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Temporal and Spatial Analysis of Forest Management: A Case Study of Kam Cha i, Thailand

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TEMPORAL AND SPATIAL ANALYSIS OF FOREST

MANAGEMENT: A CASE STUDY OF KAM CHA I,

THAILAND

by

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DISSERTATION

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ABSTRACT

Optimal forest management strategies are needed to maximize welfare for both local and global forest users. This research will focus on spatial and temporal components within the framework of forest management policy. Particularly, payment for ecosystem services (PES) programs and their effect on forest management are considered. This research provides analysis of survey data, a theoretical forest management model, and of large GIS datasets. This dissertation demonstrates how to incorporate spatial and temporal components into the study of how a PES program could be implemented in Kam Cha i, Thailand. The results from the survey analysis demonstrate mixed attitudes towards a PES program. The results from the theoretical model and GIS analysis demonstrate the potential gains to be made from implementing a PES program.

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Introduction

Deforestation is an increasing problem in areas around the world. While there are short-run benefits to the local population at a global scale, it results in a negative externality, contributing 17 percent of total greenhouse gas emissions (Pachauri and Reisinger, 2007). Policies that focus on reducing the level of deforestation are being developed at an international level, but the efficacy of those policies will depend on the incentives provided at the local level. This dissertation focuses on incorporating spatial analysis, and decisions to harvest timber within a forest management framework. Contributions to the literature in natural resource and environmental economics include the development, administration, and analysis of data from a willingness to accept study in Kam Cha i, Thailand; the development of a spatial temporal dynamic model; and the use of GIS (geographic information systems) data and methods in forest valuation estimates to provide improved information about the impacts of a specific policy.

Chapter 1 presents the results of the first choice experiment survey conducted in Kam Cha i, Thailand. Few choice experiment surveys have been conducted in developing countries, and this dissertation presents the first study to focus on the feasibility of a forest related payment for ecosystem services (PES) program. Chapter 2 constructs a generalized spatial temporal forest management model by introducing a term for spatial interdependence. This model contributes to the natural resource literature by mathematically defining the spatial interdependence and demonstrating the impact of its introduction through a discussion of equality conditions and simulations. The model then is augmented to explore the impact of a PES program. Chapter 3 presents a new method for estimating spatially explicit values of a forest by combining survey and GIS data. These values provide policymakers with

information about specific plots of the forest and explore the differences between a PES program and local use values.

Growing concerns over climate change, and the impact that deforestation and forest degradation has on climate change, have increased the number of studies on PES programs. The literature shows that forests can either store or release a significant amount of carbon based on management policies (Pachauri and Reisinger, 2007). Despite growing interest, local feasibility or case studies on implementing PES programs are uncommon.

While mitigating climate change is important, it is not without consequences. The forests being studied do not belong to the global community; they are under the control of sovereign nations. A successful PES program would require approval and acceptance from the recipient nation. Using a choice experiment survey, this dissertation presents and analyzes the results of Kam Cha i residents' responses. A short history of stated preference models, and stated preference studies is available in the appendix at the end of the dissertation. The English and Thai versions of the survey are available in the appendix. The responses from the survey are used as a foundation to improve results of forest modeling and valuation techniques presented in subsequent chapters.

Second to obtaining funding, the most important aspect of a PES program is compliance with the recipient group (Corbera et al., 2011). The first chapter of this dissertation focuses on this question, and explores the differences in the demographics and attitudes towards a PES program among the population of Kam Cha i. The analysis began with the administration of a choice experiment survey within the area. The survey was designed to estimate a respondent's willingness to accept value for a PES program. Forest size, and distance to the forest also were included with the choice experiment's alternatives.

Demographic information, and attitudinal questions rounded out the survey. The responses show a diversity of attitudes and demographic characteristics. The results from a conditional logit and random parameter logit model confirm differences in attitudes toward a PES program. Depending on the frequency of forest visits, respondents are shown either to actively approve of or reject a PES program. These results demonstrate the possible difficulties of on-the-ground implementation of a PES program.

Another important aspect of analyzing optimal forest management policy is the concept of space. Several studies have estimated values associated with the harvesting of nontimber forest products within communities (Chopra, 1993; Saha and Sundriyal, 2012), but only recently has the role of space been introduced into the analysis (Robinson et al., 2008). Stated and revealed preference studies have a long history of estimating forest values, but the addition of spatial considerations is uncommon. Two meta-analyses of forest valuation studies cite only 3 spatially explicit papers among the 160 that were part of the study (Lindhjem, 2007; Zandersen and Tol, 2009). The increased access to GIS methods and data has made this possible. Spatial components in economic analysis have grown with the contributions of incorporating GIS (Bateman et al., 2006), marine fisheries dispersion (Sanchirico and Wilen, 2005), and forest zones (Albers and Robinson, 2007). Incorporating spatial information into the analysis can provide more efficient solutions than aggregate summaries.

The primary contribution of Chapter 2 is the inclusion of spatial interdependence among a forest in a dynamic framework. The role of space, specifically spatial interdependence, has been shown to play a part in the health of ecosystems (Dickie et al., 2012; Fukami et al., 2010). The results from the theoretical model and the subsequent

simulations demonstrate how optimal forest management strategies differ depending on whether spatial interdependence is included. There are two contributions to the literature from Chapter 2. The first is the development of a general-form spatial and temporal forest management model. While several papers have considered spatial interdependence in forest management problems in a less general form (Albers and Robinson, 2007; Swallow et al., 1997), this dissertation presents the first in general form. The second is the results from the theoretical derivation and simulations. These results are consistent with the more specific models, and also contribute new results by demonstrating the effect that spatial interdependence and PES programs have on harvest time paths.

The final chapter incorporates the spatial theme by using GIS to conduct an empirical analysis. This is done with a multicriteria evaluation framework using GIS and survey data. The use of Landsat imagery allows for spatial representations of the forest to be made at a scale of 30 by 30 meters. This information then can be used to calculate a normalized difference vegetation index (NDVI). NDVI along with survey data responses describing the market value of forest products are used to create forest valuation maps. The difference in value between timber and nontimber products is demonstrated visually. The potential overlap of these two values stresses the importance of forest management because of the trade-off involved. Finally, conservative carbon storage and sequestration valuation estimates are mapped. The results show the potential of PES programs, as well as of carbon credit programs in the area.

This dissertation demonstrates the role that space plays in forest management within the context of PES programs. The district of Kam Cha i was used as a study area for this analysis. The study was performed by theoretically modeling and empirically analyzing

multiple data sets and concepts. Chapter 1 demonstrates the heterogeneity of attitudes toward

PES programs, which primarily depends on use and access to the forest. Chapters 2 and 3

demonstrate the role that space can play in the forest management problem and in forest

valuation. The results from each chapter contribute to the "how and if" a PES program should

be implemented in Kam Cha i.

Background

History of Forestry in Thailand

The Royal Forest Department was created in 1897 to regulate and maintain the revenue created from the teak forests in Northern Thailand. In 1899, all forests became government property, and all logging without payment to the Royal Forest Department was banned. In 1956 the Forest Industry Organization was created in order to regulate the industrial uses of Thai forests. In 1962, the Thai government began to establish national parks and other forest conservation areas, but at that time their management was still under the jurisdiction of the Royal Forest Department. In the 1960s there was a large shift in the forest use in Thailand. Deforestation began to increase, but it was not due to the commercial uses in the teak forests in the North but because of the land conversion in the south due to increased export-agriculture production (Durrenberger, 1996). In the late 1960s the Thai government began to grant logging concessions, which required replanting, but they were poorly enforced.

A military coup in 1976 led to political instability that caused even less protection for Thai forests, because the military began to clear forests, especially in the Northeast to build roads to suppress rebel forces that had settled in the forests for better protection. The political instability left the government with less power to protect forests, and at the same time illegal logging was pursued more heavily by villagers. During this time of rampant illegal logging in Thailand, it is estimated that 50 to 75 percent of timber coming out of Thailand was obtained illegally (Durrenberger, 1996). In the 1980s the government created many programs to limit the speed at which Thailand's forests were disappearing, and the government set a target for 40 percent forest cover, which meant that remaining forest stands could not be converted and

that reforestation must occur. Part of the government's reforestation efforts included tree planting initiatives, and the government rented many degraded forests to third-party companies to create logging plantations. In 1988 a catastrophic flood in southern Thailand triggered a complete ban on all commercial logging (Durrenberger, 1996).

Deforestation in Thailand

Thailand continues to face problems with deforestation but certain areas of the country are more at risk. The North (Cropper et al., 1999) and the coastlands, in Mangrove forests (Barbier and Cox, 2004), have been studied for their high rates of deforestation. The majority of deforestation in the North occurs because of the old jungles and valuable teak wood. The northern provinces are also sparsely populated with minimal national government oversight making illegal harvesting easier than in other areas (Cropper et al., 1999). Mangrove forests are mostly converted to shrimp farms, which have been highly lucrative (Barbier and Cox, 2004). Forests in Thailand also have important nontimber forest products that contribute to a positive standard of living (Shackleton et al., 2011). Commercial use of timber or nontimber forest products have not been the key factor in Thailand's forest conversion in recent time (Durrenberger, 1996). The current consensus among possible causes has been the expanding population and pressures to find new agricultural land as old farms are converted to houses and other urban types of development (Barbier and Burgess, 2001).

The decline in deforestation due to commercial logging is believed to be caused by the legislation that Thailand passed in the mid-1980s limiting, eventually leading to a ban of all commercial harvesting of timber (Durrenberger, 1996). This has not stopped illegal

logging, but in 2005 only 56 square kilometers were reported to be illegally harvested (Forestry, 2008) from 167,590 square kilometers of forest cover. This suggests that most of the deforestation is development related or that most of the illegal harvesting of trees for export or for energy is not being caught and reported. It is also possible that much of the timber used for firewood and consumption on the frontiers of these forests is not being recorded. This would explain why the changes in forest cover are not entirely reconciled with the illegal logging numbers.

Kam Cha i

This dissertation focuses on the forest in the district of Kam Cha i, Thailand. The forest called Phu Sritan refers to the forested area west of the main village. Kam Cha i is located within Mukdahan Province, in northeast Thailand as shown in Figure 0.1.

The study area includes the villages of Kam Cha i, population 6,892; Ban Song, population 4,105; and Ban Lao, population 5,652 (Provincial Administration, 2012). The villages are in the eastern part of the Kam Cha i district. This dissertation reports on the results of a choice experiment survey conducted in the area. A brief summary of forest products gathered by the locals (summarized from the survey explained in the introduction and Chapter 1) is shown in Table 0.1. According to the survey results, more than half of the residents in the area use the forest for firewood, mushrooms, ant larvae, herbs, and a variety of other forest products. The mean value of products gathered was a slightly more than 1,000 Baht, or approximately $31 per household, as shown in Table 0.1.

Table 0.1

Forest Product	% Reporting	Total Value (Baht)	Mean	Std. Dev.	Min	Max
Mushrooms	51.4	515,580	1,039.5	1,473.1	0	10,000
Timber	1.6	17,013	34.3	440.9	0	6,000
Animals	1.4	6,500	13.1	191.4	0	4,000
Total	51.8	526,058	1,060.6	1,679.3	0	10,000

Number of survey responses = 496. All values reported in 2012 Thai Baht.

Figure 0. 1 Mukdahan within Thailand

Highlighting Kam Cha i district,
within Mukdahan Province, Thailand
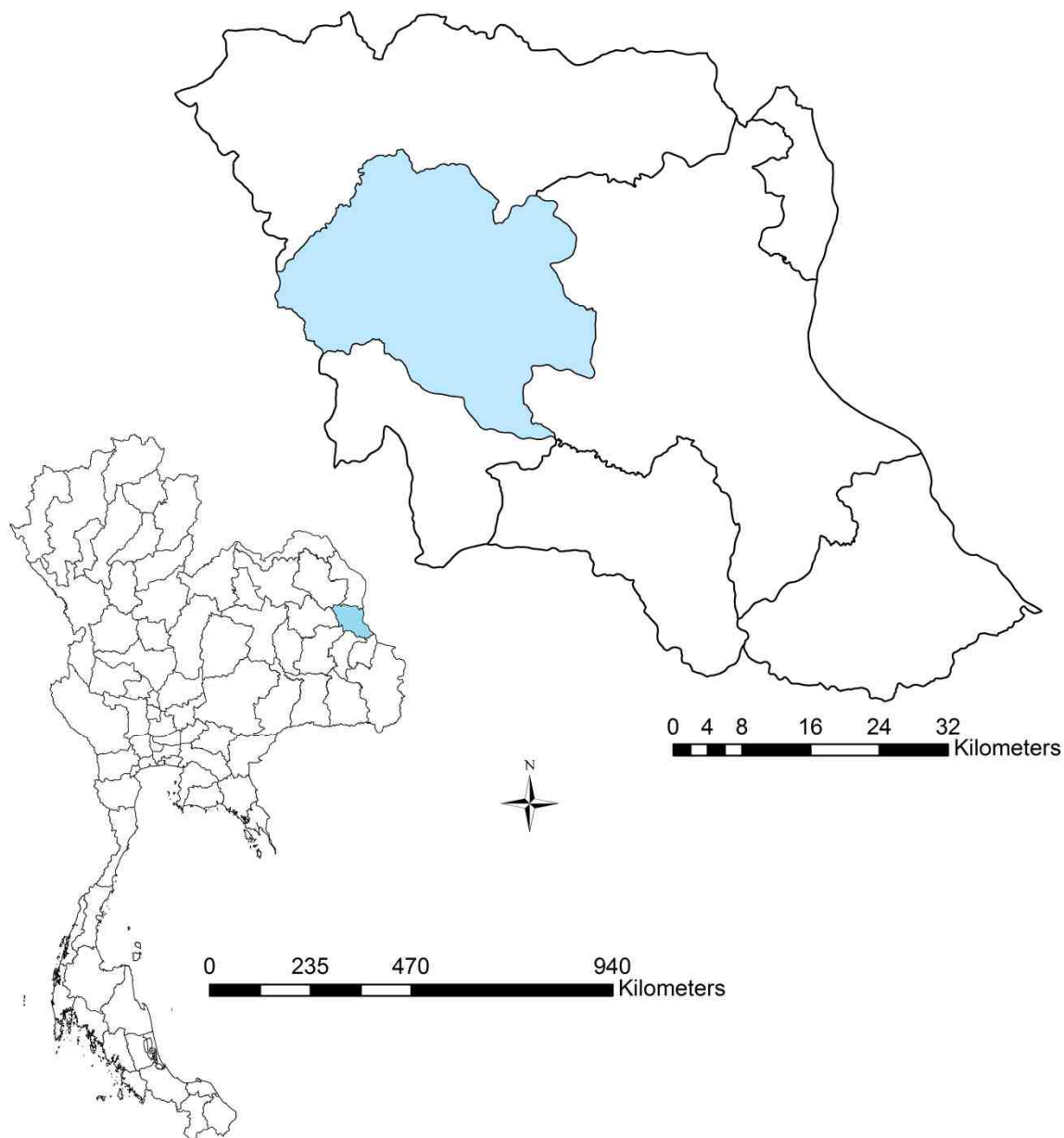
Source: Global Administration Areas[1]

To limit deforestation, the Thai government has designated certain areas for wildlife or as national parks. These are generally located in areas unsuitable for agriculture because of terrain or soil quality (Cropper et al., 2001). This is also true for the forest near Kam Cha i. While the forest is not a national park or wildlife refuge, it is still government property and is under the jurisdiction of the national and local governments in conjunction with the Thai Forestry Department. Complete conversion of Phu Sritan is unlikely due to its topography, but logging is possible. The geography of Kam Cha i is dominated by a flat valley with hills and mountains toward the northwest. Most of the land in the valley area has been converted to flood plain rice farming. The agricultural area begins at the base of the mountain (where Phu Sritan ends) and covers the valley surrounding each village.

The types of land use can be attributed to the types of people who reside in Kam Cha i. There is an "old vs. new" dynamic regarding forest use in Kam Cha i. This heterogeneity takes many forms. The following pictures show the divergence between traditional and new ideologies in the area.

Picture 0.1 shows a merchant offering her wares in the morning market, which occurs from 4a.m. to 7a.m. on a daily basis. During the morning market, the majority of vendors sell forest products and other food items such as carpenter ant larvae, mushrooms, herbs, cooked grasshoppers, and other vegetation gathered from the local forest. Foraging for nontimber forest products has the potential to increase locals incomes substantially (de Aragon et al., 2011; Saha and Sundriyal, 2012). However, in 2012 a smaller version of a popular retail chain "Tesco Lotus" opened in Kam Cha i (Picture 0.2). Tesco Lotus allows locals to buy refrigerated and frozen produce and meats in their village. Prior to the opening of the store,

locals would have to travel 35 kilometers to the provincial capital of Mukdahan order to buy these types of items.

Picture 0.1 Ant larvae for sale in local market in Kam Cha i. Source: Author's photo.

Picture 0.2 Tesco Lotus Express in Kam Cha i. Recently constructed Tesco Lotus Express allows locals to by refrigerated meats, fruits, and vegetables. Source: Author's photo.

LandSat[2] imagery for the Kam Cha i area shows two primary land uses: forest, and rice paddies. The majority of the population is located in eight villages, but the villages are relatively small compared to the total area. The larger villages are located away from the forests and near a main road, while smaller villages are located closer to the forests. Based on the survey results, the majority of frequent forest users were located in these smaller villages.

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[2] LandSat 4, image acquired January 20th, 2009. Acquired from Earth Explorer 3/22/2013.

There are two types of people identified in the survey; those who use the forest and those who do not. In an effort to protect the forest, nonusers constructed a small barbed wire fence supported by concrete posts. Picture 0.3 shows the status of this fence, where the barbed wire has been removed and only the concrete posts remain. The users of the forest removed this obstacle because it prohibited entry to gather forest products or graze their livestock. A small percentage of the residents still harvest timber. These types of differences in attitudes between locals, policymakers, and researchers are a growing field in the environmental management literature. Differences have been identified and studied in Tobago (Beharry-Borg et al., 2009) and Vietnam (Do and Bennett, 2009). However, isolating this heterogeneity through the use of surveys with the intent of determining PES feasibility could greatly improve a PES program's outcome.

Pictures 0.4-0.7 display the forest and agriculture within Kam Cha i. Picture 0.4 shows the prevalence of rice paddies among the forests located in Kam Cha i. Picture 0.5 shows an example of a road passing through the forest, and how accessibility to the forest is increased because of road construction. Picture 0.6 gives another example of land use within Kam Cha i by showing human planted trees along side rice paddies. Finally, Picture 0.7 shows an undisturbed section of the forest with mature trees and foliage.

Picture 0.3 The broken fence in Kam Cha i Thailand, Source: Author's photo

Picture 0.4 Flooded rice paddies with Phu Sritan in the background, Source: Author's photo

Picture 0.5 A forest road dividing Phu Sritan, Source: Author's Photo

Picture 0.6 Rice paddies surrounded by trees in Kam Cha i, Source: Author's photo

Picture 0.7 Frontier of the forest in Kam Cha i, Source: Author's photo

        This section of the dissertation has provided information on forest policy and deforestation trends in Thailand. Additionally, specific characteristics of the study area in Kam Cha i were introduced including land types, and how locals use the forest. This context is meant to set the stage for the future chapters which analyze the survey results and forest attitudes using statistical and GIS methods. Understanding the location, history, and traditions of this specific area put the results and policy implications into context.

Chapter 1: Forest Valuation Choice Experiment Results

Payment for ecosystem services programs such as the United Nations Reduction in Emission from Deforestation and Degradation have been created to conserve forests. The global desire for forest conservation may conflict with local landowners who prefer to harvest timber or are weary of outside groups. To test the feasibility of such a program in Kam Cha i, Thailand, a choice experiment survey was conducted. This chapter concludes that while feasible, a strong heterogeneity in attitudes among the respondents is present. Results from a conditional logit model and from a random parameter logit model show a large variation in forest management preferences and willingness to accept amounts. The difference in attitudes is explored by separating survey responses by frequency of forest use. Results demonstrate the role that frequency of forest use has on survey responses.

Introduction

This chapter explores the feasibility of management policies and incentives provided to private agents for incorporating international forest values. This research introduces a willingness to accept (WTA) framework into a survey designed to explore the feasibility of a payment for ecosystem services (PES) program. The research also contributes to the literature by introducing a design to test the feasibility of a PES program for an area in rural Thailand. Efficient forest management should consider both local and global economic benefits, which is where PES programs play a vital role. Forests have local value in the products they produce that are used for foods, shelter, and medicines (de Aragon et al., 2011; Molina and Pilz, 1998). Global values become significant when considering climate change. The Intergovernmental Panel on Climate Change estimates that deforestation and forest degradation contributes more than 17 percent of all new greenhouse gasses (Pachauri and Reisinger, 2007). From the total economic value generated by forests, research on carbon sequestration demonstrates one component of the global nonmarket value of forests (Creedy and Wurzbacher, 2001; Nelson et al., 2009)[3].

PES programs attempt to address this problem. A difficulty in potentially divergent local and global values is developing effective global policies that can be implemented locally. PES is a market-based approach for forest management that transfers money to local forest users with the expectation that they conserve their forest. These programs typically target those living on the forest frontier, which are primarily low-income households. These households would have the most to gain from a PES program (Milder et al., 2010). However, PES programs face on-the-ground implementation challenges. The commodification of

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[3] Other values (option, bequest, tourism, and existence) have been left out of this analysis. Total economic value traditionally includes direct use, indirect use, option and existence value. See Adger et al. (1995) for a thorough explanation.

ecosystems is a confusing or potentially insulting idea to those who might be offered money transfers. Substituting cultural, traditional, and local practices for monetary transfers can change the incentives for conservation. Simplification of "what part of the ecosystem service" is being paid for contributes to this confusion (Kosoy and Corbera, 2010). Despite these challenges, PES programs are gaining traction around the world. More than 15 examples and descriptions of PES programs in both developed and developing countries are described in Gomez-Baggethun et al. (2010). The largest monetary example is the United Nation's Reduction in Emissions from Deforestation and Degradation (REDD) program which currently has an operating budget of $167 million (Peskett and Todd, 2012).

Other country-level challenges must be overcome when implementing a REDD-type program. These include international and national negotiations, technological developments in land-use related processes, and coordination with the environmental and socio-economic outcomes of the programs (Corbera and Schroeder, 2011). This chapter focuses on the last of these three by examining the attitudes toward a REDD-type program in Kam Cha i, Thailand. To analyze these attitudes, a survey-based choice experiment was administered in Kam Cha i. The survey was designed to measure their attitudes toward forest location, size, and different administration styles including payment possibilities. The study area focused on the district capital of Kam Cha i and the surrounding villages near the forest Phu Sritan. Nearly 12 percent of the households in the study area were surveyed. The survey was designed to be analyzed using a variety of logit-based techniques. In addition to summary statistics, a conditional logit (CL) model and random parameter logit (RPL) model were used to analyze the responses.

The results reinforce the literature's conclusions on difficulties implementing PES programs. These difficulties include distrust of outsiders, land tenure, current forest use, and payment mechanisms (Corbera et al., 2011; Johns et al., 2008; Pagiola and Bosquet, 2009). The CL and RPL models show the heterogeneity in attitudes towards a PES program among the responses. The heterogeneity among attitudes is most apparent when separating those who actively use the forest versus the nonusers. These differences across types of respondents make estimating a single inclusive WTA value difficult, as one class of respondents has a negative WTA value.

The rest of the chapter is structured as follows. Section 2 gives a brief background of the REDD program, information about Kam Cha i is available in the Background section of the dissertation. Section 3 discusses the theoretical framework of CE studies focusing on CL and RPL models, while linking this to the survey design. Section 4 presents the results from the CE survey by presenting these two models and how they deal with heterogeneity. Finally, conclusions and policy implications are presented.

Section 2: Background

The REDD Program

The United Nation's REDD program started in 2005 and has become the largest (both monetary and scope) example of a PES program in the world. The purpose of the program is to reduce emissions from deforestation and forest degradation in developing countries(United Nations, 2013). Deforestation is the second leading cause of greenhouse gas emissions next to fossil fuel consumption (van der Werf et al., 2009). By reducing deforestation in developing countries less greenhouse gas accumulation will occur. Finding economic

alternatives (including PES programs) to deforestation can promote sustainable forest use in these areas. Deforestation also can be reduced by communicating with, and setting up PES arrangements with forest caretakers in developing countries (Corbera and Schroeder, 2011; Peskett and Todd, 2012).

The REDD program is currently in its pilot phase with several countries acting as beneficiaries and sponsors of the program. Panama, Ecuador, Indonesia, and Sri Lanka are examples of countries currently participating in the REDD program. While currently in its pilot phase, other countries plan to join including: Laos, Myanmar, and Malaysia. The current funding cycle ends in 2015 but sponsoring countries hope to extend REDD programs and the monetary transfers, potentially indefinitely (Peskett and Todd, 2012). Every country that shares a border with Thailand is involved in the REDD program, suggesting that Thailand may play a role in REDD in the future (Peskett and Todd, 2012). Several countries act as sponsors and have contributed funds to the REDD program, but Norway remains the primary contributor by transferring nearly $142 million to the REDD program. In addition, the European Union will transfer $13 million; Denmark $8 million; Japan $3 million; Luxembourg $2.6 million; and Spain $2 million. Each of these transfers has been completed except for that of the European Union, which has transferred $11.2 million as of June 2013(United Nations, 2013), and Luxembourg, which has transferred $1.3 million. The total amount transferred to the REDD program as of June 2013 is $167 million, with 99 percent going to implementing the REDD program in its partner countries (Peskett and Todd, 2012).

The dispersal mechanism for REDD may impact its effectiveness. The two categories considered for PES programs are market and nonmarket based (Johns et al., 2008). Market approaches use the price mechanism to create and sell units of emission reduction to other

countries. These purchases then may be used as a credit against the purchaser's own emissions, subject to country-specific regulations. The nonmarket approach refers to funds created by developed countries to reward recipient nations' efforts toward reducing deforestation and forest degradation (Ogonowski et al., 2007).

Whether a market-based or nonmarket-based approach is chosen, the goal is to reduce deforestation and forest degradation. Researchers can improve the understanding of a local populations' WTA which will provide better estimates for a proposed transfer amount. An offer too low will result in a rejection, while an offer too high will result in inefficient transfers. An estimate of the recipient countries' WTA is needed to attain these goals (Wunder, 2007). While stated preference studies have been conducted in developing countries (Whittington, 1998, 2002), WTA based studies are still absent and choice experiments have been only introduced recently(Do and Bennett, 2009). However, without support from the local population, no amount of money will be adequate to ensure the goals of the program (Pagiola and Bosquet, 2009). An adequate understanding of the local population, including their traditions and attitudes is important for success.

Section 3: Choice Experiment

The choice experiment (CE) method is based on the characteristics theory of value and then combined with random utility theory. Within the choice experiment framework respondents choose between different bundles of goods. The goods are described by their attributes, and the attributes vary in levels. For example, a choice experiment question about a forest may include an attribute describing forest size, while the levels may be 10 square

kilometers of forest cover or 11 square kilometers of forest cover. One of the attributes

necessary is a monetary measure, either in the form of willingness to pay or WTA.

Theory

For the survey used in this paper, a respondent is asked to choose between different

environmental bundles with respect to their local forest. The attributes include the ability to

harvest trees, forest size, location of forest (same distance or further away from the

respondent), and a monetary payment. The representative individual thus is assumed to have

a utility function as follows:

$$U_{in} = U(\boldsymbol{Z}_{in}, \boldsymbol{S}_n) \tag{1.1}$$

Equation 1.1 states, for any individual n, a given level of utility will be attained from

choosing the environmental bundle i. The alternative i will be selected instead of another

option j if and only if their associated utility from choice i is greater than choice j or $U_i > U_J$.

Utility from each option depends on the attributes of that option which are represented by the

variable $\boldsymbol{Z}$. The attributes in $\boldsymbol{Z}$ may be valued differently by individuals based on their

socioeconomic characteristics $\boldsymbol{S}$, which also enter the utility function. Following Hanley, et

al. (1998) the utility function can be separated into two parts. The first part is deterministic

and observable while the other is considered to be random and unobservable. This allows

equation 1.1 to be re-written as:

$$U_{in} = V(\boldsymbol{Z}_{in}, \boldsymbol{S}_n) + \varepsilon(\boldsymbol{Z}_{in}, \boldsymbol{S}_n) \tag{1.2}$$

where V represents the observable utility associated with the individuals. The variable

ε represents the unobservable characteristics that are assumed to be present and random.

Both parts of the utility function depend on the attributes of the environmental package and

socioeconomic characteristics. Given Equation 1.2, the probability that any individual n will

choose option i over option j is:

$$Prob(i|C) = Prob\{V_{in} + \varepsilon_{in} > V_{jn} + \varepsilon_{jn}, for\ all\ j\ \in C\ (the\ complete\ choice\ set\}$$

$$(1.3)$$

Equation 1.3 can be transformed into an estimable form by assuming the errors are

Gumbel-distributed, and independently and identically distributed in accordance with

McFadden (1974). This makes it possible to rewrite the probability of an individual choosing

choice i as:

$$Prob(i) = \frac{e^{\mu v_i}}{\sum_{j \epsilon C} e^{\mu v_j}}$$ (1.4)

In equation 1.4, the variable μ is a scale parameter. When it is equal to 1 the error

variable is constant. This equation can be estimated using a multinomial logit regression.

Doing this assumes that the choices made by individuals are consistent with the

Independence from Irrelevant Alternatives (IIA) property (Hanley et al., 1998). Equation 1.4

can be simplified if two characteristics are present in the choice experiment model. The first

requires the indirect utility function to be linear, which can be assumed. This assumption

limits the possibility of nonlinear variables entering the indirect utility function (such as

quadratic terms) or interacting attributes. Second, if only two choices are available (the

approach taken in the survey) to each individual, Equation 1.4 can be simplified to:

$$Prob(i) = \frac{e^{-\mu\beta'(X_{in} - X_{jn})}}{1 + e^{-\mu\beta;(X_{in} - X_{jn})}}$$ (1.5)

Equation 1.5 shows the estimable form for the CL model used in this paper. This

approach is valid because both of the assumptions (linear utility, and two choices) are present

in the construction of the survey. The CL model allows for tests of heterogeneous attitudes

by incorporating demographic variables into the analysis. This is done by interacting

demographic variables with the attributes defined in the survey (Sagebiel, 2011).

The RPL is different from the CL because of the randomness the RPL approach

forces upon the parameters (Sagebiel, 2011). This allows for parameters to vary across

respondents instead of the fixed value that would be estimated in the CL. The use of the RPL

model changes the definition of the parameters to

$$\hat{\beta}_{in} = \beta_{in} + \varphi_{in} \tag{1.6}$$

where the φ_{in} error term with the distribution of $f(\varphi_{in})$ and has a mean of 0 and a

variance of θ^2. This results in $\hat{\beta}_{in}$ as a random variable with a distribution of $f(\hat{\beta}_{in})$ and a

mean of β_n. The reduced form probability of individual n making choice i is given as

$$\widehat{Prob}(i) = \int_{\hat{\beta}_{1n}=-\infty}^{\infty} \int_{\hat{\beta}_{2n}=-\infty}^{\infty} Prob(i) f(\hat{\beta}_{1n}) f(\hat{\beta}_{2n}) df(\hat{\beta}_{1n}) df(\hat{\beta}_{2n}) \tag{1.7}$$

where

$$Prob(i) = \frac{e^{-\mu\hat{\beta}'(X_{in}-X_{jn})}}{1+e^{-\mu\hat{\beta};(X_{in}-X_{jn})}} \tag{1.8}$$

Equation 1.7 is limited to two integrals and functions of $\hat{\beta}$ to account for the two

choices available in the survey. There is no closed-form solution using the RPL approach so

that probabilities are estimated using simulations. Maximum likelihood estimation is the

most common approach. Using maximum likelihood, each respondent is assigned her own

coefficient, producing N different parameter values. The coefficient means and standard

deviations are reported for the RPL model.

The RPL model provides another method of exploring heterogeneity among the

respondents. By allowing the parameter values to vary, tests can be performed on the

significance of heterogeneity among the responses. This provides another test in addition to the standard method of including specific demographic information.

Survey Design

The CE survey approach is designed be a structured method for the generation of data. The method needs carefully designed choice sets to help reveal the preferences of the respondent. When designing a CE, careful consideration of attributes, and their levels need to be taken (Hanley et al., 1998). This includes asking relevant questions and including relevant attributes related to the policy concerns of the study. The CE survey in this research was constructed using methods described in Street et al. (2005) and Thacher et al. (2011).

The data used in the following analysis was generated within the research project "Thai Forest Valuation" during May 2012 in the district of Kam Cha i. The sample covers 492 households from the district of Kam Cha i. The sample includes the city of Kam Cha i (population 6,892), Ban Song (population 4,105), and Ban Lao (5,652) (Provincial Administration, 2012). The survey was approved by the head of the government in Kam Cha i. Teachers from the local high school were used as enumerators. Based on the pretests, optimal response rates and survey completion would be attained by hand delivering surveys and collecting them the following day. While this method is not as comprehensive as in-person interview, it costs less and results in higher response rates than mailing methods (Do and Bennett, 2009).

The CE consisted of 12 choice sets and each choice set included four attributes, three of which had three levels while one had two levels as shown in Table 1.1. The selection of attributes and levels was based on expert interviews, focus groups, pretests, and other sources

on efficient and optimal CE survey design (Burgess and Street, 2005; Street et al., 2005;

Thacher et al., 2011).

Table 1.1 Attribute Description

Variable	Description	Level	Code
ABILITY	The ability to harvest timber at their local forest	Yes	1
		No	0
FORSIZE	The size of the forest in square kilometers	+50 sq. kilometers	50
		No change	0
		-50 sq. kilometers	-50
DISTANCE	The distance to the local forest in kilometers	+2 kilometers	2
		+1 kilometer	1
		No Change	0
PAYMENT	The annual payment to the household in Thai Baht	1,000 Baht	1,000
		300 Baht	300
		0	0

The attributes and associated levels resulted in 54 possible alternatives. From these,

12 randomly constructed orthogonal arrays were chosen. These 12 choice sets then were

altered based on feedback from area experts, focus groups, and the pretests. Changes were

made to improve utility balance, and unrealistic choice sets were altered (Hanley et al.,

1998). The alternatives then were separated into two surveys, so that each respondent would

answer six choice sets, each having two alternatives.

The attribute ABILITY refers to the ability of the respondent to cut down trees

located in the nearby forest. This attribute represents the sovereignty of the local population

over their forest. If level of ABILITY displays "no", then locals are not allowed to harvest

timber and have no sovereignty over their local forest. This attribute was included to

represent the standard demands of an outside agency administering a PES system. The PES

system would be violated if trees continued to be harvested within the forest. One would

expect locals to choose to have control over their forests or not, and therefore the expected

sign for the estimated coefficient on ABILITY is positive.

The second attribute FORSIZE, represents the size of the forest. The size of the forest

in Kam Cha i is nearly 500 square kilometers. The levels for FORSIZE offered in the survey

represent a ten percent change in forest size. A positive coefficient value is expected on the

size of the forest, meaning that larger forests are preferred. The third attribute, DISTANCE,

represents a 50 to 100 percent increase in travel distance to the local forest by the survey

respondents. Being located near a forest should be positive, so the hypothesis for

DISTANCE is a negative coefficient.

The last attribute, PAYMENT, represents the transfer vehicle presented in the WTA

format. This attribute offers respondents a hypothetical annual payment from an outside PES

program. Everything else being equal, having a larger PAYMENT should result in a higher

likelihood of an alternative being chosen. Accordingly, the hypothesis is that PAYMENT has

a positive and significant coefficient.

The transfer vehicle in this design is a transfer payment between an international

program (such as REDD) to the local population. This takes the form of a standard PES

format, and therefore a WTA approach. The transfer vehicle is represented by PAYMENT.

The other attributes being considered are forested area in square kilometers (FORSIZE),

distance to forested area from their house (DISTANCE), and the ability to cut down the

forest/sovereignty over the forest (ABILITY).

This produces a choice model that would evaluate design *i* in terms of:

$$Z_i = Z(ABILITY_i, FORPLACE_i, FORSIZE_i, PAYMENT_i) \hspace{3cm} (1.9)$$

In the previous utility function, each attribute is viewed as a positive except, for distance from the forest. This fact contributes to the following naïve hypotheses:

Hypothesis one: The coefficient on ABILITY will be equal to zero. Utility theory predicts that the coefficient on ABILITY will not be equal to zero. Having the ability to cut or not cut is expected to be a positive attribute because of the larger choice set. This alternative demonstrates a desire to retain control over the forest.

$$H_0; \beta\_ABILITY = 0 \qquad H_A; \beta\_ABILITY \neq 0$$

Hypothesis two: The coefficient on FORSIZE will be equal to zero. Utility theory predicts that the coefficient on FORSIZE will be positive. Larger forests have been found to be a positive good in the extant literature (Lindhjem, 2007).This demonstrates a desire to have a larger forest.

$$H_0; \beta\_FORSIZE = 0 \qquad H_A; \beta\_FORSIZE \neq 0$$

Hypothesis three: The coefficient on DISTANCE will be equal to zero. Utility theory predicts that the coefficient on DISTANCE will be negative. Hedonic studies performed in the United States and Europe find that the people desire to live closer to the forest (Tyrväinen and Miettinen, 2000). This demonstrates a desire to live close to the forest.

$$H_0; \beta\_DISTANCE = 0 \qquad H_A; \beta\_DISTANCE \neq 0$$

Hypothesis four: The coefficient on PAYMENT will be zero. Utility theory predicts that the coefficient on PAYMENT will be positive. Everyone should like money. This demonstrates a desire to receive money from a PES program.

$$H_0; \beta\_PAYMENT = 0 \qquad H_A; \beta\_PAYMENT \neq 0$$

However, exploration of the data contributes to the development of additional hypotheses.

Data Summary Statistics

An abridged summary of the results of the survey can be found in Table 1.2. A total of 600 households were approached during the administration of the survey. Of these households, 492 included households with someone present. Of the 492 persons approached, 482 agreed to take part in the survey. From these 482 surveys, 405 were completely filled out. This results in a total response rate 67.5 percent for completed surveys and an 80.3 percent response rate overall. If households with nobody home are excluded, the response rate increases to 82.3 percent for completed surveys and a 98 percent response rate overall. Thai people are generally receptive to surveys because surveys are still relatively new in the country. Occasionally the government also will administer surveys in a similar manner where prompt response is mandatory.[4] For the analysis in the subsequent sections, only surveys that were completely filled out will be included.

Responses to the survey show the degree to which the respondents differ in their actions, attitudes, and demographics. For example, 83 percent of the respondents reported visiting the local forest during their lifetime. In the past two years, 63 percent of the respondents said they had visited the local forest. Visits to the local forest within the past two years varied from 0 to 400 with a mean of 15.47. About 51 percent of the respondents reported gathering mushrooms from the local forest, with a mean market value of 1,038 baht. Nearly two percent of the respondents said they had harvested timber in the forest during the past two years.

The responses to attitudinal questions, in the survey, regarding the forest also varied greatly[5]. The two questions most agreed upon by the respondents are the "physical beauty of

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[4] This was the explanation given by enumerators and those questioned during the focus group.
[5] This refers to the Likerd scale questions 20-27 in the survey.

the forest", and "the number of animals in the forest". Both of these questions had more than

64 percent of the respondents choose the "very important" response. The question with the

greatest variation was the "distance to the forest" question where 35 percent chose the

"neutral" response. The majority of respondents chose "very important" for the "forest size",

and "saving the forest for future generations" as well. Questions that received the highest

response rates for "somewhat important" or "neutral" include the PES monetary amount,

number of mushrooms in the forest, and amount of firewood in the forest.

Occupation, education, and income also demonstrate the differences between the

respondents. Almost 48 percent of those who took the survey said they had less than primary

school education, while 16 percent reported obtaining a bachelors degree. Income varied

between 2,500 baht per month to more than 80,000 baht per month with the majority earning

less than 12,500 baht per month.[6] The survey also obtained a fairly equal gender balance with

51 percent of the respondents being female.[7]

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[6] In June 2012 the exchange rate was 31.05 Baht to $1. So 12,500 Baht is about $400.
[7] Formal comparisons to the Thai census were not performed because of accessibility and language issues. Comparisons could be made to the greater Mukdahan province, but forest use, education, and income in Kam Cha i are very different. Area experts reviewing the data considered the statistics representative of the area.

Table 1.2 Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
Visits to the forest in the past two years	15.47	33.61	0	400
Harvested timber in forest in the past two years	0.02	0.13	0	1
Gathered mushrooms in forest past two years	0.51	0.50	0	1
Estimated market value of mushrooms	1038.35	1480.05	0	10000
Estimated market value of timber harvested	35.25	447.10	0	6000
Total estimated market value of forest products	1062.44	1690.97	0	10000
Have you ever visited the local forest?	0.83	0.38	0	1
Visited the local forest in the past two years?	0.63	0.48	0	1
Are you female?	0.51	0.50	0	1
Work full time	0.62	0.48	0	1
Homemaker	0.21	0.41	0	1
Less than primary school education	0.48	0.50	0	1
Junior high school education	0.10	0.31	0	1
High school level education	0.15	0.36	0	1
Bachelors degree	0.16	0.37	0	1
Income less than 2,500 baht per month	0.07	0.25	0	1
Between 2,500 and 5,000	0.17	0.38	0	1
Between 5,000 and 7,500	0.25	0.43	0	1
between 7,500 and 10,000	0.12	0.33	0	1
Between 10,000 and 12,500	0.10	0.31	0	1
Income more than 80,000 baht per month	0.04	0.20	0	1

Observations=482, 1,000 baht is about $32.50

Note: Select responses are included, full summary statistics are available in the appendix.

Based on the possible heterogeneity among the responses, refined hypotheses can be made. These hypotheses break the population into three groups based on the survey responses. Three types of forest visitation rates were identified. Those who had no visits to the forest in the past two years were categorized as V1 and made up 41.2 percent of the sample. Those who, on average, visited the forest more than twice a month were categorized as V3 and made up 19.8 percent of the population. Others were classified as light users and represented the base case (39 percent) . These new categories can be multiplied by ABILITY

and PAYMENT to explore the possibility that the different categories result in different behavior in the survey. This results in four new variables: ABILITY_V1, PAYMENT_V1, ABILITY_V3, PAYMENT_V3. The refined hypotheses are:

Hypothesis five: The coefficient values on ABILITY will not change among the users and nonusers of the forest. Nonusers would be expected to have a negative or not significant coefficient, and users to have a positive coefficient.

$$H_0; \beta\_ABILITY\_V1 = 0 \qquad H_A; \beta\_ABILITY\_V1 \neq 0$$

$$H_0; \beta\_ABILITY\_V3 = 0 \qquad H_A; \beta\_ABILITY\_V3 \neq 0$$

Hypothesis six: The coefficient values on PAYMENT may change among the users and nonusers of the forest. Nonusers would be expected to have a positive coefficient, and users to have a negative or not significant coefficient.

$$H_0; \beta\_PAYMENT\_V1 = 0 \qquad H_A; \beta\_PAYMENT\_V1 \neq 0$$

$$H_0; \beta\_PAYMENT\_V3 = 0 \qquad H_A; \beta\_PAYMENT\_V3 \neq 0$$

Hypothesis seven: The standard deviation on the coefficients in the RPL model will be statistically significant, demonstrating the heterogeneity among the respondents. This result would demonstrate a lack of support for a one size fits all policy.

$$H_0; S.D._{RPL} = 0 \qquad H_A; S.D._{RPL} \neq 0$$

Section 4: Results

The estimation was performed using STATA 11.2. Two models were run using CL and RPL. Models 1 and 3 include the attribute variables described in Table 1.1. Models 2 and 4 include these variables, as well as interaction variables between the forest user type and the attribute. The results for the CL models are presented in Table 1.3.

Table 1.3 Conditional Logit

VARIABLES	Model 1	Model 2
PAYMENT	5.65e-05	-5.49e-05
	(0.000)	(0.000)
ABILITY	-0.738***	-0.997***
	(0.0869)	(0.131)
FORSIZE	0.006***	0.007***
	(0.001)	(0.001)
DISTANCE	0.182***	0.175***
	(0.045)	(0.049)
ABILITY_V1		-0.769***
		(0.165)
PAYMENT_V1		0.001**
		(0.000)
ABILITY_V3		2.085***
		(0.176)
PAYMENT_V3		-9.78e-06
		(0.000)
Observations	4,860	4,860
Log-likelihood	-1645.04	-1423.93
LR Chi2	721.85	1164.06
Psuedo R2	0.180	0.290

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

All parameters are significant at the 1 percent level except for the PAYMENT

parameter and its interactions. Surprisingly, the PAYMENT coefficients were negative and

not significant for the V3 and the base groups i.e., those that visit the forest at least 2 times or

more each month. This could display their apprehension towards a foreign group having

control over their forest. The results for the PAYMENT coefficients are consistent with the

heterogeneity of the sample with the negative and positive coefficients for V1 and V3 that

are statistically different from the base group. Focusing on nonusers, we see that the

PAYMENT coefficient is positive and statistically significant. Members of the V1 group

likely respond positively to the PAYMENT attribute because they will observe no change in their behavior, because they do not use the forests.

The coefficient on the ABILITY parameter also demonstrates this heterogeneity. Those who use the forest frequently are more likely to choose the option that allows them to harvest timber. Even though those who actually harvest timber make up a small percentage of the population, a positive coefficient on ABILITY could represent a desire either to have the option to harvest timber in the future, or the desire to exclude foreign bodies from having control. Infrequent and nonusers are much more likely to choose the option not allowing harvest. This could be the result of the desire to have a beautiful forest, saving it for future generations, or as a habitat for animals. Each of these reasons received high responses of importance in the survey. Finally, the results also show that all respondents are more likely to choose options resulting in a forest that is further away, or a larger forest size.

An RPL model was estimated with all coefficients being randomly and normally distributed using the techniques reported in Hole (2007). A normal distribution was chosen because it allows for positive and negative values. This best fits the data because of the heterogeneous nature of the responses. Other distributions also can yield this result, but a normal distribution is most commonly used in the literature (Espinosa-Goded et al., 2010; Sagebiel, 2011). In fact, the only consistently positive parameter coefficient from the CL model occurred with FORSIZE. The other coefficients in the survey change in both significance and sign. The results from the RPL model are shown in Table 1.4.

Table 1.4 Random Parameter Logit

VARIABLES	Model 3: Mean	Model 3: Stand. Dev.	Model 4: Mean	Model 4: Stand. Dev.
PAYMENT	-0.000	-0.003***	-0.000	0.003***
	(0.000)	(0.001)	(0.000)	(0.001)
ABILITY	-4.747***	9.211***	-4.694***	-6.115***
	(0.665)	(1.067)	(0.870)	(0.912)
FORSIZE	0.025***	-0.029***	0.0258***	0.0368***
	(0.004)	(0.004)	(0.004)	(0.007)
DISTANCE	0.050	0.270	0.140	0.231
	(0.109)	(0.330)	(0.121)	(0.208)
ABILITY_V1			-3.073***	8.258***
			(0.965)	(1.628)
PAYMENT_V1			0.001	0.003***
			(0.001)	(0.001)
ABILITY_V3			16.840***	15.050***
			(3.032)	(3.230)
PAYMENT_V3			-0.0004	-0.005***
			(0.001)	(0.001)
Observations	4,860	4,860	4,860	4,860
Log-likelihood	-1201.34		-1116.26	
LR Chi2	887.38		615.35	

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The results of the RPL models are consistent with the CL results. The RPL models result in the same signs for every coefficient except for DISTANCE. The RPL demonstrates in two ways the heterogeneity present among the responses. Similar to the CL model, the interaction coefficients demonstrate the switching preferences towards the ABILITY coefficient. However, the coefficient on the PAYMENT variable is no longer significant.

The second demonstration of heterogeneity resides in the standard deviation estimates of the coefficients. Unlike CL, the RPL estimates a coefficient value for each individual, and the standard deviation of the coefficient is reported in addition to the mean value of the coefficient. The RPL models found every standard deviation to be statistically significant

except for DISTANCE. A close inspection of the standard deviation coefficients confirms they are larger in magnitude than the mean values of the coefficient. This suggests that coefficient signs likely change across respondents. FORSIZE demonstrates the most stable preferences, where the standard deviation coefficient is only slightly larger than the coefficient of the mean.

Given the results above, the hypotheses are revisited:

Hypothesis one: The coefficient on ABILITY will be equal to zero. Utility theory predicts that the coefficient on ABILITY will be different from zero. Having the ability to cut or not cut is expected to be a positive attribute because of the larger choice set. This alternative demonstrates a desire to retain control over the forest.

$$H_0; \beta\_ABILITY = 0 \qquad H_A; \beta\_ABILITY \neq 0$$

Hypothesis one fails to be rejected based on the results of CL Model 1. CL Model 2 also fails rejects Hypothesis one for high and medium forest users.

Hypothesis one is rejected based on results from the RPL Model 3. RPL Model 4 similarly rejects Hypothesis one for all forest users. These results demonstrate an independent attitude for high forest users toward their forest. All other categories of forest user seem indifferent to having the ability to harvest timber.

Hypothesis two: The coefficient on FORESIZE will be equal to zero. Utility theory predicts that the coefficient on FORSIZE will be positive. Larger forests have been found to be a positive good in the extant literature (Lindhjem, 2007).This demonstrates a desire to have a larger forest.

$$H_0; \beta\_FORSIZE = 0 \qquad H_A; \beta\_FORSIZE \neq 0$$

Hypothesis two is rejected in all models across the CL and RPL approaches. This demonstrates a uniform positive attitude toward forest size for the three different types of forest users.

Hypothesis three: The coefficient on DISTANCE will be equal to zero. Utility theory predicts that the coefficient on DISTANCE will be negative. Hedonic studies performed in the United States and Europe find that people desire to live closer to the forest (Tyrväinen and Miettinen, 2000). This demonstrates a desire to live close to the forest.

$$H_0; \beta\_DISTANCE = 0 \qquad\qquad H_A; \beta\_DISTANCE \neq 0$$

Hypothesis three is rejected in the CL models. Hypothesis three fails to be rejected in the RPL models. Both CL models have positive coefficients, while the RPL models lack statistical significance. This demonstrates either a desire to live further from the forest, or indifference toward the geographical location of the forest. This result is the opposite of findings in the United States and Europe. It demonstrates different attitudes towards the location of the forest. The insignificance found in the RPL models could be the result of strong heterogeneity among the respondents. Interactions on this term could explain the lack of significance.

Hypothesis four: The coefficient on PAYMENT will be zero. Utility theory predicts that the coefficient on PAYMENT will be positive. Everyone should like money. This demonstrates a desire to receive money from a PES program.

$$H_0; \beta\_PAYMENT = 0 \qquad\qquad H_A; \beta\_PAYMENT \neq 0$$

Hypothesis four fails to be rejected for all models except for nonusers in CL Model 2. This is a curious result that likely occurred due to two possible reasons. The first could be the values included in the survey instrument. The range and variation of the WTA amounts

chosen could have compelled respondents to ignore or not find the attribute significant. Respondents also could believe that actual payment would never occur, having little faith in international or governmental programs. Literature demonstrates that PES programs have trouble being implemented due to distrust or ignorance towards PES programs (Kosoy and Corbera, 2010; Kosoy et al., 2008).

Hypothesis five: The coefficient values on ABILITY will not change among the users and nonusers of the forest. Nonusers would be expected to have a negative or not significant coefficient, and users to have a positive coefficient.

$$H_0; \beta\_ABILITY\_V1 = 0 \qquad\qquad H_A; \beta\_ABILITY\_V1 \neq 0$$

$$H_0; \beta\_ABILITY\_V3 = 0 \qquad\qquad H_A; \beta\_ABILITY\_V3 \neq 0$$

Hypothesis five is rejected. Results from CL Model 2 and RPL Model 4 show that low and non-forest users have a negative and statistically significant coefficient, while high users have a positive and statistically significant coefficient. These results demonstrate the different desires of the respondents, with the ABILITY coefficient having a stronger and positive effect in their decision-making process.

Hypothesis six: The coefficient values on PAYMENT may change among the users and nonusers of the forest. Nonusers would be expected to have a positive coefficient, and users to have a negative or not significant coefficient.

$$H_0; \beta\_PAYMENT\_V1 = 0 \qquad\qquad H_A; \beta\_PAYMENT\_V1 \neq 0$$

$$H_0; \beta\_PAYMENT\_V3 = 0 \qquad\qquad H_A; \beta\_PAYMENT\_V3 \neq 0$$

Hypothesis six is rejected for all models except CL Model 2. Results from CL Model 2 show that nonusers have a positive and statistically significant coefficient while low and high users have a negative but not statistically significant coefficient. Results from RPL

Model 4 show no statistical significance, with low and high forest users having negative coefficients, and nonusers having positive coefficients. These results demonstrate an openness among nonusers for monetary transfers, while higher transfers to high users are negatively associated.

Hypothesis seven: The standard deviation on the coefficients in the RPL model will be statistically significant, demonstrating the heterogeneity among the respondents. This result would reinforce the opposition to a one size fits all policy.

$$H_0; S.D._{RPL} = 0 \qquad\qquad H_A; S.D._{RPL} \neq 0$$

Hypothesis seven fails to be rejected for every coefficient within the RPL approach except for DISTANCE. The standard deviation is statistically significant for PAYMENT, ABILITY, and FORSIZE even when interacting them with nonusers and high forest users. The statistical significance of the standard deviation coefficients demonstrates the high variability among the mean coefficient values. While the coefficient means still can be statistically significant, a statistically significant standard deviation value confirms the presence of heterogeneity even among the different classes of forest users.

Conclusion

The goal of this investigation was to explore the feasibility of a REDD-type program for Kam Cha i, Thailand. The results show that while possible, it is not a one size fits all process. The results indicate a willingness for losing access to the forest from those respondents who have little interaction with the forest now. Those who do use the forest on a frequent basis have revealed a strong preference toward keeping their sovereignty and refusing a payment from international programs.

This result may seem surprising to those who support international PES programs, but two factors should be considered. First, distrust or lack of information about international programs may cause the perceived likelihood of receiving monetary transfers for protecting the forest to be near zero. While no data is available to suggest a direct link in support of distrust of government, two qualitative judgments can be made. The first is the lack of importance of the PES program reported by respondents in the survey. The most common result was 3 (neutral) on a scale of 1 to 5. The second is feedback received from focus groups. Some participants were aware of carbon credit programs, but no one had participated in one. They conveyed skepticism toward actually receiving payment. This issue should diminish as more carbon credit programs enter the area.

Last, lack of education or a misunderstanding of the survey questions could be a contributing factor. It remains possible that respondents "guessed" or "casually responded" to the survey. This could explain both the high response rate and the presence of strong heterogeneity within the results. It also may be the result of the survey delivery method. Future research could explore the implications of choosing an in-person, drop-off, or mail delivery method.

The feasibility of a PES program being implemented in Kam Cha i was explored in this paper. This was done by administering a CE survey regarding respondent's preferences for forest characteristics. The results suggest no clear answer, but the majority of the sample demonstrated preferences toward not allowing the harvest of timber to occur in the forest. However, the heterogeneity among the results was large and therefore was explored. Two models were used to analyze the data, CL and RPL. The results from the two models

demonstrate the presence of heterogeneity within the sample- specifically, that the frequency

of forest use among the respondents plays a significant role in the choice of their responses.

Chapter 2: Temporal and Spatial Dynamic Model for Forest Management

Understanding the spatial as well as the temporal effects of forest use are important when considering forest management policy. Space can play a critical role in both local and global forest policy. By including spatially explicit ecosystem considerations, forest management policy will better consider the ecological relationships present in a forest. This chapter presents a dynamic temporal and spatial forest management model by extending the standard "cake eating" scenario. The analytical and economic implications of the model are discussed. Results indicate that lower harvest amounts occur in spatially dependent forests when compared to a spatially independent model. We consider varying levels of discount rates, spatial interdependence, and carbon credit programs, via a dynamic simulation. The results demonstrate that changes in these factors have an impact on initial harvest levels and the harvest time paths.

Introduction

Current forest management approaches have changed in the scope of objectives and criteria considered. Certain forest manager's objectives have shifted from commercial products and optimal rotation to multiuse and sustainable practices (Saha and Sundriyal, 2012; Swallow et al., 1997). The economics literature has changed the criteria present in forest management problems by introducing spatial components into the established dynamic optimization framework. With the development of geographic information systems (GIS) forest management problems can provide greater spatial accuracy by including spatial heterogeneity and interdependence. This allows easier consideration of externalities such as climate change and the impact of migration on the forest. This research introduces a model that incorporates spatial heterogeneity and interdependence into the dynamic framework, and presents simulation results demonstrating their impact on management outcomes.

The concerns over climate change and the introduction of payment for ecosystem services (PES) programs can change the approach taken by forest management problems. Some argue that it is no longer the goal to obtain an optimal "harvest" but that the goal is to keep forests standing as a form of carbon stock (Locatelli and Pedroni, 2004; Pachauri and Reisinger, 2007). With concerns over the impact of climate change occurring within the next 50 to 100 years, global forest management goals should consider these effects. Protecting wilderness areas, including natural forests, has become a goal of both local and global policy (Johns et al., 2008; Peskett and Todd, 2012). While developed countries have been able to institute and enforce protected areas, similar policies in the developing world are prone to cheating and corruption which can lead to deforestation. Instead, focus has shifted to sustainable management of forests located within developing countries where the forests are

most at risk for conversion. PES programs aim to mitigate the effect that deforestation has on climate change by compensating local users of these resources in developing countries (Peskett and Todd, 2012).

Several papers have considered the spatial aspects of forest management (Albers, 1996; Alix-Garcia, 2007; Robinson et al., 2008; Swallow et al., 1997). The approaches used by the literature have included isolating different plots of forest stands (Alix-Garcia, 2007; Swallow et al., 1997), zones (Albers, 1996; Albers and Robinson, 2007), and distance (Robinson et al., 2008). Each of these models studies the optimal management or outcomes of certain policies while incorporating temporal and spatial characteristics. However, there is an opportunity to create a generalized forest management model that analyzes the spatial dependence of forest products and sustainable uses as well as the potential effect that PES programs will have on harvesting behavior.

This chapter contributes to the forest management literature by augmenting a discrete-time resource-allocation model with spatial interdependence. A potential PES policy then is added to the model to consider the possible outcomes such a policy would create. Simulations then are performed in Excel by assuming an additively separable functional form (based on two input goods for the utility function) for the theoretical model and developing parameters for the model using estimates from survey and geography data.

This chapter is organized into the following sections. Section 2 introduces relevant literature on temporal and spatial forest management, as well as a brief discussion on marine systems management and its relationship to the forest product analysis. In Section 3, a theoretical forest management model is presented. The model is altered to consider varying levels of discount rates, spatial interdependence, and carbon credit programs which then are

simulated in Section 4. The results demonstrate that changes in these factors have an impact on both initial harvest levels and on the harvest time paths. Finally, the conclusion summarizes the chapter and describes the shortcomings of the model and opportunities for future improvement with respect to forest management research.

Section 2: Background

Common Considerations in Dynamic Resource Modeling

The literature on dynamic optimization over space and time regarding natural resources has tended to focus on two identifiable areas: marine systems and forest systems. The marine management literature has been established by Sanchirico and Wilen (1999), with numerous papers on the subject (Sanchirico and Mumby, 2009; Sanchirico et al., 2003; Sanchirico and Wilen, 2001, 2005). The forest management side began with Albers (1996) and has continued with contributions from others (Robinson et al., 2008; Swallow et al., 1997).

The spatial temporal marine management literature has focused on the presence of patches and on the amount of biomass (fish) located within these patches. There is no identification of a discrete space within this ecosystem because it depends on the patch characteristics and how they interact with each other. For example, patches are considered to have one of many spatial relationships with other patches. These levels of relationships can vary from full integration (every patch has some relationship to every other patch) to closed systems (where every patch is completely independent from the others) (Sanchirico and Wilen, 1999).

The marine management literature provided by Sanchirico and Wilen (2005) provides a good template for the spatial temporal framework. However, certain components can be simplified when applying them to the management of a public forest. First, biologically dictated patches can be modeled as forest plots that take on a discrete area. Second, growth and dispersion criteria need to be altered. Trees and forest products do not grow and disperse as fish do. Because of this, the growth and dispersion functions can be changed to accurately represent the ecology of a forest. Finally, the effort function, the authors use, can be simplified to the process of individual tree harvesting versus the complicated methods associated with regulated commercial fishing.

A different approach is taken by the spatial temporal forest management literature. This literature separates the forest areas over space, and the areas often are divided into zones based on similar characteristics. Division of a forest into zones allows for models to be constructed to fit the available data. However, problems remain with acquiring spatial interdependence estimates, as exact ecological relationships within the forest will vary based on species, time of year, climate, etc.

Albers (1996) introduces a cost-benefit framework to account for different assumed levels of spatial interdependence over a time frame of 20 years. Two of the three frameworks considered for this paper include "full-spatial", and "independent zones". The "full-spatial" approach considers the different plots of the forest and the associated interactions among the plots. The independent zones approach considers each plot independently, as if there were no spatial interactions. This is similar to the classical approach because the optimal management of each plot would be calculated independently. The final "block" approach is not considered

in this paper because plots of forest are not divided into management zones but consider a single forest manager in each scenario.

The two approaches presented in this paper demonstrate the advantages and disadvantages of the "independent" and "full spatial" frameworks. While computationally easier, and requiring less data, the "independent" model does not consider the spatial dependence of the forest. This can result in nonoptimal harvest decisions being made in each time period. Including the spatial interdependence incorporates the positive externality of a healthy forest plot into the aggregate stand. This will result in higher utility values (everything else equal). It also will introduce the spatial heterogeneity necessary to discover more accurate measures of forest value over space.

Albers and Robinson (2007) discuss the need for explicit spatial and temporal data when conducting analysis on forest management. The authors focused on a cost-benefit study for forest management in the Khao Yai National Park in Thailand. The paper combines the modeling structure created by Albers (1996) with detailed data obtained from the Khao Yai National Park. They explored the issues surrounding park management decisions, the incentives facing the local population, and the need for explicit spatial-temporal data. Because of a lack of complete spatial-temporal data, they argue for the need to create such data to improve future analysis.

The authors approach the problem by dividing the national parks into zones. Each zone has its own classification that includes developed, temporary agriculture, and preservation areas. The three zones form an ellipsoid with preserved lands in the middle, intact habitat that is used by locals for forest product gathering surrounding the middle, and then encroached and degraded areas making up the frontier. Using two scenarios, the zones

are managed independently or as one group. The independent managers do not incorporate spatial interdependence, while the group managers take this into consideration. The results show how different scales of management (with respect to space) choose to develop or preserve forested areas based on the inclusion of spatial interdependence (Albers and Robinson, 2007).

The time frame from which management decisions are made is an important consideration in testing the feasibility of a PES program. Many studies investigate the optimal rotation of a forest stock while considering carbon credit payments or their sequestration values (Asante et al., 2011; Romero et al., 1998). Once concern associated with these studies is the time frame of the analysis. While decisions regarding 60-year to 120-year rotation cycles provide meaningful results, these cycles quickly approach the time frame for the negative effects of climate change (Liski et al., 2001). These types of models would benefit from a more immediate type of modeling framework that studied the decision to harvest timber right away, similar to established land use models (Barbier and Cox, 2004).

Review of the spatial and temporal resource management literature demonstrates the complexity of the models. Researchers must choose how to model the human interaction and ecological system. With respect to forest management, human activity will induce variation across the ecology of the forest. While harvesting has direct, visible impacts on the forest, the gathering of nontimber forest products also will alter ecosystem processes. Spatial issues within the topography of the land also will cause variations in the benefits to humans. Large areas of contiguous forest provide habitats for forest products such as ant larvae and mushrooms (Loreau et al., 2003). Forest managers need to consider the spatial heterogeneity

of an area to understand the interactions between these different areas. This is a necessary condition for accurately estimating the flow of benefits to users of the forest (Albers, 1996).

Section 3: Theory

The theoretical model of temporal and spatial forest management begins with Conrad and Clark's (1987) model on natural resource use. The method of Lagrange multipliers is used in setting up this problem. First, a modified version of the natural resource problem is presented, then spatial components are added. Including multiple locations in the optimization problem will result in the same outcome as solving the single location model multiple times. Spatial interdependence is introduced, and the modified results are discussed. Finally, a PES program is modeled as a simple augmentation to the theory and the effects on the model are explored.

The problem requires some finite time period where the time step between periods is sufficiently small that no significant change in forest growth can occur, however is long enough that sustainable forest uses are able to regenerate. Based on survey evidence (discussed in the background and in Chapter 1), locals in the Kam Cha i area are able to sustainably gather many products from the local forest, including firewood, ant larvae, mushrooms, herbs, and vegetables. According to interviews with the forest service, the gathering of these forest products has minimal impact on the ecosystem and forest cover as the gathering of forest products has been occurring for generations. These sustainable uses contrast with timber harvest, which reduces forest cover and the supporting ecosystem on which the sustainable uses depend. For these reasons, let

$t = 0,1,...,T$ be the set of time periods of concern for the dynamic problem, where t=0 represents the current time period and t=T represents the last time period, which is chosen for this problem.

$i = 1,2,...,N$ be the set of spatial locations for the dynamic problem, where i=1 represents the first plot, and i=N represents the last plot.

X_{ti} be the state variable, which represents the relative forest cover. Initial values are based on the NDVI (normalized difference vegetation index).

h_{ti} be the control variable, which represents the harvest amount. Harvest decisions are assumed to occur in 0.1 increments according to the NDVI measure; however, entire plots can be harvested in a single time period.

$V = V(X_{ti}, h_{ti})$ represent the utility function or net economic return for spatial plot i in time period t. Here harvest and forest cover present positives in the utility function.

$F(X_{Ti})$ represent the values of the forest or state variable at the final time period T.

$X_{t+1,i} = X_{ti} - h_{ti}$ be the difference equation that defines the change in the forest cover from period t to period $t+1$.

β be the discount factor $(0 < \beta < 1)$

q_i be the initial forest stock for each plot

λ_{ti} be the Lagrangian multiplier, which can be interpreted as the shadow value or user cost.

The simple approach to forest management would consider a homogenous forest with a terminal time period. The following problem will be set up assuming no spatial characteristics which means that $N=1$.

$\max_{h_t} \sum_{t=0}^{T-1} \beta^t V(X_t, h_t) + \beta^T F(X_T)$

subject to $X_{t+1} = X_t - h_t$ (2.1)

with $X_0 = q$

As shown by Conrad and Clark (1987), the objective in Equation 2.1 is to maximize the sum of net values in each time period, including the final value associated with the terminal state. The maximization occurs while being subject to the difference equation that describes the change in forest cover over time. The beginning amount of forest cover is assumed to be value q. This problem is designed to find the optimal values for h_t in every time period. In doing so, the model indirectly determines the value for X_t in each time period via the difference equation.

The difference equation then can be entered into the maximization problem using the method of Lagrangian multipliers (Conrad and Clark, 1987; Swallow et al., 1997). This is done by defining the difference equation as a constraint and rewriting the problem as

$$L = \sum_{t=0}^{T-1}\{\beta^t V(X_t, h_t) + \beta^{t+1}\lambda_{t+1}(X_t - h_t - X_{t+1})\} + \beta^T F(X_T) \tag{2.2}$$

Where L represents the Lagrangian, and λ_{t+1} is the user cost or optimal value of harvesting a unit of forest versus saving the stock for the future. The necessary first-order conditions for Equation 2.2 are obtained by taking the partial derivative of the Lagrangian with respect to the control variable, the stock variable, and the Lagrangian multiplier.

$$\frac{\partial L}{\partial h_t} = \frac{\partial V(X_t, h_t)}{\partial h_t} - \beta\lambda_{t+1} = 0 \tag{2.3}$$

$$\frac{\partial L}{\partial X_t} = \frac{\partial V(X_t, h_t)}{\partial X_t} + \beta\lambda_{t+1} - \lambda_t = 0 \tag{2.4}$$

$$\frac{\partial L}{\partial \lambda_{t+1}} = X_t - h_t - X_{t+1} = 0 \tag{2.5}$$

Equation 2.3 can be rearranged into the following:

$$\frac{\partial V(X_t, h_t)}{\partial h_t} = \beta\lambda_{t+1} \tag{2.6}$$

Equation 2.6 demonstrates the marginal condition that h_t must satisfy. The equation

shows us that the marginal benefit obtained from harvesting one more unit of forest stock

must be equal to the discounted marginal user cost or to the future value of forest stock plus

the option to harvest in the future. Equation 2.4 can be rearranged to demonstrate this

equality

$$\frac{\partial V(X_t, h_t)}{\partial X_t} = -\beta \lambda_{t+1} + \lambda_t \tag{2.7}$$

Equation 2.7 is the difference equation for the Lagrange multiplier which displays

how it will change through time. Equation 2.7 shows that the marginal benefit of having one

more unit of stock is equal to the discounted marginal cost. We assume forest stock is

positively related to utility, and therefore the sign on the left side will be positive. This

requires $\lambda_t > \beta \lambda_{t+1}$ to hold in every time period, which means the current user cost (or value

of future forest stock) must be larger than the discounted user cost in the next time period.

This simple approach can be extended to allow forest stands and harvesting to differ

spatially. Assuming independence over space, this new problem with N plots can be written

as

$$L = \sum_{t=0}^{T-1} \sum_{i=1}^{N} \{\beta^t V(X_{ti}, h_{ti}) + \beta^{t+1} \lambda_{t+1,i} (X_{ti} - h_{it} - X_{t+1,i})\} + \sum_{i=1}^{N} \beta^T F(X_{Ti})$$

subject to $X_{t+1,i} = X_{ti} - h_{ti}$ \hfill (2.8)

with $X_{i0} = q_i$

Equation 2.8 allows for forest stocks, harvest rates, and the Lagrangian multiplier to

change over time and space. This provides a more general format for analyzing the optimal

harvest decision-making process. Because Equation 2.8 assumes independence across space,

it can be broken into N identical equations. Each of these equations will be equal to Equation

2.2. This makes the addition of space in Equation 2.8 an unnecessary complication. However,

the spatial independence among the forest stock can be introduced into the utility function. The addition of spatial interdependence requires each of the N plots to be considered simultaneously. This process is described below.

Spatial interdependence between biological systems can be broken into five types: fully integrated, closed, sink-source, multiple source, and spatially linear (Sanchirico and Wilen, 1999). This paper assumes a modified, fully integrated relationship based on inverse distance between locations. This also can be thought of as a two-dimensional grid, where the interdependence occurs across the grid. Areas located adjacent to one another will display higher levels of spatial interdependence. This process can be represented using the following spatially interdependent model

$$L = \sum_{t=0}^{T-1} \sum_{i=1}^{N} \{\beta^t V(\Omega_{ti}, h_{ti}) + \beta^{t+1} \lambda_{t+1,i}(X_{ti} - h_{it} - X_{t+1,i})\} + \sum_{i=1}^{N} \beta^T F(X_{Ti})$$

(2.9)

where Ω_{ti} represents $\sum_{j=1}^{N} \gamma_{ij} X_{tj}$, and γ_{ij} represents the spatial interdependence matrix that links forest plot i with forest plot j. The spatial interdependence matrix shows the spillover effect that plot i will have on plot j. The term γ_{ij} is represented as

$$\begin{bmatrix} 1 & \gamma_{12} & \cdots & \gamma_{1N} \\ \gamma_{21} & 1 & & \gamma_{2N} \\ \vdots & & \ddots & \vdots \\ \gamma_{N1} & \gamma_{N2} & \cdots & 1 \end{bmatrix}$$

(2.10)

In its simplest form, each element of γ_{ij} would be a parameter between 0 and 1 that is dependent on the distance, and ecological relationship between two forest plots. For example, plots closer to each other may have larger values of γ_{ij} while plots further away would have a smaller value or potentially a 0 value. For the unique case where $i=j$, then γ_{ij} would take on a value of 1. In the special case where γ_{ij} is a diagonal matrix of 1s, then we reproduce

Equation 2.8. Equation 2.9 demonstrates a method of accounting for spatial heterogeneity across a forest stand.

The introduction of γ_{ij} allows the model to include the spatial interdependence that occurs with sustainable forest product gathering. For example, the ecosystem for mushrooms, ant larvae, and herbs becomes stronger with larger and denser forest cover (Fukami et al., 2010; Molina and Pilz, 1998). It is possible to have mushroom fungus established underground that crosses several forest plots. The conversion of forest on one plot would have ramifications for above-ground mushroom growth in the adjacent plot (Krijger and Sevenster, 2001; Molina and Pilz, 1998). Similarly, ant colonies, other animals, and plants depend on contiguous areas of forest growth to function properly and grow (Molina and Pilz, 1998; Peay et al., 2007). For this reason, selective clear-cutting could have damaging effects on spatially interdependent ecosystems and would be captured by the γ_j parameter.

The necessary first-order conditions associated with Equation 2.9 are[8]

$$\frac{\partial L}{\partial h_{ti}} = \frac{\partial V(\Omega_{ti}, h_{ti})}{\partial h_{ti}} - \beta \lambda_{t+1,i} = 0 \tag{2.11}$$

$$\frac{\partial L}{\partial X_{ti}} = \frac{\partial V(\Omega_{ti}, h_{ti})}{\partial \Omega_{ti}} \sum_{j=1}^{N} \gamma_{ji} + \beta \lambda_{t+1,i} - \lambda_{ti} = 0 \tag{2.12}$$

$$\frac{\partial L}{\partial \lambda_{t+1,i}} = X_{ti} - h_{ti} - X_{t+1,i} = 0 \tag{2.13}$$

The important differences occur (relative to Equations 2.3 and 2.4) in Equation 2.11 and 2.12 where the new summation term has appeared. This addition increases the effect that harvesting will have on the utility function by accounting not only for the effects of harvest on the local plot, but also on the spatially dependent plots. Inclusion of these effects increases the marginal cost of harvesting. The marginal cost of harvesting now includes the value of

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[8] See appendix for derivation of Equation 2.12

future harvest, sustainable use of that plot, and the spatial interdependence effects of that forest stock on neighboring plots.

Rearranging Equations 2.11 and 2.12 provide insight

$$\frac{\partial V(\Omega_{ti}, h_{ti})}{\partial h_{ti}} = \beta \lambda_{t+1,i} \tag{2.14}$$

$$\frac{\partial V(\Omega_{ti}, h_{ti})}{\partial \Omega_{ti}} \sum_{j=1}^{N} \gamma_{ji} = -\beta \lambda_{t+1,i} + \lambda_{ti} \tag{2.15}$$

Where Equation 2.14 demonstrates the equality condition that must hold in every time period for the optimal harvest choice for the ith plot. The marginal benefit of harvesting will be equal to the discounted opportunity cost of future values, again for the ith plot.

Equation 2.15 shows how the user cost will change over time. The left side of this equation has become more complicated with the introduction of spatial interdependence. The resulting effects now depend on the degree to which the plots are interdependent. Higher values of γ_{ji} will result in a scaling up of the marginal effects, which then need to be accounted for in the difference of the user cost over time.

Finally, the model can be extended to include a PES system. This is done by including a payment based on the relative density of each forest plot over time. This would enter the equation as a constant multiplied by the forest stock variable for each plot and in each time period. This final optimization Lagrangian would take the form

$$L = \sum_{t=0}^{T-1} \sum_{i=1}^{N} \{\beta^t V(\Omega_{ti}, h_{ti}) + \beta^{t+1} \lambda_{t+1,i} (X_{ti} - h_{it} - X_{t+1,i}) + \sum_{i=1}^{N} \beta^t S(X_{ti})\} +$$

$$\beta^T \sum_{i=1}^{N} F(X_{Ti}) \, 4 \tag{2.16}$$

The necessary first-order conditions with this added subsidy payment will be

$$\frac{\partial L}{\partial h_{ti}} = \frac{\partial V(\Omega_{ti}, h_{ti})}{\partial h_{ti}} - \beta \lambda_{t+1,i} = 0 \tag{2.17}$$

$$\frac{\partial L}{\partial X_{ti}} = \frac{\partial V(\Omega_{ti}, h_{ti})}{\partial \Omega_{ti}} \sum_{j=1}^{N} \gamma_{ji} + \beta \lambda_{t+1,i} - \lambda_{ti} + S'(X_{ti}) = 0 \tag{2.18}$$

$$\frac{\partial L}{\partial \lambda_{t+1,i}} = X_{ti} - h_{ti} - X_{t+1,i} = 0 \tag{2.19}$$

Rearranging Equation 2.19 to show the time path of the Lagrange multiplier results in

$$\frac{\partial V(\Omega_{tij}, h_{ti})}{\partial \Omega_{tij}} \sum_{j=1}^{N} \gamma_{ji} + S'(X_{ti}) = -\beta \lambda_{t+1,i} + \lambda_{ti} \tag{2.20}$$

Where the addition of a PES system has a positive effect on the time path of the user cost.

Section 4: Simulations

The model is examined using a simplified ecosystem that consists of three zones (*N=3*). Including more zones is possible, but limiting it to three zones allows for analysis of many different types of spatial interdependencies while limiting computation time. This specification allows for several cases to be simulated, homogeneous forest, spatial interdependence, different discount rates, and inclusion of PES programs. The following simulations will include stylized parameter values and parameter estimates derived from the "Thai Forest Valuation" survey conducted during the summer of 2012.[9] The simulations in this study were coded and performed within Excel 2010. The results of the first two simulations demonstrate the difference in management actions when taking spatial interdependencies into account versus treating the forest as homogenous.

Various functional forms can be assigned to the utility function to explore the possible the implications of Equations 2.16.

These simulations assume an additively separable functional form

$$V(\Omega_{ti}, h_{ti}) = \Omega_{ti}{}^{a} + h_{ti}{}^{b} \tag{2.21}$$

which means that

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[9] Please see Chapter 1 for more information about the survey.

$$V(\Omega_{ti}, h_{ti}) = \sum_{j=1}^{N} \gamma_{ij} X_{tj} + h_{ti}{}^{b} \tag{2.22}$$

While the use of other functional forms is plausible, this form was used because it allows for an interior solution and well-behaved time paths for the harvest amount. Assuming the exponents to be less than one allows for diminishing returns to each of the inputs. Future research can improve on this functional form by explicitly modeling monetary gains or losses from timber, forest products, travel costs, and substitutability or complementarily among the goods.

The parameter values for the stock variable in the simulations were calibrated for forest use in Kam Cha i by using NDVI measures from the forest and by parameter estimates taken from the survey and Chapter 1. The forest was divided into three equal-sized zones to be consistent with the simulation methods. These zones were constructed based on the distance from the villages and therefore represent three distinct types of accessibility. The first zone represents the center of the forest, which was classified as being located a minimum of 1.25 km from the forest edge. The second zone represents the area surrounding the first zone, and is located between 0.50 km and 1.25 km from the forest edge. The third zone represents the area of the forest that makes up the edge of the forest up to 0.50 km within the forest. These zones each have their own average NDVI values and therefore forest quantity measures. The first zone had the highest NDVI average value of 0.45. The second zone had an average NDVI value of 0.25. The third zone had an average NDVI value of 0.15. While there is no consensus among the literature about translating NDVI measures to biomass, there are studies that attempt to correlate NDVI measures with biomass.

Boelman et al. (2003) estimate the relationship between NDVI values and biomass. While their research did not focus on tropical forests, the nonlinear relationship between

NDVI and biomass should hold. This nonlinear relationship was used to state the relationship between NDVI value and the amount of trees that would be located within each zone of the forest. The NDVI values are therefore used to seed the model. Starting values for the forest stock are 1,000 for Zone 1, 500 for Zone 2, and 300 for Zone 3. For simplicity, one unit of stock will be discussed as if it were a tree. Therefore, Zone 1 begins with 1,000 trees, Zone 2 with 500 trees, and Zone 3 with 300 trees. This allows, for comparison purposes, a fluid discussion of the effects of spatial interdependence, discount rates, and PES programs.

The amount of nontimber forest products gathered will depend on the relative value of the product and accessibility. Forest Zone 1, being furthest from the villages, will have the lowest accessibility. Zone 3 will have the highest, because it is on the edge of the forest. The relative accessibility of the different forest zones determines the utility from gathering the nontimber forest products. Additionally, nontimber forest products exhibit diminishing returns (see Equation 2.30) in each time period, but are assumed to regenerate to their prior levels each time period. This follows the qualitative research about forest foraging and prior literature on ecosystems within forests (Dickie et al., 2012). Therefore, the utility from gathering nontimber forest products is assumed to diminish. This would be the result of lower nontimber forest product density in each zone of the forest, which would increase search time associated with gathering.

The utility derived from timber harvesting follows a similar format. While less common than the gathering of nontimber forest products, timber harvesting does exist. Common practice in Kam Cha i is to cut down single trees sparingly. Because of the legal gray area, open logging or commercial logging does not exist. Timber harvesting would not

decay at the same rate[10] as gathering of nontimber forest products, but would be limited in amount due to the costs associated with transportation.

Discount rates are assumed to be positive, but relatively small. The discount rate of 0.2 percent translates to an annual rate of about 2.5 percent.

The spatial interdependence of the forest stands was created using results from the literature regarding ecosystem and forest quality. While numeric values of the interdependence do not exist, it is agreed upon that they have a nonzero value. The following simulations show the implications of introducing a spatial interdependence value, and offer a brief description of the sensitivity analysis.

Finally, for simplicity the value of the forest in the last time period is assumed to be the value of the forest products available during the last time period. This results in a use it or lose it mentality for the simulation results, but any other choice of a final value would be arbitrary and would directly impact the initial harvest levels and harvest time paths.

The first simulation is performed for reference and has no spatial interdependence using parameters described in Table 2.1. The results are presented in Figure 2.1.

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[10] Utility from timber is assumed to decay slower compared to forest products because of the abundance of timber and the traditionally low harvest levels.

First Simulation: No Spatial Interdependence

Table 2.1 Parameters for the First Simulation, no Spatial

Interdependence

Model Component	Variables	Stylized Parameters
Utility of timber	a_i	$a_1 = 0.8$
		$a_2 = 0.9$
		$a_3 = 1.0$
Utility of forest products	b_i	$b_1 = 0.4$
		$b_2 = 0.5$
		$b_3 = 0.9$
Discount rate	β	0.002
Forest amount (NDVI)	q_i	$X_1 = 1000$
		$X_2 = 500$
		$X_3 = 200$
Spatial interdependence	γ_{ij}	$\gamma_{12} = \gamma_{21} = 0.0$
		$\gamma_{13} = \gamma_{31} = 0.0$
		$\gamma_{23} = \gamma_{32} = 0.0$

Figure 2.1
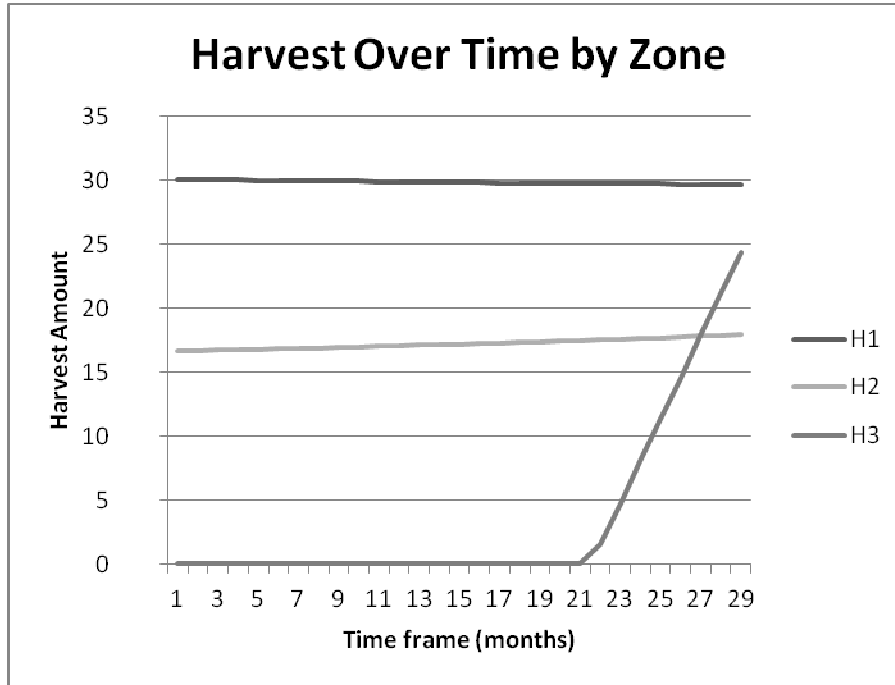
H1=Harvest from Zone 1, H2=Harvest from Zone 2, and H3=Harvest from Zone 3
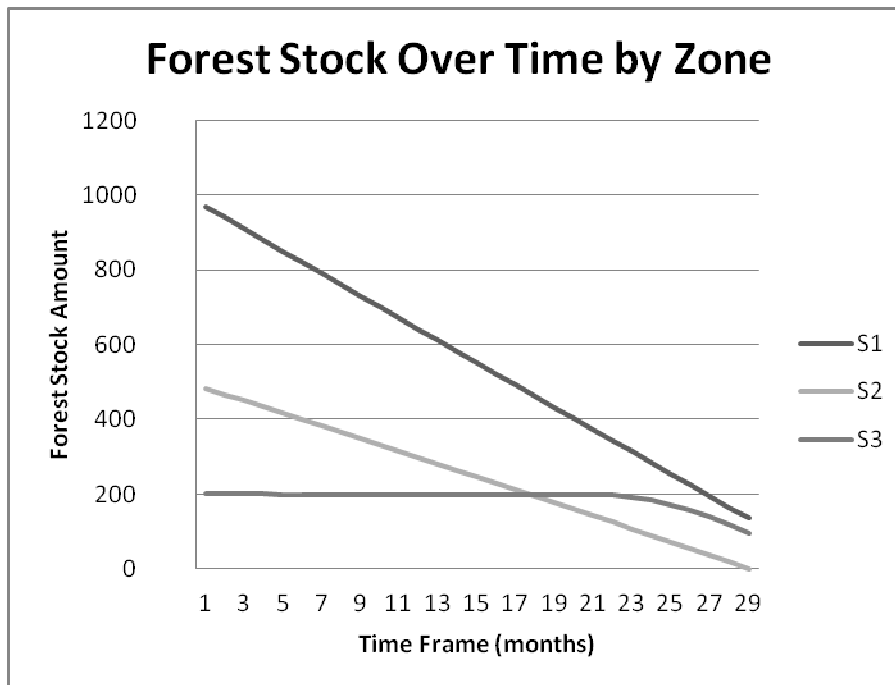
S1=Stock in Zone 1, S2=Stock in Zone 2, and S3=Stock in Zone 3

Simulation 1, the simulation without spatial interdependence, shows that consistent timber harvesting will take place in Zones 1 and 2. Zone 3 has no harvest occurring until later time periods. Simulation 1 demonstrates the need for maintaining the quality of the most accessible part of the forest (Zone 3) for the gathering of non-timber forest products. The areas of the forest that are less accessible to the local population then are set aside for timber harvesting at a relatively constant rate. The increase in harvesting for Zone 3 is due to the terminal time condition that forces marginal benefit from harvesting to be equal to the marginal benefit for nontimber forest products. Until time period 20, it is in the best interest of the local population to preserve that forest, then harvest at increasing rates until the terminal period. The implication is that with a specific management horizon, timber harvest will occur so that the marginal benefit of nontimber products will be equal to the marginal benefit of timber products in the terminal time period.

The second simulation introduces spatial interdependence, as shown by the introduction of the non-negative γ_{ij} as shown in Table 2.2 and is presented in Figure 2.2.

Second Simulation: Spatial Interdependence

Table 2.2 Parameters for the Second Simulation, Including Spatial

Interdependence

Model Component	Variables	Stylized Parameters
Utility of timber	a_i	$a_1 = 0.8$
		$a_2 = 0.9$
		$a_3 = 1.0$
Utility of forest products	b_i	$b_1 = 0.4$
		$b_2 = 0.5$
		$b_3 = 0.9$
Discount rate	β	0.002
Forest amount	q_i	$X_1 = 1000$
		$X_2 = 500$
		$X_3 = 200$
Spatial interdependence	γ_{ij}	$\gamma_{12} = \gamma_{21} = 0.5$
		$\gamma_{13} = \gamma_{31} = 0.1$
		$\gamma_{23} = \gamma_{32} = 0.2$

Figure 2.2

H1=Harvest from Zone 1, H2=Harvest from Zone 2, and H3=Harvest from Zone 3
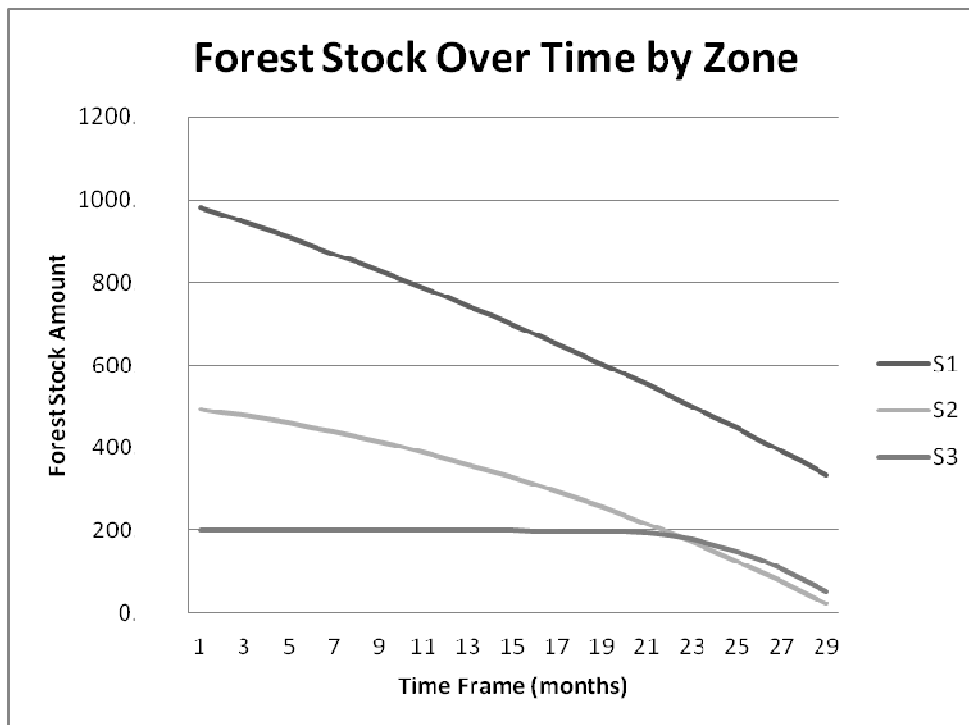
S1=Stock in Zone 1, S2=Stock in Zone 2, and S3=Stock in Zone 3

Simulation 2 shows the different results that occur when incorporating spatial interdependence. The initial harvest amount for Zone 1 is reduced by 13 trees, and Zone 2 is reduced by 6 trees. This is due to the increased benefit of keeping forest stocks around for future time periods. By conserving forests, the value of nontimber forest products rises in the spatially dependent zones. The interdependence changes the relationship between the marginal benefits of timber and nontimber products. This results in a harvest path through time that increases for Zones 1 and 2. For Zone 3, the initial harvest (in relation to Simulation 1) begins earlier. This is due to the increase in the value of forest stocks because of the inclusion of spatial interdependence. Utility optimization now considers the benefits of forest stock to both the local zone, as well as the benefit spillovers based on the spatial interdependence value. Zones 1 and 2 see increases in the rate of increase for harvesting when compared to Simulation 1. Harvest patterns for Zone 3 are similar to the results in the first simulation but have lower harvest amounts throughout.

Simulation 3 decreases the spatial interdependence values by 50 percent using parameters described in Table 2.3. The results from Simulation 3 are presented in Figure 2.3.

Third Simulation: Low Spatial Interdependence

Table 2.3 Parameters for the Second Simulation, Including Spatial Interdependence		
Model Component	Variables	Stylized Parameters
Utility of timber	a_i	$a_1 = 0.8$
		$a_2 = 0.9$
		$a_3 = 1.0$
Utility of forest products	b_i	$b_1 = 0.4$
		$b_2 = 0.5$
		$b_3 = 0.9$
Discount rate	β	0.002
Forest amount	q_i	$X_1 = 1000$
		$X_2 = 500$
		$X_3 = 200$
Spatial interdependence	γ_{ij}	$\gamma_{12} = \gamma_{21} = 0.25$
		$\gamma_{13} = \gamma_{31} = 0.05$
		$\gamma_{23} = \gamma_{32} = 0.1$

Figure 2.3
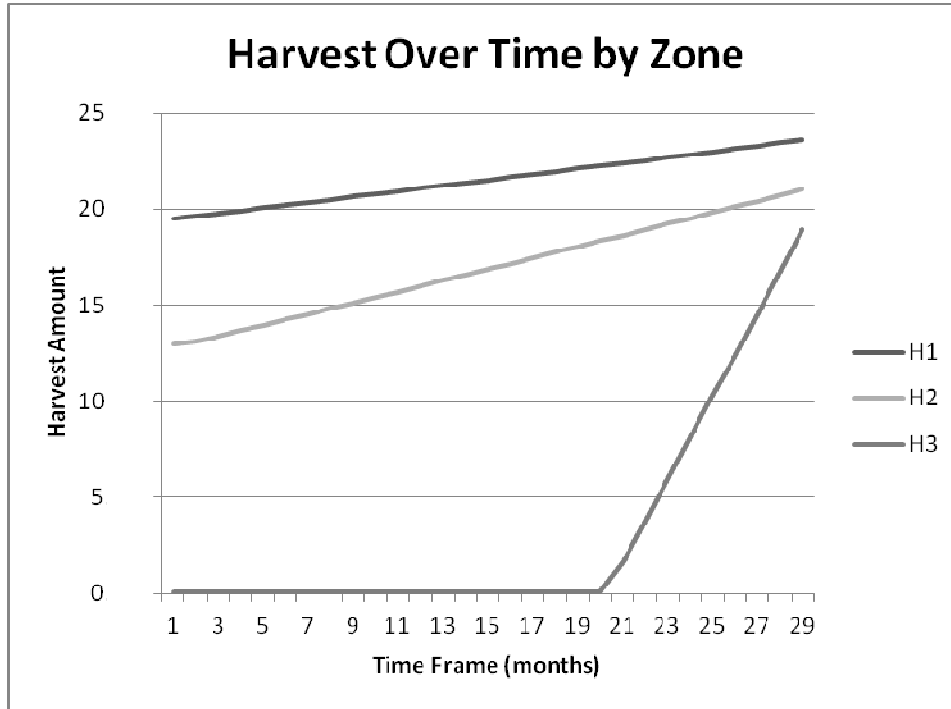
H1=Harvest from Zone 1, H2=Harvest from Zone 2, and H3=Harvest from Zone 3
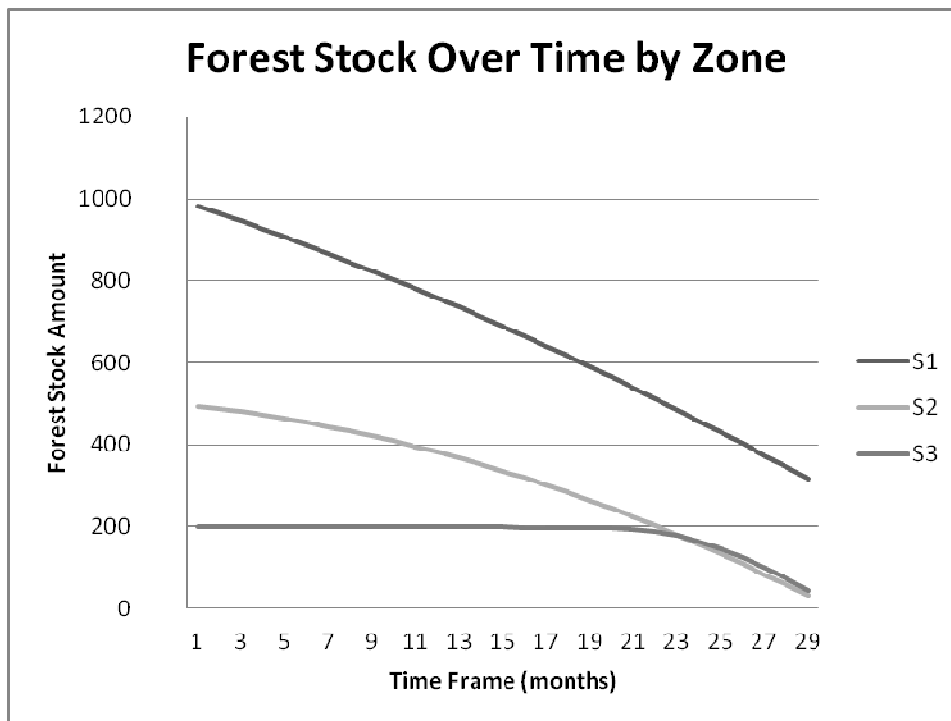
S1=Stock in Zone 1, S2=Stock in Zone 2, and S3=Stock in Zone 3

In Simulation 3, as shown in Figure 2.3, we see patterns similar to Simulation 2. That is, harvest in zones 1 and 2 is increasing over time and being delayed in Zone 3. Simulation 3, which uses lower spatial interdependence values, shows results between the prior two simulations. This occurs because the low spatial interdependence values increase the future benefits of forest stock over the base case but not as much as the high spatial interdependence values will. The initial harvest amount for Zone 1 is reduced by 10, and Zone 2 is reduced by 3 compared to the Simulation 1, but is higher than Simulation 2, which has a larger value for spatial interdependence.

The fourth simulation increases the monthly discount rate from 0.002 to 0.008 as shown in Table 2.4. The results are presented in Figure 2.4.

Fourth Simulation: Increases in the Discount Rate

Table 2.4. Parameters for the Second Simulation, Increasing the

Discount Rate

Model Component	Variables	Stylized Parameters
Utility of timber	a_i	$a_1 = 0.8$
		$a_2 = 0.9$
		$a_3 = 1.0$
Utility of forest products	b_i	$b_1 = 0.4$
		$b_2 = 0.5$
		$b_3 = 0.9$
Discount rate	β	0.008
Forest amount	q_i	$X_1 = 1000$
		$X_2 = 500$
		$X_3 = 200$
Spatial interdependence	γ_{ij}	$\gamma_{12} = \gamma_{21} = 0.5$
		$\gamma_{13} = \gamma_{31} = 0.1$
		$\gamma_{23} = \gamma_{32} = 0.2$

Figure 2.4

H1=Harvest from Zone 1, H2=Harvest from Zone 2, and H3=Harvest from Zone 3
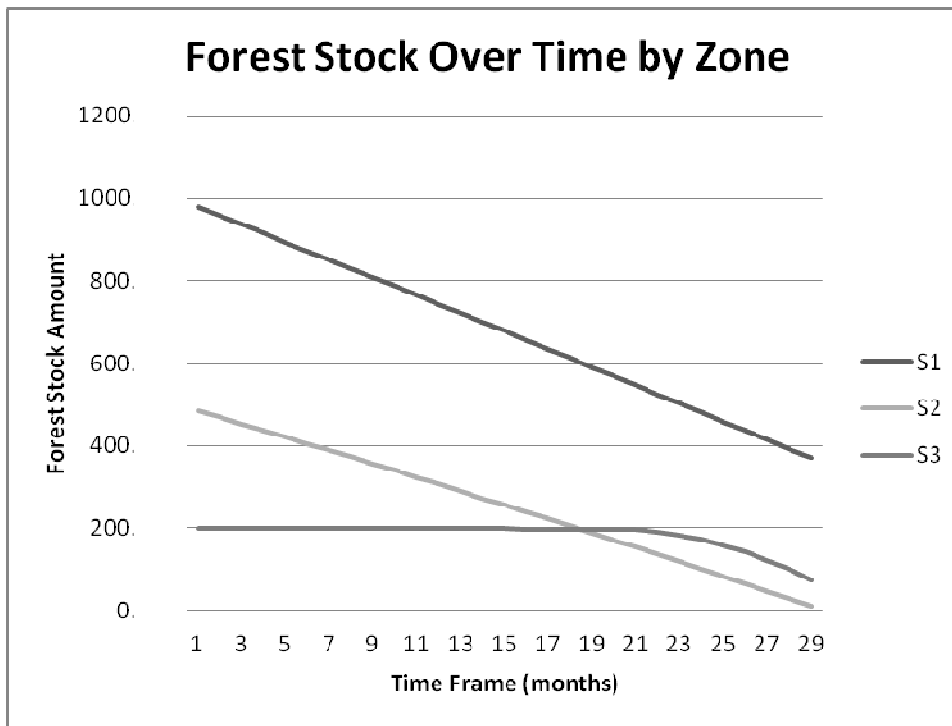
S1=Stock in Zone 1, S2=Stock in Zone 2, and S3=Stock in Zone 3

Increases in the discount rate reduce the value of the forest stocks in the future, which increases the initial harvest amounts for Zone 1 and Zone 2 by two trees. The change in harvest amount over time decreases, resulting in a more stable harvest time path because over time there is a smaller change in the marginal benefit of future forest stock. For the other simulations, the marginal benefit of the forest stock decreases rapidly as the final time period approaches. In this simulation, because the benefit of the forest stock begins much lower, the time path of the harvest rate is smoother. The change in harvest amount for Zone 3 changes substantially, with the increased discount rate motivating higher amounts of harvesting in the later time periods than the lower discount rate.

The fifth simulation introduces a PES program. The PES pays .05 for each tree existing in every time period as shown at the bottom of Table 2.4. The results are presented in Figure 2.5.

Fifth Simulation: Introduction of a PES Program

Table 2.5. Parameters for the Second Simulation, Introducing a PES program

Model Component	Variables	Stylized Parameters
Utility of timber	a_i	$a_1 = 0.8$
		$a_2 = 0.9$
		$a_3 = 1.0$
Utility of forest products	b_i	$b_1 = 0.4$
		$b_2 = 0.5$
		$b_3 = 0.9$
Discount rate	β	0.002
Forest amount	q_i	$X_1 = 1000$
		$X_2 = 500$
		$X_3 = 200$
Spatial interdependence	γ_{ij}	$\gamma_{12} = \gamma_{21} = 0.5$
		$\gamma_{13} = \gamma_{31} = 0.1$
		$\gamma_{23} = \gamma_{32} = 0.2$
PES amount per tree	S	$S=.05$

Figure 2.5
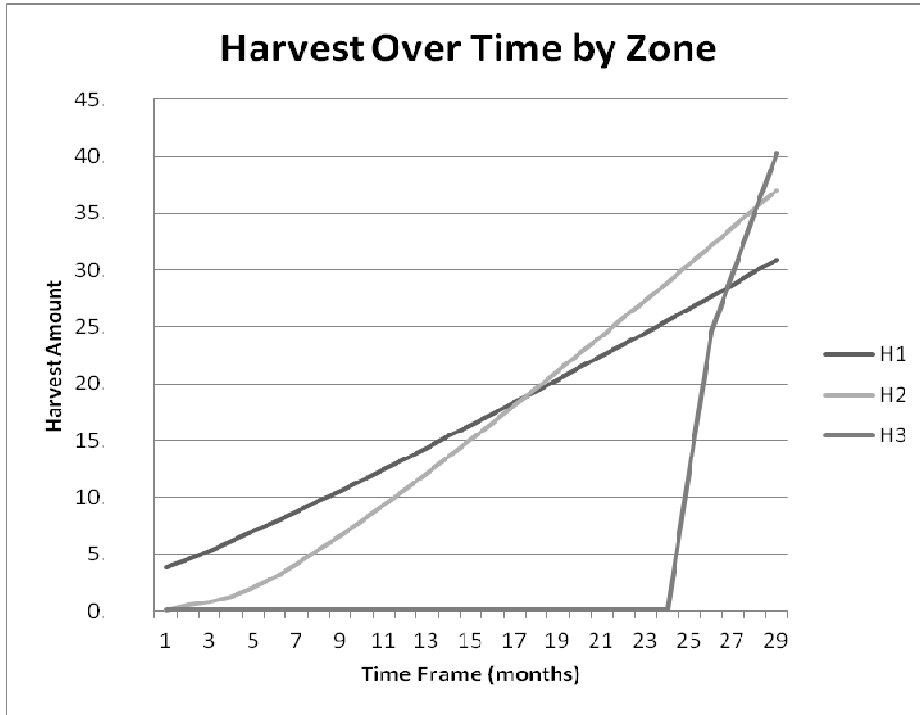
H1=Harvest from Zone 1, H2=Harvest from Zone 2, and H3=Harvest from Zone 3

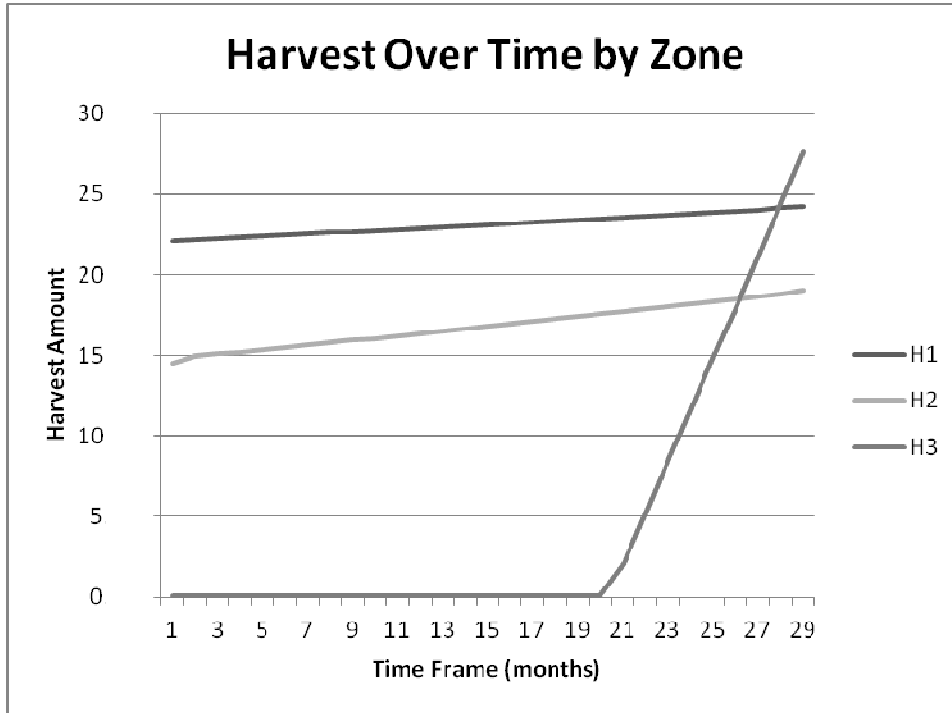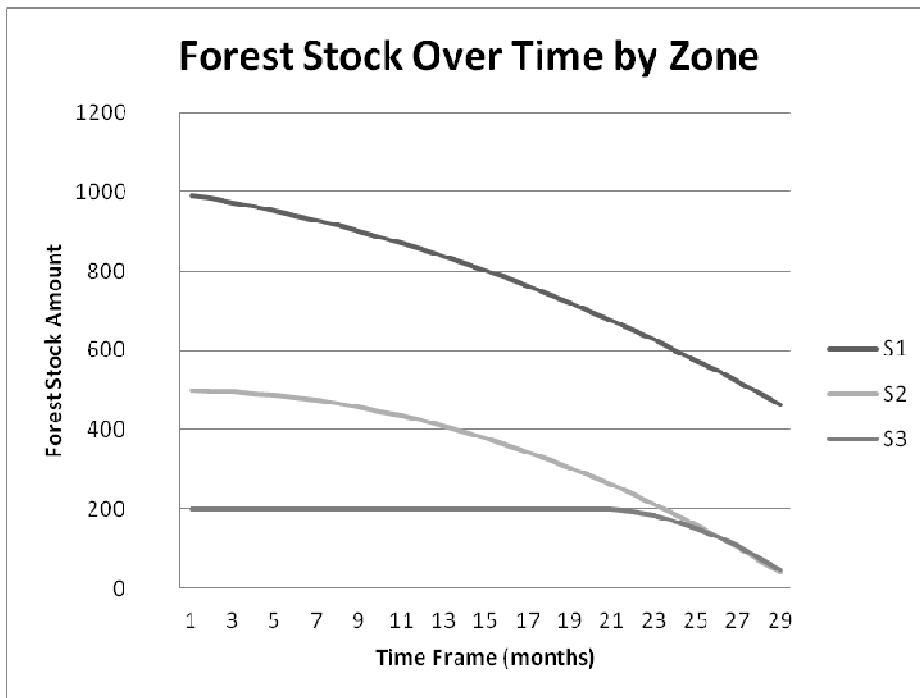S1=Stock in Zone 1, S2=Stock in Zone 2, and S3=Stock in Zone 3

The introduction of a PES program into Simulation 5 substantially reduces the initial harvest amounts because of the increased benefit derived from the forest stock. Harvest for Zone 1 decreases to four trees in the initial time period, and harvest for Zone 2 begins at zero. However, these initial low amounts are replaced later by much larger rates of increase in harvesting because of the impending final time period where future values of the forest stock will be equal to zero. The results of the simulation demonstrate the potential power of implementing an enforceable PES program because of the lower initial harvest rates. If the simulations were performed over a longer time frame the harvest time paths would be smoother, resulting in lower harvest levels for an extended period of time compared to the base case. The next simulation uses lower values for the PES programs. The different values demonstrate the sensitivity of the harvest time paths with respect to monetary amount transferred by the PES program.

The sixth simulation changes the PES program payment amount to .01 shown in Table 2.6. The results from the sixth simulation are presented in Figure 2.6.

Sixth Simulation: Introduction of a Lower Amount PES Program

Table 2.6. Parameters for the Second Simulation, Introducing a PES program

Model Component	Variables	Stylized Parameters
Utility of timber	a_i	$a_1 = 0.8$
		$a_2 = 0.9$
		$a_3 = 1.0$
Utility of forest products	b_i	$b_1 = 0.4$
		$b_2 = 0.5$
		$b_3 = 0.9$
Discount rate	β	0.002
Forest amount	q_i	$X_1 = 1000$
		$X_2 = 500$
		$X_3 = 200$
Spatial interdependence	γ_{ij}	$\gamma_{12} = \gamma_{21} = 0.5$
		$\gamma_{13} = \gamma_{31} = 0.1$
		$\gamma_{23} = \gamma_{32} = 0.2$
PES amount per tree	S	$S = .01$

Figure 2.6
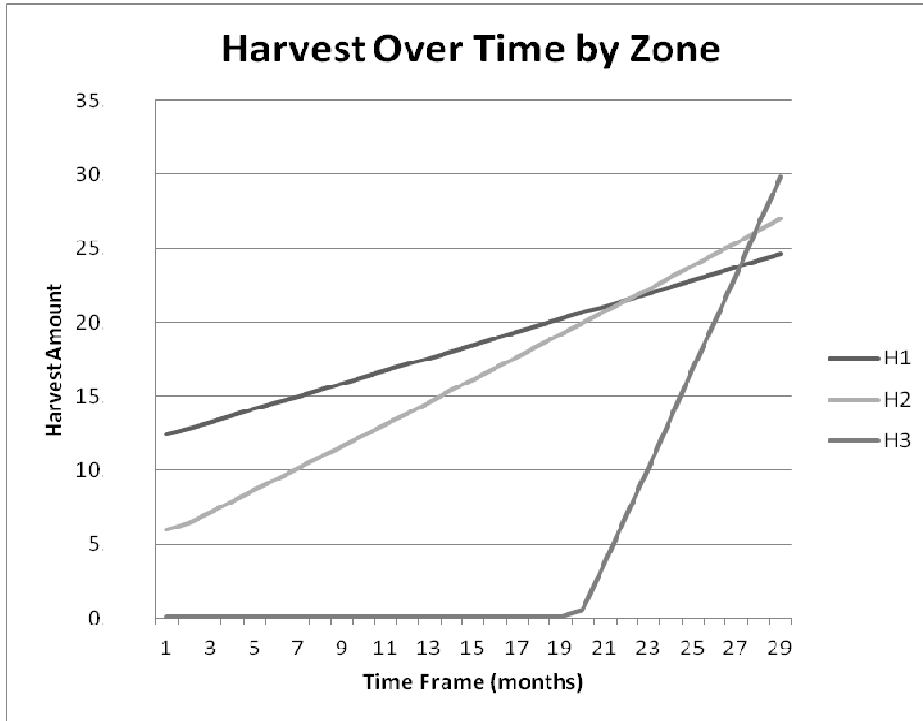
Harvest Over Time by Zone

H1=Harvest from Zone 1, H2=Harvest from Zone 2, and H3=Harvest from Zone 3,

Forest Stock Over Time by Zone
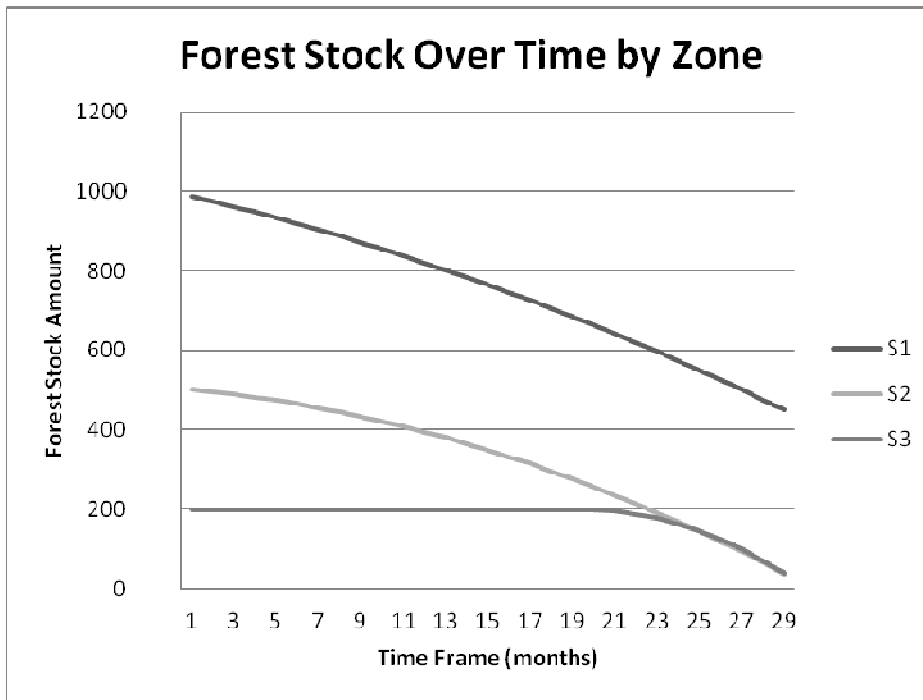
S1=Stock in Zone 1, S2=Stock in Zone 2, and S3=Stock in Zone 3,

Simulation 6 with the lower PES amount obtains harvest results between the large subsidy and no subsidy simulations. The initial harvest amounts are lower than the no-subsidy simulation but are not as low as Simulation 5 with the higher PES transfer. The rate of growth in harvest amounts is much lower than the large subsidy simulation. These results indicate there may be an optimal amount of money that a PES program could use to motivate forest users to protect their forest given a long enough time period.

The PES simulations demonstrate the ability of a PES program to lower initial harvest amounts. The model (with respect to Equation 2.16) predicts this would occur because of the increase in the marginal benefits from existing forest stock. This increases the marginal benefit from harvesting that is necessary to satisfy the optimum condition. Simulations 5 and 6 demonstrate that the payment amount in the PES program is important. The PES amounts used in the simulations were much lower than either the harvest or nontimber forest product values. However, the payment was enough to have significant effects. A PES payment of 0.05 per tree was enough to stop initial harvesting in Zone 2 and significantly reduced initial harvesting in Zone 1.

Discussion

The previous simulations show the different effects that inclusion of spatial interdependence, discount rates, and PES systems have over time on harvest choice and stock levels. The following tables provide a summary of the initial harvest levels, their rate of change (slope), and comparisons between simulations. Table 2.7 demonstrates the changes using the raw numbers, where comparisons between the actual harvest levels and rate of change in harvest level can be made. Table 2.8 Presents the results as a percentage of the

base case (Simulation 2), to explore the relative effects that changes in the parameters will

have on the harvest levels.

Table 2.7 Initial Harvest Amounts and Rate Changes (Parentheses show what time period harvesting starts, if harvest is 0 in the first time period)

Simulation	Zone 1 Initial	Zone 1 Rate	Zone 2 Initial	Zone 2 Rate	Zone 3 Initial	Zone 3 Rate
1. No spatial	30	0	16	0.2	0	2.5 (21)
2. Base	17	0.4	6	0.7	0	3 (20)
3. Low spatial	19	0.2	14	0.3	0	2 (20)
4. High discount	22	0.1	15	0.1	0	2.7 (20)
5. PES	4	0.9	0(2)	1.2	0	7 (24)
6. Low PES	13	0.4	6	0.7	0	3 (20)

Table 2.8 Harvest Amounts as Percent of Base (Simulation 2 shows percent of Simulation 1)

Simulation	Zone 1 Initial	Zone 1 Rate	Zone 2 Initial	Zone 2 Rate	Zone 3 Initial	Zone 3 Rate
1. No spatial	-	-	-	-	-	-
2. Base	56%	-	37%	350%	-	120%
3. Low spatial	111%	50%	233%	42%	-	66%
4. High discount	129%	25%	250%	14%	-	90%
5. PES	23%	225%	0%	171%	-	233%
6. Low PES	76%	100%	100%	100%	-	100%

As shown in Table 2.7, Simulation 1 shows the highest initial level of harvest compared to the other simulations. Simulation 2, the base case with spatial interdependence, results in lower initial levels of harvest but higher rate changes. Lowering the degree of spatial interdependence has the expected effected of increasing the initial harvest levels for Zones 1 and 2. Additionally, an increase in the discount rate has the expected effect of increasing harvest rates in the earlier time periods. Finally, the introduction of a PES program has the expected effect of lowering the initial harvest amounts, with higher PES transfer amounts significantly decreasing the initial harvest choices. An interesting result is the initial harvest choice for Zone 2 with the high PES transfer amount. There is no initial harvest in the first time period, and harvest choices are put off until the next time period because of the

benefits made possible by the spatial interdependence and the monetary transfers from the PES program.

Table 2.8 reports the harvest amounts as percentages of the base case. Simulation 5 produces the strongest percentage result with only 23 percent of the initial harvest amount for Zone 1. Lowering the PES amount in Simulation 6 still decreases the initial harvest amount for Zone 1 but results in identical results to the base case for the other zones. Differences in the discount rate can have a strong effect on harvest time paths as the results for Simulation 4 demonstrate.

The simulations provide general comparisons and trends across different situations. Basically, higher initial harvesting occurs with no or low spatial interdependence and delays in harvesting for Zone 3 due to the heterogeneity. But in all cases, we see harvesting to approximately the same stock level so as to equate the marginal benefit of harvesting with the marginal cost. The equality in the final time period is a result of the assumption of a fixed management horizon, which implicitly imposes a lower value on forest stock in the final time period. This certainly is a caveat to the current form of the model. By limiting the scenarios to 30 months, certain behaviors were exaggerated, including the rush to harvest timber as the end time period approaches. This limitation provides unrealistic results but demonstrates the power associated with property rights and the forest manager's perceived control. For example, if managers did fear a loss of control after 30 months, the simulations' results would be accurate.

A second caveat is the choice of the functional form for utility. Alternate approaches could introduce more goods, include prices, and incorporate explicit travel or harvesting

costs into the function. Other functional forms, including Cobb-Douglas or constant returns to scale, could be considered.

The final caveat concerns the exclusion of growth in the model. The introduction of growth for both the forest and forest products would increase the realism of the model. This also would change the dynamics of the problem over longer time frames, potentially decreasing the decision to harvest in favor of larger forest stands. Future research should use different software capable of handling these complications, along with more spatial zones, and a longer time frame.

Conclusion

This chapter considered the spatial issues associated with forest management in dynamic problems. A theoretical model integrating spatial interdependence was introduced and the implications discussed. The addition of spatial interdependence demonstrated how optimal management of a forest can change with the additional information. Interpretation of the first-order conditions shows how the optimal criteria has changed to incorporate the marginal effects of forest stock not only on the given plot but to its neighbors. Additionally, the general form of the model allows it to take different functional forms and spatial relationships depending on the types of uses and the ecology of the system in question.

To demonstrate the possible empirical implications of the model, multiple simulations were performed. The primary purpose of the simulations was to demonstrate the difference in optimal harvesting that occurs when spatial interdependence is included. The simulation results confirm that changes occur over time in both the initial harvest amounts and rate of

change for harvest amounts. The magnitude of these changes depends on the relative size of the spatial interdependence.

Finally, the impact of a PES program is introduced and the models simulated. As expected, the PES program acted to increase the value of maintaining forest stands, decreasing harvest amounts and rates. Future research should explore more sophisticated methods of populating the parameters of this model. If specific welfare functions, spatial interdependence relationships, and initial values were used the model could be used for predictive purposes and to estimate optimal PES monetary amounts.

Chapter 3: Spatially Explicit Estimation of Forest Values Using GIS

Forest valuation studies traditionally value the whole forest, or specific characteristics of a forest. Understanding the spatial aspects of forest values can improve valuation detail and therefore provide information at a finer level. Finer-level analysis demonstrates the spatial variability of data and results that are not present in aggregate analysis. This paper provides valuation estimates on spatially heterogeneous forest plots for a forest in Kam Cha i, Thailand. Monetary values of timber, mushrooms, and carbon credits are considered. The forest product values are taken from the survey conducted in Kam Cha i during the summer of 2012. Carbon credit values are obtained from prior literature. Geographic information system multicriteria evaluation (GIS-MCE) is used to combine the previous data with travel cost and vegetation cover estimates. The MCE demonstrates how to obtain spatially explicit estimations of forest values. The results for forest use and conservation values are compared, and the results of the MCE show that a majority of the forest has positive net conservation values to the local population.

Introduction

Forest management in developing countries has become a widely discussed topic. Issues including soil erosion, agriculture yields, logging, population pressure, and climate change are indirect consequences of forest management decisions (Adamowicz et al., 2004; Barbier and Burgess, 2001; Diaz-Balteiro and Romero, 2008). To understand the implications of these management decisions, researchers perform forest valuation studies. However, these studies traditionally have focused on the value of the whole forest, or a specific characteristic of a forest. Forest management decisions can be improved by allowing for spatially explicit estimation of small plots within a forest. This chapter demonstrates a method for the spatially explicit estimation of local and global values using forest product harvesting and carbon credit markets as examples.

Geographic information systems (GIS) allow incorporation of spatial variation in forest management analysis (Bateman and Lovett, 2000; Diaz-Balteiro and Romero, 2008). GIS allows users to identify spatially heterogeneous data within a specific area that can lead to improvements in the scale and accuracy of analysis (Malczewski, 2006, 2010). The study of spatial heterogeneity of forests is a growing field in natural resource economics (Albers, 1996; Alix-Garcia, 2007; Robinson et al., 2008), and the frequency of GIS in the analysis is increasing (Bateman et al., 2006; Bateman and Lovett, 2000). However, these studies tend to focus on homogenous spatial zones (Albers and Robinson, 2007) or distance measures (Bateman et al., 2006), instead of analyzing forests at a finer scale. Using GIS-MCE (multicriteria evaluation) methods, this chapter presents a novel approach to multiperspective valuation of forest resources at a scale of 30 by 30 meters.

The major trade-off in forest management is the conflicting interest between use and conservation. The decision to harvest results in the loss of future forest products or of conservation opportunities from that area. A decision to preserve maintains the benefits from the forest and allows harvest decisions to be made in the future, but users forego the benefits of harvest in the present. One approach to analyze conflicting objectives and multiple attributes is MCE (Malczewski, 2006). This method allows decision makers to include and compare different criteria to make an appropriate decision or evaluation. Additionally, MCE methods allow for the consideration of payment for ecosystem services (PES) programs as a criteria.

The introduction of the United Nation's Reduction in Emissions of Deforestation and Degradation (REDD) has prompted research into the feasibility of PES programs (Johns et al., 2008; Wendland et al., 2010). PES programs can play a crucial role in valuation analysis because carbon credit markets and Western nongovernment organizations are willing to purchase rights to carbon storage or sequestration in approved markets. Forest managers in developing countries should consider this new source of revenue in their decision making process.

GIS lends itself to analyzing the feasibility of a PES program because it allows analysis with spatial variability. This established verification process naturally leads to the use of GIS in analyzing a PES program's feasibility. By including the potential payments spatially, it is possible to identify areas where PES systems should or should not be implemented. The implementation of these programs is reliant on forest certification, which is generally performed through remote sensing (Dong et al., 2003; Ingram et al., 2005). No standard method or database is available for governments or carbon credit firms to acquire

local forest use or carbon values. Data sets must be created using information gathered from surveys and remote sensing as performed in this paper.

In this chapter, GIS-MCE methods are used to answer the following questions. What are the nontimber and timber forest product values for each 30 by 30 meter area of the forest? What are the values of each forest area for carbon credit programs? In what areas should conservation be actively promoted? The results conclude that nontimber forest products have higher monetary values than the timber forest products for every cell in the forest. The value of carbon sequestration and storage (from a PES program) shows large potential values for the forest. Finally, the results demonstrate the importance of forest access when deciding which areas of the forest should be conserved.

The rest of the chapter is structured as follows: Section 2 presents a brief background of MCE. The literature covers forest management and GIS-based MCE in particular. Section 3 introduces a new MCE approach to obtain spatially explicit forest value estimates. This valuation combines data from Landsat images and a choice experiment survey, a new approach to providing valuation estimates. Section 4 describes the results of the MCE and discusses the implications. The conclusion presents the benefits of this approach to policymakers and highlights some of the shortcomings of the approach.

Section 2: Background

GIS-MCE/MCDA

The use of multicriteria decision analysis (MCDA) and MCE is motivated by the necessity to evaluate complex scenarios that contain a number of possible objectives and criteria (Huth et al., 2004). For the purposes of this chapter, MCE is considered a subset of

MCDA as described in by Wood and Dragicevic (2007). Several examples where MCDA has been used with respect to forest management can be found in Diaz-Balteiro and Romero (Diaz-Balteiro and Romero, 2008; Huth et al., 2004, 2005; Schlaepfer et al., 2002). Including GIS into the MCDA process improves the richness of spatial data and analysis (Malczewski, 2010).

The GIS-MCDA literature has gained acceptance and grown considerably in the past 20 years. The first GIS-MCDA papers were published in the late 1980s, and significant growth in the number of published GIS-MCDA articles occurred from 1995-2000 (Malczewski, 2006). The first GIS-MCDA papers explicitly concerning forest management appeared in the early 2000s (Schlaepfer et al., 2002). There are three recognized causes for this upward trend. First, there has been a wider recognition of MCDA as an essential part of GIS. Second, specialized, easy to use and low-cost software has been introduced. Finally, the integration of MCDA components within traditional GIS software has improved the possibility of performing this type of analysis easily and promptly (Malczewski, 2006).

There are a variety of differences between the GIS-MCDA frameworks. The five general components included in GIS-based MCDA procedures according to Malczewski (1996) are: evaluation criteria, decision makers, a set of alternatives, different states of nature, and a set of outcomes. The evaluation criteria include the attributes considered to be important in the decision making process. For example, tree location, quality, and density are important criteria for forest management problems (Huth and Tietjen, 2007). Similarly, land use, distance to populations, and location of water sources are important to landfill location queries (Chang et al., 2008). The decision makers involved in the MCDA are either an individual or a group. The alternatives represent possible courses of action that may be taken

by the decision makers. The states of nature can change the way in which evaluation criteria are perceived and the implications of the implementation of certain alternatives. Finally, the set of outcomes considers all of the above information and presents the relevant conclusions and repercussions the possible actions.

GIS-MCDA has been an important tool in evaluating environmental management problems. According to Malczewski (2006) approximately 17 percent of the published articles using GIS-MCDA techniques were applied to environmental or ecological problems. Of these 55 articles, 18 dealt with scenario evaluation or resource allocation problems. The number of articles using GIS-MCDA techniques related to forest management scenarios are expected to grow (Diaz-Balteiro and Romero, 2008). This is due to the increasing concern regarding forest management's impact on greenhouse gas emissions. Discussions regarding climate change have increased in magnitude, and new approaches to analysis (both software and modeling) are becoming more common.

This chapter uses GIS-MCE because of its approach to analysis. Several attributes are combined and then weighted to arrive at the valuation measures. The MCE approach allows for the combination of weights and data to fit together. For example, total forest product values are divided up spatially and then weighted based on a number of criteria. The criteria are study area, accessibility, and quality. The tools and methods introduced with GIS provide a base of reference for the valuation as well as for the remote sensing data used in the production of the weights.

Section 3: Methodology

To characterize the value of forest areas to local users and to western carbon credit firms, two MCE models were constructed. The first combines accessibility and quality measures to measure timber and nontimber forest products for local users. Local users value forest areas in many ways including forest products, recreation, cultural, and other ecological services the forests provide. The second model estimates carbon storage and sequestration values based on biomass estimates and on carbon prices from the literature. Western carbon credit firms value forests for their ability to sequester and store carbon. These firms match companies that produce carbon with forest caretakers willing to supply carbon services. Carbon credit firms are interested in new sources of carbon storage, also known as carbon sequestration. In these scenarios land is converted to forest to increase the biomass, and therefore carbon, in or on the land (Asante et al., 2011; Gorte, 2009). Other programs, such as REDD, transfer payments to local populations to maintain their forest. This prevents the stored carbon from being released into the atmosphere through deforestation or degradation.

Four steps are performed when conducting the GIS-MCE on the study area in Kam Cha i. First, the market value for forest products was established. These are acquired from the survey conducted in Kam Cha i in the summer of 2012. Second, the forest product values are given appropriate weights based on the travel costs from the village and the NDVI weights for every plot of the forest. The travel costs are calculated by developing a friction surface and calculating minimum friction-path values for each cell using the village as a starting point. The NDVI weights are used as a proxy for forest quality and are normalized to one. Third, carbon storage and sequestration estimates are made based on prior literature and NDVI values. Finally, these two values are spatially compared to demonstrate the difference

in values, to the local population, between carbon credit-based conservation program and local use.

Application of GIS-MCE

As described in Section 2, five criteria need to be evaluated to perform the GIS-MCE for the forest area near Kam Cha i.

- The goal or a set of goals the decision maker is trying to achieve is based on the evaluation criteria. In this paper, we consider the forest product value of the forest. These values include the market price of carbon storage, carbon sequestration, timber, mushrooms, animals, and other products gathered in the forest by the surveyed population.

- The decision makers in this problem depend on the scale of the problem being considered. For example, the simplest version of the problem considers only the goals of the local population. In this scenario, the value of the forest depends on timber values, foraged product values, and carbon values, which provide only value to those who can directly benefit.

- The third condition deals with the decision alternatives, to preserve or not. Because the purpose of this paper is to discuss an improved method of employing multicriteria evaluation, this condition is not addressed, but net conservation values are presented.

- The states of nature associated with this problem include the characteristics of the study region. For example, forest size and location, roads, and distance from the villages are included in the study of the forested areas.

- Finally, the outcomes or consequences associated with each evaluation. The maps detailing the results of the MCE method are presented and discussed in the next section.

Study Area

The analysis for this paper focuses on the local forest (Phu Sritan) in the district of Kam Cha i, Thailand. The study area specifically refers to a section of the forest west of the main village. Kam Cha i is located within Mukdahan Province, in northeast Thailand.

The study area is roughly 12 by 12 kilometers, and includes the villages of Kam Cha i (population 6,892), Ban Song (population 4,105), and Ban Lao (population 5,652) (Provincial Administration, 2012). The villages are in the central and eastern parts of the Kam Cha i district. The areas to the north and east of the study area are also forested but are located closer to other populated areas. A map highlighting the study area within the district of Kam Cha i is shown in Figure 3.2. More than half of the residents in the area use the forest for firewood, mushrooms, ant larvae, herbs, and a variety of other forest products.

The summary statistics of the survey responses of foraged forest products are shown in Table 3.1. Mushrooms were gathered by more than half of the survey sample, while timber and animal products made up a much lower percentage. The mean value of products gathered was a little larger than 1,000 Baht, or approximately $31 per household.

Table 3.1

Forest Product	% Reporting	Total Value (Baht)	Mean	Std. Dev.	Min	Max
Mushrooms	51.4	515,580	1,039.5	1,473.1	0	10,000
Timber	1.6	17,013	34.3	440.9	0	6,000
Animals	1.4	6,500	13.1	191.4	0	4,000
Total	51.8	526,058	1,060.6	1,679.3	0	10,000

Number of survey responses = 496. All values reported in 2012 That Baht.

Figure 3.2 Study Area within Kam Cha i.

Kam Cha i and the Study Area
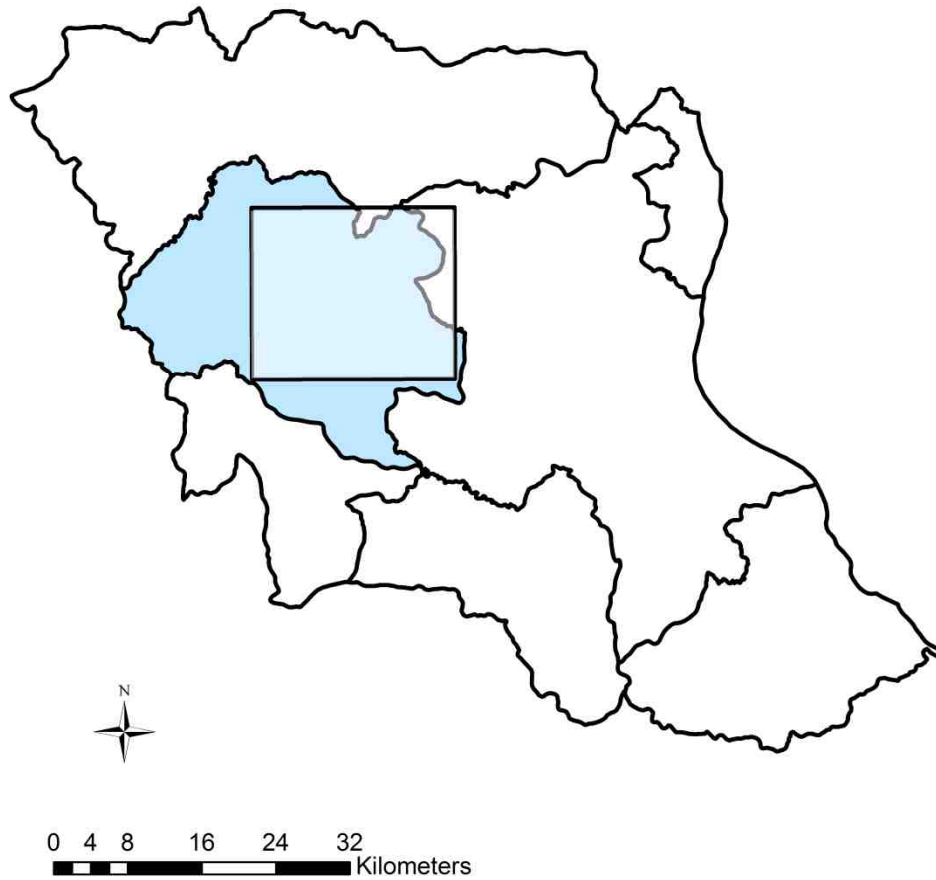
Source: Global Administration Areas, Earth Explorer, USGS.

Data

      This paper uses raster data to estimate the value of each 30 by 30 meter plot in the forest neighboring the villages in Kam Cha i. The satellite image was acquired by Landsat 5 on January 21, 2009. This specific image was used because it is the most recent Landsat image showing the Kam Cha i area with minimal cloud cover. The time of year (January) is

also the best representative of the true forest cover within the area. This is because the

moisture brought by the monsoon season (May through October) can distort the Normalized

Difference Vegetation Index (NDVI) by altering the infrared band (Weier and Herring,

1999). Additionally, during harvest season (September through November) the surrounding

rice paddies will have similar vegetation density to the forests, which could result in less

accurate measures of forest/agriculture boundary estimates (De Datta, 1981).

The Landsat image was acquired from USGS, using Earth Explorer, as a geo-

referenced TIFF format file. These files include seven mages representing the different

multispectral wavebands present in Landsat 5. The near infrared (band 4) and visible red

band (band 3) were then used to calculate an NDVI for the Kam Cha i area:

$$NDVI = \frac{(Near\ Infrared - Visible\ Red)}{(Near\ Infrared + Visible\ Red)} \qquad\qquad (3.1)$$

NDVI estimates the location and overall density of the forest biomass in 30 by 30

meter plots. The study area was limited in size to be consistent with focus group responses

regarding the actively used areas. Members of the focus group stated they generally would

enter the forest only enough to fill their quota for forest products and they rarely travel more

than 4 kilometers into the forest. This resulted in the rectangular map shown as the study area

in Figure 3.2.

Forest Values

The NDVI map was used to obtain travel cost estimates from the villages to each

forest plot. The first step in this procedure is to create a friction surface, which describes the

relative costs associated with movement across a map (Eastman, 2009). For example, roads

typically have low friction values, while mountains have high friction values. NDVI also can

be used to predict what type of land cover a given raster cell represents. The friction surface was created using the NDVI layer, which was used to classify cells as either forest or nonforest. The forested cells had an NDVI greater than 0.10 while the nonforest cells were lower. The majority of the nonforested areas are rice paddies[11], although developed areas do exist. The road network was then added to the map using hands-on digitizing. The first road network was estimated using roads visible in Google maps. Questionable roads, and access restrictions were physically checked on-site during the administration of the survey. Because some roads are private or not well traveled, only the government-maintained public roads were included. Polygons representing the developed areas (villages) then were added to the map based on land-use estimates from satellites, on the ground confirmation, and location of survey responses. Some forested areas exist outside of the public forest on private land. These areas occur on private land where landowners have grown enough trees that have a relatively high NDVI value for certain areas. These areas generally are used only by family and friends and therefore were excluded from the analysis.

The friction surface was created using the friction values shown in Table 3.2. The friction values were developed based on interviews and conversations with Kam Cha i residents and the forest experts. When using a road, it is possible for a vehicle to provide transportation to a forest frontier or to a spot within the forest. Otherwise, gathering of forest products generally occurs on foot. For this reason movement through the villages and roads is low cost, while movement through forests has a higher cost. Moving through private and agricultural areas, while possible, presents a high cost due to the terrain, and this type of travel is not common. When harvesting trees for timber or firewood, vehicles become necessary. This makes the cost of travelling in agriculture and forested areas much higher

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[11] On-site verification confirms the majority presence of rice paddies.

when gathering timber. The costs for traversing this type of terrain increase to address this change.

Table 3.2

Land Use	Parcels	Area Sq. km	% of Study Area	Travel Cost (Non-wood)	Travel Cost (Wood)
Forest	290,055	261	68.8	3	10
Private Land (Agriculture)	124,340	111	29.5	10	100
Private Land (Developed)	5,123	4.6	1.2	1	1
Roads	1,783	1.6	0.5	1	1

To determine the accessibility of the particular cell to locals a travel cost map was created using the friction surface. The costs were determined using villages as the origin, resulting in village cells having 0 value. Each cell then is assigned a cost based on the minimum sum of friction values that create a path to the target cell. For example, take three cells that are linearly adjacent with costs of 1, 2, and 3. The cost to move across the first cell is 1, while moving across the first and second cells will be 1+2 or 3. The cost of moving across all three cells is the sum of the friction amounts for each cell, or 1+2+3 or 6. The resulting raster displays the travel cost from the villages for each cell in the region. Cells

closer to the villages or roads will display lower costs, while those accessible only via agriculture and forested land will have higher costs.

The raster image with the cost data was limited by the forested study area within Kam Cha i(using Boolean constraints). The forested area was determined by NDVI values of the area, Google maps, and on-the-ground field work. This limited the cost data to only the public forested area around Kam Cha i. The inverse of the cost data for each cell then was divided by the sum of the inverses across the forest. This gave a percentage weight for the ease of access to that particular cell, shown in Equation 3.2.

$$Cost\ Percentage_i = \frac{Cost\ in\ each\ cell_i}{\sum_1^{410,000} Cost\ in\ each\ cell_i} \tag{3.2}$$

The distribution of forest product values was then estimated by multiplying the timber and non-timber market value of reported forest products by the cost percentage, shown in equation 3.3.

$$Raster\ Cell\ Value_i = Cost\ Percentage_i * Value\ of\ Forest\ Products \tag{3.3}$$

Assigning forest-use values based on accessibility shows one estimate of forest valuation. Including forest-quality would improve the realism of the values. Explicit data on forest density and quality is not available, but NDVI provides an estimate of vegetation biomass located within each cell (Dong et al., 2003; Foody and Curran, 1994; Ingram et al., 2005; Running et al., 2004). The NDVI values across cells were standardized to a mean of 1 based on the average and standard deviations. This resulted in forest density weights that could be used as a proxy for forest quality (Boelman et al., 2003; Isaev et al., 2002) and maintained the total value of the forest products gathered.

Carbon Values

The value of potential carbon credit programs also is explored. Estimation of the amount of biomass located within the forest is necessary before carbon storage estimates can be made. Brown et al. (1991) estimate the mean biomass of a Thai forest at 225 tons/ha. However, other papers researching the relationship between NDVI and biomass find much lower values (Boelman et al., 2003; Isaev et al., 2002). For this reason, conservative biomass estimates between 0 tons/ha and 70 tons/ha were made based on the NDVI ranging in values from 0 to 0.7. The biomass values then were divided by two to approximate the amount of carbon present (Kirby and Potvin, 2007).

Nelson et al. (2009) use a social (including nonmarket) carbon credit value of $43 per ton. The authors also report a low value of $12.61 per ton. A conservative carbon storage[12] value was derived by multiplying this low carbon price by the estimated carbon present in each raster cell. The results derived from Equation 3.4 are shown in Figure 3.5. Conservative values were used to account for administrative and transaction costs not included in the calculations. As discussed above, biomass and carbon credit values can vary significantly, to the point where choices could be made to influence a specific result. In this chapter, conservative values were used to show the lowest feasible value that carbon programs could have based on prior literature. Additionally, transaction and administrative costs were not included in this analysis and would be present in a real world transaction.

$$Raster\ Cell\ Value_i = 10 * NDVI_i * 12.61 \tag{3.4}$$

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[12] The low value from Nelson et al. (2009) was used for the following reasons: It is consistent with the low carbon credit prices exchanged on the open market in the European Carbon Exchange market.

The previous analyses then can be used in an MCE framework to identify plots suited for conservation. The following analysis measures the tradeoff that occurs between giving up the right to gather forest products for carbon credit payments.

Identifying the net value for conserving each forest plot requires assumptions to be made. These include extrapolating the forest product value attained from the survey sample to the relevant population, and deciding on an appropriate time frame and discount rate. A time frame of 20 years is used, consistent with real life carbon credit programs and other carbon credit analyses (Locatelli and Pedroni, 2004; McKenney et al., 2004). A discount rate of 3 percent was chosen to be comparable with Chapter 2 and the literature (Pohjola and Valsta, 2007). Nearly 16,000 people reside within the study area. The survey results identify an average of 3.88 people per household. This means that about 4,000 households are present in the study area. Responses from nearly 500 of these households were obtained. Therefore, a reasonable extrapolation of the forest product values would multiply the survey result by eight, to estimate the value attained by the entire population.

The responses from the survey were divided into an annual format and then discounted over 20 years. The sum was distributed spatially over the forest using the same methods described for the timber and nontimber value estimates. This total forest use value was subtracted from the sum of the estimated storage and sequestration values shown in Figures 3.5 and 3.6. The total storage and sequestration values were combined to demonstrate the total possible value of carbon credits within the area. While it is not typical to receive payments for both storage and sequestration, they do hold value independently, and a true carbon value would consider both uses. The resulting map spatially details the net conservation values for each plot.

Section 4: Results and Discussion

Forest Product Values

The following figures are shown using distributions of values so that each range is represented in the map. These figures display spatially explicit information useful for identifying characteristics for certain parts of the forest, including timber and nontimber values, and two types of carbon credit values. The spatial representation of the values provides forest users and policymakers with information about the location of high and low monetary values. This information can be used to understand the spatial variation of the forest, as well as to identify specific areas that are more or less important to the local population from a monetary standpoint. These valuation estimates then are combined to estimate a net conservation value, which considers all of the information. Finally, to improve clarity about the distribution of the values, a table accompanies each figure with five categories of equally spaced values. These tables provide information on the distribution of forest product values in the forest.

The first value calculated is the nontimber value. Figure 3.3 shows the distribution of nontimber values for forest.

Figure 3.3 Shows the nontimber value of the forest

Nontimber Value
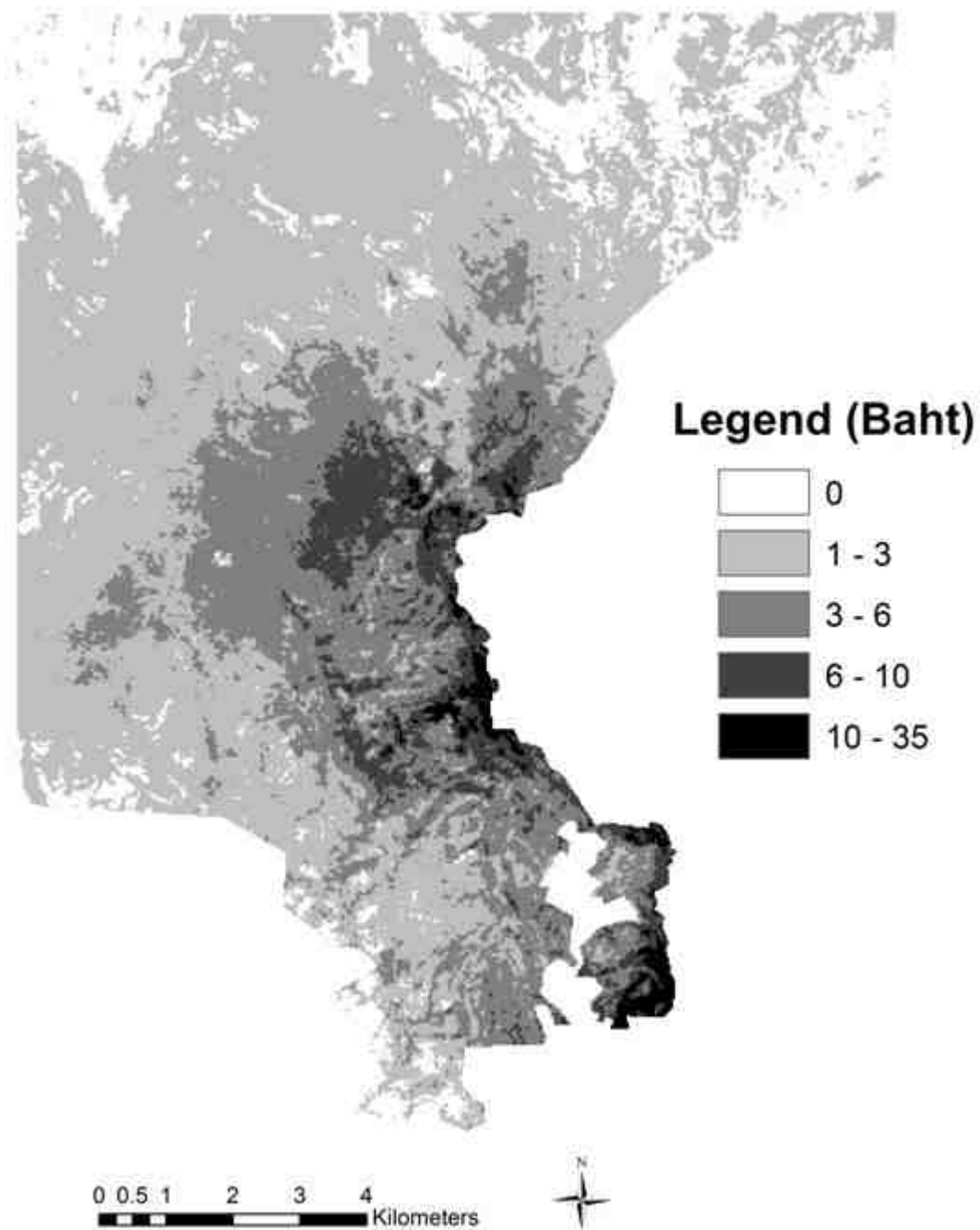
Table 3.3

Nontimber Value (Baht)

From	To	Plots	Percentage
0.01	6.96	136,524	95.11%
6.96	13.91	6,490	4.52%
13.91	20.85	479	0.33%
20.85	27.80	38	0.03%
27.80	34.75	7	0.00%

Table 3.3 shows the distribution of estimated values for nontimber forest products. The majority of the area lies in the 0 to 7 Baht range. Figure 3.3 shows that the more accessible areas show higher values and are clustered largely around the forest frontier and roads through the forest. Accessibility to the forest then is weighted by the inclusion of NDVI values. Areas west of the forest frontier and roads have larger values than more accessible areas. This is a result of the higher quality of forest in these areas.

The next valuation exercise is timber value. Figure 3.4 displays the distribution of timber values throughout the forest.

Figure 3.4 Shows the timber value of the forest

Timber Value
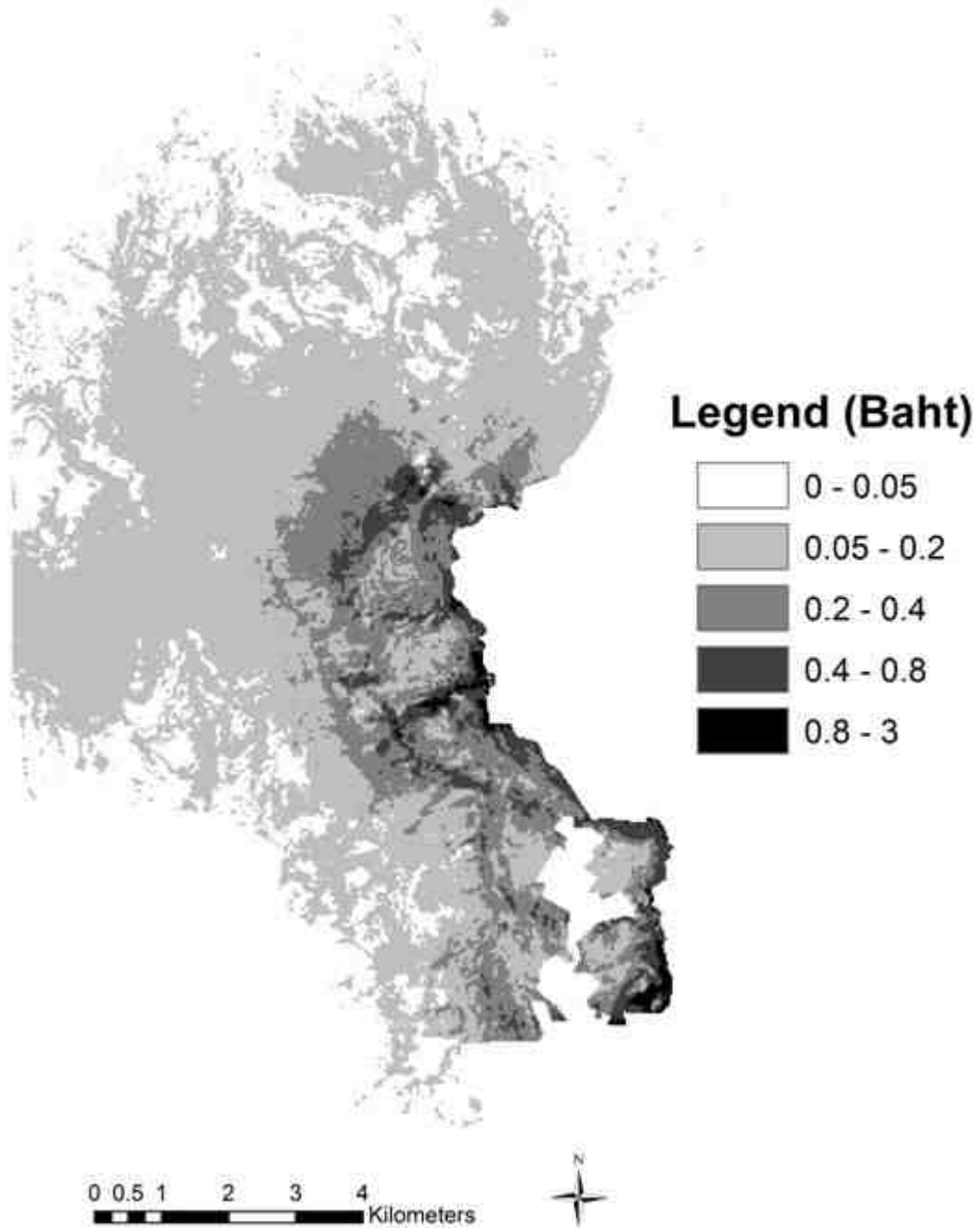
Table 3.4

Timber Value (Baht)

From	To		Plots	Percentage
0	0.5		139,093	98.31%
0.5	1.1		2,210	1.56%
1.1	1.6		165	0.12%
1.6	2.1		11	0.01%
2.1	2.7		5	0.00%

Table 3.4 shows the distribution of estimated timber values. Low values are the result of three factors. First, timber harvesting represents a very low forest product value as reported in the surveys. This could be a result of low timber harvesting amounts, confusion, or respondents lying about actual timber harvesting. Second, access to the forest is a significant factor in determining where timber harvesting will occur. Only plots near the forest frontier or near roads will be highly accessible. This results in quickly diminishing values from these accessible areas. Finally, low NDVI values near the accessible regions lowers the value further. Possibly because of the accessibility of the forest in these regions, the quality proxy is lower than in other less accessible regions.

Comparisons of Figure 3.3 and 3.4 demonstrate the difference in values between timber and nontimber values. Local gathering of non-timber products generally is considered a sustainable forest use. Prior literature has studied the impact that forest product foraging has on the ecosystem. Although incentivized commercial extraction of nontimber products can degrade forests and lower incomes for poorer users (Arnold and Perez, 2001), moderate

use from local populations has been shown to have little impact on forest health (Ticktin, 2004). The location of high timber values specifically shows areas that are at high risk for degradation. These areas are prime targets for conservation policies and regulations.

Carbon Storage and Sequestration Values

This paper also considers two types--storage and sequestration--of carbon credit programs and their values. The first considers the current carbon storage value based on NDVI values. Programs such as REDD transfer money to local populations to maintain their current forests and to not degrade them. The second type considers carbon sequestration. Several carbon credit programs offer to buy rights to the carbon that is sequestered by the creation of new, or improved forests. The two types of programs are similar in that both incentivize the creation or protection of forest biomass. They differ by creating an incentive to either protect a created forest, or create a new forest.

The first carbon value map displayed is the carbon storage value. The results from this valuation exercise are displayed in Figure 3.5.

Figure 3.5 Shows the current carbon storage value of the forest

Carbon Storage Value

Legend (Baht)

	84 - 100
	100 - 150
	150 - 200
	200 - 260
	260 - 430

0 0.5 1   2   3   4
Kilometers
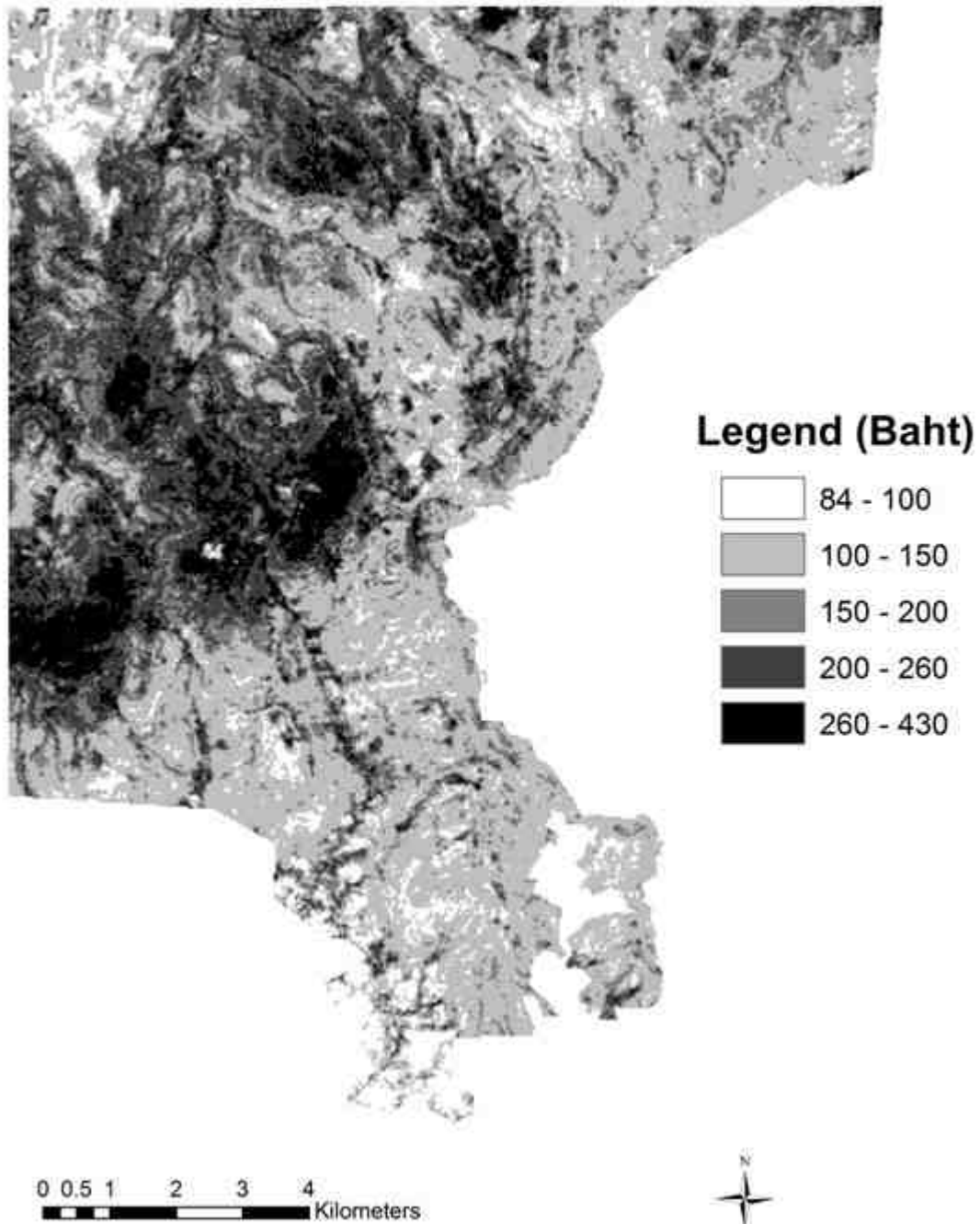
Table 3.5

Carbon Storage Values (Baht)

From	To	Plots	Percentage
84	151	70,558	49.14%
151	219	42,276	29.45%
219	286	25,525	17.78%
286	353	4,777	3.33%
353	421	439	0.31%

Table 3.5 shows the distribution of values for carbon storage. The majority of the

plots are low, value signifying the magnitude of degradation within the forest. However, a

significant portion of the plots ranges from values of 150 to 286. The individual plot values

may seem low, but this is due to the finer scale of the analysis. Most studies report higher

forest values because the values are associated with larger areas and are reported for forests

as a whole instead of value divided by area. The total value would be the market value of the

carbon stored in the forest that could be transferred by a REDD-type program to prevent

deforesting for degradation.

Most of the opportunity in carbon credit programs resides in carbon sequestration.

Because the forested area is established, no new forests can be created. The degraded forests,

however, may be improved. By allowing the current forested area to mature, the biomass,

and therefore carbon, would increase. Figure 3.6 shows the possible carbon sequestration

values if all forest plots were allowed to mature to an NDVI value of 0.7, which can be

considered the saturation point for biomass (Boelman et al., 2003). The maximum NDVI value for the study area was 0.64, even for the mature plots located in the center of the forest. For the previous two reasons, an NDVI value of 0.7 was used to determine the maximum biomass attainable for a given plot in the study area.

Figure 3.6 Shows the possible carbon sequestration value if forests are allowed to mature.

Carbon Sequestration Value
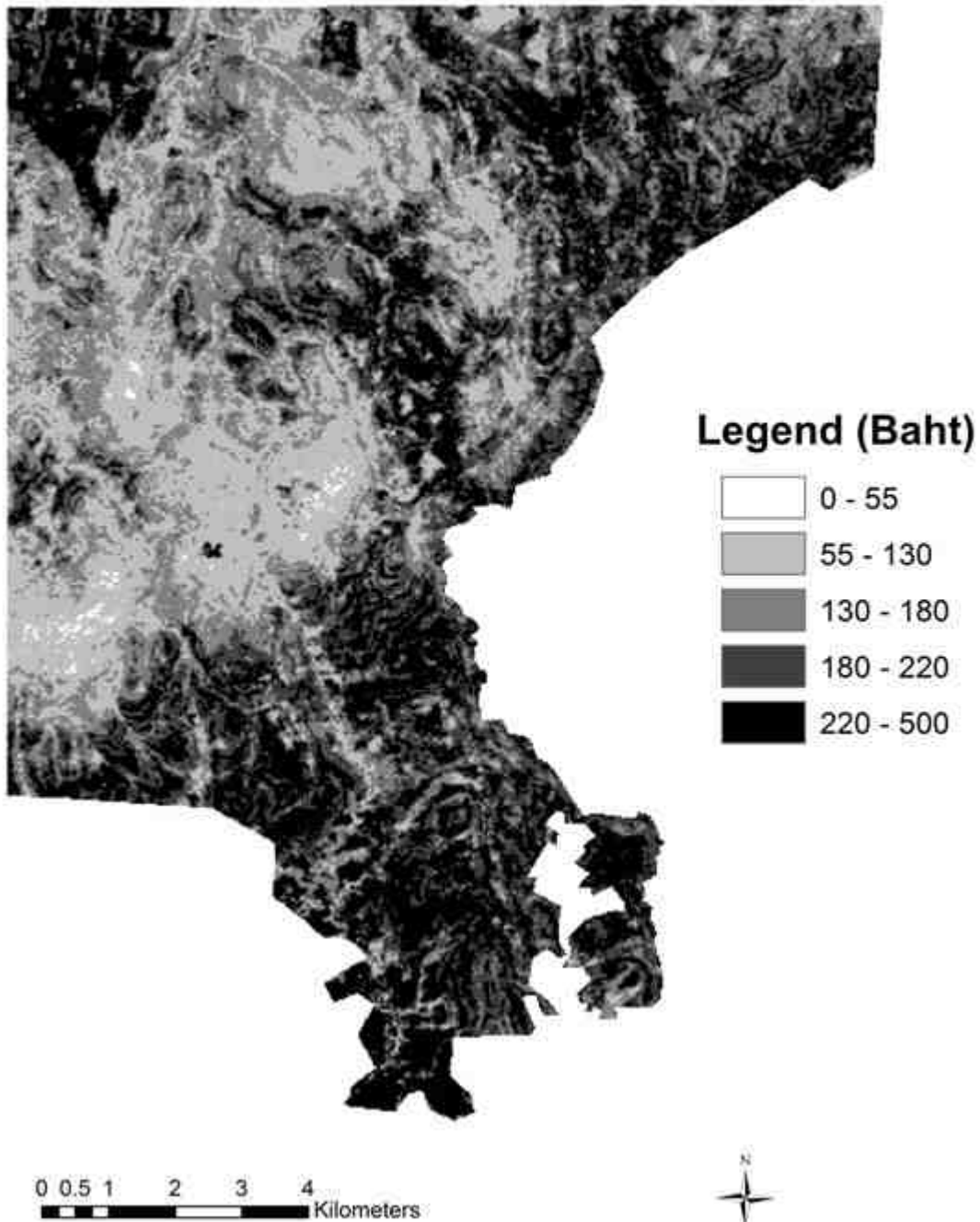
Table 3.6

Carbon Credit (Baht)

From	To	Plots	Percentage
0	183	7,570	5.27%
183	366	73,050	50.88%
366	550	62,750	43.70%
550	733	195	0.14%
733	917	16	0.01%

Table 3.6 shows the distribution of carbon sequestration values. The majority of the values fall in the 183 to 550 range. This represents an opportunity for locals to sell carbon credits to improve the quality of the local forest. By setting aside these areas for conservation, the forest would mature and store more biomass. This would result in carbon sequestration, which then could be sold on the carbon credit market.

The carbon storage and carbon sequestration values are displayed in Figures 3.5 and 3.6. Potential carbon storage values give an estimate to policymakers interested in developing a PES program. PES programs can pay locals for the carbon already stored in the higher quality areas of the forest. If forested areas are successfully conserved, this will result in fewer greenhouse gasses entering the atmosphere. Alternatively, traditional carbon credit programs look for new sources of carbon sequestration. The degraded forests located in the southern and northwestern areas could be protected and allowed to mature. The growth in biomass would lead to increases in carbon sequestration. This newly sequestered carbon

could be purchased on open exchanges in developing countries to offset carbon created abroad.

The monetary estimates shown are conservative estimates of the willingness to pay for carbon offsets. No estimates were made on the local's willingness to accept a given amount. For a PES or carbon credit program to succeed, communication between the international agencies and the Kam Cha i government would need to take place. Cooperation with the local populations also would be necessary. However, based on the comparison between carbon storage and sequestration values and the forest product values, there seems to be potential for a mutually beneficial agreement. Chapter 1 demonstrated the difference in attitudes of the local population with respect to a PES program. Further investments in education about sustainable nontimber forest product foraging and in education about the potential to improve forest quality while selling carbon credits may help reverse this trend.

One should use caution when observing these estimates. They ignore many uncertainties with respect to time. They assume that forest product yields will be constant, no population growth, no new government or institutional rules, no shocks to forest cover (clear cutting/flooding/fire), and that the climate remains stable. There also is potential for large price variation in carbon credits or forest products, which could change the results. Finally, creating carbon mass estimates from remote sensing is a developing field. The procedure used in this chapter attempts to be conservative with every assumption, but it is possible for variations to exist without on-the-ground confirmation.

The results from the net conservation value exercise are shown in Figure 3.7.

Figure 3.7 Net Conservation Values

Net Conservation Value

Legend (Baht)

High : 1426.99

Low : -1358.04

0 0.5 1 2 3 4
Kilometers
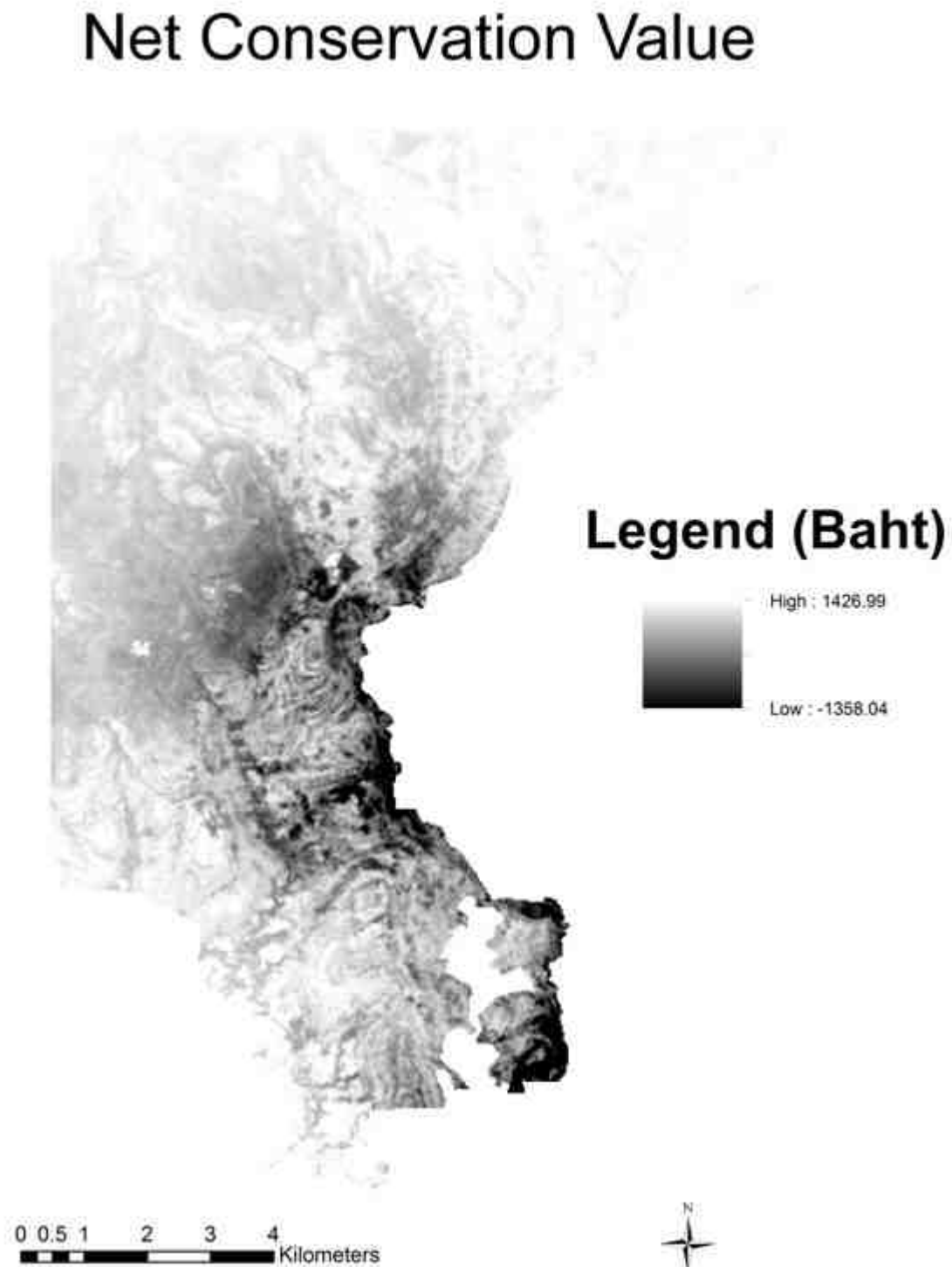
The results show that the majority of the forest has a positive net conservation value,

but areas most accessible to the villages have negative net values. These results demonstrate

the potential welfare gains to be made from implementing a PES type program within the area. However, the presence of areas where the net conservation value is negative should caution policymakers. These areas should not be conserved if total welfare measures are the primary consideration. The fact that negative net conservation values exist demonstrates the importance of the results in Chapter 1. Identifying these areas, and allowing sections of the forest to remain accessible to the local population are critical if success of the PES program is the goal.

While the net conservation calculations demonstrate the value of a PES program, an important consideration is how to implement it. As discussed in Chapter 1, the Thai national government has failed to restrict entrance into the forest. If a PES program is to be successful, it will have to be done in conjunction with the local population within Kam Cha i. One size fits all policies targeting the whole forest or the entire population have little chance of success (Corbera et al., 2011; Pagiola and Bosquet, 2009). Designating accessible vs. nonaccessible areas may help return parts of the forest to mature and grow. However, there will always be the incentive to cheat when gathering forest products. This means that enforcement mechanisms will play an important role, and transparency of these mechanisms will be important for compliance.

5. Conclusion

This chapter has introduced a novel method of accounting for spatial heterogeneity when valuing a forest. By using Landsat images, individual forest plot values can be estimated at a micro scale of 30 by 30 meters. By surveying a sample of the population from Kam Cha i, the market value of forest products attained every two years was acquired. These

values were then spread over the local forest using two conditions. First, estimating surface friction values and calculating travel costs gave us an accessibility weight. Second, the vegetation cover estimates allowed for the calculation of a forest quality proxy. These two conditions then were used to estimate where the forest products were most likely to be gathered and therefore provided a spatially explicit representation of the forest value by plot.

The increased accessibility of GIS to nongeographers has improved the ability of economists to incorporate spatial components into their analysis. This chapter demonstrates the power of combining economic survey methods with GIS-MCE. The resulting figures display the distribution of forest product values and highlight at-risk areas. This provides policymakers with immediate information about the forest. Forest managers and PES program administrators can use these maps when considering policies. The use of GIS also allows researchers to incorporate new data sources, including satellite image data.

The benefits of including a remote sensing-based measure of vegetation health are twofold. First, the forest value estimates are improved by the introduction of NDVI. While accessibility is of primary importance, low quality will significantly lower the presence of nontimber values but also will increase the sequestration potential. This is most apparent in the changes between Figures 3.1 and 3.3 in the southern area. While accessibility is relatively high in the southern area, the low quality measures presented by the NDVI negate the high accessibility value. Inclusion of NDVI in the analysis simultaneously identifies high quality areas that are also of highest value to the local population.

Second, areas of low-quality forest can be identified by policymakers as possible targets for reforestation or conservation efforts. These locations are prime candidates for carbon credit programs interested in increasing forest area or quality. The potential gain from

future carbon storage would increase current payments to reforest these sites. However, in the current time period, these areas offer less value for nontimber use and programs such as REDD that promote sustaining current forest cover. This makes them prime candidates for conservation and carbon sequestration programs. The combination of the relatively low value they offer in nontimber forest products would increase in value from a carbon credit program. At the end of such a program, the high quality mature forests then would produce more nontimber forest products.

The results of this chapter demonstrate the trade-offs that occur between conservation and local use at a more micro scale, which allows for spatial variation. These trade-offs were estimated using survey data, satellite imagery, and estimates from the literature regarding carbon values. The figure displaying the net conservation values highlights the importance of this research in implementing PES programs. No project can be universally applied successfully. Information about local practices and attitudes needs to be considered. However, if successful collaboration is possible, the results show that total welfare can be increased with the introduction of a PES program.

Conclusion

Research on forest management policy is growing because of climate change and deforestation trends. This dissertation contributes to the literature by creating and implementing the first choice experiment survey in Kam Cha i, Thailand. Few choice experiment surveys performed in developing countries have focused on the implementation of a PES system, and none have approached the survey using "willingness to accept" approach. Results from the survey show a mixed attitude toward a PES program. This dissertation also constructed the first generalized model for forest management that included a term for spatial interdependence. Simulations then were performed with this model to analyze the effect that inclusion of spatial interdependence, and a PES system would have on forest management outcomes. The third chapter presents new methods to combine survey data with GIS data to estimate spatially explicit values at a scale of 30 by 30 meters for the forest in Kam Cha i. These values were used to calculate a net conservation value that provides policymakers with information about specific plots of the forest and how best to manage forest plots to maximize social welfare.

No previous studies have been conducted in Kam Cha i. Several papers have studied the role of forest management and deforestation in Thailand, but studies exploring the attitudes toward or possible outcomes of a PES program have not been performed. Finally, this dissertation contributes to the growing field of the PES literature. Chapters 2 and 3 support the idea that efficient implementation of a PES program does increase local welfare. Chapter 1's main contributions is an exploration of possible reasons behind failed implementations of PES program.

The use of spatial analysis in forest management analysis is growing. The introduction of GIS into nongeography-specific disciplines has assisted in this process. Additionally, research into climate change has stressed the importance of using methods to include local and global values in forest management policy. The role of PES has yet to find mainstream acceptance, but progress is being made. As more research is conducted and case studies of PES are implemented, the programs can be expected to achieve greater success. While eliminating timber harvesting is not the optimal solution, the implementation of PES programs should correct for the undervaluation of forests by the local populations. This dissertation has presented three approaches to analyzing forest management issues with the goal of informing policymakers about the implementation of PES programs, and spatial considerations of forest management.

The first chapter described the theory, implementation, and empirical results of a choice experiment survey administered in Kam Cha i. The purpose of the survey was to measure resident's attitudes towards the possible implementation of a PES program. The results demonstrate a strong heterogeneity in behavior among the respondents. Conditional logit and random parameter logit models were used to test several hypotheses. The results lead to the conclusion that the amount of times a respondent visits the local forest plays a role in their attitude towards a PES program.

The results from Chapter 1 give one example of the possible difficulty of implementing PES programs in developing countries. However, this does not mean that this policy tool should be ignored. A significant portion of the respondents had positive attitudes toward protecting their forest and implementing a PES program. This suggests that other forest conservation methods to be successful. For example, education, conservation, and

other development programs aimed at helping people find alternatives to timber harvesting could help. An important step in determining allocation of resources would involve working with the locals most interested in the forest, as well as with those who use it often.

The second chapter introduces a spatial and temporal dynamic framework. The chapter shows two of the possible ways that space can play a role in the dynamic framework. First, more than one plot of trees can be considered simultaneously. Second, the different plots of trees present could exhibit spatial interdependence. This spatial interdependence would take the form of an improved ecosystem that benefits from contiguous forest. Improved ecosystems would impact the value of gathered non-timber forest products for the local residents. The results from the theoretical model demonstrate the differences in the optimal conditions. Timber harvest amounts will change depending on the magnitude and direction of the spatial interdependence. This change was demonstrated through the presentation of several simulations.

The simulations were populated with different parameters to demonstrate the effect that changes in the discount rate, spatial interdependence, and PES transfer amounts would have on the model. The results of the simulations were consistent with expectations: increases in the discount rate caused increased harvest levels, increases in zone interdependence caused decreased harvesting levels, and increases in the PES program amount decreased harvest levels. While the results of the simulations demonstrate the effect of spatial interdependence and a PES program on the model, the results rely entirely on the prior assumptions made. Additional research should attempt to identify specific functional forms for utility, and spatial interdependence functions. Better calibration of tree cover and the relationship between nontimber forest products and tree cover would improve the model.

Finally, estimates of monetary transfer payments that end up in the hands of locals will be needed to obtain reliable predictions from the model.

Chapter 3 addresses some of the assumptions made in Chapter 2. By assuming only three zones and using average NDVI measures for these large areas, information is lost due to aggregation. Including GIS data from Landsat images helps address this problem because data is available at a more micro scale. This changes the scale from three zones (in Chapter 2) to more than 290,000 (in Chapter 3). The use of GIS-MCE demonstrates how values can be taken from a survey and distributed over the study area based on multiple criteria. The criteria considered were: accessibility to the forest (determined by roads and land cover) and NDVI measures (as a proxy for quality). The two criteria were assigned different weights based on the forest product type. Estimates of the forest product value of each forest plot then were made and presented. Results show each 30 by 30 meter plot varies in value between 0 and 35 baht per two years.

The carbon sequestration and potential carbon storage values also were estimated. The estimates based on prior NDVI, carbon credit, and biomass accounting literature ranged from 0 to 1,000 baht for both storage and sequestration values. The results suggest that the forest near Kam Cha i could benefit from carbon storage and carbon sequestration programs. This is due to the degraded nature of forests located closest to the villages, and the mature pristine forests located deeper within the forest. However, plots closest to the villages had a negative net conservation value. This means forest managers need to consider local's needs if conservation efforts are to be accepted.

This dissertation explored several concepts of forest management including empirical, theoretical, and GIS-based models. The goal was to study the feasibility of a PES program

and explore the roles that space can play in the analysis. The results from each chapter show the potential, and limitations, of a PES program in Kam Cha i. The results also demonstrate how including spatially explicit characteristics of the forest can improve valuation scope and analysis. If implementing PES is the goal, future research should address other possible causes of the heterogeneity among the attitudes of the survey respondents. Possible improvements in the theoretical model include identifying specific functional forms and parameter values. Incorporating GIS demonstrates the power of micro spatial data, but inclusion of all potential forest values (soil erosion, habitats, biodiversity, and nonuse values) is needed in future research. Until that that time, the results can guide policymakers towards areas at risk of deforestation and suggest methods for understanding attitudes towards PES programs.

APPENDICES

Appendix A:

Table 1.5: Summary Statistics from Survey

Variable	Mean	Std. Dev.	Min	Max
Visits to the forest in the past two years	15.47	33.61	0	400
Used the forest for recreation in past two years	0.27	0.45	0	1
Gathered firewood from forest in past two years	0.32	0.47	0	1
Harvested timber in forest in the past two years	0.02	0.13	0	1
Gathered mushrooms in forest in past two years	0.51	0.50	0	1
Hunted animals in the forest in past two years	0.01	0.12	0	1
Other gathering one	0.37	0.48	0	1
Other gathering two	0.34	0.47	0	1
Estimated market value of mushrooms gathered	1038.35	1480.05	0	10000
Estimated market value of timber harvested	35.25	447.10	0	6000
Estimated market value of animals hunted	13.48	194.07	0	4000
Total estimated market value of forest products	1062.44	1690.97	0	10000
Years of residency in Kam Cha i	49.77	18.18	0	91
Household size	3.88	1.81	0	15
Distance to the forest (km)	0.03	0.25	0.01	3.96
Have you ever visited the local forest?	0.83	0.38	0	1
Visited the local forest in the past two years?	0.63	0.48	0	1
Are you female?	0.51	0.50	0	1
PES amount: No answer	0.01	0.08	0	1
PES amount:1	0.00	0.05	0	1
PES amount: 2	0.08	0.28	0	1
PES amount: 3	0.58	0.49	0	1
PES amount:4	0.10	0.30	0	1
PES amount: 5	0.22	0.42	0	1
Forest Size: no answer	0.00	0.05	0	1
Forest size: 2	0.06	0.24	0	1
Forest size: 3	0.22	0.41	0	1
Forest size: 4	0.16	0.37	0	1
Forest size: 5	0.55	0.50	0	1
Distance to the forest: no answer	0.00	0.00	0	0
Distance to the forest: 1	0.03	0.17	0	1
Distance to the forest: 2	0.23	0.42	0	1
Distance to the forest: 3	0.35	0.48	0	1
Distance to the forest: 4	0.30	0.46	0	1

Table 1.5 continued

Distance to the forest: 5	0.09	0.28	0	1
Number of animals in the forest: no answer	0.00	0.06	0	1
Number of animals in the forest: 1	0.00	0.05	0	1
Number of animals in the forest: 2	0.03	0.18	0	1
Number of animals in the forest: 3	0.20	0.40	0	1
Number of animals in the forest: 4	0.12	0.33	0	1
Number of animals in the forest: 5	0.64	0.48	0	1
Number of mushrooms in the forest: no answer	0.00	0.05	0	1
Number of mushrooms in the forest: 1	0.00	0.05	0	1
Number of mushrooms in the forest: 2	0.03	0.17	0	1
Number of mushrooms in the forest: 3	0.55	0.50	0	1
Number of mushrooms in the forest: 4	0.23	0.42	0	1
Number of mushrooms in the forest: 5	0.19	0.39	0	1
Amount of firewood in the forest: no answer	0.00	0.05	0	1
Amount of firewood in the forest: 1	0.00	0.06	0	1
Amount of firewood in the forest: 2	0.07	0.26	0	1
Amount of firewood in the forest: 3	0.30	0.46	0	1
Amount of firewood in the forest: 4	0.53	0.50	0	1
Amount of firewood in the forest: 5	0.09	0.28	0	1
Physical beauty of the forest: no answer	0.00	0.06	0	1
Physical beauty of the forest: 2	0.01	0.08	0	1
Physical beauty of the forest: 3	0.14	0.35	0	1
Physical beauty of the forest: 4	0.17	0.37	0	1
Physical beauty of the forest: 5	0.68	0.47	0	1
Future generations: no answer	0.00	0.05	0	1
Future generations: 3	0.39	0.49	0	1
Future generations: 4	0.09	0.29	0	1
Future generations: 5	0.52	0.50	0	1
Work Full time	0.62	0.48	0	1
Part time student	0.03	0.17	0	1
Work part time	0.04	0.19	0	1
Retired	0.03	0.16	0	1
Homemaker	0.21	0.41	0	1
Unemployed and looking	0.01	0.07	0	1
Full time student	0.01	0.10	0	1
Unemployed and not looking	0.05	0.22	0	1
Occupation 10	0.00	0.05	0	1
Less than primary school education	0.48	0.50	0	1
Junior high school education	0.10	0.31	0	1
High school level education	0.15	0.36	0	1

Table 1.5 continued

High school education but no degree	0.02	0.15	0	1
High school degree	0.03	0.17	0	1
Associate degree	0.02	0.13	0	1
Bachelor's degree	0.16	0.37	0	1
Graduate degree	0.01	0.11	0	1
Other education	0.01	0.12	0	1
Income less than 2,500 baht per month	0.07	0.25	0	1
Between 2,500 and 5,000	0.17	0.38	0	1
Between 5,000 and 7,500	0.25	0.43	0	1
Between 7,500 and 10,000	0.12	0.33	0	1
Between 10,000 and 12,500	0.10	0.31	0	1
Between 12,500 and 15,000	0.02	0.15	0	1
Between 15,000 and 17,500	0.06	0.24	0	1
Between 17,500 and 20,000	0.01	0.12	0	1
Between 20,000 and 25,000	0.03	0.17	0	1
Between 25,000 and 30,000	0.02	0.13	0	1
Between 30,000 and 35,000	0.02	0.15	0	1
Between 35,000 and 40,000	0.01	0.11	0	1
Between 40,000 and 45,000	0.01	0.11	0	1
Between 45,000 and 50,000	0.01	0.12	0	1
Between 50,000 and 55,000	0.02	0.14	0	1
Between 55,000 and 60,000	0.01	0.08	0	1
Between 60,000 and 65,000	0.00	0.05	0	1
Between 65,000 and 80,000	0.00	0.05	0	1
Income over 80,000 baht per month	0.04	0.20	0	1

Observations=482, 1,000 baht is about $32.50

Appendix B: Supplemental math for Chapter 2

Note that

$$\sum_{t=0}^{T-1}\sum_{i=1}^{N}\Omega_{tij} = \sum_{t=0}^{T-1}\sum_{i=1}^{N}\sum_{j=1}^{N}\gamma_{ij}X_{tj}$$

Can be represented as (for every time period t)

$$\begin{bmatrix} 1 & \gamma_{12} & \cdots & \gamma_{1N} \\ \gamma_{21} & 1 & & \gamma_{2N} \\ \vdots & & \ddots & \vdots \\ \gamma_{N1} & \gamma_{N2} & \cdots & 1 \end{bmatrix}\begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_N \end{bmatrix}$$

This results in

$$X_1 + \gamma_{12}X_2 + \gamma_{13}X_3 + \cdots \gamma_{1N}X_N + \gamma_{21}X_1 + X_2 + \gamma_{23}X_3 + \cdots \gamma_{2N}X_N + \cdots \gamma_{N,N-1}X_{N-1} + X_N$$

Therefore, solving for

$$\frac{\partial V(\Omega_{tij}, h_{ti})}{\partial X_{ti}}$$

Results in

$$\frac{\partial V(\Omega_{tij}, h_{ti})}{\partial \Omega_{tij}}\frac{\partial \Omega_{tij}}{\partial X_{ti}} = \frac{\partial V(\Omega_{tij}, h_{ti})}{\partial \Omega_{tij}}\sum_{j=1}^{N}\gamma_{ji}$$

Appendix C: Brief History of Stated Preference Methods and Stated Preference Studies in Developing Countries

Background of Stated Preferences

The first published contingent valuation (CV) study was performed on waterfowl recreation hunting by Davis in 1963 in the Natural Resources Journal (Davis, 1963). Since that time hundreds of CV studies have been published in the economics literature. Although CV has made great strides in reliability, the introduction of choice experiments (CE) into surveys has shown to be a better method when measuring marginal changes (Hanley, 1988) or individual attributes such as income or welfare changes (Adamowicz et al., 1998). This distinction is important for this survey because of its need to value the change in ability to clear the forest, or changes in size and attributes of the forest in question. Another important aspect of the survey is the ability to gather proximity data of the respondent to the forest in question.

Valuing ecosystem services and environmental amenities has been a field studied by many economists for a long period of time. Non-market valuation began by estimating the value of an environmental good, such as a forest stand. Once a dollar value was estimated for this good, several issues came up, such as what part of the good is really being valued. Over time economists developed methods for estimating use and non-use values (Champ et al., 2003; Grafton et al., 2004).

Use values are values that agents consume directly, such as recreation or hunting in a forest, or carbon sequestration (Adamowicz et al., 2004; Bateman and Lovett, 2000; Huhtala and Pouta, 2008). There are also non-use values that agents derive utility from (Sutherland and Walsh, 1985). These include option values, bequest values, and existence values. Option

values are derived from the agents desire to have the possibility of visiting the site in the future, possibly for recreation. The bequest value is derived from an agents desire to leave the option of using a good to her children, or the next generation. The last value, existence value, is a value placed on a good simply for existing (Champ et al., 2003).

Another important aspect in non-market valuation is the role of space and distance. Space plays two major roles in the valuation procedure. The first and most studied by economists are the distance from the amenity. Older studies did not consider distance from the environmental good in question. More recent studies that have considered distance treated distance as a number and have not considered location (i.e., north 5 miles, or south 5 miles) (Bateman et al., 2006; Pate and Loomis, 1997; Sutherland and Walsh, 1985). There are papers that have taken this into consideration, but it is still a maturing part of the field.

The first authors to specifically consider distance in CV studies were Sutherland and Walsh (Sutherland and Walsh, 1985). They focused on the role that (Euclidian) distance played in determining a person's WTP for water quality. The authors argued that all previous studies implicitly assumed that the role distance played was constant across the study region and zero outside of it. Sutherland and Walsh showed in their paper that this assumption is highly unlikely. The conclusion of their paper shows that distance plays a significant role determining someone's WTP estimate. Sutherland and Walsh also concluded that distance plays the most significant role in decaying use value, then non-use values. The non-use values (option value, existence value, and bequest value) see lower initial values of WTP but they degrade slower with respect to distance. This results in people far away from the study site having positive WTP for non-use values, but zero WTP for use values (Sutherland and Walsh, 1985).

Another paper that focused on the role (Euclidian) distance plays in WTP studies was Pate and Loomis (Pate and Loomis, 1997). The author's study focused on environmental programs in the San Joaquin Valley in California. Pate and Loomis found that WTP for certain programs did decay with respect to distance from the study site. They also found that the decay functions were different depending on the nature of the program (three different programs were included). These programs differed in their use/non-use nature and could be compared to this Thai study comparing mushroom gathering (active use) and carbon sequestration (passive use). For a non-use value, people closer to the study site do not benefit any more than people further away. Because of the non-rival, non-excludable properties, it could be described as a public good. They conclude by suggesting further research into WTP for a pure public good and the possible association with a distance decay function (Pate and Loomis, 1997).

The role of CE in stated preferences

Welfare estimates can be found from CE models (given a change in the attribute levels) using equations 1.4 and 1.5. This is done by interpreting the coefficient on the willingness to pay/accept attribute in the logit equation as equal to the marginal utility of income. Using a linear utility function, we can solve for compensating surplus by using the following equation:

$$V_1 = a(Y) + b(Q_1) = a(Y - CS) + b(Q_2) \tag{1.10}$$

Here V_1 is equal to the initial level of utility or the status quo. Y represents income, and Q_1 and Q_2 represent the differing levels of environmental quality. In order to maintain

the equality of equation (1.10) the agent needs to be compensated for the differing level of environmental quality. This compensating surplus is represented by CS. In the above equation the quality of Q_2 is assumed to be greater than Q_1 so that the CS must be subtracted from the agent's income in order to maintain equality of equation (1.10).

The CE approach has many advantages to the traditional CVM format (Hanley et al., 1998). These include:

1. Individual attributes are much easier to measure because of the set up of the CE survey. This distinction is important because it allows the measurement of changing attribute levels as opposed to the value of the amenity as a whole which is better measured using a CVM survey approach.

2. Using the CE approach allows us to identify the marginal values of attributes that normally do not lend themselves to easy estimation because of co-linearity or lack of variation in the attribute itself.

3. If the environmental goods being studied can be broken up into different attributes with monetary values, then the CE approach is superior to the CVM approach for benefit transfer purposes. This will only be the case if socioeconomic variables are included in the CE surveys when attempting to estimate the marginal values of environmental attribute changes.

4. CE can also avoid the "yea-saying" problem of discrete choice surveys by offering several alternatives. However, in this particular survey respondents are only given two hypothetical choices, with the status quo being introduced as one of the possible options for the attribute levels.

5. Embedding problems are also addressed using the CE format because tests of scope are built in to the CE method. This becomes apparent when choosing the scales associated with the individual attributes being questioned as well as the choice of the individual attributes being included.

6. CE also benefits from the opportunity to conduct internal consistency tests meaning that models can be tested on sub-sets of the available data gathered from the administered survey.

Problems with Stated Preference Studies in Developing Countries

Poor Survey Implementation.

Whittington (2002) argues that many CV surveys conducted in developing countries are poorly executed. Most economists are not trained in household survey methods or the practical issues involved in sampling in developing countries and tend to underestimate the importance. Whittington points out the importance of enumerators in the process, and the resulting enumerator bias. The enumerator, according to Whittington, is the ability of the person implementing the survey to get across the well designed survey to the respondents. Even the most efficient or effectively designed CV or CE study can make little sense to a respondent if a well-trained enumerator does not deliver it in an understandable manner. Whittington identifies this as a principle agent problem with the CV researcher not having a long term relationship with the enumerators. Training and incentivizing enumerators in a developing country is not an easy thing to accomplish.

The CE survey had to satisfy two key criteria. The first was statistical efficiency, which can be achieved reading the literature by Louviere and Woodworth (1983) among

others (Burgess and Street, 2005; Hanley et al., 1998; Kuhfeld et al., 1994; Street et al., 2005). Having an efficient design allowed for the statistical estimation of unknown coefficient values. The second criteria is to make a feasible survey that can be completed by the target population. This is not a trivial task. Understanding the history and motivation of possible respondents is crucial to acquiring useful information from the constructed CE survey.

Poorly Crafted Contingent Valuation Scenarios

It is common for designers of CV scenarios in developing countries to ask for something they did not really mean to. Constructing carefully designed, and understood scenarios is necessary, and testing and understanding these scenarios within the local context is crucial. Whittington suggests that a good CV scenario involves writing a short story about the situation and then posing an interesting choice available to the respondent. Having decide to accept this "hypothetical deal" results in a better outcome then using other approaches. However, constructing a useful and understood "hypothetical deal" can be an arduous process.

One of the biggest problems facing CV scenarios in developing countries is that the scenarios themselves do not make economic sense to the respondents answering the survey. For example, many CV researchers fail to adequately understand the economic theory of household decisions that occur in these developing countries. For this reason, seemingly simple choices created by the researcher involve much more complicated decision making analysis on the part of the respondent. These outside details can have a big impact on the

final choice, and are not controlled for or even considered by the CV researcher. An explicit example of this is the choice of bid vehicle where a WTP vehicle may substantially underestimate the true "willingness" but not "ability" to pay(Whittington, 1998).

Whittington (1998) describes the optimal balance necessary for a successful CV scenario in a developing country. First, the scenario itself must not be two complex or difficult to understand that the majority of the respondents will not be able to answer the question. Second, the scenario must not be too simple as to insult their intelligence and perhaps receive a bias answer. At a an absolute minimum, focus groups and pretests are required to understand the strengths and weaknesses of the CV scenario in question. However, these steps can also themselves be subject to the same problems that are present in the construction of the CV scenario itself. For this reason, Whittington suggests researchers place themselves in the shoes of the respondents to attempt to understand their perspective and exactly what they are considering when they are responding to the hypothetical CV scenario that is presented to them.

These issues are addressed in the CE study performed in Thailand through the careful design of a two stage survey construction method. The first stage of the survey construction involved review of the CE literature and the construction of an efficient, tested experimental design that had yielded usable results when conducted. This design was then adapted for use in the forest management WTA study by changing the attributes and their associated levels to be relevant for the study area in Kam Cha i.

Whittington then goes on to describe four different possible cases regarding CV set ups in developing countries. Those involve either an open or close ended question about a

private or public good allowing for the four possible cases. This study would fall into case four because it is a close ended question (either scenario A or B) and is involving a public good (the local forest).

A common mistake run into while performing CV studies in developing countries involves the bid vehicle and perceived fairness. It can be very difficult for an individual or household to answer an open ended WTP question without knowledge of others WTP. Respondents heavily weigh the idea of fairness into their decision, and if they find that others have answered with much higher or lower amounts this could bias their response. Likewise, respondents want to be assured that if the hypothetical situation were to come to pass, that each person would have to share in their contribution to the public good regardless of what they may have answered in their open ended WTP response. Finally, coming up with a real world example where a public good manager came to collect the proposed WTP amount is unreal to most survey respondents. Having this disconnect between the hypothetical scenario and possible real world applications makes answering any WTP question difficult for both ethical and logistical reasons.

For public good valuation, Whittington (1998) recommends using a closed ended discrete choice format. This is because of the potential biases resulting from the "fairness" issue using an open ended format. This discrete choice approach is consistent with the CE model where both are closed ended. Another concern with the approach is the current politics facing the respondents with respect to the bid vehicle. Having little trust in, or a corrupt government could potentially change how the respondents choose to answer the survey. With the CE survey, the bid vehicle tries to minimize this problem by introducing an outside international agency whose goal is to preserve the stock of standing forest. This change

should have the desired effect of removing bias towards the local and national government from their true preferences, but may have an unintended bias introduced against foreign intervention into their domestic matters.

Failure to Test Survey Design Variations and their Possible Effect on Outcomes

This can have an important influence on outcomes. Unfortunately, due to budgetary concerns, only a pretest was conducted to test this sort of issue on outcomes of the survey design. For example, after the pretest the values that are present in the survey were changed to make the choices more utility balanced, and the ordering of the survey questions as well as possible enumerator interaction was changed in order to further understanding of the survey.

From this design, the forested area in square kilometers can take on 3 possible different values, -50 sq. kilometers of forest, +50 sq. kilometers of forest or no change in the size of the forest. The distance to the forested area can take on 3 different possible values beginning with no change in distance to the forest, 1 km increase in distance to the forest, and 2 km increase in distance to the forest. The ability to cut down the forest can take on two difference values, either they are able to harvest lumber or not. Finally, the bid vehicle can take on three different values, including no payment (0), 300 baht per year, or 1000 baht per year. This means that the total number of combinations is equal to $(3^3 * 2^1)$ or 54. Optimal design would also consider the possible interactions between the attributes. For example, forest size could potentially be related to distance to the forest or ability to cut down the forest be related to the amount offered in the bid vehicle. This however, need not be the case

for lumber harvesters with advanced equipment could harvest lumber further from the

frontier while maintaining the forest cover of the area closest to the village.

Appendix D: Survey in English and Thai

Thank you for participating in our survey!

Jeff Felardo from the Department of Economics, at the University of New Mexico is conducting a research study. You have been chosen to participate in a survey about the feasibility of new type of forest management policy occurring in Kam Cha i, Thailand.

Your participation will involve filling out and mailing in a survey. The survey should take about 15 minutes to complete. Your involvement in the study is voluntary, and you may choose not to participate. There are no names or identifying information associated with this survey. Only the zip code in which you live is recorded.

Deforestation and forest degradation, through agricultural expansion, conversion to pastureland, infrastructure development, destructive logging, fires etc., account for nearly 20% of global greenhouse gas emissions, more than the entire global transportation sector and second only to the energy sector. It is now clear that in order to constrain the impacts of climate change within limits that society will reasonably be able to tolerate, the global average temperatures must be stabilized within two degrees Celsius. This will be practically impossible to achieve without reducing emissions from the forest sector, in addition to other mitigation actions.

Reducing Emissions from Deforestation and Forest Degradation (REDD) is an effort to create a financial value for the carbon stored in forests, offering incentives for countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development.

It is predicted that financial flows for greenhouse gas emission reductions from REDD+ could reach up to US$30 billion a year. This significant flow of funds could reward a meaningful reduction of carbon emissions and could also support new development, help conserve biodiversity and secure vital ecosystem services.

Your participation in this survey is voluntary, and the results of the survey will be kept confidential.

If you have any questions about this research project, please feel free to call Jeff Felardo at (+66 42 612 596). If you have questions regarding your legal rights as a research subject, you may call the UNM Human Research Protections Office at +1 (505) 272-1129.

By returning this survey in the envelope provided, you will be agreeing to participate in the above described research study.

1. Have you ever visited your local forest? *Circle one.*
1 Yes
2 No – Skip to 8

2. Have you visited your local forest in the past 24 months? *Circle one.*
1 Yes
2 No – Skip to 8

3. How many times have you visited your local forest in the past 24 months?

_____

4. For which of the following reasons have you visited your local forest?
(Circle all that apply.)
Recreation
Firewood gathering
Timber
Mushrooms
Game
Other _____

5. What is the estimated value of mushrooms gathered from the local forest in the past 24 months?

_____

6. What is the estimated value of timber gathered from the local forest in the past 24 months?

_____

7. What is the estimated value of game hunted from the local forest in the past 24 months?

_____

8. What is the estimated value of firewood, honey, eggs, shellfish, frogs, ants and all other products from the local forest in the past 24 months?

_____

9. Are you a member of any organized group with an interest in natural resources or outdoor activities?
Yes or no?
If yes, the name of the group: _____

10. How long have you lived in Kam Cha i?

_____

11. Review the following scenario, and choose the choice that you would prefer:

Scenario A (*circle one choice*)

Choice 1   **Choice 2**

Able to cut down trees	No	Able to cut down trees	Yes
Distance to the forest	1 km. further	Distance to the forest	Same
Size of forest	Same	Size of forest	50 sq. km less
Amount given by a program to your household annually	B1000	Amount given by a program to your household annually	B300

12. Review the following scenario, and choose the choice that you would prefer:

Scenario A (*circle one choice*)

Choice 1   **Choice 2**

Able to cut down trees	Yes	Able to cut down trees	No
Distance to the forest	Same	Distance to the forest	Same
Size of forest	50 sq. km more	Size of forest	Same
Amount given by a program to your household annually	None	Amount given by a program to your household annually	B1000

13. Review the following scenario, and choose the choice that you would prefer:

Scenario A (*circle one choice*)

Choice 1		**Choice 2**	
Able to cut down trees	Yes	Able to cut down trees	Yes
Distance to the forest	2 km. further	Distance to the forest	1 km. further
Size of forest	50 sq. km more	Size of forest	Same
Amount given by a program to your household annually	B300	Amount given by a program to your household annually	None

14. Review the following scenario, and choose the choice that you would prefer:

Scenario A (*circle one choice*)

Choice 1		**Choice 2**	
Able to cut down trees	No	Able to cut down trees	No
Distance to the forest	Same	Distance to the forest	2 km. further
Size of forest	50 sq. km less	Size of forest	50 sq. kilometers more
Amount given by a program to your household annually	B1000	Amount given by a program to your household annually	B1000

15. Review the following scenario, and choose the choice that you would prefer:

Scenario A (*circle one choice*)

Choice 1		**Choice 2**	
Able to cut down trees	No	Able to cut down trees	Yes
Distance to the forest	Same	Distance to the forest	1 km. further
Size of forest	50 sq. km more	Size of forest	Same
Amount given by a program to your household annually	B300	Amount given by a program to your household annually	B300

16. Review the following scenario, and choose the choice that you would prefer:

Scenario A (*circle one choice*)

Choice 1		**Choice 2**	
Able to cut down trees	Yes	Able to cut down trees	No
Distance to the forest	1 km. further	Distance to the forest	Same
Size of forest	50 sq. km less	Size of forest	Same
Amount given by a program to your household annually	B1000	Amount given by a program to your household annually	None

17. What is your gender? *Circle one.*
1 Female
2 Male

18. What year were you born? _____

19. How many people are part of your household? _____ people

For the following questions, please circle the number that most corresponds to the level of importance you have for the following attributes:

Question	Not at all important	Not very important	Neutral	Somewhat important	Very important
20. Monetary benefit to your household of any forest conservation program to maintain or increase forest cover in Kam Cha i	1	2	3	4	5
21. Square kilometers of forest cover in Kam Cha i	1	2	3	4	5
22. Geographic location of forest	1	2	3	4	5
23. Number of animals per square kilometer	1	2	3	4	5
24. Number of mushrooms per square kilometer	1	2	3	4	5
25. Amount of firewood per square kilometer	1	2	3	4	5
26. Physical beauty of forest	1	2	3	4	5
27. Availability of forest for future generations	1	2	3	4	5

28. What is your occupational status? *Circle all that apply.*

1 Work full-time   6 Part-time student
2 Work part-time   7 Active duty Armed Forces
3 Retired   8 Military Reserves or National Guard
4 Homemaker   9 Unemployed – looking for a job
5 Full-time student   10 Unemployed – not looking for a Job

29. What is the highest level of schooling you have completed? *Circle one category.*

1 Fourth grade or less
2 Fifth through eighth grades
3 Ninth through eleventh grades
4 Twelfth grade, no diploma
5 High school graduate

6 Technical/trade school degree
7 Associates degree
8 Bachelor's degree
9 Graduate or professional degree
  Other

30. What was your total household income in last month? *Circle one category.*

1 Less than B2,500		B30,000 to B34,999
2 B2,500 to B4,999	10	B35,000 to B39,999
3 B5,000 to B7,499	11	B40,000 to B44,999
4 B7,500 to B9,999	12	B45,000 to B49,999
5 B10,000 to B12,499	13	B50,000 to B54,999
6 B12,500 to B14,999	14	B55,000 to B59,999
7 B15,000 to B17,499	15	B60,000 to B64,999
8 B17,500 to B19,999	16	B65,000 to B69,999
B20,000 to B24,999		B70,000 to B79,999
B25,000 to B29,999		More than B80,000

31. Comments:

………

………

………

………

………

………………………………………………………………

ขอขอบพระคุณทุกท่านที่ให้ความร่วมมือการสำรวจครั้งนี้

เจฟฟ์ เฟอราโค จากคณะเศรษฐศาสตร์ มหาวิทยาลัยนิวเม็กซิโก เป็นผู้ดำเนินการศึกษาวิจัย โดยคัดเลือกผู้ร่วมตอบ
แบบสอบถามในการสำรวจวิจัย ในหัวข้อ รูปแบบใหม่ของนโยบายการจัดการป่าไม้ในอำเภอคำชะอี จังหวัดมุกดาหาร
ประเทศไทย

ผู้วิจัยใคร่ขอความร่วมมือในการกรอกแบบสอบถามและนำส่งแบบสำรวจ โดยในการตอบแบบสอบถามใช้เวลาประมาณ
การมีส่วนร่วมในของ นาที 15ผู้ตอบแบบสอบถามเป็นความสมัครใจซึ่งสามารถตอบรับหรือปฏิเสธ การเข้าร่วมก็ได้
สามารถระบุนามและเป็นผู้ไม่ประสงค์จะออกนามในการสำรวจครั้งนี้ก็ได้ เพียงระบุรหัสไปรษณีย์ที่คุณอาศัยอยู่เพื่อบันทึก
ไว้

การตัดไม้ทำลายป่าและความเสื่อมโทรมของป่าผ่านการขยายตัวทางการเกษตร การเปลี่ยนแปลงของพื้นที่ ทุ่งเลี้ยงสัตว์
การพัฒนาโครงสร้างพื้นฐาน การป้องกันไฟไหม้ป่า เป็นต้น เกือบ %20 ของสถิติการปล่อยก๊าซเรือนกระจกทั่วโลก จาก
ภาคการขนส่งทั้งระดับโลกเป็นส่วนแรกและส่วนที่สอง คือ ส่วนของพลังงาน ซึ่งปัจจุบันเป็นที่ชัดเจนว่า มีผลกระทบต่อ
การเปลี่ยนแปลงสภาพภูมิอากาศภายในสังคมโลก อุณหภูมิเฉลี่ยทั่วโลกจะต้อง มีความเสถียรภายในสององศาเซลเซียส
สิ่งนี้ทำให้ต้องลดการปล่อยก๊าซจากภาคการเกษตร และป่า นอกเหนือ จากการกระทำเพื่อบรรเทาผลกระทบอื่นๆ

การลดการปล่อยก๊าซจากการตัดไม้ทำลายป่าและความเสื่อมโทรมของป่าไม้)REDD (เป็นความพยายามที่จะสร้างมูลค่า
ทางการเงินสำหรับคาร์บอนที่เก็บไว้ในป่าที่นำเสนอแรงจูงใจสำหรับประเทศที่จะลดการปล่อยก๊าซ เรือนกระจกจาก
ดินแดนที่มีพื้นที่ป่าและลงทุนในเส้นทางที่มีคาร์บอนไดออกไซด์ต่ำเพื่อการพัฒนาที่ยั่งยืน

กระแสทางการเงินสำหรับการลดการปล่อยก๊าซเรือนกระจกจาก REDD เป็นที่คาดการณ์ว่าต้องใช้เงินถึง 30 เหรียญ
สหรัฐฯพันล้านต่อปี ซึ่งการเคลื่อนไหวอย่างมีนัยสำคัญของเงินทุนที่สามารถตอบแทนความหมายของการลดการปล่อย
ก๊าซคาร์บอนและสนับสนุนการพัฒนาใหม่ที่ช่วยอนุรักษ์ความหลากหลายทางชีวภาพและระบบนิเวศถือเป็นบริการระบบ
รักษาความปลอดภัยที่สำคัญมาก

การมีส่วนร่วมของ ผู้ตอบแบบสอบถามในการสำรวจนี้เป็นความสมัครใจและผลของการสำรวจจะถูกเก็บ เป็นความลับ
ถ้าคุณมีคำถามหรือข้อสงสัยใด ๆ เกี่ยวกับโครงการวิจัยนี้ สามารถโทรสอบถาม ได้ที่ สำนักวิจัย UNM สำนักงานคุ้มครอง
การวิจัยมนุษยชน (Human Research Protections Office) หมายเลขโทรศัพท์1129-272 (505)

การตอบแบบสำรวจนี้กรุณาส่งกลับมาโดยซองจดหมายที่แนบมาด้วย ซึ่งถือเป็นการยอมรับให้เข้าร่วมเป็นผู้ตอบ
แบบสอบถามในการศึกษาวิจัยข้างต้นที่อธิบายไว้

แบบสอบถาม 1

1. ท่านเคยเข้าเยี่ยมชมป่าในท้องถิ่นของท่านหรือไม่   (เลือกวงกลมเพียง 1 ข้อ)

    1. เคย

    2. ไม่เคย   **ข้ามไปข้อที่ 8**

2. ในระยะเวลา 2 ปี ย้อนหลัง ท่านเคยเข้าเยี่ยมชมป่าในท้องถิ่นของท่านหรือไม่ (เลือกวงกลมเพียง 1 ข้อ)

    1. เคย

    2. ไม่เคย   **ข้ามไปข้อที่ 8**

3. ในระยะเวลา 2 ปี ย้อนหลัง ท่านเคยเข้าเยี่ยมชมป่าในท้องถิ่นของท่าน กี่ครั้ง _____ ครั้ง

4. สาเหตุใดต่อไปนี้เป็นสาเหตุในการเข้าป่าในท้องถิ่นของท่าน   )สามารถวงกลมได้มากกว่า 1 ข้อ(

    1. การพักผ่อนหย่อนใจ

    2. เก็บฟืน

    3. ตัดไม้

    4. เก็บเห็ด

    5. ล่าสัตว์

    6. อื่น ๆ……………………………..(ระบุ)

5. ในระยะเวลา 2 ปี ย้อนหลัง ท่านมีรายได้จากการเก็บเห็ดจากป่าในท้องถิ่น ประมาณ _____ บาท

6. ในระยะเวลา 2 ปี ย้อนหลัง ท่านมีรายได้จากการตัดไม้จากป่าในท้องถิ่น ประมาณ _____ บาท

7. ในระยะเวลา 2 ปี ย้อนหลัง ท่านมีรายได้จากการล่าสัตว์ในท้องถิ่น ประมาณ _____ บาท

8. ในระยะเวลา 2 ปี ย้อนหลัง ท่านมีรายได้จากการเก็บฟืน หอย น้ำผึ้ง ไข่มดแดง กบ เขียดและอื่นๆ

   ประมาณ _____ บาท

9. ท่านเป็นสมาชิกของกลุ่ม/องค์กร ใด ๆ ที่มีความสนใจในการอนุรักษ์ธรรมชาติ หรือกิจกรรมในการพักผ่อน

    หย่อนใจในป่าหรือไม่?

    เป็น หรือ ไม่เป็น? _____   ถ้าเป็นกรุณาบอกชื่อของกลุ่ม/องค์กร :_____

10. ท่านอาศัยอยู่ในคำชะอีมากี่ปี? _____ ปี

11. จากสถานการณ์ต่อไปนี้ ให้ท่านเลือกสถานการณ์ที่ท่านต้องการ:

<u>**สถานการณ์ที่ 1**</u>

สถานการณ์สมมติ 2 สถานการณ์ ให้ท่านเลือกสถานการณ์ที่ท่านอยากให้เป็นในโลกอนาคต (ให้ท่านวงกลมเลือกเพียงหนึ่งสถานการณ์เท่านั้น)			
สถานการณ์ทางเลือกที่ 1		**สถานการณ์ทางเลือกที่ 2**	
การตัดไม้	ไม่ได้ตัด	การตัดไม้	ตัดได้
ระยะทางเพื่อไปป่า	ไกลกว่าเดิม 1 กม.	ระยะทางเพื่อไปป่า	เท่าเดิมที่เป็นอยู่ในปัจจุบัน
ขนาดพื้นที่ป่า	เท่าเดิมที่เป็นอยู่ในปัจจุบัน	ขนาดพื้นที่ป่า	น้อยลงกว่าเดิม 50 ตารางกิโลเมตร
เงินสนับสนุน	1,000 บาท	เงินสนับสนุน	300 บาท

12. จากสถานการณ์ต่อไปนี้ ให้ท่านเลือกสถานการณ์ที่ท่านต้องการ:

<u>**สถานการณ์ที่ 2**</u>

สถานการณ์สมมติ 2 สถานการณ์ ให้ท่านเลือกสถานการณ์ที่ท่านอยากให้เป็นในโลกอนาคต (ให้ท่านวงกลมเลือกเพียงหนึ่งสถานการณ์เท่านั้น)			
สถานการณ์ทางเลือกที่ 1		**สถานการณ์ทางเลือกที่ 2**	
การตัดไม้	ตัดได้	การตัดไม้	ไม่ได้ตัด
ระยะทางเพื่อไปป่า	เท่าเดิมที่เป็นอยู่ในปัจจุบัน	ระยะทางเพื่อไปป่า	เท่าเดิมที่เป็นอยู่ในปัจจุบัน
ขนาดพื้นที่ป่า	มากกว่าเดิม 50 ตารางกิโลเมตร	ขนาดพื้นที่ป่า	เท่าเดิมที่เป็นอยู่ในปัจจุบัน
เงินสนับสนุน	0 บาท	เงินสนับสนุน	1,000 บาท

13. จากสถานการณ์ต่อไปนี้ ให้ท่านเลือกสถานการณ์ที่ท่านต้องการ:

สถานการณ์ที่ 3

สถานการณ์สมมติ 2 สถานการณ์ ให้ท่านเลือกสถานการณ์ที่ท่านอยากให้เป็นในโลกอนาคต (ให้ท่านวงกลมเลือกเพียงหนึ่งสถานการณ์เท่านั้น)			
สถานการณ์ทางเลือกที่ 1		**สถานการณ์ทางเลือกที่ 2**	
การตัดไม้	ตัดได้	การตัดไม้	ตัดได้
ระยะทางเพื่อไปป่า	ไกลกว่าเดิม 2 กม.	ระยะทางเพื่อไปป่า	ไกลกว่าเดิม 1 กม.
ขนาดพื้นที่ป่า	มากกว่าเดิม 50 ตารางกิโลเมตร	ขนาดพื้นที่ป่า	เท่าเดิมที่เป็นอยู่ในปัจจุบัน
เงินสนับสนุน	300 บาท	เงินสนับสนุน	0 บาท

14. จากสถานการณ์ต่อไปนี้ ให้ท่านเลือกสถานการณ์ที่ท่านต้องการ:

สถานการณ์ที่ 4

สถานการณ์สมมติ 2 สถานการณ์ ให้ท่านเลือกสถานการณ์ที่ท่านอยากให้เป็นในโลกอนาคต (ให้ท่านวงกลมเลือกเพียงหนึ่งสถานการณ์เท่านั้น)			
สถานการณ์ทางเลือกที่ 1		**สถานการณ์ทางเลือกที่ 2**	
การตัดไม้	ไม่ได้ตัด	การตัดไม้	ไม่ได้ตัด
ระยะทางเพื่อไปป่า	เท่าเดิมที่เป็นอยู่ในปัจจุบัน	ระยะทางเพื่อไปป่า	ไกลกว่าเดิม 2 กม.
ขนาดพื้นที่ป่า	น้อยกว่าเดิม 50 ตารางกิโลเมตร	ขนาดพื้นที่ป่า	มากกว่าเดิม 50 ตารางกิโลเมตร
เงินสนับสนุน	1,000 บาท	เงินสนับสนุน	1,000 บาท

15. จากสถานการณ์ต่อไปนี้ ให้ท่านเลือกสถานการณ์ที่ท่านต้องการ:

สถานการณ์ที่ 5

สถานการณ์สมมติ 2 สถานการณ์ ให้ท่านเลือกสถานการณ์ที่ท่านอยากให้เป็นในโลกอนาคต				
(ให้ท่านวงกลมเลือกเพียงหนึ่งสถานการณ์เท่านั้น)				
สถานการณ์ทางเลือกที่ 1			**สถานการณ์ทางเลือกที่ 2**	
การตัดไม้	ไม่ได้ตัด		การตัดไม้	ตัดได้
ระยะทางเพื่อไปป่า	เท่าเดิมที่เป็นอยู่ในปัจจุบัน		ระยะทางเพื่อไปป่า	ไกลกว่าเดิม 1 กม.
ขนาดพื้นที่ป่า	มากกว่าเดิม 50 ตารางกิโลเมตร		ขนาดพื้นที่ป่า	เท่าเดิมที่เป็นอยู่ในปัจจุบัน
เงินสนับสนุน	300 บาท		เงินสนับสนุน	300 บาท

16. จากสถานการณ์ต่อไปนี้ ให้ท่านเลือกสถานการณ์ที่ท่านต้องการ:

สถานการณ์ที่ 6

สถานการณ์สมมติ 2 สถานการณ์ ให้ท่านเลือกสถานการณ์ที่ท่านอยากให้เป็นในโลกอนาคต				
(ให้ท่านวงกลมเลือกเพียงหนึ่งสถานการณ์เท่านั้น)				
สถานการณ์ทางเลือกที่ 1			**สถานการณ์ทางเลือกที่ 2**	
การตัดไม้	ตัดได้		การตัดไม้	ไม่ได้ตัด
ระยะทางเพื่อไปป่า	ไกลกว่าเดิม 1 กม.		ระยะทางเพื่อไปป่า	เท่าเดิมที่เป็นอยู่ในปัจจุบัน
ขนาดพื้นที่ป่า	น้อยกว่าเดิม 50 ตารางกิโลเมตร		ขนาดพื้นที่ป่า	เท่าเดิมที่เป็นอยู่ในปัจจุบัน
เงินสนับสนุน	1,000 บาท		เงินสนับสนุน	0 บาท

17. กรุณาระบุเพศของท่าน? (เลือกวงกลมเพียง 1 ข้อ)

      1. หญิง   2. ชาย

18. วัน/เดือน/ปี เกิด วันที่............เดือน.............................พ.ศ. ....

19. จำนวนสมาชิกในครอบครัวของท่านมีจำนวน _____ คน

กรุณาวงกลมหมายเลขที่สอดคล้องกับระดับของความสำคัญต่อความจำเป็นของท่านจากคำถามดังต่อไปนี้:

คำถาม/ระดับความสำคัญ	ไม่สำคัญเลย	ไม่สำคัญ	สำคัญ	ค่อนข้างสำคัญ	สำคัญมาก
20. การได้รับเงินสนับสนุนจากกลุ่ม/องค์กรใดๆ ในการอนุรักษ์ป่าไม้หรือ ปลูกป่าในคำชะอี	1	2	3	4	5
21. ขนาดของป่าในคำชะอี	1	2	3	4	5
22. ระยะทางจากบ้านของท่านถึงป่า	1	2	3	4	5
23. ปริมาณของสัตว์ที่อาศัยในป่า	1	2	3	4	5
24. ปริมาณของเห็ดในป่า	1	2	3	4	5
25. ปริมาณของฟืนในป่า	1	2	3	4	5
26. ความงดงามของป่า	1	2	3	4	5
27. การอนุรักษ์ป่าไม้สำหรับลูกหลาน ในอนาคต	1	2	3	4	5

28. อาชีพของท่าน

    1. ทำงานเต็มเวลา   2. ทำงาน/เรียนนอกเวลา

    3. งานนอกเวลา   4. ทหาร

    5. เกษียณอายุ   6. สำรองทหารหรือดินแดนแห่งชาติ

    7. แม่บ้าน   8. กำลังหางานทำ

    9. นักเรียน   10. ว่างงาน (ไม่คิดหางานทำ)

29. ท่านสำเร็จการศึกษาสูงสุดในระดับใด (เลือกวงกลมเพียง 1 ข้อ)

    1. ชั้นประถมศึกษาปีที่ 4 – 6

    2. ชั้นมัธยมศึกษาปีที่ 1 - 3

    3. ชั้นมัธยมศึกษาปีที่ 4 - 6

    4. ปวช.

    5. ปวส.

    7. อนุปริญญา

    8. ปริญญาตรี

    9. สูงกว่าปริญญาตรี

    10. อื่น ๆ…………………………..(ระบุ)

หมายเหตุ ระบบการศึกษาไทยแตกต่างจากอเมริกัน

30. รายได้ของครัวเรือนในเดือนล่าสุด (เลือกวงกลมเพียงหนึ่งประเภท)

    1. น้อยกว่า 2, 500 บาท   11. 30,000 บาท ถึง 34, 999 บาท

    2. 2, 500 บาท ถึง 4, 999 บาท   12. 35, 000 บาท ถึง 39, 999 บาท

    3. 5,000 บาท ถึง 7, 499 บาท   13. 40,000 บาท ถึง 44, 999 บาท

    4. 7, 500 บาท ถึง 9,999 บาท   14. 45, 000 บาท ถึง 49, 999 บาท

    5. 10,000 บาท ถึง 12, 499 บาท   15. 50,000 บาท ถึง 54, 999 บาท

    6. 12,500 บาท ถึง 14, 999 บาท   16. 55, 000 บาท ถึง 59, 999 บาท

    7. 15,000 บาท ถึง 17,499 บาท   17. 60,000 บาท ถึง 64, 999 บาท

    8. 17,500 บาท ถึง 19,999 บาท   18. 65,000 บาท ถึง 69, 999 บาท

    9. 20,000 บาท ถึง 24,999 บาท   19. 70,000 บาท ถึง 79, 999 บาท

    10. 25, 000 บาท ถึง 29, 999 บาท   20. 85,000 บาท ขึ้นไป

31. ข้อเสนอแนะอื่น ๆ...

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