland productivity | 0% | 70% | |
| Control method | Biological control | Chemical control | |
| Check ONE box only: | Program A (   ) | Program B (   ) | None (   ) |

Stage 4: Develop survey questionnaire

It will be very difficult for respondents to repeat the choice procedure of 84 profiles. To reduce the burden of respondents, this study randomly grouped these profiles in different questionnaire versions, and each respondent was given only one questionnaire version to evaluate. Originally, 15 versions of the survey questionnaire were designed, and each version contained 15 choice sets. However, a pre-test showed that the questionnaire was too long and fatigued respondents, and there was also too many versions, which increased the difficulties of survey administration[7]. Previous research has showed that easing respondent burden and administration difficulties are crucial to obtaining accurate survey data (Lusk and Norwood 2005). Moreover, design tests revealed that fewer questionnaire versions with fewer choice sets within each version still met the requirements of design efficiency (see Appendix A). Finally, this study reduced the number of questionnaire versions to seven, while each version included only 12 choice sets instead of 15 (Appendix B shows one version of the questionnaire).

Stage 5: Perform a pre-test and finalize the survey questionnaire

This study conducted a pre-test to ensure the experimental design was effective. The pre-test interviewed 21 farmers in Chuxiong Prefecture, Yunnan Province, China. The pre-test mainly examined the importance of attributes, the appropriate levels of each attribute, the optimal number of choice sets, and how often the "none" choice was selected. The pre-test discovered that levels of control program costs were inappropriate. The initial experimental design set the levels of cost as 0.50 CNY, 1.00

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[7] Details about the pre-test will be explained in "stage 5: Perform a pre-test and finalize survey questionnaire"

CNY and 1.50 CNY based on the current annual cost of Crofton Weed control. However, data analysis of the pre-test showed that cost was insignificantly and the positive coefficient sign of cost was unexpected. The results meant this cost range was too low to influence respondents' evaluation of program costs when making their decisions. The other four attributes (spread, native grassland productivity reduction, livestock loss, and control methods) were significant factors affecting respondents' preferences for Crofton Weed control program. They also had the expected coefficient signs.

Moreover, the results of the pre-test revealed that 15 questionnaire versions with 15 choice sets in each version were too complicated. The feedback from respondents showed that 15 choice sets in each questionnaire version made respondents tired because they had to repeat similar procedures 15 times. For this reason, several respondents submitted incomplete surveys.

Furthermore, data analysis of the pre-test concluded that the "none" response rate was lower than 5%, which was statistically low enough to maintain sufficient survey response (Orme 2006).

Finally, the questionnaire was shortened to 12 choice sets, and had only seven versions. The levels of cost were also changed to 5.00 CNY, 10.00 CNY and 20.00 CNY because most of the respondents' maximum WTP in the pre-test was in the range of 10.00 to 20.00 CNY (Final version of the questionnaire is shown in Appendix B).

3.3 Data collection

Data were collected in Chuxiong Prefecture, Yunnan Province, China, from June to July 2007. A total of 197 farm households, 50 government resource management officials, and 42 scientists were interviewed face-to-face using the survey questionnaire. The response rate was 99% because most people considered the spread of Crofton Weed a serious problem, and they were willing to contribute their opinions for controlling this weed.

3.3.1 Survey location

Surveys were conducted in Chuxiong Prefecture, Yunnan Province (Figure 2.1 shows the location of Chuxiong Prefecture, and 10 counties in Chuxiong Prefecture).

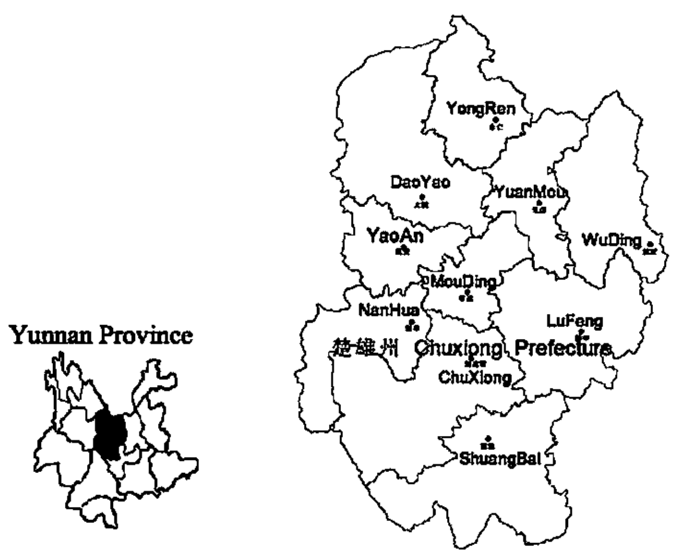


**Figure 2. 1**: Location of Chuxiong Prefecture, Yunnan Province (source: http://www.chinadiscover.net/china-tour/yunnanguide/yunnan-chuxiong.htm; Chuxiong Prefecture map is made by Zhang Rengong)

Chuxiong Prefecture is located in the central part of Yunnan Province, where Crofton Weed has been recorded in every county (CFB 2005). Since the 1980s, various control methods have been implemented, such as manual removal and biological control (Liang and Zhang 2004; YAD 2004). Agriculture is very important in Chuxiong Prefecture. According to 2005 Yunnan Agriculture Department Report (2006), agricultural contributes 37.4% of the Gross Prefecture Product to the prefecture of Chuxiong, and 85.9% of the Chuxiong population live in a farm household. To obtain representative results, the surveys covered all the 10 counties in Chuxiong Prefecture.

3.3.2 Survey instrument

Surveys in this study used a questionnaire-based method. The survey questionnaire consisted of three sections. The first section includes a brief background information about Crofton Weed and its damages. The information helped respondents to establish a basic level of knowledge about Crofton Weed regardless of their prior knowledge. The second section includes 12 choice sets of CCE program profiles. Respondents were asked to choose one program profile they preferred from each choice set. Section three has demographic questions of the respondent. (Appendix B shows one version of the questionnaire).

3.3.3. Date collection and administration

Face-to-face interviews were the main technique employed to collect data in this study due to several benefits of this technique: (1) One of the group to be interviewed was farmers with limited educational backgrounds. In a face-to-face interview procedure, interviewers could provide necessary clarification or explanation when respondents did not understand the questions; (2) Incomplete surveys or unintended answers would have significantly affected the study results. By using face-to-face interviews, interviewers could assist respondents if they overlooked a question or otherwise failed to follow the instructions in the questionnaire; and (3) Obtaining an equal number of respondents for each of the seven questionnaire versions was crucial for CCE data analysis. Face-to-face interviews ensured this response equality (Fowler 2002).

To assist with the data collection, three Chinese graduate students were trained to conduct the survey. Interviewers read background information and past literature prior to their fieldwork. To supplement reading the background information to respondents, interviewers also showed pictures and live specimens of Crofton Weed. This step helped the respondents that were not familiar with Crofton Weed better understand its environmental and economic damages. Then, each respondent was randomly given one of the seven versions of the survey questionnaire to choose their preferred Crofton Weed control programs. Interviewers read all the questions to respondents, and recorded all the answers to avoid respondents that do not read or write. Moreover, interviewers read survey questions slowly to encourage respondents to take their time and provide thoughtful and accurate answers.

### 3.3.4 Sample population

Based on an analysis of 21 CCE studies, Johnson and Orme (1996) concluded that increasing the number of choice sets for each respondent can obtain very similar statistical gains proportional to a greater number of respondents. Thus, Orme (2006) recommends that a general sample size range be from 150 to 1,200 respondents. This study completed 289 surveys (197 farm households, 50 officials, and 42 scientists) in summer 2007, which is within the range recommended by Orme study. Each questionnaire version almost had equal numbers of farmer, official, and scientist respondents, respectively.

Regarding the farm household surveys, two towns from each county were randomly selected. Respondents were interviewed in farmers' markets, farm fields, streets in the villages, and farmers' home. Furthermore, only those individuals that are 18 years or older were interviewed. Table 3. 6 shows the farmer respondents' social-demographic profile.

**Table 3. 6**: Socio-demographic comparison of farmers, officials and scientists profiles

| Variables | Farmers | Officials | Scientists |
|---|---|---|---|
| **Gender (%)** | | | |
| Female | 34.0 | 30.0 | 23.8 |
| Male | 66.0 | 70.0 | 76.2 |
| **Age (in years)** | | | |
| Mean age | 43.25 | 35.46 | 49.21 |
| **Education (in years)** | | | |
| Mean education | 6.75 | 13.68 | 16.67 |
| **Household income (%)** | | | |
| < 10,000 CNY | 71.1 | 0 | 0 |
| 10,000 – 49,999 CNY | 28.4 | 94.0 | 69.0 |
| > 50,000 CNY | 0.5 | 6.0 | 31.0 |
| **Number of observations** | 197 | 50 | 42 |

The age and education distribution of the respondents match the socio-demographic characteristics of Chuxiong farmers, but gender distribution did not match. More males (66.0%) than females (34.0%) participated in the survey because males preferred to be the spokesperson of the farm household for the interviews. The average age of farmers is 43, and the average year of schooling is 6.75. More than two third (71%) farm households' income in 2006 is lower than 10,000 CNY, while 28% respondents' household income in 2006 ranges from 10,000 to 49,999 CNY. A small portion of farmers (0.5%) have household income more than 50,000 CNY.

Aside from the farm households, this study also interviewed 50 officials working in forest management bureaus or agricultural management bureau in Chuxiong Prefecture, and 42 scientists working in universities and scientific institutions located in Yunnan Province (including both provincial level institutions and prefecture level institutions). The sample of officials and scientists did not correspond to the resources management official population and scientist population in Chuxiong Prefecture and Yunnan Province because not all of them work on Crofton Weed issues. Only officials and scientists they have been working on Crofton Weed control issues for several years, and having experiences on Crofton Weed control were considered stakeholders of control programs, and their preferences influence the program design, policy making procedures and the budget for controlling Crofton Weed.

Table 3. 6 shows that most socio-demographic characteristics of officials and scientists are different from farmers except gender. This study interviewed more male officials (70%) and scientists (76%) than females. Compared to farmers, officials are a younger, higher education, and wealthier group. The average age of officials is 35,

and the average educational background is 13.68 years of schooling. Almost all (94%) officials' household income ranges from 10,000 to 49,999 CNY, while the rest (6%) has a higher income greater than 50,000 CNY. Similar as officials, scientists have higher education and more household income than farmers, but older than farmers. The average age of scientists is 49, and scientists have the highest educational background with an average of 16.67 years of schooling. Scientists are also the highest income group. Two third (69%) of the respondents' household income ranges from 10,000 to 49,999 CNY, and one third (31%) is higher than 50,000 CNY.

Crofton Weed control programs are non-market environmental goods that cannot be valued by using most of the normal market valuation techniques. Thus, this study employed a stated preference technique called conjoint choice experiment (CCE) to estimate stakeholders' preferences for Crofton Weed control programs. Five key attributes were identified as important to decide which control programs are important and each attribute included three levels. By using a fractional factorial design, this study generated a questionnaire, including 12 choice sets, and each choice set has two full-profiles and a "none" response for respondent to pick from. To ensure the efficient coverage of all attribute levels, seven versions of the questionnaire were developed, and each version has different choice sets of 12. From June to July 2007, the primary data was collected from Chuxiong Prefecture, Yunnan Province, Southwest China. The survey conducted using the face-to-face interview method. In total, this study interviewed 289 respondents with 197 farm households, 50 resource management officials, and 42 scientists. The next chapter will include data analysis and result discussion.

# CHAPTER 4

## DATA ANALYSIS AND RESULT DISCUSSION

Data collected among local farmers, resource management officials, and scientists was analyzed to evaluate stakeholders' preferences for Crofton Weed control programs. Results of the analysis include: attribute utility parameter estimates, calculated relative importance of each attributes, and the valuation of environmental resources using the expenditure equivalent index. Respondents' socio-demographic factors, such as gender, age, household income, along with their occupations, were included in the data analysis to determine if these factors make a difference in preferences for Crofton Weed control programs. The method used for analyzing the CCE data is a latent class analysis.

### 4.1 Data analysis

Latent class analysis (LCA) has been increasingly used to analyze choice-based conjoint data since the mid-1990s (SSI 2004). LCA is used to evaluate respondent choice behavior by capturing both observable attributes of choice and unobservable factors found in the heterogeneity of individuals (Greene and Hensher 2003; Milon and Scrogin 2006). In other words, respondents are placed into distinct classes (groups) based on their choices when answering the conjoint choice experiment questions. The part-worth utilities of the attributes by the respondents are similar within each class, but differ across classes. Normally, researchers estimate aggregated part-worth utilities for all respondents (SSI 2004). However, LCA calculates part-worth utilities for each class. At the same time, LCA provides information on the probability that each respondent belongs to each class (SSI 2004).

Compared to other alternative market segmentation estimation methods, such as cluster analysis and Hierarchical Bayesian (HB) analyses, LCA can provide advantages for analyzing conjoint choice experiment data. While other methods attempt to allocate each respondent entirely in one class or another, LCA assumes that each respondent has some probabilities of belonging to each class (SSI 2004). Moreover, some methods provide analyses with only continuous attributes, but LCA works with both continuous and categorical attributes, or any combination of different attribute types. In addition, LCA provides models that are easy to integrate exogenous variables into the analysis procedures, such as socio-demographic factors (Bhattacharjee 2005). Previous studies have revealed that LCA can produce better results than other analysis approaches using choice or conjoint data (DeSarbo, Ramaswamy, and Cohen 1995; Moore, Gray-Lee, and Louviere 1996; Vriens, Wedel, and Wilms 1996).

The LCA utility model is closely linked with random utility theory. The basic assumption of random utility theory in a choice-based approach is that respondents are expected to choose the alternative (in this study, it is called the *profile*) that maximizes individual utility. For example, respondent $n$'s preference to select profile $i$ can be presented by the utility function (1):

(1) $$U_{ni} = X_{ni} + \varepsilon_{ni}$$

Where, the utility of individual $n$ ($U$) depends on the value of a deterministic component ($X$) and a random error component ($\epsilon$). In this study, the probability that respondent $n$ selects profile $i$ from a choice set $I$ to any alternative profile $h$, can be expressed as equation (2):

$$(2) \qquad P_{ni} = P\left[U_{ni} > U_{nh}\right] = P\left[\left(X_{ni} - X_{nh}\right) > \left(\varepsilon_{nh} - \varepsilon_{ni}\right)\right]; (i \neq h), (i, h \in I)$$

Where the probability, $P_{ni}$, that the utility of choosing profile $i$ exceeds the utility of choosing all other profile options expresses the probability that a particular respondent prefers profile $i$ to profile $h$.

Conditional logit models are used as a regression model to estimate probabilities (McFadden 1974). Generally, conditional logit models are used to deduce individual choice behavior from choice behavior properties of a population of individuals. In a conditional logit model, the dependent variable is a set of choices, and the independent variables vary across respondents (McFadden 1974). In LCA studies, the probability of making a specific choice among a set of profiles is based on the value of program attributes, predictors (replication or individual characteristics), and covariates of respondents (such as respondent socio-demographic factors) (Vermunt and Magidson 2005). The value of program attributes and respondent socio-demographic factors were major factors valuated in this study.

In a conditional logit model, the probability ($P_{ni}$) that individual $n$ chooses profile $i$ can be represented by the following equation (McFadden 1974):

$$(3) \qquad P_{ni} = \frac{\exp\left(\eta X_{ni}\right)}{\sum_{h=1}^{I} \exp\left(\eta X_{nh}\right)}$$

Where $\eta$ denotes a scale parameter, usually normalized as 1.0 (Boxall and Adamowicz 2002; Shen and Saijo 2007). $X_{ni}$ is the deterministic component that is assumed to be a linear function of explanatory variables. Thus, equation (3) can be represented as the equation (4):

$$(4) \qquad P_{ni} = \frac{\exp(\eta \beta Z_{ni})}{\sum_{h=1}^{I} \exp(\eta \beta Z_{nh})}$$

Where $Z_{ni}$ are explanatory variables of $X_{ni}$, including an profile-specific constant, program attribute of profile $i$, and socio-demographic factors of respondent $n$. $\beta$ is a parameter coefficient which does not denote a specific respondent.

In a latent class analysis, respondents are sorted into $M$ classes (groups) in terms of individuals' observable attributes of choice, and the unobservable heterogeneity among individuals. The value of estimated parameter coefficient $\beta$ is different from class to class because this parameter coefficient is expected to capture the unobservable heterogeneity among individuals (Greene and Hensher 2003). Then, the choice probability of individual $n$ belong to class $m$ (m = 1, ..., M) can be expressed as equation (5):

$$(5) \qquad P_{ni\,|\,m} = \frac{\exp(\eta_m \beta_m Z_{ni})}{\sum_{h=1}^{I} \exp(\eta_m \beta_m Z_{nk})}$$

Where $\eta_m$ is the class-specific scale parameter and $\beta_m$ is the class-specific utility parameter. Following the approaches and assumptions utilized by Swait (1994), and Gupta and Chintagunta (1994), Boxall and Adamowicz (2002), the probability of individual $n$'s membership in class $m$ can be described as the following:

(6) $$P_{nm} = \frac{\exp(\gamma\delta_m S_n)}{\sum_{m=1}^{M}\exp(\gamma\delta_m S_n)}$$

Where $\gamma$ denotes a scale parameter, normally assumed to equal to 1.0 (Boxall and Adamowicz 2002), $\delta_m$ is a parameter coefficient in class $m$, and $S_n$ represents a set of individual characteristics affecting respondents' probability of class membership, such as socio-demographic factors of respondent $n$. By combining equations (5) and (6), the joint probability that individual $n$ in class $m$ selects profile $i$ can be expressed as equation (7):

(7) $$P_{nim} = \sum_{m=1}^{M} P_{ni\mid m}P_{nm} = \sum_{m=1}^{M}\left[\frac{\exp(\eta_m\beta_m Z_{ni})}{\sum_{h=1}^{I}\exp(\eta_m\beta_m Z_{nk})}\right]\left[\frac{\exp(\gamma\delta_m S_n)}{\sum_{m=1}^{M}\exp(\gamma\delta_m S_n)}\right]$$

This model considers the effects of observable attributes of choice, as well as heterogeneity of individuals (Appendix C lists the donations). In this study, socio-demographic factors were examined to explain the heterogeneity of individuals. Therefore, both the control program attributes and socio-demographic factors of respondents can be simultaneously estimated to explain respondents' choice preferences. The specialized conditional logit regression software that was used in this analysis to conduct the LCA was Latent Gold Choice™, Version 4.0.

## 4.2 Results and discussion

<u>Model specification</u>

The probability for individual $n$ in class $m$ choosing control program $i$ is measured by two types of characteristics: (1) control program attributes, including control program cost (C), spread of Crofton Weed (S), reduction of native grassland productivity (G), livestock loss (L), control methods (CM); and (2) individual socio-demographic factors, including age (A), gender (GE), household income (HI), and occupation (OC)[8]. The preference model is specified in equation (8).

(8) $P(i) = f(C, S, G, L, CM, A, GE, HI, OC)$

where:

- $P(i)$ = Probability of choosing program A. Each program is represented by a combination of values taken in C, S, G, L, CP, A, GE, HI, and PR,
- C = Control program cost, taking values of 5.00 CNY, 10.00 CNY, or 20.00 CNY,
- S = Spread of Crofton Weed, taking values of 10km/yr, 30km/yr, or 50km/yr,
- G = Reduction of native grassland productivity, taking values of 0%, 35%, or 70%,
- L = Loss of livestock, taking values of 0%, 50%, or 100%,
- CM = Control method, $CM_M$ – Manual control, $CM_C$ – Chemical control, or $CM_B$ – Biological control,
- A = Age,
- GE = Gender, $GE_M$ – Male or $GE_F$ – Female,
- HI = Household income in 2006, $HI_L$ -- <10,000 CNY, $HI_M$ -- 10,000 to 49,999 CNY, or $HI_H$ -- > 50,000 CNY,
- OC = Occupation, $OC_F$ – farmer, $OC_S$ – scientist, or $OC_O$ – official.

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[8]At the beginning, education was also considered in this study, but the correlation matrix showed that education was significantly correlated to age, household income, and occupations. Hence, this study dropped the education variable to avoid multicollinearity problems.

In this model, cost, spread, reduction of native grassland productivity, livestock loss, age, and household income, are continuous variables, whereas control method, gender, and occupation, are categorical variables. These categorical variables are specified using effects coding. Effects coding is very similar to dummy coding, but the value of reference category is assigned as -1 instead of 0 (Bech and Gyrd-Hansen 2005).

Determining the number of latent classes

The number of latent classes, $M$, cannot be defined prior to the analysis procedure. The appropriate way to determine the class number is to use statistics criterion to assess a set of alternative number of latent class solutions (m=1, 2, 3, 4, 5, 6…). Related studies have recommended a number of statistical criteria to compare estimated models (Boxall and Adamowicz 2002; Gupta and Chintagunta 1994; Swait 1994). Among these criteria, the Bayesian Information Criterion (BIC), which was first proposed by Schwarz (1974), is a popular approach used for selecting the optimal number of latent classes. The calculation of BIC is the following:

$$BIC = -LL + \frac{(E \times \log D)}{2} \tag{9}$$

Where $LL$ denotes log likelihood at convergence, $E$ is number of parameters in a particular model, and $D$ represents the sample size (number of observations). This study analyzed models with different number of classes (m=1, 2, 3, 4, 5, 6), and utilized BIC (the lower the number the better) as the main criterion to examine the best model. In addition, standard $R^2$ was also used in this study to evaluate the goodness of model selection. $R^2$ statistics assess the percentage of variance explained in each dependent variable compared to the null model. In this case, the null model is defined as the model including only the "constants" as the parameter (Magidson 1981). Table 4. 1 shows the statistics for these models.

**Table 4. 1**: Statistics for models with different number of latent classes

| Number of classes (M) | Number of parameters (E) | BIC | $R^2$ |
|---|---|---|---|
| 1 | 7 | 5396.94 | 0.10 |
| 2 | 21 | 5064.40 | 0.14 |
| 3 | 35 | 4984.20 | 0.24 |
| 4 | 49 | 4963.27 | 0.30 |
| 5 | 63 | 4929.60 | 0.35 |
| 6 | 77 | 4939.05 | 0.36 |

The results show that the values of BIC decrease from the 1-class solution to the 5-class solution, but increase from the 5-class solution to the 6-class solution. The 5-class solution is clearly the best one in this study because this solution has the lowest BIC value. Moreover, the values of $R^2$ increase from 0.10 for the 1-class solution to 0.35 for the 5-class solution. Although the $R^2$ value also increases from the 5-class solution (0.35) to the 6-class solution (0.36), the marginal change (0.01) is relatively small compared to the change from the 4-class solution to the 5-class solution (0.05). Thus, this study chooses the 5-class solution based on the BIC and $R^2$ values as the LCA model to analyze stakeholders' preferences for Crofton Weed control programs.

<u>Parameter estimation for the 5-class latent class analysis solution</u>

Table 4. 2 shows the results of the 5-class solution.

**Table 4. 2**: Parameter estimates for the 5-class latent class analysis solution

| Variables | 5-class solution | | | | |
|---|---|---|---|---|---|
| | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 |
| (289 observations) | (37.90%) | (23.04%) | (15.72%) | (13.30%) | (10.04%) |
| **cost** | -0.1588** | -0.2176** | 0.0501 | -0.1099 | -0.3376** |
| | (-3.0968) | (-2.1647) | (0.5900) | (1.0013) | (2.7339) |
| **spread** | -0.3793** | -0.2623** | 0.0350 | -0.0735 | 0.1067 |
| | (-7.1647) | (-2.8003) | (0.3534) | (-0.7703) | (-0.8942) |
| **grassland** | -0.3748** | -0.4697** | 0.0965 | -0.0300 | -0.5257** |
| | (-6.6257) | (-4.1731) | (0.9912) | (-0.2880) | (-3.9351) |
| **livestock** | -0.2985** | -1.4902** | -0.1655* | -0.0903 | -1.3142** |
| | (-4.6963) | (-9.3396) | (-1.7594) | (-0.7854) | (-8.9700) |
| **control method** | | | | | |
| manual | -0.4132** | 0.2098* | 0.5464** | 1.0706** | -0.3298** |
| | (-5.4345) | (1.8540) | (4.9694) | (7.6949) | (-2.3130) |
| chemical | 0.2533** | -0.3081** | -1.0679** | 0.2469* | -0.2575* |
| | (3.8182) | (-2.7195) | (-6.7152) | (1.8098) | (-1.8214) |
| biological | 0.1599** | 0.0983 | 0.5215** | -1.3175** | 0.5873** |
| | (2.4392) | (0.9367) | (3.8080) | (-7.8588) | (4.0731) |
| **gender** | | | | | |
| male | 0.0819 | -0.1972 | 0.3682 | -0.3619* | 0.1089 |
| | (0.5969) | (-1.0987) | (1.5417) | (-1.8573) | (0.5094) |
| female | -0.0819 | 0.1972 | -0.3682 | 0.3619* | -0.1089 |
| | (-0.5969) | (1.0987) | (-1.5417) | (1.8573) | (-0.5094) |
| **age** | 0.0115 | -0.0447** | 0.0130 | 0.0473** | -0.0271 |
| | (1.0580) | (-2.6464) | (0.8920) | (3.1294) | (-1.5476) |
| **income** | | | | | |
| <10,000 | 0.0851 | -1.1356* | 0.3323 | 0.3234 | 0.3948 |
| | (0.1354) | (-1.7519) | (0.4771) | (0.1592) | (0.5232) |
| 10,000 to 49,999 | 0.2153 | 0.0280 | -0.0538 | 0.3972 | -0.5867 |
| | (0.3665) | (0.0453) | (-0.0885) | (0.1956) | (-0.9364) |
| >50,000 | -0.3004 | 1.1076 | -0.2784 | -0.7207 | 0.1919 |
| | (-0.2590) | (0.9235) | (-0.2401) | (-0.1784) | (0.1675) |
| **occupation** | | | | | |
| farmer | -0.4587 | 1.5942 | -1.4429** | 1.7412 | -1.4338** |
| | (-0.7953) | (1.0190) | (-2.2075) | (1.1804) | (-1.9572) |
| scientist | 0.3837 | -2.6384 | 1.7242* | -1.8075 | 2.3381** |
| | (0.3679) | (-0.8675) | (1.6371) | (-0.6332) | (2.1942) |
| official | 0.0751 | 1.0442 | -0.2813 | 0.0663 | -0.9043 |
| | (0.1300) | (0.6844) | (-0.4388) | (0.0418) | (-1.3058) |

Note: Numbers in parentheses are z statistics;

*, ** parameters are significantly different from 0 at 0.10 and 0.05 level, respectively.

Class 1 contains the most observations (37.90% of the total observations), followed by Class 2 that consists of 23.04% of the total observations. Almost two thirds (61%) of the respondents have the probability to be members in these two classes. The remaining one third (39%) of the observations are somewhat relatively evenly distributed in Class 3 (15.72%), Class 4 (13.30%), and Class 5 (10.04%).

Results confirm that all the five program attributes examined in this study, program costs, spread of Crofton Weed, reduction of native grassland productivity, loss of livestock, and control methods, are important attributes when choosing control programs, although there are differences in the significant levels among classes. In Class 1, Class 2, and Class 5, all attributes are statistically significant except Crofton Weed spread in Class 5. These three classes contain 71% of the observations. That is, the majority of respondents consider all the attributes when they are making decisions on control programs. Moreover, all the significant parameters have the expected signs. Programs with lower costs, slower Crofton Weed spread, less native grassland productivity reduction, and less livestock loss are preferred by majority of the respondents.

Type of control methods is the most important attribute amongst all the attributes. All respondents evaluate control methods as an important attribute when making their choices. However, there is no one common method preferred by all classes. Class 2, Class3, and Class 4 (52.06% of the sample population) prefer manual removal, Class 1 and Class 4 (51.20% of the sample population) prefer chemical control, and Class 1, Class 3, and Class 5 (63.66% of the sample population) prefer biological control.

Livestock loss is also important for majority respondents. Respondents in Class 1, Class 2, Class 3, and Class 4, that is 86.7% of the respondents, consider livestock loss as an important attribute in a control program. Moreover, the common negative sign implies that majority respondents expect an optimal control program can reduce livestock loss.

In this study, socio-demographic factors are considered latent variables to explain the unobservable factors affecting individuals' preferences for Crofton Weed control programs. This study examines four factors: gender, age, household income, and occupations. The parameter estimates indicate respondents' socio-demographic characteristics influence on program choices because socio-demographic factors are statistically significant in Class 2, Class 3, Class 4, and Class 5. These socio-demographic characteristics provide information to distinguish among the five classes. Examination of the significance of socio-demographic factors among classes helps to explain preferences for control program attributes.

Table 4. 3 summarizes the significant parameters across classes. This study focuses on stakeholders' preferences for Crofton Weed control programs. Thus, Table 4. 3 also provides distribution of stakeholders in each class in terms of occupations. Farmers and officials have similar preferences because majority farmers (65%) and majority officials (80%) are members in Class 1 and Class 2. However, scientists' preferences are different from farmers and officials because majority scientists (78%) are members in Class 3 and Class 4.

**Table 4. 3**: Summary of significant parameters of each class

| | Class 1 (37.90%) | Class 2 (23.04%) | Class 3 (15.72%) | Class 4 (13.30%) | Class 5 (10.04%) |
|---|---|---|---|---|---|
| **Program attributes** | | | | | |
| cost | (-) ** | (-) ** | | | (-) ** |
| spread | (-) ** | (-) ** | | | |
| grassland | (-) ** | (-) ** | | | (-) ** |
| livestock | (-) ** | (-) ** | (-) * | | (-) ** |
| preferred control method (+) | chemical & biological | manual | manual & biological | manual & chemical | biological |
| **Socio-demographic factors** | | | | | |
| gender | | | | (-) male* | |
| age | | (-) ** | | (+) ** | |
| income | | (-) low* | | | |
| occupation | | | (-) F**(+) S* | | (-) F**(+) S* |
| **Distribution of occupation by classes** | | | | | |
| farmers | 38.77% | 26.02% | 10.20% | 18.88% | 6.12% |
| officials | 48.00% | 32.00% | 14.00% | 2.00% | 4.00% |
| scientists | 22.22% | 0 | 44.44% | 0 | 33.33% |

Note: *, ** parameters are significantly different from 0 at 0.10 and 0.05 level, respectively;
(+) the sign of parameter is positive, (-) the sign of parameter is negative;
F: farmers; S: scientists.

*Class 1*

All the socio-demographic factors are not statistically significant in Class 1, therefore, it can be concluded that gender, age, household income, and occupation do not affect individuals' likelihood of membership to be in this class. The possible reason is that most respondents have the same common preferences for control program attributes no matter how different their gender, age, household income, and occupation are. Thus, Class 1, which contains the largest population of respondents, evaluates all attributes as somewhat equally important, and all socio-demographic factors are not statistically significant for this class. However, the results show that most farmers (39%) and officials (48%) are members in this class, but fewer scientists

(22%) are in Class 1 as compared to Class 3 and Class 5.

In Class 1, four control program attributes, cost, spread, reduction of native grassland productivity, and livestock loss, are significant at the 0.05 level, indicating that these attributes are important factors when choosing control programs. The negative estimated parameters for the four attributes imply that Class 1 has strong preferences for control programs with lower cost and higher capability of controlling Crofton Weed spread, reduction of native grassland productivity, and loss of livestock.

For control methods, all the control method parameters are significant at the 0.05 level. The negative sign of the manual control method shows that Class 1 members are less likely to choose this control method, while the positive signs of chemical control and biological control method parameters indicate that Class 1 considers these two approaches as preferred methods for controlling Crofton Weed.

*Class 2*

Age and household income factors are significant at the 0.10 or 0.05 levels in Class 2. Moreover, the sign of age is negative, and the sign of lower household income (lower than10,000 CNY) is also negative. Thus, this class can be classified as younger people or middle or high household income (greater than 10,000 CNY) respondents. In addition, the second most number of farmer respondents (26%) and official respondents (32%) are in this class, but almost no scientists belong in this class.

The preferences for control programs of Class 2 are very similar to Class 1. However, for control methods, there are several differences between Class 1 and Class

2. Both classes prefer the manual control method, but Class 2, with the negative sign for the chemical control method parameter signifies that respondents in this class are less likely to choose this control method. In terms of the biological control methods, the parameter in Class 2 is not statistically significant at 0.10 or 0.05 level. This insignificance reveals that when respondents are faced with various control programs, using biological control methods is not an important factor for respondents making decisions.

*Class 3*

The occupation parameter estimate for farmers is significant at the 0.05 level, and the occupation parameter estimate for scientists is significant at the 0.10 level in Class 3. The negative sign for farmers implies that farmers are less likely to be members of this class, whereas the positive sign for scientists indicates scientists are more likely to be members in Class 3. The stakeholder distribution statistics also confirms this conclusion. Almost half (44%) of the scientists are in this class, but the probability of farmers being in this class is only 10%. In addition, 14% of the officials are members of this class.

In Class 3, all control method parameters are significant at the 0.05 level, but for the rest of the other control program attribute parameters, only livestock is significant at the 0.10 level, others are not statistically significant. This result indicates that respondents in this class consider only livestock loss and the type of control methods when choosing their preferred control programs. Loss of livestock has an expected negative sign indicating that lower the loss of livestock it is more preferred in this class. For the type of control methods, the positive signs for manual removal and chemical control method parameters imply that respondents in this class are more likely to accept control programs using either one of these control methods. In contrast, the negative sign for biological control method conveys the information that this control method is not preferred by members of Class 3.

*Class 4*

Gender and age are significant at the 0.10 or 0.05 level for this class. Class 4 membership tends to be female or older respondents since the sign of gender is negative and the sign of age is positive. Regarding the stakeholder occupation distribution of respondents, 19% are farmers and 4% are officials, and the probability of scientists being in this class is zero.

In Class 4, control method parameters are significant at the 0.10 or 0.05 level, while the other four program attributes are not statistically significant. The results indicate that control method is the only factor affecting individual's choice of control programs in this class. The positive signs for the manual removal and chemical control method parameters and the negative sign of the biological control method parameter imply that respondents in this class prefer manual removal and chemical control methods, but they are less likely to choose biological control method to control Crofton Weed.

*Class 5*

The characteristics of Class 5 are similar to Class 3. Occupation parameter for farmers and scientists are significant at the 0.05 level. The positive sign implies that scientists are more likely to be members in this class, while the negative sign implies that farmers are less likely to be in this class. Accordingly, one third (33%) of the members are scientists, and only 6% of the members are farmers in Class 5. Probability of government officials being in this class is also very low. Only 4% of the members are officials in Class 5.

In Class 5, cost, reduction of native grassland productivity, and loss of livestock have negative signs and are significant at the 0.05 level. As expected, this result reveals that lower cost, slower spread, less reduction of native grassland productivity, and less loss of livestock are preferred attributes for individuals in this class. Spread is not statistically significant. For control methods, Class 5 favors biological control but opposes manual removal and chemical control. All control method parameters are significant at the 0.10 or 0.05 level.

Discussion of socio-demographic factors' influence on respondents' class membership

The LCA approach provides evidences that respondents in this study can be divided into five classes, and gender, age, household income, and occupations significantly affect individual's membership of being in a particular class. In other words, these factors affect individual's preferences of choosing Crofton Weed control programs.

Gender affects respondents' membership to be in Class 4. Compared to males, females are more likely to be members in this class. Regarding to the occupation distribution, there are no scientists and only a small population of officials (2%) belongs in this class. It can be conclude that most females in this class are farmers.

Typically, in rural area, female farmers have fewer education opportunities than males in rural areas of Yunnan Province, and therefore, their understanding on problems caused by Crofton Weed is perhaps less than males. This might be the reason why they only consider control methods and overlook other attributes when they are evaluating control programs. However, besides farming, females are also responsible for housework, including cooking and raising children. In general female may also pay more attention to food security and environmental friendly activities for their family due to their household and parental duties. Thus, it is reasonable that female farmers prefer manual removal, but oppose chemical control.

Age is an important factor to determine respondents' preferences in Class 2 and Class 4. Class 2 is classified as a "younger person" class, and Class 4 is classified as an "older person" class. On average, younger people have a higher educational background and their environmental consciousness and concerns are stronger than older people. Thus, in Class 2, younger people value all attributes as important components in a Crofton Weed control program. In contrast, in Class 4, older people only consider control methods when they are choosing control programs.

For control methods, both younger and older people prefer manual control. However, these two classes have different attitudes towards chemical control and biological control. Class 2 does not support using chemical control methods and ignores biological control methods, but Class 4 prefers using chemical control methods and opposes biological control methods. Compared to older people, younger people usually have more knowledge related to environment because they have higher educational background and more access to information sources. Therefore, they prefer environment-friendly programs such as manual removal. Also, for younger people, biological control is a relatively new method, they do not outright oppose it, but they may be hesitant to accept untested methods. For older people, they are willing to accept manual removal and chemical control because these two methods that are traditionally used. Since biological control is still in the experimental phase, older people might not have an awareness of, or confidence in a new method and do not value it as a viable control method.

Household income is an important factor to distinguish Class 2. Individuals with medium or higher income are more likely to be members in this class. Normally, wealthier people demand more environmental amenities and fewer environmental damages as compared to poorer people (Franzen 2003). Thus, they expect an optimal control program to solve all problems of spread, grassland degradation, livestock loss with lower program cost. Moreover, medium or higher income people consider long-term benefits and are more aware of the potential environmental problems from using chemical control methods. For biological control methods, wealthier respondents may have great access to education and understand the potential long-term benefit of biological control methods. Therefore, they do not oppose the methods. However, the spread of Crofton Weed threatens their livelihood, thus, they do not have confidence on biological control, and do not consider it to evaluate control programs.

As expected, occupations do affect individual's preferences for control programs. Farmers are less likely to be in Class 3 and Class 5. In contract, scientists are more likely to be in these two classes. The importance of parameter estimates of these two classes imply that some scientists prefer programs that deal only livestock loss and control methods, such as in Class 3, while some scientists prefer programs that address all program attributes except spread, such as in Class 5. However, scientists have adequate knowledge of any negative impacts from chemical control and long-term benefits of biological control. In addition, some scientists have conducted research on biological control methods. Therefore, they all tend to bias against chemical control and prefer biological control.

Since in some cases cost, spread, native grassland productivity reduction, and livestock loss are not necessarily linearly impacting the choice decisions of the respondents, this study also tested non-linearity for the four continuous variables by testing if the coefficient of the squared variables are significant: cost squared ($C^2$), spread squared ($S^2$), native grassland productivity reduction squared ($G^2$), and livestock loss squared ($L^2$). Results indicate that these variables, expect for cost squared, are not statistically significant in all classes. Cost squared is only significant in one class. Moreover, adding the four squared continuous variables in the model only slightly changes the parameter estimates. Considering model fit and parsimony, the final preference model did not include these four squared variables.

<u>Relative importance (RI) of Crofton Weed control program attributes</u>

Relative importance (RI) of Crofton Weed control program attributes is another important criterion for evaluating stakeholders' preferences by program attributes. RIs measure how much influence each attribute has on individuals' choices. Thus, it is possible to evaluate which attribute respondents view as the most important one. Halbrendt et al., (1995) have provided the formula for estimating RIs:

$$(10) \qquad RI_j = 100 \times \frac{UR_j}{\sum_{k=1} UR_k}$$

Where, $j$ is a particular attribute, $UR_j$ denotes the range of estimated utility change of different levels of the attribute $j$, and $\Sigma UR_k$ denotes the sum of such ranges for all attributes (the number of attributes is k, k=1,2,3,...) of the program. The relative importance of attribute, $RI_j$, is measured by the ratio of $UR_j$ over $\Sigma UR_k$. Table 4. 4 shows results of the estimated RIs.

**Table 4. 4**: Estimated relative importance of Crofton Weed control program attributes

| Attribute | Relative Importance (%) | | | | |
|---|---|---|---|---|---|
| | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 |
| Cost | 10.28 | 8.07 | 4.34 | 7.33 | 12.30 |
| Spread | 24.55 | 9.37 | 3.02 | 4.92 | 3.88 |
| Grassland | 24.27 | 17.35 | 8.37 | 2.00 | 19.23 |
| Livestock | 19.34 | 55.25 | 14.33 | 6.03 | 47.89 |
| Control method | 21.56 | 9.60 | 69.92 | 79.73 | 16.70 |

Compared to other classes, Class 1, i.e. the largest class, has relatively small difference in the RIs among the program attributes. The spread of Crofton Weed and reduction of native grassland productivity are slightly more important in determining respondents' choices of control programs. They are 24.55% and 24.27%, respectively. The RIs of livestock loss (19.34%) and control methods (21.56%) are very close.

However, cost (10.28%) is the least important characteristic of members of this class. The results imply that respondents in the largest class are more likely to support a control program that equally addresses all the program attributes when evaluating a control program.

In Class 2, livestock loss is the most important attribute with a RI of 55.25%. Reduction of native grassland productivity is the distant second important attribute with a RI of 17.35%. The RIs of cost (8.07%), spread (9.37%), and control methods (9.60%) have similar importance but not a major factor in choosing a control program. The results indicate that Class 2 prefers control programs that reduce livestock loss.

For Class 3, the most important attribute is control methods (69.92%) followed by livestock loss (14.33%). The RIs of cost, spread of Crofton Weed, and reduction of native grassland productivity are relatively small at 4.34%, 3.02%, and 8.37%, respectively. The results show that members in Class 3 strongly support control programs that utilize either the manual removal or biological control methods.

Class 4 has similar RIs to Class 3. The type of control methods is also the most important attribute when respondents are determining their preferred control programs. The RI of control methods (79.73%) in this class is even higher than Class 3. The RIs of other attributes are all less than 10%: cost (7.33%), spread (4.92%), reduction of native grassland productivity (2.00%), and livestock loss (6.03%). Respondents in Class 4 will accept control programs with manual removal or chemical control method.

In Class 5, the most important attribute is livestock loss with the RI of 47.89%.

Two relatively equal attributes are reduction of native grassland productivity (19.23%) and control methods (16.70%), followed by cost (12.30%). Spread of Crofton Weed is the least important attribute in the respondents' choice of control programs (3.88%). The results suggest that respondents in this class prefer control programs that can reduce livestock loss.

Attribute relative importance reveals the largest class (Class 1) equally considers all attributes when choosing preferred control programs. Moreover, the majority of RI is either livestock loss or control methods. Respondents in Class 2 and Class 5 consider livestock loss the most important attribute, and type of control methods is the most important attributes in Class 3 and Class 4. In addition, cost across all classes is not as important as other attributes. It is the least important attributes in Class 1 and Class 2.

Valuation of environmental resources using Expenditure Equivalent Index (EEI)

One of the purposes of this study is to examine how respondents evaluate environmental resources monetarily. Among the five attributes, cost is the price of control program; spread is the measurement of area covered by Crofton Weed; livestock loss is related to local residents' livelihood; and type of control methods are method used to control the weed. These four attributes are not directly related to environmental resources. Thus, native grassland productivity reduction, which is closely related to replacing native species, destroying habitats, and decreasing biomass, is considered the representative to estimate respondents' WTP for environmental resources in this study.

Holding other attributes and their levels constant, while independently changing levels of native grassland productivity reduction, the expenditure equivalent index (EEI) of this attribute can be estimated. EEI is used to measure the quality change in price corresponding to the change in program characteristics (Payson, 1994).

Native grassland productivity reduction is a continuous attribute. The calculation of the EEI started from the base level (70%) to the attainable highest level (0%). This study uses equation (11), which was developed by Payson (1994) to calculate the EEI of native grassland productivity reduction.

$$EEI_j = 1 - \frac{\sum_{j=1}^{J} \beta_j B_j}{\theta C} \qquad (11)$$

Where, $\beta_j$ is the estimated parameter for the attribute $j$, $B_j$ is the change of the levels in the attribute $j$, $\theta$ is the estimated parameter for base cost, and $C$ is the base level of cost. In this case, the base level of cost is 20 CNY, which is assumed to be the least preferred by the respondents.

The baseline EEI is equal to one when $B_j$ is zero in equation (11). Using the baseline as a comparison, the EEI shows the proportional changes in respondents' average willingness to pay (WTP). Thus, respondent's WTP for native grassland productivity reduction can be calculated. The results are presented in Table 4. 5.

**Table 4. 5**: EEI and WTP for native grassland productivity reduction in each class

| Levels | Class 1 | | Class 2 | | Class 3 | | Class 4 | | Class 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | EEI | WTP | EEI | WTP | EEI | WTP | EEI | WTP | EEI | WTP |
| 70% | 1.00 | 20.0 | 1.00 | 20.0 | 1.00 | 20.0 | 1.00 | 20.0 | 1.00 | 20.0 |
| 35% | 5.13 | 102.6 | 4.78 | 95.6 | 4.37 | 87.4 | 1.47 | 29.4 | 3.73 | 67.4 |
| 0% | 9.26 | 185.2 | 8.55 | 171.0 | 7.74 | 154.8 | 1.95 | 39.0 | 6.45 | 129.0 |

Note: WTP = EEI × 20 CNY

The results show that respondents in this study are willing to pay certain amount of money to protect native grassland, although their WTP for native grassland productivity reduction are different across classes. The highest EEI occurs in Class 1 (the largest class). The value of WTP shows that respondents in Class 1 are willing to pay 5.13 times more than 20 CNY, which is equivalent to 102.4 CNY, not to reduce native grassland productivity caused by the spread of Crofton Weed by 35%. Also, respondents in Class 1 are willing to pay 9.26 times more than 20 CNY, which is equivalent to 185.2 CNY, not to reduce native grassland productivity by 70%. Respondents in Class 4 (older or female respondent group) have the lowest EEI which demonstrates that respondents are willing to pay only 1.47 times more than the base cost, which is equal to 29.4 CNY, to avoid native grassland productivity reduced by 35%. For avoiding 70% native grassland productivity reduction, respondents' WTP is 31.22 times higher than the baseline, which is equivalent to 1.95 CNY.

The EEI and WTP of Class 2 (younger or higher income respondent group), Class 3 (scientist group), and Class 5 (scientist group) are relatively similar to Class 1. Respondents in Class 2 are willing to pay 95.6 CNY and 171.0 CNY to not reduce native grassland productivity by 35% and 70%. For Class 3, respondents' WTP for avoiding 35% and 70% reduction of native grassland productive are 87.4 CNY and 154.8 CNY. Similarly, respondents in Class 5 are willing to pay 67.4 CNY and 129.0 CNY to avoid native grassland productivity reduction by 35% and 70%.

The WTP results imply that respondents' highest WTP for avoiding 35% native grassland productivity reduction is 102.6 CNY. For avoiding 70% native grassland productivity reduction, respondents' highest WTP is 185.2 CNY. Considering respondents' annual household income, the results are reasonable. The annual income per capita of farmers in Chuxiong Prefecture is 2,385 CNY, and on average, one household has 3.54 persons (CBS 2007). That is, farmers' average household income is 8442.9 CNY. The WTP results indicate that farmers are willing to spend maximum 1% and 2% of their household income not to reduce native grassland productivity by 35% and 70%, respectively. Resources management officials' and scientists' household income is higher than farmers. Therefore, their maximum WTPs for avoiding 35% and 70% native grassland productivity reduction are less than 1% and 2% of their annual household income, respectively.

The stakeholders interviewed included farmers, natural resource management officials, and scientists. Their preferences varied in terms of age, gender, household income, occupations, and other unobservable factors. Thus, this study employed latent class analysis (LCA) as the data analysis method to capture both observable attributes of choice and unobservable socio-demographic factors of individuals. The results show that the 5-class solution is the best LCA model to analyze stakeholders' preferences for Crofton Weed control programs. These classes can also be defined according to their socio-demographic factors, and the parameter estimates of attributes are different across classes. Relative importance (RI) measures how much influence each attribute has on individuals' choices. RI is also used in this study to evaluate which attribute respondents view as the most important one by class. Attribute RI reveals Class 1 (the largest class) weighs all attributes as equally important except for cost, but in other classes, RI of either livestock loss or control method exceeds 50% of the weight. Moreover, expenditure equivalent index (EEI) and respondents' WTP for native grassland productivity reduction are estimates. This study found that respondents are willing to pay maximum 1% and 2% of their household income to protect native grassland.

# CHAPTER 5

# CONCLUSION AND IMPLICATIONS

Similar to other natural resource management programs, invasive species control is facing the challenge of developing appropriate policies to meet stakeholders' various needs and obtain the most support from the public. This study contributes to Crofton Weed control program evaluation in a significant way to analyze stakeholders' preferences for program attributes. Moreover, this study provides information on what are among the attributes affect stakeholders' evaluation of Crofton Weed control programs by analyzing their choice of control programs.

The experiment design, data analysis, and results indicate that conjoint choice experiment (CCE) and latent class analysis (LCA) can be use to evaluate preference differences between socio-demographic background groups. CCE provides respondents with various control program profiles to choose, and each profile is defined in terms of key attributes. LCA evaluates respondent choice behavior by capturing both observable attributes of choice and unobservable factors found in the heterogeneity of individuals. These advantages of CCE and LCA help to understand how people evaluate alternative Crofton Weed control programs, and how people's preferences differ based on their individual heterogeneity.

The results show that respondents should be segmented into five classes in terms of respondents' preference choices of the control program attributes. The majority of the respondents consider all attributes when they are making decisions on control programs. The results of the model parameter estimates demonstrate that an optimal control program should simultaneously consider cost, spread of Crofton Weed, reduction of native grassland productivity, loss of livestock, and the type of control methods. However, amongst the five attributes, livestock loss and the type of control methods are more important attributes than others.

Stakeholders have similar preferences for livestock loss. They prefer control programs that can avoid livestock diseases and death. Livestock is important to rural people's livelihood. It is the source of cash income and home consumption. Livestock provides food, such as milk and meet protein, and assists in farming activities, such as ploughing and transporting goods. Moreover, it can be sold on the markets and livestock manure improves the fertility of farmland. Since 86% of the population in Chuxiong Prefecture lives in a farm household, Crofton weed has posted threats to the economic development and social welfare. Hence, some respondents gave this attribute a weight of over 50% in choosing a control program.

Stakeholders have different preferences for the type of control methods used to control Crofton Weed. Although all respondents placed control methods as an important attribute in a particular program, preference on the type of control methods is different across classes, and there is not one common method preferred by all respondents. Farmers prefer manual removal and chemical control because these two methods are easy to implement, and can quickly and effectively eradicate Crofton Weed from their farmland. Scientists, however, are interested in biological control. They consider the environmental safety and long-term benefits of control programs.

In addition, Crofton Weed does not directly affect scientists' economic welfare. Although it takes a long period of time to experiment with various control methods, scientists still think it is valuable to introduce this relatively new method to control Crofton Weed. Officials' attitude is in the middle position. They understand farmers' urgent economic needs and, therefore, prefer manual removal and chemical control. They also consider advantages of biological control and support scientists on going effects in biological control.

As expected, the most preferred control program design is to reduce program cost, slower the spread Crofton Weed, avoid native grassland productivity reduction caused by Crofton Weed, and to lower livestock death. For control methods, the most preferred control program should adopt control methods preferred by farmers because 86% of the population in Chuxiong Prefecture lives in a farm household. Since most respondents are willing to support two of the control methods (such as respondents in Class 1, Class 3, and Class 4), and all methods have both advantages and disadvantages, policy makers may consider implementing control programs by integrating two or three control methods. In future studies, the feasibility of combining any two methods or all methods in one control program may be further explored.

As a result, this study suggests that government agencies should provide annually committed and sufficient funding to ensure an optimal control program simultaneously addressing problems of cost of program, spread of Crofton Weed, reduction of native grassland productivity, loss of livestock, and type of control methods. However, preventing livestock loss and adopting farmer preferred control methods should be given more consideration when there is inadequate funding for controlling Crofton Weed.

In this study, stakeholders do not evaluate native grassland productivity reduction as important as other attributes, such as livestock loss and the type of control methods. However, native grassland degradation affects not only agricultural productivity and animal husbandry, but also biodiversity conservation. The results of EEI and WTP show that stakeholders are willing to pay 1% to 2% of their annual household income to protect native grassland. This provides decision makers with the information of what local people are willing to pay for the protection of environmental resource management. Additional government funds for effectively addressing the problem of native grassland degradation are expected.

Regarding natural resource management, it will be much easier to give an invasive species control program a higher priority for funding if the cost-benefit of the program has been estimated. This study reveals that cost is not as important as other attributes. Moreover, respondents' WTP for protecting native grassland exceeds the current expenditure for controlling Crofton Weed. These results imply that respondents value the benefits from Crofton Weed control programs higher than the current cost. However, cost is still an important attribute in a particular control program, and respondents prefer program with lower cost. Therefore, for Crofton Weed control programs, it is important to conduct the cost-benefit analysis in future studies to design more economically desirable programs.

The analyses of relationships between respondents' choice behavior and socio-demographic factors reveal that age, gender, household income, and occupations significantly influence stakeholders' preferences for alternative control programs. This study shows that identification of socio-demographic factors can provide information to explain some differences in preferences for control program attributes and how to focus on marketing the various control programs. Understanding these differences will help in developing control strategies that are accepted by the majority of the people. In future studies, psychometric factors suggested by previous research, such as people's environmental attitudes and ethical motives (Milon and Scrogin 2006; Spash 2000b), can be further explored to explain people's choice behavior.

Ideally, government funding should support control programs accepted by the majority of the people. However, county and regional decision makers should take into consideration the socio-demographic makeup of their constituents when devising the best strategy to assist their local farmers. For example, the parameter estimates show that higher income respondents prefer only manual control method. In Chuxiong Prefecture, the annual income per capita of farmers in Yuanmou County is the highest (CBS 2007). Thus, control program with manual removal method may be the most accepted program in this county.

In this study, most farmers and natural resource management officials have very similar preferences for control programs. They expect a control program that can address problems of spread, native grassland productivity, and livestock loss with low cost. However, scientists do not think the same way. This study found that scientists tend to concentrate more on the type of control methods and how they reduce livestock loss. Control method and livestock loss are more location specific. A control program may be effective at one place, but may not be able to be adopted in other places. In contrast, cost, spread, and native grassland degradation issues deal with a wide range of social, economic, and environmental issues that covers relatively larger areas. To develop an effective control program that is accepted by local people, these three attributes, cost, spread, and native grassland productivity reduction, should not be ignored.

In Chuxiong Prefecture, 86% of the population lives in farm households. Farmers' needs represent the majority of local people. Therefore, farmers' preferences should be weighted heavily when decisions are made as to the type of Crofton Weed control to implement. Scientific research is the foundation for finding an effective control program. For developing more acceptable control programs, thus, scientists should consider research that is economically sustainable and, at the same time, can reduce Crofton Weed spread, native grassland productivity reduction, and livestock loss.

Farmers are interested in controlling Crofton Weed, but their orientation is usually to solve the problems 'here and now'. In contrast, scientists are oriented toward the future, and their interests are on the type of control program technology. However, long period of time of research and experiments often cannot provide immediate solutions within the time desired by public. Natural resource management officials stand in between farmers and scientists. One of the responsibilities of officials should be filling the information gaps between farmers and scientists and incorporate those differences in controlling Crofton Weed when developing the preferred control programs.

To be specific, education programs and information forums are needed for both farmers and scientists. Officials may provide face-to-face discussion opportunities for farmers and scientists. If scientists listen to farmers' opinions, and understand more farmers' urgent problems, their research can help to solve more farmers' needs and be supported by more local people. Moreover, the research extension can help farmers understand more long-term benefits of control program. Then, new control programs will quickly adapted and be more effective.

Finally, risk assessment systems for specific regions are needed. These systems should consider both the current and potential impact of Crofton Weed and local people's socio-demographic factors. Based on the assessment, decision makers can develop appropriate targeting control programs for a particular region. As the optional programs, both short-term strategies and long-term strategies should be considered. Short-term strategies, such as prevision and treatment of livestock diseases caused by Crofton Weed, will solve local people's urgent economic needs, whereas long-term strategies, such as biological control research and education of local people's invasive species control knowledge, will ensure Crofton Weed control program to be effective over a long period of time.

APPENDIX A

## DESIGN EFFICIENCY (COMPUTER OUTPUT OF SAWTOOTH)

| Att/Lev | | Freq. | Actual | Ideal | Effici. | |
|---|---|---|---|---|---|---|
| 1 | 1 | 56 | (omitted level) | | | 5.00 CNY |
| | 2 | 56 | 0.2193 | 0.2182 | 0.9903 | 10.00 CNY |
| | 3 | 56 | 0.2187 | 0.2182 | 0.9956 | 20.00 CNY |
| 2 | 1 | 56 | (omitted level) | | | 10km/year |
| | 2 | 56 | 0.2201 | 0.2182 | 0.9828 | 30km/year |
| | 3 | 56 | 0.2195 | 0.2182 | 0.9888 | 50km/year |
| 3 | 1 | 56 | (omitted level) | | | 0% |
| | 2 | 56 | 0.2188 | 0.2182 | 0.9946 | 50% |
| | 3 | 56 | 0.2195 | 0.2182 | 0.9881 | 100% |
| 4 | 1 | 56 | (omitted level) | | | 0% |
| | 2 | 56 | 0.2193 | 0.2182 | 0.9900 | 35% |
| | 3 | 56 | 0.2193 | 0.2182 | 0.9899 | 70% |
| 5 | 1 | 56 | (omitted level) | | | Manual control |
| | 2 | 56 | 0.2194 | 0.2182 | 0.9890 | Chemical control |
| | 3 | 56 | 0.2195 | 0.2182 | 0.9883 | Biological control |

* "Freq." displays the number of times each level occurs in the design;
"Actual" displays estimated standard errors for the data file analyzed
"Ideal" gives an estimate of what those standard errors would be if the design were precisely orthogonal and had the same number of observations;
"Effic." gives the relative efficiency of this design, compared to the hypothetical orthogonal design

## APPENDIX B

## SURVEY QUESTIONNAIRE FOR FARMERS (VERSION 1)

**Survey number:** **Location:** **Date:**

**Interviewer's Name:** **Gender:** **Male**
**Female**

***READ THE STATEMENTS OF CONFIDENTIALLY AND SURVEY AGREEMENT TO RESPONDENT IF THEY ARE WILLING TO PARTICIPATE.***

**Q1. Have you ever heard about Crofton weed? (Circle one)**

1 Yes

2 No

**Background Information for Respondent**

In Yunnan province where has been well known as "the kingdom of fauna and flora" due to the abundant biodiversity, invasive species are a major problem since they cause biodiversity loss and ecosystem degradation. Crofton weed (*Eupatorium adenophorum*), which is native to Mexico and Costa Rica, is one of the invasive species currently invading the region as a fast growing, global noxious highly invasive weed. Since it was spread into southern Yunnan from Myanmar in the 1940s, it has now covered 248,000 $km^2$ (67% of the total area) in Yunnan, and are found widely in southwest China. Once the population of Crofton weed has been established, it absorbs enormous water. Crofton also produces a certain toxin that restrains other species from growing and forms dense mono-specific stands, displacing native species. According to related studies, only three years after invading into the natural working landscape, Crofton weed can cover up to 85-95% of the open pasture lands, reduce grass land output by 70-80% and crop yields by 5-10%. Moreover, Crofton weed is an aggressive weed which is poisonous to livestock and horses causing an acute pulmonary consolidation of the large livestock. In Mojiang County of southern Yunnan in 1968, almost all the horses died due to asthma caused by Crofton weed.

Currently, the primary approaches of Crofton weed control include manual and mechanical removal, chemical control, and biological control. However, it still spreads at the rate of 30-60 km per year although Yunnan provincial government spends more than 800,000 RMB (US$100,000) per year trying to control the spread of Crofton weed. The purpose of this survey is to solicit responses from you as to your willingness to support for different Crofton weed control programs. Each of the proposed programs below has 5 features: costs of program, control methods, degree of spread, loss of livestock, and reduction of natural native grassland productivity. The latter 3 features are the possible impacts due to the existence of Crofton weed.

**Q2. If it coat ¥10.00 per year for 20 years to obtain eradication of Crofton weed, would you be willing to pay that amount? (circle one)**

**Yes** **No (if choose this answer, please skip to Q4)**

**Q3. If Yes, what about ¥20.00 per year?**

**Yes** **No**

**Q4. If No, what about ¥5.00 per year?**

**Yes** **No**

**Q5. What is your maximum willingness to pay to eradicate Crofton weed?**

**____________________ CNY / year**

Conjoint Choice Questions (Q6-Q17)

Group 1

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 5.00 CNY | 20.00 CNY | I wouldn't |
| Spread | 10km/yr | 50km/yr | choose any |
| Loss of livestock | 0% | 100% | of these |
| Reduction of grassland productivity | 35% | 70% | |
| Control practices | Manual control | Chemical control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 2

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 5.00 CNY | 10.00 CNY | I wouldn't |
| Spread | 50km/yr | 30km/yr | choose any |
| Loss of livestock | 0% | 50% | of these |
| Reduction of grassland productivity | 35% | 0% | |
| Control practices | Chemical control | Biological control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 3

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 10.00 CNY | 20.00 CNY | I wouldn't |
| Spread | 10km/yr | 30km/yr | choose any |

| | | | |
|---|---|---|---|
| Loss of livestock | 50% | 100% | of these |
| Reduction of grassland productivity | 70% | 0% | |
| Control practices | Manual control | Biological control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 4

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 5.00 CNY | 20.00 CNY | I wouldn't |
| Spread | 50km/yr | 10km/yr | choose any |
| Loss of livestock | 50% | 0% | of these |
| Reduction of grassland productivity | 0% | 70% | |
| Control practices | Manual control | Biological control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 5

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 10.00 CNY | 5.00 CNY | I wouldn't |
| Spread | 30km/yr | 50km/yr | choose any |
| Loss of livestock | 100% | 50% | of these |
| Reduction of grassland productivity | 35% | 70% | |
| Control practices | Chemical control | Biological control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 6

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 20.00 CNY | 10.00 CNY | I wouldn't |
| Spread | 30km/yr | 10km/yr | choose any |
| Loss of livestock | 100% | 0% | of these |
| Reduction of grassland productivity | 35% | 0% | |
| Control practices | Manual control | Chemical control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 7

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 5.00 CNY | 20.00 CNY | I wouldn't |
| Spread | 30km/yr | 10km/yr | choose any |
| Loss of livestock | 0% | 50% | of these |
| Reduction of grassland productivity | 70% | 35% | |
| Control practices | Manual control | Chemical control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 8

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Cost of Program | 10.00 CNY | 5.00 CNY | I wouldn't |
| Spread | 50km/yr | 30km/yr | choose any |
| Loss of livestock | 100% | 50% | of these |
| Reduction of grassland productivity | 0% | 70% | |
| Control practices | Biological control | Chemical control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 9

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 20.00 CNY | 10.00 CNY | I wouldn't |
| Spread | 10km/yr | 50km/yr | choose any |
| Loss of livestock | 100% | 0% | of these |
| Reduction of grassland productivity | 0% | 35% | |
| Control practices | Manual control | Biological control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 10

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 20.00 CNY | 5.00 CNY | I wouldn't |
| Spread | 30km/yr | 10km/yr | choose any |
| Loss of livestock | 0% | 100% | of these |
| Reduction of grassland productivity | 0% | 35% | |
| Control practices | Chemical control | Biological control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 11

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 5.00 CNY | 10.00 CNY | I wouldn't |
| Spread | 10km/yr | 50km/yr | choose any |
| Loss of livestock | 100% | 50% | of these |
| Reduction of grassland productivity | 0% | 70% | |
| Control practices | Chemical control | Manual control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 12

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Additional Cost of Program | 10.00 CNY | 20.00 CNY | I wouldn't |
| Spread | 50km/yr | 30km/yr | choose any |
| Loss of livestock | 0% | 50% | of these |
| Reduction of grassland productivity | 70% | 35% | |
| Control practices | Manual control | Biological control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

**Q18. Do you own or lease the land you farm on?** ***(Circle one number,*** **If choose "Both" answer Q19, else skip to Q20*)***

1 Own
2 Lease
3 Both

**Q19. If both, then** ***(Fill in number)***

a) How many acres do you own? ................*mu*

b) How many acres do you lease? ..................*mu*

**Q20. How mach** ***mu*** **do you farm on (Farm size)?** ***(Fill in number)***

____________ *mu*

**Q21. What crops do you grow?** ***(Please specify)***

| | Crop | Area (*mu*) | Productivity (kg/*mu*) |
|---|---|---|---|
| 1 | rice | | |
| 2 | corn | | |
| 3 | wheat | | |
| 4 | barley | | |
| 5 | horsebean | | |
| 6 | cole | | |
| 7 | tobacco | | |
| 8 | soybean | | |
| | | | |

**Q22. Do you have large livestock?** ***(Circle one number)***

1 Yes
2 No (If choose this answer, please skip to Q24)

**Q23. How many large livestock do you have? (*****Fill in number*****)**

1 House ___________
2 Cattle ___________
3 Sheep/goat ___________
4 Others (please specify)___________________________

**Q24. Have you ever experienced damages caused by Crofton weed?** ***(Circle one number)***

1 Yes
2 No (If choose this answer, please skip to Q26)

**Q25. If yes, what kind of damage?** ***(please specify)***

___________________________

**Q26. Have you ever participated Crofton weed control activities?** ***(Circle one number)***

1 Yes
2 No (If choose this answer, please skip to Q28)

**Q27. If yes, what kind of activities?** ***(Circle one number)***

1 Manual removing
2 Mechanical removing
3 Chemical control
4 Biological control experiment
5 Others (please specify)____________________________

**Q28. Which one do you prefer for supporting Crofton weed control?**

1 Pay cash
2 Labor force

**Q29. What year were you born? (How old are you?)** ______

**Q30. What is your ethnicity (Please specify)?**

_______________________________

**Q31. How many years do you complete education?** ***(Fill in number of years)***

____________________ years

**Q32. What is your total household income before tax from all sources for 2006?** ***(Circle one number)***

| | | |
|---|---|---|
| 1. under 1,000 CNY | 2. 1,000 CNY-- 1,999 CNY | 3. 2,000 CNY -- 2,999 CNY |
| 4. 3,000 CNY -- 3,999 CNY | 5. 4,000 CNY -- 4,999 CNY | 6. 5,000 CNY -- 5,999 CNY |
| 7. 6,000 CNY -- 6,999 CNY | 8. 7,000 CNY -- 7,999 CNY | 9. 8,000 CNY -- 8,999 CNY |
| 10. 9,000CNY --9,999CNY | 11. 10,000CNY --49,999CNY | 12. over 50,000 CNY |

**Q33. How long have you been living at your current county?** ***(Fill in number of years)***

______________ years

**Q34. Are you (*Please check one.* If "part-time" please go to Q35, else skip to Q36)**

1 Part-time farmer
2 Full-time farmer

**Q35. If part time, do you have another source of income?** ***(Check all that apply)***

1 Pension
2 Investment
3 Other Jobs

**Q36. Is there any family member in you household works outside your village?**
1 Yes
2 No

**Q37. Among your household income: (*Fill in number*)**
1 ____________% comes from agriculture activities
2 ____________% comes from livestock husbandry

**Q38. How many children under 18 years old live in your household?**
_________________Number of children

**Q39. How many family members are in you household? (*Fill in number*)**
______ persons

**That is all. Do you have any questions?**

**MAHALO!**

## APPENDIX C

## SURVEY QUESTIONNAIRE FOR OFFICIALS AND SCIENTISTS

## (VERSION 1)

**Survey number:** **Location:** **Date:**

**Interviewer's Name:** **Gender:** **Male** **Female**

***READ THE STATEMENTS OF CONFIDENTIALLY AND SURVEY AGREEMENT TO RESPONDENT IF THEY ARE WILLING TO PARTICIPATE.***

**Q1. Have you ever heard about Crofton weed? (Circle one)**

1 Yes
2 No

**Background Information for Respondent**

In Yunnan province where has been well known as "the kingdom of fauna and flora" due to the abundant biodiversity, invasive species are a major problem since they cause biodiversity loss and ecosystem degradation. Crofton weed (*Eupatorium adenophorum*), which is native to Mexico and Costa Rica, is one of the invasive species currently invading the region as a fast growing, global noxious highly invasive weed. Since it was spread into southern Yunnan from Myanmar in the 1940s, it has now covered 248,000 km$^2$ (67% of the total area) in Yunnan, and are found widely in southwest China. Once the population of Crofton weed has been established, it absorbs enormous water. Crofton also produces a certain toxin that restrains other species from growing and forms dense mono-specific stands, displacing native species. According to related studies, only three years after invading into the natural working landscape, Crofton weed can cover up to 85-95% of the open pasture lands, reduce grass land output by 70-80% and crop yields by 5-10%. Moreover, Crofton weed is an aggressive weed which is poisonous to livestock and horses causing an acute pulmonary consolidation of the large livestock. In Mojiang County of southern Yunnan in 1968, almost all the horses died due to asthma caused by Crofton weed.

Currently, the primary approaches of Crofton weed control include manual and mechanical removal, chemical control, and biological control. However, it still spreads at the rate of 30-60 km per year although Yunnan provincial government spends more than 800,000 RMB (US$100,000) per year trying to control the spread of Crofton weed. The purpose of this survey is to solicit responses from you as to your willingness to support for different Crofton weed control programs. Each of the proposed programs below has 5 features: costs of program, control methods, degree of spread, loss of livestock, and reduction of natural native grassland productivity. The latter 3 features are the possible impacts due to the existence of Crofton weed.

**Q2. If it coat ￥10.00 per year for 20 years to obtain eradication of Crofton weed, would you be willing to pay that amount? (circle one)**

**Yes** **No (if choose this answer, please skip to Q4)**

**Q3. If Yes, what about ￥20.00 per year?**

**Yes** **No**

**Q4. If No, what about ￥5.00 per year?**

**Yes** **No**

**Q5. What is your maximum willingness to pay to eradicate Crofton weed?**

**____________________ CNY / year**

Conjoint Choice Questions (Q6-Q17)

Group 1

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 5.00 CNY | 20.00 CNY | I wouldn't |
| Spread | 10km/yr | 50km/yr | choose any |
| Loss of livestock | 0% | 100% | of these |
| Reduction of grassland productivity | 35% | 70% | |
| Control practices | Manual control | Chemical control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 2

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 5.00 CNY | 10.00 CNY | I wouldn't |
| Spread | 50km/yr | 30km/yr | choose any |
| Loss of livestock | 0% | 50% | of these |
| Reduction of grassland productivity | 35% | 0% | |
| Control practices | Chemical control | Biological control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 3

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 10.00 CNY | 20.00 CNY | I wouldn't |
| Spread | 10km/yr | 30km/yr | choose any |
| Loss of livestock | 50% | 100% | of these |

| | | | |
|---|---|---|---|
| Reduction of grassland productivity | 70% | 0% | |
| Control practices | Manual control | Biological control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 4

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 5.00 CNY | 20.00 CNY | I wouldn't |
| Spread | 50km/yr | 10km/yr | choose any |
| Loss of livestock | 50% | 0% | of these |
| Reduction of grassland productivity | 0% | 70% | |
| Control practices | Manual control | Biological control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 5

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 10.00 CNY | 5.00 CNY | I wouldn't |
| Spread | 30km/yr | 50km/yr | choose any |
| Loss of livestock | 100% | 50% | of these |
| Reduction of grassland productivity | 35% | 70% | |
| Control practices | Chemical control | Biological control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 6

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 20.00 CNY | 10.00 CNY | I wouldn't |
| Spread | 30km/yr | 10km/yr | choose any |
| Loss of livestock | 100% | 0% | of these |
| Reduction of grassland productivity | 35% | 0% | |
| Control practices | Manual control | Chemical control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 7

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 5.00 CNY | 20.00 CNY | I wouldn't |
| Spread | 30km/yr | 10km/yr | choose any |
| Loss of livestock | 0% | 50% | of these |
| Reduction of grassland productivity | 70% | 35% | |
| Control practices | Manual control | Chemical control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 8

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 10.00 CNY | 5.00 CNY | I wouldn't |

| | | | |
|---|---|---|---|
| Spread | 50km/yr | 30km/yr | choose any |
| Loss of livestock | 100% | 50% | of these |
| Reduction of grassland productivity | 0% | 70% | |
| Control practices | Biological control | Chemical control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 9

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 20.00 CNY | 10.00 CNY | I wouldn't |
| Spread | 10km/yr | 50km/yr | choose any |
| Loss of livestock | 100% | 0% | of these |
| Reduction of grassland productivity | 0% | 35% | |
| Control practices | Manual control | Biological control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 10

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 20.00 CNY | 5.00 CNY | I wouldn't |
| Spread | 30km/yr | 10km/yr | choose any |
| Loss of livestock | 0% | 100% | of these |
| Reduction of grassland productivity | 0% | 35% | |
| Control practices | Chemical control | Biological control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 11

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Cost of Program | 5.00 CNY | 10.00 CNY | I wouldn't |
| Spread | 10km/yr | 50km/yr | choose any |
| Loss of livestock | 100% | 50% | of these |
| Reduction of grassland productivity | 0% | 70% | |
| Control practices | Chemical control | Manual control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

Group 12

| Features of Control Program | Program A | Program B | None |
|---|---|---|---|
| Additional Cost of Program | 10.00 CNY | 20.00 CNY | I wouldn't |
| Spread | 50km/yr | 30km/yr | choose any |
| Loss of livestock | 0% | 50% | of these |
| Reduction of grassland productivity | 70% | 35% | |
| Control practices | Manual control | Biological control | |
| Check ONE box only: | Program A ( ) | Program B ( ) | None ( ) |

**Q18. What year were you born? (How old are you?) ______**

**Q19. What is your nationality (Ethnic Group)?**

1 Han
2 Yi
3 Lishu
4 Miao
5 Hui
6 Dai
7 Bai
8 Others: ____________________ please specify

**Q20. Please indicate the highest level of education completed *(Circle one number)***

1 Primary school
2 Junior high school
3 Vocational or technical school
4 Some college
5 College graduate (BS or BA)
6 Master's degree (MS, MA, MBA)
7 Doctoral degree (PhD)
8 Others: ____________________ please specify.

**Q21. What is your total <u>household income</u> before tax from all sources for 2006? *(Circle one number)***

| | | |
|---|---|---|
| 1. under ￥10,000 | 2. ￥10,000 -- ￥19,999 | 3. ￥20,000 -- ￥29,999 |
| 4. ￥30,000 -- ￥39,999 | 5. ￥40,000 -- ￥49,999 | 6. ￥50,000 -- ￥59,999 |
| 7. ￥60,000 -- ￥69,999 | 8. ￥70,000 -- ￥99,999 | 9. over ￥100,000 |

**Q22. How long have you been living at your current county/city? *(Fill in number of years)***

______ years

**Q23. Which of the following best describes where you live now? *(Circle one number)***

1 Rural area or town
2 Suburban town
3 Urban area
4 Others, __________________ please specified

**Q24. Do you, or does someone in your immediate family, work on a farm, garden, or in a business closely related to farming? *(Circle one number)***

1 Yes
2 No

**Q25. What is your employment status?** ***(Circle one number)***

1 Retired
2 Unemployed
3 Employed

**Q26. About how far is it from your house to the nearest natural open space?** ***(Circle one number)***

1 Next to your house
2 Within one kilometer but not adjacent
3 One to two kilometers
4 Two to five kilometers
5 Five kilometers or more

**Q27. How many children under 18 years old live in your household?**

________________Number of children

**Q28. How many persons live in your household? (*Fill in number*)**

________________ persons

**That is all. Do you have any questions?**

**MAHALO!**

# APPENDIX D

# NOTATION

| | |
|---|---|
| $A$ | age |
| $B_j$ | the change of the levels in the attribute $j$ |
| $C$ | control program cost |
| $CM$ | control method |
| $D$ | the sample size |
| $E$ | the number of parameters in a particular model |
| $G$ | reduction of native grassland productivity |
| $GE$ | gender |
| $h$ | alternative profile |
| $HI$ | household income |
| $i$ | profile |
| $I$ | a choice set |
| $j$ | a particular attribute |
| $k$ | the number of attributes |
| $L$ | loss of livestock |
| $LL$ | log likelihood at convergence |
| $m$ | a particular class (m = 1, …, M) |
| $M$ | number of classes |
| $n$ | respondent |
| $OC$ | occupations |
| $P_{(.)}$ | probability |
| $RI$ | relative important |
| $S$ | spread of Crofton weed |
| $S_n$ | a set of individual characteristics affecting respondents' probability of class membership |
| $U$ | utility of individual $n$ |
| $UR_j$ | the range of estimated utility change of different levels of the attribute $j$ |

| | |
|---|---|
| $\Sigma UR_k$ | the sum of such ranges for all attributes |
| $X$ | a deterministic component |
| $Z_{ni}$ | explanatory variables of $X_{ni}$ |
| $\epsilon$ | a random error component |
| $\eta$, $\gamma$ | scale parameters |
| $\beta$ | parameter coefficient which is different from class to class |
| $\beta_m$ | a class-specific utility parameter |
| $\theta$ | the estimated parameter for base cost |
| $\eta_m$ | a class-specific scale parameter |
| $\delta_m$ | a parameter coefficient in class $m$ |

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