A STUDY of the RELATIONSHIP BETWEEN CROP DAMAGES INFLICTED by the ONE-HORNED INDIAN RHINOCEROS and the DEFENSIVE RESPONSE to these DAMAGES by FARMERS in CHITWAN NATIONAL PARK, NEPAL

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Abstract

Crop damages inflicted by the one-horned Indian rhinoceros are viewed as one of the most serious problems plaguing the relationship between farmers and wildlife in communities that surround Chitwan National Park (CNP), Nepal. In response to these damages, many farmers implement defensive measures, which range from erecting a fence to more extreme measures such as the use of a firearm, in an effort to deter future damages from occurring. This study uses an econometric model to understand the factors that are hypothesized to influence the decision of a farmer to invest in defensive measures to combat these damages. Additionally, an economic model rooted in the theory of alliances is adapted and applied to the basic defensive measures model to determine if the decision to implement these measures is influenced by the defensive action of neighboring farmers. The results indicate that various factors, such as the distance a farm is located from the CNP boundary and the amount of land under cultivation, are responsible for a farmer investing in defensive measures. Further and in conjunction with the theory of alliances, when defensive measures within a Village Development Committee (VDC) increase, an individual farmer will feel sufficiently protected from this additional effort and opt to free-ride on the defensive effort of neighboring farmers instead of investing in personal defensive measures. These results will be helpful to assist resource managers to evaluate and create more effective environmental conservation strategies and policy recommendations in the CNP region.

Keywords: Nepal; rhinoceros; crop damages; econometrics; theory of alliances; defensive measures

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Chapter 1: Introduction

1.1 Introduction

Since the late 1970's, Nepal has heavily invested in natural resource management programs, with a large share of the budget dedicated to wildlife conservation. As the focal point for wildlife protection within the country, the one-horned Indian rhinoceros *(Rhinoceros unicornis)* has been at the centre of the conservation movement. Listed as an endangered species in Nepal, the one-horned rhino is protected within the country and primarily inhabits the national parks in the low-lying Terai region of the south. Specifically, Chitwan National Park (CNP – formerly Royal Chitwan National Park) in the Chitwan Valley is home to the vast majority of the rhinoceros in Nepal and the preservation of rhinos in this park is viewed as one of most successful testimonies to the potential of nature conservation in the developing world (Martin & Vigne, 1996). The species was approaching extirpation from the region in the late 1960's as CNP contained less than 100 rhinos (Caughley, 1969), but according to the 2000 census, the rhino population in the park recovered to 544 individuals. Despite the success in preserving the rhinos, the region is characterized by a longstanding conflict between humans and rhinos that threatens the long-term viability of the species within CNP. Following poaching, the damages inflicted by the rhino on the farmer's crops, or simply crop damages, are viewed as one of the most serious problems plaguing the relationship between humans and wildlife (Sharma, 1990; McLean & Straede, 2003). Moreover, crop damages not only represent an overwhelming source of conflict between both parties, but also represent a serious obstacle to maintain and enhance the success of the many conservation initiatives present within CNP.

For centuries, farmers residing in the vicinity of CNP have employed a host of defensive measures, ranging from erecting a fence to digging a trench, to combat perpetual crop damages from the rhino. In addition to crop damages, a variety of other factors such as the distance a farm is located from a park or the total amount of land under cultivation, are hypothesized to influence the decision of a farmer to implement defensive measures. However, it is not clearly known whether this decision is influenced by the defensive action of neighboring farmers. This study will explore this possibility by introducing the theory of alliances to the crop damage/defensive measure quandary. Moreover, and more generally, there has not been an attempt to study the motivating factors that influence a farmer to implement defensive measures using an econometric model. This study will also attempt to develop and empirically estimate such a model.

1.2 Background to the Problem

Due in large part to its wide variation in elevation, Nepal possesses one of the richest and most diverse ecologies worldwide. A critical component of this ecology is the one-horned Indian rhinoceros which inhabits the low-lying Terai region in the southern portion of the country. While the species has modestly recovered since historical population lows in the 1970's, the long-term viability of the one-horned rhino is still threatened by a variety of human-rhino, or more generally, park-people, conflicts. One of these conflicts stems from the widespread crop damages caused by the rhino in villages surrounding CNP. In response to these damages, many farmers implement defensive measures, which range from erecting a fence to more extreme measures such as the use of a firearm, in an effort to deter future damages from occurring. Considering that crop damages often represent a serious threat to the livelihood of local farmers and rhinos alike, it is critically important to reduce the damages that occur. An integral component to achieving this reduction is to gain a better understanding of the factors that motivate a farmer to implement defensive measures to combat crop damages. Acquiring this information could provide decision makers with additional insight towards the problem, thereby equipping them with the knowledge and tools needed to tackle this complex issue.

Chitwan National Park itself possesses many charismatic land mammals, including the endangered one-horned Indian rhinoceros. However, it is an area characterized by a longstanding conflict between humans and rhinos as each year, the rhinoceroses inhabiting the park destroy a considerable amount of agricultural crops in communities located adjacent to CNP (Nepal & Weber, 1995; Uprety, 1995). In a study conducted by Uprety (1995), rhinos were determined to be the most destructive animal raider in the region, accounting for 40.3% of all crop damage based on the frequency of their visits to farms that resulted in crop damages. Furthermore, 100% of the interview respondents reported the rhino as being a perceived threat to their agricultural crops, compared to 75% for chital and 70% for wild boar. Depending on the time of year and the quantity of preferred diet found within the park, rhinos raid crops such as maize, rice, lentils, mustard, vegetables, and wheat, amounting to substantial welfare losses to local farmers (Studsrod & Wegge, 1995; Uprety, 1995). Currently, farmers residing near CNP are not compensated for the damages caused by wildlife and as such, engage in implementing a variety of defensive measures designed to mitigate the loss of crop damages (Ferraro & Kramer, 1996; Straede & Treue, 2006). Methods to ward off wildlife in the CNP include digging trenches, planting hedgerows, constructing ‘noise’ systems to frighten approaching animals, building physical barriers such as fences, both electric and non-electric, and patrolling the fields either on foot or from a watchtower (Studsrod & Wegge, 1995; Uprety, 1995).

Crop damages inflicted by rhinos in villages surrounding CNP not only represent an overwhelming source of conflict between farmers and rhinos, but also correspond to a formidable impediment to achieving successful conservation initiatives in the park. Consequently, resource managers have a vested interest in mitigating this contentious conflict, and a number of policy options have been identified to achieve this goal. Specifically, four primary options exist to combat the aforementioned crop damage problem, each of which represents a potential response by a farmer to reduce the magnitude of damages:

1. implement defensive measures in an effort to reduce the amount of crop damages that occur;
2. adopt a mitigation/adaptation strategy that involves switching the crops planted in an effort to deter rhinos from destroying crops; or
3. participate in crop damage compensation and/or insurance programs run by a government agency (if such programs exist); or
4. accept the crop losses that occur.

An important aspect of policy option number 1 is an understanding of the factors that are hypothesized to influence the decision of a farmer residing near CNP to invest in defensive measures to combat crop damages from the rhino. While the literature suggests various factors that contribute to this decision, such as the total amount of land under cultivation, it is not well understood whether this decision is also influenced by the defensive action of neighboring farmers. For example, will a farmer be more or less inclined to construct a fence to ward off invading rhinos if his/her neighbor already has a fence in place? To answer this question, this study will apply the theory of alliances to the crop damage/defensive measure quandary. The theory of alliances itself was first studied in the mid-1960’s and was applied to military partnerships with a specific focus on the North Atlantic Treaty Organization (NATO). One feature of this application was an analysis of whether the total quantity of resources that any NATO ally invested towards alliance-wide defensive effort was influenced by the defensive expenditures of the other allies. For the purpose of this study however, the theory is applied to the agricultural setting in CNP to determine if farmers base their decision to implement defensive measures on the defensive action of neighboring farmers.

1.3 Research Objectives

The objectives of this research are two-fold: 1) to examine the factors that are hypothesized to influence the decision of a farmer residing near CNP to invest in defensive measures to combat crop damages from the rhino; and 2) to apply the theory of alliances to determine whether the decision of a farmer to implement defensive measures is motivated by the defensive action employed by neighboring farmers. Determining the factors that motivate farmers to implement defensive measures is important because the crop damages inflicted by the rhino causes conflict and understanding the motivating factors involved in this decision will hopefully aid in reducing the level of hostility.

The approach taken to achieve the objectives of this research is to:

1. Develop an appropriate theoretical framework for analyzing the factors that are hypothesized to influence the decision of a farmer residing near CNP to invest in defensive measures to combat crop damages from the rhino;
2. Estimate numerous economic models that consider the motivating factors of a farmer to invest in defensive measures;
3. Adapt and apply an economic model rooted in the theory of alliances to the basic defensive measures model to determine if the decision of a farmer to implement defensive measures is influenced by the action of neighboring farmers; and
4. Develop a series of recommendations that will assist planners and policy makers in their ongoing efforts to ameliorate human-wildlife conflicts

Chapter 2: Literature Review

2.1 Analysis of Park-People Conflict: An Overview

Protected areas throughout the developing world provide countless benefits for both human enjoyment and the preservation of natural ecosystems, such as biodiversity conservation (Uprety, 1995), recreational areas, wildlife refuges, and heritage and educational resources (Rao et al., 2002). Although these aforementioned functions benefit various stakeholders such as tourists, local inhabitants employed in the tourism industry, and regional and national governments, it is often the local residents living adjacent to protected areas that bear the direct costs of conservation (Adhikari et al., 2005). When protected areas are established, local residents are frequently omitted from the critical decision making processes that directly impact their health and well-being, although it is now viewed as increasingly important to include these residents in planning decisions (Uprety, 1995; McLean & Straede, 2003). As a result, the many benefits provided by natural conservation projects are often overshadowed by a myriad of problems that exist between the humans who live in and around protected areas and various aspects of the protected areas themselves. Often referred to as park-people conflict (PPC) (Straede & Helles, 2000; Mehta & Heinen, 2001), or more specifically, human-wildlife conflict (Kaswamila et al., 2007), contention arises for a host of reasons. For instance, crop damage inflicted on farmer's fields and livestock depredation by wild animals wandering out of protected areas are frequently viewed as the most detrimental form of PPC (Kharel, 1997; Perez & Pacheco, 2006). From elephants and hippopotamus in Africa (Gillingham & Lee, 2003), to rhinoceros and monkeys in Asia (Sharma, 1990), crop damages and livestock depredation are a significant problem throughout the world. Every year, local inhabitants residing in the vicinity of protected areas lose considerable quantities of crops and livestock to wild animals, often directly amounting to considerable losses of their primary food source and monetary resources and indirectly through a wealth of social costs (i.e. children not attending school to patrol fields instead) (Linkie et al., 2007).

A second major source of PPC stems from the use of park resources. Prior to the establishment of protected areas, local inhabitants were often free to collect, harvest and utilize natural resources as they pleased (Sharma, 1990; Sekhar, 1998). This included activities such as: harvesting wild game, collecting fodder to feed livestock and firewood to use as a source of energy, and grazing livestock on park land or watering them on park rivers (Ibid). However, after a protected area is created, locals are restricted from their use of traditional resources for subsistence purposes (Nepal & Weber, 1995; Sekhar, 1998). In response to such a ban, local inhabitants protest park regulations by engaging in a suite of illegal activities such as smuggling firewood, grazing livestock, and collecting timber and grass (Uprety, 1995). This response however, often results in fines being issued for engaging in these illegal activities, which produces or further exacerbates an already bitter conflict between local inhabitants and park authorities over the use and management of park resources (Uprety, 1995; Sekhar, 1998).

In addition to crop damages/livestock depredation and the strife surrounding the use of park resources, a multitude of other PPC sources exist. This comprehensive, but not exhaustive, list includes: injuries or fatalities to humans caused by wild animals (Nyhus et al., 2000; Williams et al., 2001), increased competition for resources between animals, livestock and humans (Weladji & Tchamba, 2003), harassment of local inhabitants by park/reserve rangers (Kaswamila et al., 2007), the threat of wildlife diseases transmitted to both humans and livestock (Kaswamila et al., 2007), no right to shoot/destroy troublesome animals (Uprety, 1995), and the loss of cultural values and of indigenous knowledge and skills (Weladji & Tchamba, 2003). Each of these aforementioned problems represents a formidable hindrance to conservation initiatives and must be appropriately dealt with on a case-by-case basis in an attempt to remedy the situation.

2.2 The Problem of Crop Damages from Wildlife

In the realm of park-people conflict within the developing world, crop damages inflicted by wildlife are viewed as one of the most serious problems plaguing the relationship between humans and wildlife (Sharma, 1990; Gillingham & Lee, 2003; McLean & Straede, 2003). While crop raiding can result in significant losses on a regional and national basis, it may represent devastating welfare losses for an individual household (Hoare, 1995; Bulte & Rondeau, 2007a). For farmers living in and around protected areas, crop damages represent a considerable barrier to securing a sustainable livelihood as agricultural production not only supplies families with food for consumption, but is often their primary source of income as well (Gadd, 2005). Moreover, crop losses are associated with more than simply an economic burden as these losses can spawn other costs to farming households such as: an increased risk of injury/death from wildlife, disruption/withdrawal from school as children are needed to guard crops, and a heightened risk of contracting diseases (i.e., malaria) if crop patrolling occurs at night (Hill, 2000; Hill, 2004). Crop raiding also has negative implications for the conservation of wildlife as farmers occasionally seek fatal retribution when their crops are destroyed (Uprety, 1995; Wang, Curtis & Lassoie, 2006). Perceptions of farmers residing near the Selous Game Reserve in Tanzania, where 95% of respondents reported crop damages as a factor hindering their agricultural productivity (Gillingham & Lee, 2003) and the Sariska Tiger Reserve in India where 74% of villages report that crop raiding was severely problematic in their community (Sekhar, 1998), confirms the extent of the crop damage problem in communities located near protected areas.

2.2.1 Factors influencing crop damages

In an attempt to alleviate the tension between humans and wildlife caused by crop damages, it is important to understand the factors influencing these damages. The literature suggests that crop damages are influenced by: the distance between the protected area and the farmer's crops (Kharel, 1997; Hill, 2000; Rao et al., 2002), the presence or absence of preferable diet found within the conservation area (Tweheyo et al., 2005), the distribution of wildlife in the protected area (Wang et al., 2006), the population of animals within the park (Rao et al., 2002), the specific type of crop grown (Studsrod & Wegge, 1995; Wang et al., 2006), the timing of crop harvests (Tweheyo et al., 2005), the density of forest cover adjacent to agricultural fields (Nyhus et al., 2000) and the effectiveness of defensive measures employed by farmers (Studsrod & Wegge, 1995). In essence, the presence and influence of each of these aforementioned factors contributes towards crop damages will dictate the severity of damages incurred.

2.3 Behavioral and Interventionist Responses to Crop Damages from Wildlife

Farmers from countries throughout the world typically respond in four different ways to crop raiding by wildlife: employ defensive measures, adopt mitigation/adaptive action, participate in compensation and/or insurance programs, or accept the losses that occur.[1] Each response will be discussed in turn.

2.3.1 Defensive measures

Implementing defensive measures to ward off crop-raiding wildlife is a common and widespread technique used by farmers globally. Osborn & Parker (2003) divide defensive measures into two broad categories: passive and active. Passive methods are designed to prevent

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[1] These three responses are viewed solely from the perspective of an individual farmer and not from a government agency, as the latter faces a variety of options to tackle this issue.

wildlife from entering agricultural fields and include: erecting biological fences (Wang et al., 2006) and/or electric fences (Thouless & Sakwa, 1995), constructing stone and mud walls (Sekhar, 1998), and digging trenches (Nyhus et al., 2000). Active systems are designed to frighten wildlife away from planted fields and include: utilizing scare tactics such as yelling, deploying fireworks, and banging metal objects together (Uprety, 1995; Osborn & Parker, 2003), and patrolling the fields during the day and night (Hill, 2000; Gillingham & Lee, 2003). Additionally, when a specific 'pest' animal causes a catastrophic amount of damage, more aggressive measures such as trapping and hunting are employed (Wang et al., 2006). More recently, chili-based deterrents such as hand-held pepper sprays and applying chili grease to rope fences that surround agricultural fields have been promoted to reduce crop raiding from elephants (Hedges & Gunaryadi, 2009). The farmer's choice of a defensive method depends on the availability of local resources (Weladji & Tchamba, 2003), the specific type of animal causing the destruction (Weladji & Tchamba, 2003), the wealth of the household (Wang et al., 2006), and the relative incentives/returns of implementing one method over another (Bulte & Rondeau, 2007b).

2.3.1.1 Factors influencing defensive measures

The literature suggests that the decision of a farmer to engage in implementing defensive measures to mitigate the amount of damage inflicted upon his/her crops by wild animals is influenced by many factors. Not surprisingly, a key factor affecting this decision is the presence and severity of crop damages themselves. It is well documented that farmers who suffer damage to their crops are highly inclined to implement defensive measures (Studsrod & Wegge, 1995; Sekhar, 1998; Nyhus et al., 2000). Simply suffering crop damages however, does not necessarily translate into farmers investing in defensive measures. For instance, a crop raiding study based in Kerinci Seblat National Park, Sumatra, Indonesia, revealed that while all 50 farmers surveyed experienced crop damages on an annual basis from a variety of species, only 30% of farmers employed crop protection (defensive) measures (Linkie et al., 2007). Moreover, 90% of these farmers stated that crop damages were the main hindrance to achieving agricultural success yet still did not invest in defensive measures. Clearly, a variety of other factors beyond crop damages influence the choice of a farmer to employ defensive measures. For simplicity, I will group these factors into two broad categories; risk factors and demographic factors. Each category will now be discussed in turn.

According to Caplan & Douglas (as cited in Hill, 2004) an individual's perception of risk is created from both cultural and social factors and is often influenced by prior experience. The combination of these factors essentially shapes the extent to which farmers consider their crops to be at risk from damage caused by raiding wildlife, and as such, invest in defensive measures.[2] For example, Hill (2004) discusses how farmers' perceptions of risk are influenced by species that are more visible, both in term of the animal's size and the how often the animal is seen by the farmer. Thus, a farmer will associate a large animal that he/she sees frequently with a high level of risk as opposed to a smaller animal that is rarely seen and as such, will be more inclined to invest in defensive measures.

Numerous studies (Hill, 1997; Kharel, 1997; Naughton-Treves, 1998; Hill, 2000) have confirmed that the distance between an individual farm and a protected area is the primary factor that places farmers at risk to crop damages from wildlife. Hill (1997) describes how those farmers whose land is located close to the edge of a protected area are at greater risk of crop damages and, accordingly, have a greater desire to invest in defensive measures. Conversely,

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[2] Defensive measures are obviously implemented to avoid crop damages, but being at risk to damages by wildlife does not imply that damage has already occurred to one's crops.

farmers whose fields are located further away from the boundary of a protected area and are buffered by neighboring farms situated between it and the boundary are at a lower risk of experiencing crop damages and, thus, have less motivation to implement defensive measures.

Another factor associated with an increased risk of incurring crop damages from wild animals is the amount of land under cultivation. An econometric analysis of crop raiding elephants conducted by Oppong et al., (2008), discovered that, everything else being equal, larger farms were more susceptible to damages than smaller ones. It is therefore reasonable to infer that the larger a farm is, the more inclined a farmer would be to invest in defensive measures, as he/she has a great quantity of crops to lose.

Financial incentives are also hypothesized to influence the choice of a farmer to employ defensive measures. Sitati & Walpole (2006) describe how farmers that receive only minimal financial support from park authorities implement and maintain defensive measures more poorly, or in many cases, do not put in place any defensive measures at all.

2.3.1.2 Economics of defensive measures

Investing in defensive measures also represents a significant cost on behalf of an individual farmer. In an effort to maximize profits, farmers will seek to minimize their capital costs, of which implementing defensive strategies are a part. Therefore, in the interest of efficiency, individual farmers will only want to employ defensive measures if the cost of doing so is less than the economic value of expected damages from crop-raiding species over the life of the defensive tactic implemented. While the economic value of expected damages depends on a myriad of dynamic factors (Hill, 2004) it is nonetheless an important consideration. In reality, however, the choice of a farmer to implement defensive measures is often based on the value of crop damages suffered from previous years as opposed to the expected damages in the future (Rollins & Briggs, 1996).

Although a host of defensive methods are available for farmers to ward off crop raiding animals, no combination of defensive measures is totally effective. The effectiveness of defensive effort is uncertain, as it depends on a multitude of factors: types of defensive tactics employed, effort levels applied, the number of destructive animals, and random environmental factors (Rollins & Briggs, 1996). In their study of crop damage caused by geese in Wisconsin, Rollins & Briggs (1996) argue that, holding all other factors constant, the probability of reducing crop losses increases with the level of effort exerted. Further, research conducted at the Sariska Tiger Reserve in India revealed that many farmers employed a combination of two or more defensive measures to ensure effective protection of their crops (Sekhar, 1998). However, in her analysis of crop damages by various species in Kibale National Park, Uganda, Naughton-Treves (1998) found that an increased investment in defensive measures did not equate to a significant reduction in crop losses.

2.3.2 Mitigation/Adaptation

In essence, mitigation or adaptive action taken by farmers to reduce crop damages involves modifying land-use. Altering land-use entails crop switching, whereby a farmer replaces a crop that has experienced a high incidence of damage with a crop that is less palatable to the raiding species in an effort to deter future damages. In addition to deterring wildlife, however, the less palatable crop often places farmers at an economic disadvantage. Considering that all farmers attempt to maximize the economic profit of their crops, each farmer has a vested interest in planting the most profitable crop. However, as discussed by Yoder (2002), when the marginal benefits of production across crops vary, a farmer could earn additional revenues by shifting a unit of land away from the crop with the lower marginal value to a crop that yields a higher marginal value of production. Alternatively, a farmer may sacrifice potential revenues if he/she decides to plant a less palatable crop, as this crop intuitively has a lower marginal value than the original crop. Consequently, it may be the case that the foregone economic profit associated with crop switching may indeed be greater than the relinquished profit from the original damages themselves. Clearly, crop switching should only be undertaken with sufficient knowledge about the economic viability of the new crop to be planted.

A crop switching scenario is depicted by Yoder (2002), who developed a multi-crop model of crop damage from deer in Wisconsin, USA. The model presents a series of hypotheses about how the acreage of a certain crop will change in response to the parameters contained within the model. Each of the hypotheses are then tested in the context of an econometric model, where a damage rate is employed and the acreage allocation of each crop is analyzed in the presence of crop damage. The main finding of the paper is that an effective method for landowners to combat crop damage is to alter land-use patterns by replacing the acreage devoted to high-damage crops in favor of low-damage crops.

In contrast to Yoder (2002), Vijayan & Pati (2002) discovered that altering crop patterns may result in various unintended consequences and ultimately, may exacerbate human-wildlife conflicts. The authors analyzed the cropping patterns in the Talala sub-district on the periphery of Gir National Park and Sanctuary in Gujarat, India, and reported that sugarcane and mango cultivation had increased by 87% and 103%, respectively, between 1992 and 1999. These crops however, possess a high density of organic material, and as such, provide ideal shelter for both Asiatic lions (*Panthera leo persica*) and leopards (*Panthera pardus*). In turn, these sheltered areas attract large numbers of wild cats and exacerbate human-wildlife conflicts in the region, including: human injury/death due to an increase in the level of contact with the animals, domestic livestock predation by the wild cats, and fear of the animals among villagers leading to a loss of field labor days and an accompanying reduction in annual earnings from agriculture. The authors conclude that adequate research must be invested into any significant changes in cropping patterns in order to prevent a host of adverse impacts.

Additional crop based measures employed to reduce potential crop damages include planting 'lure' crops within a protected area and engaging in an early harvest to avoid calamitous damages immediately prior to harvesting (Nyhus et al., 2000).

2.3.3 Compensation programs

When protected areas are created in developing countries, local inhabitants frequently shoulder many of the costs associated with their creation, ranging from a loss of traditional resource use, to crop damages inflicted by wildlife. In an attempt to alleviate the burden of either of these aforementioned costs, programs designed to compensate the impacted inhabitants are commonly implemented (Straede & Treue, 2006). While compensation can take the form of infrastructure development, a provision of social services, or the introduction of alternative production technologies (Ferraro & Kramer, 1996), contemporary programs have typically focused on compensating residents through economic initiatives such as sharing tourism revenues obtained through park user fees, direct monetary payments, or providing a plot of government land outside the park (Straede & Treue, 2006). Conversely, if compensation or insurance is not provided, farmers will usually accept the losses to their crops if the overall damage is minimal and/or they simply do not have the financial and/or human resources to respond to the damages (Kaswamila et al., 2007).

From the perspective of a well-endowed non-governmental organization or the government of a developed nation, compensation programs possess a host of merits. For instance, the programs are often relatively inexpensive to implement in impoverished areas of developing nations and the approach is often eagerly accepted by local communities that are empowered with some responsibility and management of the compensation funds (Bulte & Rondeau, 2005).

However, compensation programs are also plagued by a suite of practical hurdles (Ferraro & Kramer, 1996) and various problems associated with both the economic and biological systems of a region where a compensation program has been introduced. Examples of practical barriers include: local residents engaging in strategic behavior in an attempt to maximize their welfare, estimating a suitable level of compensation, choosing the appropriate beneficiaries of compensation, selecting the form of compensation, and generating local conservation support (Ferraro & Kramer, 1996). Regarding perturbations to economic and biological systems, Bulte & Rondeau (2007b) developed a model whereby the introduction of a compensation scheme possesses the ability to produce the most disastrous results possible as each stakeholder in the program suffers a substantial loss; the sponsoring agency/donors pay for the compensation payments, the welfare of the local residents decreases, and the wild animal stock is reduced.[3]

Additionally, as discussed by Rollins & Briggs (1996), compensation programs also suffer from moral hazard, whereby individuals (farmers) with insurance (compensation) take greater risks (i.e. do not implement defensive measures) than they would without insurance because they know they are financially protected against any adverse situation. The moral hazard problem arises owing to the fact that it is both extremely difficult and costly to directly monitor defensive

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[3] This 'worst case' scenario arises due to the effect of wildlife damage compensation on labour and the associated effect of labour reallocation on the wildlife stock. In essence, introducing a compensation program makes growing crops more profitable resulting in an expansion of farming activity. An increase in the amount of cultivated land reduces the overall quantity of wildlife habitat, thereby lowering the stock of the animal. This increased profitability from farming also results in reduction in wildlife harvest benefits (i.e. the consumption and sale of meat). The authors note however, that the introduction of a compensation program will also reduce hunting pressure on wildlife (owing to farming being more profitable) and that the compensation transfer itself increases the welfare of the household. Ultimately, the model shows that compensation programs have an ambiguous effect on both wildlife stock and net welfare for local people but possess the ability to result in this 'worst case' scenario.

effort implemented by farmers. This discrepancy leads to uncertainty regarding defensive techniques which creates asymmetric or imperfect information between the payers and recipients of compensation. Clearly, implementing compensation programs in developing countries should be considered very cautiously.

2.4 Theory of Alliances

Generally, alliances are regarded as organizations that have been created to serve the common interests of their members with the anticipated goal of obtaining additional benefits above and beyond what could be obtained if acting individually (Gonzalez & Mehay, 1991). The economic theory of alliances itself was first studied some 44 years ago by Mancur Olson & Richard Zeckhauser (1966), who analyzed the subject with reference to military alliances, with a specific focus on the North Atlantic Treaty Organization (NATO). Historically, the vast majority of scholarly literature on the economic theory of alliances has employed NATO as representative of alliances in general (Thies, 1987). The primary reason for this concentrated view on NATO is the availability and reliability of time-series data pertaining to both national income and military spending of member nations, which allows for the testing of hypotheses derived from the theory (Thies, 1987).

In their seminal paper on the economic theory of alliances, Olson & Zeckhauser (1966) describe how a common objective or collective goal that is shared amongst a group of individuals can result in the successful development of a cohesive organization. Using NATO as an example, they discuss how deterring aggression against any NATO ally through a pledged retaliatory response of overwhelming proportions, is both the common objective and primary interest that all members possess. Moreover, the authors were the first to present a public goods approach to the study of alliance behavior where the goods and services provided to meet the common interest of the alliance are pure public goods both within and between allied states which are non-rival in consumption and non-excludable in its benefits (in this case the pure public good is national defense). Essentially, one unit of defense was postulated to provide a complete unit of defense services to all inhabitants of the alliance irrespective of their specific location.

Empirically, Olson & Zeckhauser (1966) developed a formal model where they showed that the non-excludability of pure public goods enabled certain allies to 'free-ride' whereby they were able to obtain an uneven amount of the benefits provided by the alliance without expending a balanced share of their own scarce resources. Additionally, the authors demonstrated that a pure public good is associated with an exploitation hypothesis, whereby the large and rich allies of an alliance tend to supply a disproportionately large share of the defense benefits relative to the smaller allies. Lastly, their model also depicted alliance defense expenditures as suboptimal owing to non-cooperative behavior amongst allies, whereby certain allies reduce their defense spending as a result of defense spill-ins that arise from the other allies expenditures. An example of a defense spill-in is a military base, where the benefits of the base not only arise for the host nation, but these benefits also 'spillover' to other allied nations. As described by Sandler & Murdoch (1982), this sub-optimality results when the marginal benefits bestowed upon other allies are not included when a particular ally equates the marginal benefits and marginal costs associated with defense expenditure decisions.

The Olson & Zeckhauser model laid the foundation for a vast literature pertaining to the theory of alliances. Van Ypersele de Strihou (1967) was the first academic to recognize that, in addition to purely public deterrence, defense expenditures could also generate ally specific private benefits such as protection of colonies and provide national relief in times of disaster. Later analyses (Sandler & Cauley, 1975; Sandler, 1977) evolved to consider both the deterrent and damage limiting protection (required when deterrence fails) characteristics of defense by focusing on the properties of impure public goods, which in essence, are hybrid goods that possess certain features of both public and private goods. These latter contributions paved the way for the creation of the joint product model, which is recognized as the most comprehensive model of alliance behavior because it includes private, impure public, and pure public outputs of defense expenditures (Conybeare & Sandler, 1990). Concomitantly, various changes in the global military system during the 1970's, such as the development of new weapons systems and an alteration in NATO's military strategy, essentially extinguished the direct application of the pure public good model to explain alliance behavior (Sandler & Forbes, 1980). Thus, a combination of the multiple outputs of defense expenditures and the aforementioned changes in the 1970's heavily favored the employment of the joint product model to alliance behavior (Sandler & Forbes, 1980).

Perhaps the greatest insight of Olson & Zeckhauser's seminal paper is the acknowledgment that economic principles of military alliances can apply to a diverse range of both transnational issues and institutions (Hartley & Sandler, 1999). Moreover, and as discussed by Sandler & Hartley (2001), more recent applications of the theory of alliances have occurred with reference to reducing environmental degradation, promoting world health, and eliminating trade barriers.

Chapter 3: Study Methodology

Chapter 3 presents the methodology used to answer the research objectives posed in chapter 1. Section 3.1 provides a detailed account of the study area. Section 3.2 describes the data requirements of the study, including how the sample size was selected and a comprehensive analysis of each variable employed in the empirical models presented in chapter 4.

3.1 Study Area

The study area for this project was based in numerous villages located in the vicinity of Chitwan National Park (CNP – formerly Royal Chitwan National Park), Nepal. Chitwan National Park is located in a region of sub-tropical lowlands known as the Terai, which straddles the Indian border to the South and comprises roughly 20 percent of Nepal's area (Brown, 1996). The park presently covers 932 km^2, with an additional 750 km^2 designated as a buffer zone surrounding the park (see Figure 1 – highlighted with red rectangle) (Heinen & Mehta, 2000). Chitwan National Park is renowned worldwide for its unique and diversified ecosystems as well as being home to many endangered flora and fauna species, including the endangered one-horned Indian rhinoceros (Straede & Helles, 2000). Of the five protected areas in the Terai, CNP is the most important for the current and long-term viability of the rhinoceros in Nepal.

The data obtained for this study was collected in six Village Development Committees (VDC's) located throughout the buffer zone of CNP. Village Development Committees represent the smallest political and administrative unit in Nepal, of which there are 3,913 throughout the country (Government of Nepal, 2010). The six VDC's chosen for the study are all located in the Chitwan District and include: Dibyapuri, Pithauli, Patihani, Ratnanagar, Bachhauli, and Piple (see Figure 2). Dibyapuri and Pithauli comprise the westernmost VDCs of the study area and are situated less than five kilometers from each another and approximately one kilometer from the CNP boundary. Patihani, Ratnanagar, and Bachhauli are all centrally located within the study area with Ratnanagar situated approximately six kilometers from the park border and is thus, the furthest VDC from the perimeter. Piple is the easternmost VDC of the study region, is positioned roughly two kilometers from the CNP boundary, and is relatively isolated from the other VDCs. Each VDC is further divided into a series of wards, with the average VDC containing approximately nine wards. A ward consists of a single village, a group of villages, or a portion of a large village depending upon the population density of the associated village(s) (Government of Nepal, 2010).

Figure 1: A map of Nepal showing the location of Chitwan National Park (DNPWC, 1999)

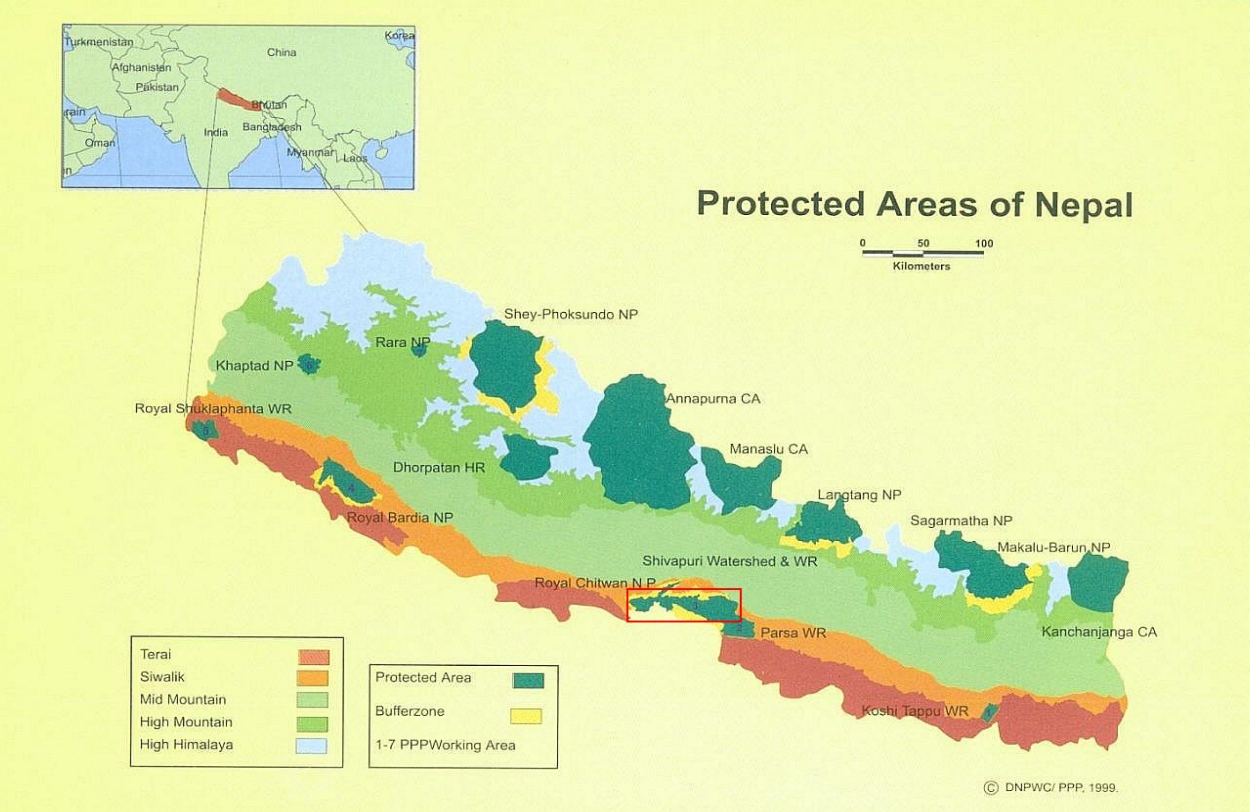
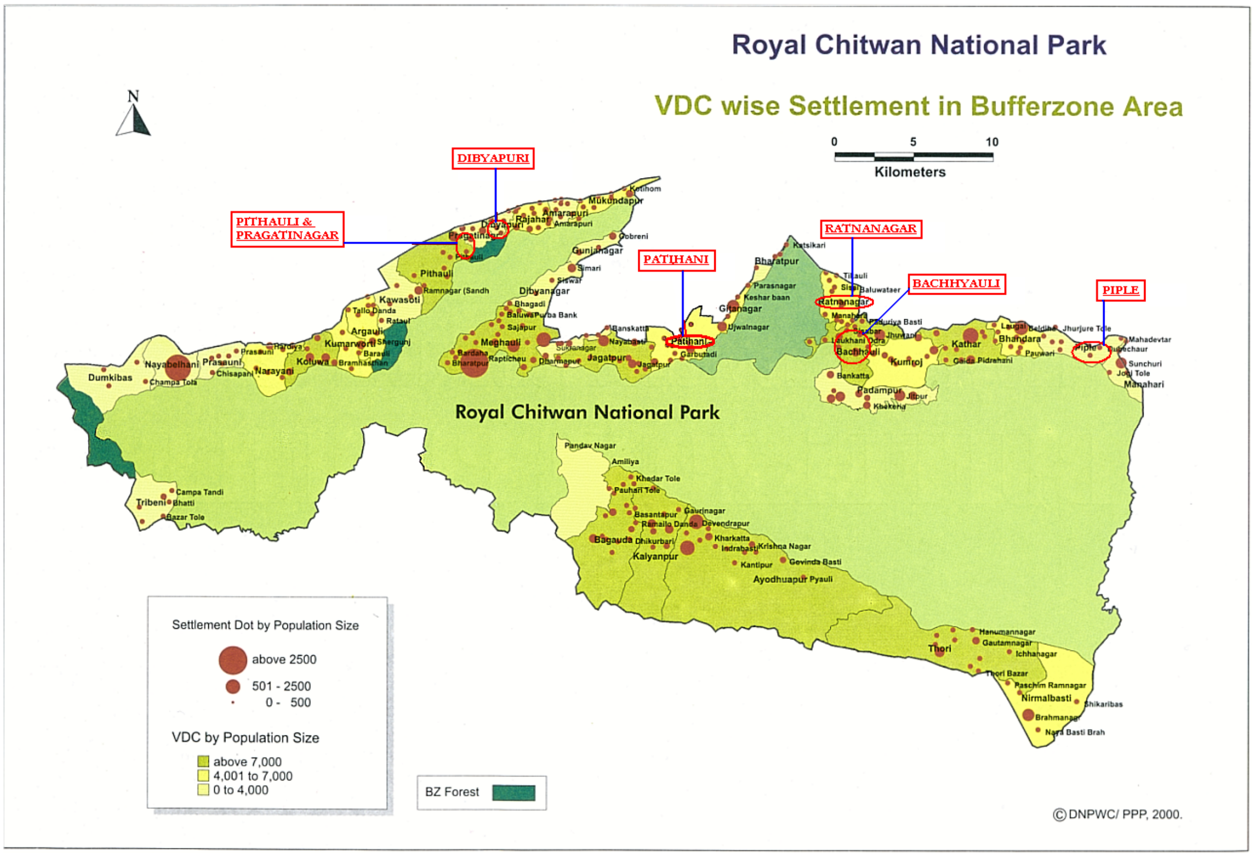


Figure 2: A map of Chitwan National Park displaying the location of selected VDCs in Chitwan District (DNPWC, 2000)



3.2 Data Requirements

The data employed for this research was gathered by a group of international scholars and local Nepalis over the course of five days in December 2003 and ten days in January 2004. Of primary importance for this project are the results of an extensive household questionnaire, in which 444 farmers located in six different VDCs in the vicinity of CNP were surveyed. The questionnaire accumulated information on the socio-economic status of households, crop production systems, household use of park resources, and households' perceptions towards rhino conservation and park management. Of more importance for the sake of this study however, are the questions related to crop losses suffered by farmers, the behavioral response that farmers exhibited towards these damages and the frequency of rhino sightings by farmers during both the winter and monsoon seasons.

3.2.1 The sample

The sample employed for this study was reduced from the 444 farmers that participated in the survey to a final value of 244.[4] Individual farmers were excluded from the sample for the following three reasons:

1) Credible threat level – Only those farmers that faced a credible threat level from the rhinoceros were included in the sample for this study. A credible threat level is defined as any farmer that experienced 'daily' or 'weekly' rhino sightings in either the winter or monsoon seasons. This level of threat was chosen as the cut-off criterion from the hypothesized relationship between rhino sightings and defensive measures that is presented in Table 1, whereby higher threat levels are associated with a greater probability that a farmer engages in investing in defensive measures. It is evident from Table 1 that there is a sharp decline in the number of farmers who decided to employ defensive measures if they reported either 'monthly' or 'never' responses to rhino sightings for both the winter and monsoon seasons. Thus, any farmer who reported either 'monthly' or 'never' responses to rhino sightings in both the winter and monsoon were excluded from the sample, which reduced the overall observation total from 442 to 328.

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[4] Two outliers were omitted from this sample. One experienced unusually high levels of crop damages, while the second invested an exceptionally high amount of rupees towards defensive measures.

Table 1: Rhino sightings and defensive measures by season

Sightings Season Combination		# of Farmers	# of Farmers with Defensive Expenditures	% of Farmers with Defensive Expenditures
Winter	Monsoon			
Daily	Daily	67	32	47%
Daily	Weekly	48	15	31%
Weekly	Daily	9	3	33%
Weekly	Weekly	25	13	52%
Daily	Monthly	89	19	21%
Monthly	Daily	2	0	0%
Weekly	Monthly	48	7	15%
Monthly	Weekly	3	2	67%
Daily	Never	18	4	22%
Never	Daily	0	0	~
Weekly	Never	19	1	5%
Never	Weekly	0	0	~
Monthly	Monthly	30	2	7%
Monthly	Never	46	0	0%
Never	Monthly	2	0	0%
Never	Never	36	1	2%
~		N = 442	N = 99	~

2) VDC #1 – All observations from VDC #1 (Ratnanagar) were also omitted from the sample due to its lengthy distance from the park boundary.[5] The mean distance of farmers from the park in VDC #1 was 6.61 km while the mean distance for the other VDC’s ranged from a low of 1.30 km to a high of 1.68 km. Personal communication with farmers residing in VDC #1 revealed that, due to its distance from the park, rhino sightings were essentially nonexistent in this region. Therefore, due to the extremely low threat level in VDC #1, all observations in this VDC were excluded from the sample which further reduced the overall observation total from 328 to 273. Sharma (1991) confirms this observation in acknowledging that virtually all crop damages by park wildlife occur within a five km belt around the park.

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[5] Several farmers in VDC #1 invested in defensive measures but were nonetheless omitted from the sample because of distance.

3) Crop production/defensive measures – All farmers who reported a combination of zero crop production and no investment in defensive measures were excluded from the final sample[6]. It is logical to omit such observations because if a farmer does not have any crops in his/her field for the rhino to damage, the threat level, irrespective of how high it is, is effectively meaningless. This last exclusion reduces the overall sample from 273 to its final value of 244.

3.2.2 The variables

An empirical estimation of the factors hypothesized to influence the decision of a farmer to implement defensive measures required data on a suite of variables including:

3.2.2.1 The dependent variable

(i) Defensive Expenditures, DE, (measured in Nepalese Rupees [NR]): All models presented in this study employ the total monetary cost in defensive measures per farmer as the dependent variable. This variable was comprised of two components: the investment cost in defensive measures and the maintenance/repair cost of existing defensive measures.

The first component, the investment cost, consists of three types of defensive measures (fences, trenches and machans [watchtowers]), with each type having an associated monetary and labour cost.[7] The labour cost for each type of defensive measure was converted into a monetary equivalent and was then added to the monetary cost to obtain the investment cost for each variety

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[6] Two farmers that invested in defensive measures but reported zero crop production were nonetheless included in the final sample because of how certain questions in the survey were designed. Specifically, the survey asked respondents to report their crop production from the previous year, and their investment in defensive measures over the last three years. Thus, it is possible that although the aforementioned two farmers did not produce any crops in the previous year, they may have grown crops in the two years prior to that which explains their decision to invest in defensive measures.

[7] The fence component is an amalgamation of two different types of fences (wire/wooden and biological) because only one respondent implemented a biological fence.

of defensive measure.[8] In turn, the investment costs for all three defensive measures were summed together to obtain the total value of investment costs in defensive measures for each household.

The second component, the maintenance/repair cost, was derived using the same process as outlined above for the investment cost. Summing these two values produced the total monetary cost in defensive measures for an individual farmer.

3.2.2.2 The independent variables [9]

(i) Thinning, THIN:[10] The thinning variable is the ratio of the total number of days/nights spent patrolling by the total amount of all agricultural land under cultivation. It is included to determine whether a farmer's investment in defensive measures and his/her associated thinning variable are compliments or substitutes to one another. These variables are complementary to each another if a high amount of time devoted to patrolling is associated with an increased investment in defensive measures. Conversely, THIN and DE are substitutes for each other if a low amount of time devoted to patrolling is associated with an increased investment in defensive measures. Evidence from the field suggests that THIN and DE are complementary to each another and thus, THIN is expected to have a positive association with defensive measures, as the

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[8] The household survey measured the labour cost of defensive measures in days which needed to be converted into a monetary figure. From the survey, the average daily salary of an agricultural worker was determined to be 90 NR. Mahesh Poudyal (personal communication, October 4th, 2010), revealed that the monetary equivalent of a labour day invested towards defensive measures was valued at 50% of the agricultural wage, and thus, equalled 45 NR.

[9] Considering the important role that crop damages play in influencing the decision of a farmer to engage in implementing defensive measures, it may seem odd that crop damages were not included as an independent variable. However, this was not possible owing to an issue of simultaneity (i.e. did farmers invest in defensive measures owing to prior damages or were the defensive measures implemented in anticipation of future damages occurring).

[10] Despite the possibility that the issue of simultaneity may be present between the thinning variable and the dependent variable, THIN is nonetheless included as an independent variable. Employing a patrolling component as part of the THIN variable is consistent with Sandler (1982) who constructs the THIN variable with the ratio of an ally's military personnel to its exposed border, where in essence, the military personnel is patrolling the exposed border (see section 5.1 for additional detail).

more time a farmer invests in patrolling per unit of area, the more likely it is that the farmer will invest in defensive measures.

(ii) Distance, DIST, (measured in km): The distance a respondent is located from the CNP boundary. This variable is expected to have a negative association with defensive measures, as the farther away a farm is located from CNP, the less likely it is that the farmer will invest in defensive measures.

(iii) Cultivated Area, CULTAREA, (measured in katha):[11] This variable is a summation of a farmer's total amount of all agricultural land under cultivation for the six types of crops grown in the region. It is expected to have a positive association with defensive measures, as a larger cultivated area implies that the farmer has more crops that are subject to possible damages, and thus, it is more likely that the farmer will invest in defensive measures.

(iv) Income, INCOME, (measured in NR): The total income of respondents. This variable represents a summation of the income associated with all sources of employment including: tourism, CNP, other government sectors, private sector, daily labour, small business, remittances, other sources, and farming. The income generated from farming required a two step calculation; a) Only those respondents who reported 12 months of household food sufficiency and who produced a minimum of 20 quintals of crops were deemed to generate income from farming;[12] b) Each quintal of crops produced above the sufficiency level was multiplied by 975 NR to determine the total value of earned crop income.[13] This variable is expected to have an ambiguous association with defensive measures as a higher income suggests both a greater ability to pay for defensive measures, but also, if income is higher (especially relative to crop

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[11] One katha is 67 m^2

[12] One quintal is 100 kg

[13] A quintal of rice was valued at 975 NR (constant 2005 prices) from the Government of Nepal (2007) and Pant (2009). For simplicity, given that rice is overwhelmingly the primary crop grown in the region, all crops above the 20 quintal threshold were assigned a monetary value of 975 NR, irrespective of what crop it was.

subsistence) then farming is less important to the household. This implies that the household depends less on farming for income and in turn, devotes less time and effort towards defensive measures.

(v) Age, AGE: The age of a respondent. This variable is expected to have a negative association with defensive measures, as the older a farmer is, the less physically able he/she will be to implement defensive measures. Also, older farmers tend to be less innovative/responsive to emerging technologies.

(vi) Schooling, SCHOOL, (measured in years): The number of formal schooling years completed by a respondent. The higher the number of schooling years completed by a respondent, the less likely it is that his/her primary occupation will be farming. This variable is expected to have an ambiguous association with defensive measures.

(vii) Threat Level, MBOTH: The frequency of daily and weekly rhino sightings in the monsoon season by each respondent.[14,15] Dummy variables were created for all four levels of sightings (i.e. daily, weekly, monthly, and never) with the lowest level (never) dropped from the analysis to avoid multicollinearity, while the dummy variable for monthly sightings was omitted as it was not significant. The two remaining dummy variables (daily and weekly) were then summed together to produce a single, high level of threat variable. This variable is expected to have a positive association with defensive measures as a higher frequency of sightings implies a greater threat and thus, a farmer will be more inclined to protect his/her crops.

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[14] Model pre-testing revealed that winter sightings were not significant, and thus, were excluded from the analysis. This is intuitive because rice, the primary crop grown both in Nepal and the Chitwan district, grows and matures throughout the monsoon season (May-October) and is harvested at the end of the season. Consequently, many fields are left fallow during the winter (Uprety, 1995) and thus, do not contain any crops for the rhino to raid.

[15] Even though winter sightings were excluded from the analysis, a farmer that experienced daily/weekly winter sightings were nonetheless included in the sample for this study. The rationale is that irrespective of whether a farmer’s fields are left fallow in the winter or not, the mere presence of rhinos wandering through the fields on a daily basis can certainly be viewed as a possible threat and thus, provide the impetus for implementing defensive measures.

(viii) Spill-over, SPILLAVG, (measured in NR): The average investment in defensive measures by all other farmers in the VDC. This variable was constructed by first summing the total investment in defensive expenditures of all farmers residing in an individual VDC and then subtracting each farmer's personal defensive expenditure investment from that total to obtain a unique spill-over value for that farmer. This unique value was then divided by the total number of farmers residing in that VDC (minus the farmer in question) to obtain an average spill-over value. Depending on how farmers react to the defensive expenditures of other farmers within his/her VDC, this variable is expected to have an ambiguous association with defensive measures.

(ix) Quadratic variable, THINSQ: This variable is the thinning variable squared. The quadratic variable is included to test whether the relationship between THIN and DE is non-linear. Given that this variable is simply the thinning variable squared, it is expected to have the opposite effect (i.e. negative) of the THIN variable on defensive expenditures.

(x) Interaction variable, MBOTHIN: This variable multiples thinning and rhino sightings to determine if their effect on defensive measures is not only additive, but multiplicative as well. This variable is expected to have a positive effect on defensive measures given that each variable independently was also expected to have a positive association with the dependent variable.

The codes and descriptions of the variables used in the models are presented in Table 2, while the descriptive statistics of the variables are presented in Table 3.

Table 2: Variables used in the estimation of defensive expenditures

Variable Code	Definition
Dependent Variable:	
DE	The total monetary cost in defensive measures
Independent Variables:	
THIN	The ratio of the total number of days/nights spent patrolling by the total amount of all agricultural land under cultivation
DIST	The distance a farmer is located from the CNP boundary in kilometers
CULTAREA	The total amount of all agricultural land under cultivation
INCOME	Total income per farmer
AGE	The age of a respondent
SCHOOL	The number of schooling years completed by a respondent
MBOTH	The frequency of daily and weekly rhino sightings by a farmer during the monsoon season
SPILLAVG	The average investment in defensive measures by all other farmers in the VDC
THINSQ	The THIN variable squared
MBOTHIN	The THIN variable multiplied by the MBOTH variable

Table 3: Descriptive statistics of the dependent and independent variables

Variable	Mean	Std. Deviation	Minimum	Maximum
DE	181.31	475.88	0.00	4140.00
THIN	1.14	3.67	0.00	40.00
DIST	1.34	0.67	0.10	4.00
CULTAREA	35.48	33.16	0.00	252.00
INCOME	41585.70	58842.1	0.00	527300.00
AGE	41.62	14.47	16.00	84.00
SCHOOL	3.73	4.30	0.00	16.00
MBOTH	0.48	0.50	0.00	1.00
SPILLAVG	177.74	42.89	56.82	227.65
THINSQ	14.73	109.47	0.00	1600.00
MBOTHIN	0.96	3.62	0.00	40.00

Chapter 4: Basic Defensive Measure Model

In this chapter I try to empirically estimate four models designed to explain the factors that are responsible for influencing the decision of a farmer residing near CNP to invest in defensive measures. Using the theoretical anchoring of the literature, I will first present the basic defensive measure model that considers which factors motivate a farmer to implement defensive measures. The second model enhances the basic model by including two additional independent variables; an interaction variable and a quadratic variable. The third model replicates the second model, save for the omission of the interaction variable. The fourth model is an extension of model 3 as it seeks to explain the fixed effects present within the model.

4.1 Model 1: The Implied Defensive Measure Relationship: Basic model

The literature (Hill, 1997; Kharel, 1997; Naughton-Treves, 1998; Hill, 2004; Sitati & Walpole, 2006; Oppong et al., 2008) suggests the following relationship for defensive measures:

$$DE = f(THIN, DIST, CULTAREA, INCOME, AGE, SCHOOL, MBOTH) \qquad [4.1]$$

where: DE = the total monetary cost of defensive measures; THIN = the ratio of the total number of days/nights spent patrolling by the total amount of all agricultural land under cultivation; DIST = the distance a respondent is located from the CNP boundary; CULTAREA = the total amount of agricultural land under cultivation; INCOME = total income of a respondent; AGE = age of a respondent; SCHOOL = the number of formal schooling years completed by a respondent; and MBOTH = a proxy for the external threat faced by a farmer from rhinoceros.

The units of measure for the variables are as follows: DE and INCOME are in Nepalese Rupees; THIN is the number of days/nights spent patrolling per katha; DIST is in kilometers;

CULTAREA is in katha; AGE and SCHOOL are in years; and MBOTH is the frequency of daily and weekly rhino sightings in the monsoon season.

Equation 4.1 was estimated by assuming a linear functional form and thus, the statistical relationship can be represented as:

$$\begin{aligned} DE = \alpha + \beta_1\, THIN + \beta_2\, DIST + \beta_3\, CULTAREA + \beta_4\, INCOME \\ + \beta_5\, AGE + \beta_6\, SCHOOL + \beta_7\, MBOTH + \varepsilon \end{aligned} \qquad [4.2]$$

The vector of random disturbances, ε, is assumed to be normally distributed, while α is the constant. The remaining terms β_1, β_2, β_3, β_4, β_5, β_6, and β_7 are the unknown slope coefficients and will be estimated.

4.2 Model 2: Interaction and Substitution Effects

The second model builds upon the basic model by including two additional independent variables; an interaction variable and a quadratic variable.

$$\begin{aligned} DE = f(THIN, THINSQ, DIST, CULTAREA, INCOME, AGE, \\ SCHOOL, MBOTH, MBOTHIN) \end{aligned} \qquad [4.3]$$

where: THINSQ = the quadratic variable and is simply the THIN variable squared. The quadratic variable is included to test whether the relationship between THIN and DE is non-linear; and MBOTHIN = the interaction variable and is constructed by multiplying the THIN variable by the MBOTH variable. The interaction variable is included because I suspect that the simultaneously influence of the THIN and MBOTH variables on the DE (dependent) variable is not additive, but rather, multiplicative.

Equation 4.3 was estimated by assuming a linear functional form and thus, the statistical relationship can be represented as:

$$DE = \alpha + \beta_1 \text{ THIN} + \beta_2 \text{ THINSQ} + \beta_3 \text{ DIST} + \beta_4 \text{ CULTAREA} + \beta_5 \text{ INCOME} + \beta_6 \text{ AGE} + \beta_7 \text{ SCHOOL} + \beta_8 \text{ MBOTH} + \beta_9 \text{ MBOTHIN} + \varepsilon \qquad [4.4]$$

The model interpretation is identical to equation 4.2. See section 4.1.1

4.3 Model 3: Substitution Effects

The third model is a replica of model two, save for the omission of the interaction variable, MBOTHIN, and to avoid repetition, will not be reconstructed.

Models 2 and 3 will be directly compared to one another to determine if the addition of the interaction variable improves the fit of the model. Only the model that produces superior results will be analyzed in the results section.

4.4 Model 4: The Basic Model with Fixed Effects

The fourth model is identical to Model 3 as it contains all of the same variables, and thus, will not be re-written. Unlike the previous three models which ignore any unobserved individual effects amongst the parameters, Model 4 introduces a fixed effects component to account for such an effect (Baltagi, 2008). Thus, the fixed effects model assists in controlling for any unobserved heterogeneity that may be correlated with the independent variables (Baltagi, 2008).

Chapter 5: Putting the Rhino System in the Context of the Theory of Alliances

The modeling from the previous chapter only considered the factors that motivate a farmer to implement defensive measures on an individual basis and did not consider any group dynamics that may influence this decision. For instance, an important consideration is whether the decision of a farmer to implement defensive measures is motivated by the defensive action employed by neighboring farmers. To determine if this aforementioned decision is indeed influenced by the action of neighboring farmers, an economic model developed by Murdoch & Sandler (1982) which is rooted in the theory of alliances will be adapted and applied to the defensive measure models described in the previous chapter. Section 5.1 provides a detailed summary of the article written by Murdoch & Sandler (1982) including a thorough analysis of the joint product model presented in the paper. Section 5.2 will characterize the rhino system that exists in and around Chitwan National Park within the context of the theory of alliances. Section 5.3 adapts and applies the joint product model developed by Murdoch & Sandler (1982) to the rhino system. Section 5.4 expands the joint product model by including all the variables hypothesized to influence the decision of a farmer to implement defensive measures as outlined in model 3 in section 4.3. Finally, section 5.5 details the econometrics component of the study by providing the procedure for estimating the empirical models.

5.1 Summarizing Murdoch and Sandler (1982)

A thorough review of the existing literature pertaining to the theory of alliances revealed that a variety of economic models have been constructed and applied to NATO and other military alliances.[16] While each model is unique and provides insight into the theory of alliances, only

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[16] See Appendix 1 for a comprehensive review of various economic models pertaining to the theory of alliances

those models that could be adequately adapted to the rhino system that exists in and around CNP were considered for this study. Of this group of aforementioned models, the model developed by Murdoch and Sandler (1982) was deemed the most appropriate based on the straightforward application of the variables employed in the model to the rhino system.

5.1.1 The joint product model

Since its creation in the 1970's, the joint product model (see section 2.4) has been adapted and refined by many scholars to achieve a variety of modeling objectives. For instance, Murdoch and Sandler (1982) enhanced the joint product model by enabling it to account for nuclear war alliances. In particular, the refined model contained two unique variables that were both hypothesized to influence the defense expenditures of a nation; a thinning variable and an external threat variable. The thinning variable is proxied by the ratio of an ally's military personnel to its exposed border while the external threat variable accounts for the threat faced by all NATO members. Additionally, while preceding studies demonstrated that responses to defense spill-ins solely depended upon 'income responsiveness', whereby spill-ins typically trigger allies to reduce defense expenditures (Olson & Zeckhauser, 1966), the model presented by Murdoch and Sandler (1982) indicates that allies' responses to defense spillovers not only depend upon 'income responsiveness', but also on the consumption relationship (i.e., complementarity or substitutability) of the jointly produced defense outputs of the alliance. Further, the results of the model indicate that when the jointly produced defense outputs are complementary in nature, alliance members may actually increase their defense expenditures in response to spill-ins.

5.1.2 The implied defense expenditure relationship

Murdoch and Sandler (1982) present three theoretical models for the 12 NATO allies considered in the study that ultimately suggest the following relationship for defense expenditures for each ally:[17]

$$ME = f(WEALTH, THIN, SPILL, STRAT) \qquad [5.1]$$

where: ME represents an ally's military expenditures; WEALTH is measured by an ally's gross domestic product; THIN is proxied by the ratio of an ally's military personnel to its exposed border and strives to portray the possible density of the ally's armed forces along its perimeter; SPILL is denoted as net NATO defense expenditures where an ally's own defense expenditures are subtracted from NATO's net total; and STRAT symbolizes the relative strategic strength of NATO and is expressed by the ratio of U.S long-range missiles and long-range bombers to USSR's long-range missiles and bombers. STRAT is a proxy for both the external threat faced by NATO from the USSR and the relative size of its strategic forces.

The variables ME, WEALTH and SPILL are expressed using constant 1970 U.S dollars; THIN is 10s of troops per kilometer of exposed border; and STRAT is the ratio of U.S missiles and bombers to those of the USSR.

Wealth is anticipated to have a positive and significant influence on defense expenditures for all allies given the overwhelming importance of income effects in the joint product model. Nations geographically positioned on the outer boundary of the NATO alliance (i.e. Greece) are expected to be especially responsive and negatively related to the thinning variable. When free riding is possible or when the jointly produced defense outputs are substitutes, NATO members

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[17] Although at the time of publication NATO contained 15 countries, Iceland, Luxembourg and Portugal were omitted from the analysis due to data collection issues.

will respond negatively to spill-ins. From the opposite perspective, when the jointly produced defense outputs are complimentary, nations will respond positively to spill-ins by augmenting their defense expenditures. Lastly, when U.S relative strategic strength increases, a positive sign is anticipated for the threat variable for European allies with an associated increase in defense expenditures.

5.1.3 Empirical model

Equation 5.1 was estimated by assuming a linear functional form and is represented as:

$$ME_j = \alpha_j + \beta_{1j}\ WEALTH_j + \beta_{2j}\ THIN_j + \beta_{3j}\ SPILL_j + \beta_{4j}\ STRAT + \varepsilon_j \qquad [5.2]$$

The subscript j corresponds to the country under consideration and runs from 1 to 12, while the subscript for the STRAT variable has been omitted as it is identical for each member. The vector of random disturbances ε_j is assumed to be distributed normally with a mean of zero, the variables β_{1j}, β_{2j}, β_{3j} and β_{4j} are the unknown slope coefficients while α_j is the constant. The estimates for the unknown slope coefficients were obtained using the seemingly unrelated regression (SUR) method, which produced the desired estimates by using generalized least squares (GLS).

5.2 The Rhino System

The purpose of this section is to characterize the rhino system that exists in and around Chitwan National Park within the context of the theory of alliances. In particular, this section aims to explain whether the decision of a farmer to implement defensive measures is motivated by the defensive action employed by neighboring farmers.

The earliest models pertaining to the theory of alliances portrayed defense expenditures as a pure public good supplied by all members of the NATO alliance. As the theory evolved however, defense expenditures were no longer viewed strictly as public goods, but began to assume the properties of both impure public goods and/or private goods. In the context of the rhino system, it is unclear whether the defensive measures implemented by farmers to combat crop damages at CNP represent a pure public good, an impure public good and/or a private good. For a defensive measure (i.e. a fence) to be characterized as a public good, the properties of that fence must be both non-excludable, whereby the fence protects both the crops of the farmer who erects it and those of neighbouring farmers, and non-rivalrous, whereby the consumption of the fence by the farmer who erects it does not take away from the consumption of other farmers ability to receive the benefits of the fence. A simple example will now be presented to help illustrate how defensive effort can assume the properties of a public good.

Depending on the characteristics of an invading rhino, when a farmer residing near Chitwan National Park constructs a fence on his/her territory, two possible scenarios may arise. First, if prospective invading rhinos encounter a fence and are prevented from entering the adjacent field, the animal may be sufficiently deterred by this defensive measure and retreat to the park without inflicting any damage whatsoever. If such an event were to occur, farmers who do not possess any defensive measures, yet live in the vicinity of a farmer that constructed the fence (i.e. their property is situated beside or behind the protected farmer), have essentially benefited from the mere presence of the fence as he/she has not suffered any crop damages. This benefit is referred to as a ‘spill-in’ by Olson & Zeckhauser (1966) and arises when farmers who do not implement defensive measures perceive a benefit from the presence of their neighbours fence, and thus, will be less inclined to invest in defensive measures as they can simply obtain this benefit at no cost. In effect, the farmer who does not invest in defensive measures is free-riding off of his/her neighbour, as he/she receives the benefits of the defensive measure without incurring any expenses. In this first scenario, the fence represents a public good that is jointly consumed by various farmers simultaneously, where only one farmer constructs the fence but many farmers obtain the benefits of the defensive measure.

From the opposite perspective however, a protective fence may also be classified as a private good due to the presence of exclusion and rivalrous properties. In the second scenario, if an approaching rhino encounters a fence and is deterred from invading the protected field, yet rather than retreat to the park simply wanders along the fence until it comes across an unprotected farm, the animal is liable to inflict widespread crop damages on this unguarded land. In this instance, the defensive measure is essentially responsible for ‘deflecting’ the rhino into an unprotected field and in the process, causing crop damages. This damage can actually be viewed as inflicting a ‘spill-out’ cost to the unprotected farmer, as opposed to the previous scenario where the fence produced a ‘spill-in’ benefit. The defensive measure in this scenario represents a private good as the fence only protects the crops of the farmer who erects it (i.e. excludability) and the consumption of the fence by the farmer who erects it takes away from the consumption of other farmer’s ability to receive the benefits of the fence (i.e. rivalry).

5.3 Adapted Joint Product Model

The model presented in section 5.1 will now be applied to the rhino system outlined in the previous section. In essence, each of the variables contained within the empirical model developed by Murdoch and Sandler (1982) will be adapted to the rhino system. The model appears as follows:

$$DE = f(SPILLAVG, THIN, INCOME, MBOTH) \qquad [5.3]$$

where: DE represents the defense expenditures of a farmer; SPILLAVG is denoted as the average investment in defensive measures by an individual farmer per VDC; THIN is the ratio of the total number of days/nights spent patrolling by a farmer by the total amount of all his/her agricultural land under cultivation; INCOME is the total income earned by a farmer; and MBOTH symbolizes the frequency of daily and weekly rhino sightings in the monsoon season by each farmer and represents a proxy for the external threat faced by a farmer.

The variables DE, SPILLAVG and INCOME are expressed in Nepalese Rupees; THIN is the number of days/nights spent patrolling per katha; and MBOTH is the frequency of daily and weekly rhino sightings in the monsoon season.

Equation 5.3 is empirically represented as:

$$DE_j = \alpha_j + \beta_{1j}\ SPILLAVG_j + \beta_{2j}\ THIN_j + \beta_{3j}\ INCOME_j + \beta_{4j}\ MBOTH_j + \varepsilon_j \qquad [5.4]$$

To avoid repetition, see equation 4.2 in section 4.1.1 for model interpretation.

5.4 Expanded Joint Product Model

This model expands the joint product model presented above by including all the variables hypothesized to influence the decision of a farmer to implement defensive measures as outlined in model 3 in section 4.3.

$$DE = f(SPILLAVG, THIN, THINSQ, DIST, CULTAREA, INCOME, \\ AGE, SCHOOL, MBOTH) \qquad [5.5]$$

where: THINSQ = the quadratic variable and is simply the THIN variable squared; DIST = the distance a respondent is located from the CNP boundary; CULTAREA = the total amount of agricultural land under cultivation; AGE = age of a respondent; SCHOOL = the number of formal schooling years completed by a respondent.

The units of measure for the variables are as follows: DIST is in kilometers; CULTAREA is in katha; AGE and SCHOOL are in years.

Equation 5.5 is empirically represented as:

$$DE_j = \alpha_j + \beta_{1j}\ SPILLAVG_j + \beta_{2j}\ THIN_j + \beta_{3j}\ THINSQ_j + \beta_{4j}\ DIST_j + \beta_{5j}\ CULTAREA_j \\ + \beta_{6j}\ INCOME_j + \beta_{7j}\ AGE_j + \beta_{8j}\ SCHOOL_j + \beta_{9j}\ MBOTH_j + \varepsilon_j \qquad [5.6]$$

See section 4.1.1 for model interpretation.

5.5 Estimation Procedure

The regression model used to estimate the empirical models presented above depends on the characteristics of the data at hand. The total monetary cost invested in defensive measures (the dependent variable) is cross-sectional data which cannot be negative and contains a high quantity of zeroes (i.e. many farmers do not invest in defensive measures).[18] Given these conditions, ordinary least squares (OLS) regression leads to inconsistent parameter estimates and, therefore, I used a Tobit model instead.[19,20] The standard equation for the Tobit model is:

$$y_i^* = \beta x_i + \varepsilon_i$$
$$y_i = y_i^* \quad \text{if } y_i^* > 0$$
$$y_i = 0 \quad \text{if } y_i^* \leq 0$$

where: y_i^* is the latent (unobservable) dependent variable; y = the observed dependent variable; x = a vector of independent variables hypothesized to influence the dependent variable; β = a vector of unknown coefficients to be estimated; and ε = a normally distributed error term.

In accordance with Amemiya (1973) and Greene (2012), the Tobit model uses maximum likelihood estimation techniques to generate the estimated coefficients of the parameters. Interpreting the regression coefficients for the Tobit model however, is more complex than interpreting the coefficients for an OLS model (Roncek, 1992; Gujarati, 1995). Specifically, the estimated coefficients represent the marginal effect of x on the latent variable y^* and not to the

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[18] Sigelman and Zeng (1999) discuss how, theoretically, the Tobit model is valid only if the dependent variable contains negative values that have been censored to zero. In practice, however, the Tobit model is consistently used when the values of the observed dependent variable are exclusively non-negative and contain a large quantity of zeros, regardless of whether any censoring has occurred.

[19] Both Ghosh (1991) and Sigelman and Zeng (1999) provide a comprehensive account of Tobit regression, including how to analyze and interpret the results.

[20] Various log versions of the model, including log-log, linear-log, and log-linear, were all tested but failed to improve the fit of the model. Thus, they were excluded from this study.

observed variable *y*, which is the variable of interest. Thus, the marginal effect of *x* (the vector of independent variables) on the observed dependent variable, *y*, is calculated. Marginal effects can be interpreted as the change in the dependent variable given a one unit change in the independent variable under consideration while holding all other independent variables constant. P-values were used to determine the statistical significance of the independent variables and their estimated coefficients (probability values (P) of 0.1, 0.05, 0.01).

Additionally, as discussed by Greene (2007), unlike linear regression models where R-squared is a valid measure of fit, there is no readily interpreted fit measure for the nonlinear Tobit model. However, many surrogates have been suggested and developed for the Tobit model including the ANOVA and DECOMP based fit measures. The LIMDEP 9.0 econometric software package, which was used for all regression analysis, automatically generates these aforementioned fit measures. Thus, paralleling Speelman et al. (2008), the ANOVA and DECOMP measures, which essentially mimic R-squared in OLS, will be employed as fit measures.

Chapter 6: Results and Discussion

6.1 Results

All models were estimated with the econometrics software package, LIMDEP 9.0. Models 1 – 4 included all the explanatory variables that were thought to influence the decision of a farmer residing near CNP to invest in defensive measures. The results are presented in Table 4, where column two provides the estimation results for Model 1 – The Implied Defensive Measure Relationship: Basic model, column three contains the results for Model 2 – Substitution and Interaction Effects, column four presents the results for Model 3 – Substitution Effects, and column five displays the results for Model 4 – Basic Model with Fixed Effects. The marginal effects of the independent variables are displayed in Table 5. Regarding the significance and expected sign of estimated coefficients, as well as the various model statistics, all four models produced very similar results. Specifically, all four risk factors (THIN, DIST, CULTAREA, and MBOTH) are significant while all three demographic factors (INCOME, AGE, and SCHOOL) are not significant. Moreover, the coefficient on each of the explanatory variables has the expected sign. Each model will now be discussed in turn.

6.1.1 Basic defensive measure models

The estimation results for Model 1 show that the coefficients for thinning (THIN), the total amount of all agricultural land under cultivation (CULTAREA), and the frequency of rhino sightings during the monsoon, or threat level, (MBOTH) are all significant at the 1% level. The coefficient for the distance from the CNP boundary (DIST) is significant at the 5% level (P-value = 0.0172). Of the three demographic variables, only the number of schooling years completed by a respondent (SCHOOL) was highly insignificant (P-value = 0.6929), while total income

Table 4: Estimated coefficients, p-values and model statistics for Tobit models 1 – 4

Explanatory Variables	Model 1		Model 2		Model 3		Model 4		Expected Sign
	Coefficient	P-Value	Coefficient	P-Value	Coefficient	P-Value	Coefficient	P-Value	
Constant	-341.3451	0.3573	-432.7810	0.2594	-393.6533	0.2852	~		
THIN	60.9253	0.0015***	215.0864	0.0093***	187.8188	0.0001***	184.5877	0.0001***	+
DIST	-320.8030	0.0172**	-258.6658	0.0538*	-262.2601	0.0496**	-264.0650	0.0524*	-
CULTAREA	7.3690	0.0060***	7.3513	0.0056***	7.3947	0.0052***	7.0137	0.0098***	+
INCOME	-0.0024	0.1965	-0.0020	0.2598	-0.0021	0.2440	-0.0020	0.2824	+/-
AGE	-8.8744	0.1763	-9.9593	0.1318	-10.2617	0.1173	-9.3105	0.1806	-
SCHOOL	9.0948	0.6929	2.6166	0.9096	2.1671	0.9248	1.6988	0.9427	+/-
MBOTH	533.9681	0.0027***	469.0870	0.0157**	438.9163	0.0129**	436.5418	0.0275**	+
THINSQ	~		-4.4666	0.0009***	-4.6393	0.0003***	-4.5001	0.0006***	-
MBOTHIN	~		-33.5914	0.7021	~		~		+
Model Statistics	~		~		~		~		~
Log L	-713.819		-706.630		-706.703		-706.095		~
R^2_{ANOVA}	0.4461		0.4333		0.4193		~		~
R^2_{DECOMP}	0.4367		0.4376		0.4372		~		~

Note: The dependent variable is DE for all models, N = 244
* = $P < 0.1$ (90%), ** = $P < 0.05$ (95%), *** = $P < 0.01$ (99%)

Table 5: Marginal effects of the independent variables for Tobit models 1-4

Explanatory Variable	Model 1	Model 2	Model 3	Model 4
THIN	16.1576	53.6873	46.8392	45.0960
DIST	-85.0779	-65.9342	-67.0603	-66.1251
CULTAREA	1.9542	1.8739	1.8908	1.7563
INCOME	-0.0006	-0.0005	-0.0005	-0.0005
AGE	-2.3535	-2.5386	-2.6239	-2.3315
SCHOOL	2.4120	0.6670	0.5542	0.4254
MBOTH	141.6099	119.5708	112.2314	109.3155
MBOTHIN	~	-8.5625	~	~

(INCOME) and the age of a respondent (AGE) were marginally insignificant (P-values = 0.1965 and 0.1763). Regarding the variables that are significant, the positive coefficient on the THIN variable indicates that it is positively correlated to the dependent variable meaning that as THIN increases, a farmer would be more likely to invest in defensive measures. The marginal effect of THIN implies that a one unit increase in the ratio of the total number of days/nights spent patrolling by the total amount of all agricultural land under cultivation is likely to increase the defensive expenditures of a farmer by 16.16 NR, all else being equal. Similarly, CULTAREA is also positively correlated with DE while the marginal effect of a one unit (katha) increase in the amount of agricultural land under cultivation provides an estimated increase in defensive expenditures by 1.95 NR, all else being equal. The dummy variable, MBOTH, is also positively correlated with the dependent variable while the marginal effect implies that a farmer that experienced daily and/or weekly rhino sightings during the monsoon would increase his/her spending on defensive expenditures by 141.61 NR relative to the base case (a farmer that does not experience daily and/or weekly rhino sightings during the monsoon). On the contrary, the negative coefficient on the DIST variable indicates that it is negatively correlated to the dependent variable meaning that as DIST increases, a farmer would be less likely to invest in defensive measures. The marginal effect of DIST implies that moving a distance of one kilometer away from the CNP boundary would result in a 85.08 NR decrease in defensive expenditures, all else being equal. Lastly, the overall statistical fit of the model was quite good as indicated by the R^2_{ANOVA} value of 0.4461 and the R^2_{DECOMP} value of 0.4367.

Model 2 enhances the basic model (Model 1) by including two additional independent variables; an interaction variable and a quadratic variable, while Model 3 was a replica of Model 2, save for the omission of the interaction variable. Both models produced very similar results, as their generated coefficients, marginal effects of the independent variables, log likelihoods and both pseudo R^2 values were almost identical to one another (see Tables 4 & 5). Following Ghosh (1991), a common method used to compare the fit of two models is the likelihood ratio test[21] that computes a chi-square value which is then compared to a critical value to decide whether to reject the null model in favor of the alternative model. However, given that the log likelihood functions for Models 2 & 3 are virtually identical (-706.630 & -706.703), this test provides little insight into overall model fit. Thus, considering that the interaction variable (MBOTHIN) was highly insignificant (0.7021) and that the P-values on every coefficient in Model 3 were more significant relative to those same values in Model 2, Model 3 is deemed to better represent the data compared to Model 2. Essentially, introducing interaction effect does not substantially improve the fit of the model and therefore, the simpler, non-interaction model is preferred over the alternative. As a result, only the results from Model 3 will be discussed further.

The estimation results for Model 3 demonstrate that the coefficients for THIN, CULTAREA, and THINSQ are all significant at the 1% level. The coefficients for MBOTH and DIST are significant at the 5% level. Similar to Model 1, all three demographic variables were insignificant, although there is an improvement in the significance of the coefficient for the age

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[21] $LR = -2*[\text{Log } L_{\text{null model}} - \text{Log } L_{\text{alternative model}}]$

of a respondent (AGE; P-value = 0.1173). Regarding the variables that are significant, THIN is positively correlated with DE while the marginal effect of the THIN variable implies that a one unit increase in the ratio of the total number of days/nights spent patrolling by the total amount of all agricultural land under cultivation is likely to increase the defensive expenditures of a farmer by 48.03 NR, all else being equal. Similarly, CULTAREA is also positively correlated with DE while the marginal effect of a one unit (katha) increase in the amount of agricultural land under cultivation provides an estimated increase in defensive expenditures by 1.89 NR, all else being equal. The dummy variable, MBOTH, is also positively correlated with the dependent variable while the marginal effect implies that a farmer that experienced daily and/or weekly rhino sightings during the monsoon would increase his/her spending on defensive expenditures by 112.23 NR relative to the base case (a farmer that does not experience daily and/or weekly rhino sightings during the monsoon). From the opposite perspective, the negative coefficient on the DIST variable indicates that it is negatively correlated to the dependent variable meaning that as DIST increases, a farmer would be less likely to invest in defensive measures. The marginal effect of DIST implies that moving a distance of one kilometer away from the CNP boundary would result in a 67.06 NR decrease in defensive expenditures, all else being equal. Similarly, THINSQ is also negatively correlated with DE while the marginal effect of a one unit increase in the THINSQ variable would decrease a farmer's investment in defensive expenditures by 1.19 NR, all else being equal. Lastly, the overall statistical fit of the model was quite good as indicated by the R^2_{ANOVA} value of 0.4193 and the R^2_{DECOMP} value of 0.4372.

6.1.2 Alliance models

Model 5 adapted and applied the joint product model developed by Murdoch & Sandler (1982) to the rhino system that exists in CNP, while Model 6 expanded this model by including all the variables hypothesized to influence the decision of a farmer to implement defensive measures. The estimated coefficients, p-values and model statistics for both models are presented in Table 6, while the marginal effects of the independent variables are displayed in Table 7. Each model will now be discussed in turn.

The estimation results for Model 5 reveal that all four explanatory variables possess the expected sign. Of these variables, the coefficients for the average investment in defensive measures by a farmer by VDC (SPILLVDC), thinning (THIN) and the frequency of rhino sightings during the monsoon, or threat level, (MBOTH) are all significant at the 1% level. Only the total income variable (INCOME) is insignificant. Regarding the variables that are significant, the negative coefficient on the SPILLAVG variable indicates that it is negatively correlated to the dependent variable meaning that as SPILLAVG increases, a farmer would be less likely to invest in defensive measures. The marginal effect of SPILLAVG implies that a one unit increase in SPILLAVG would result in a 1.60 NR decrease in defensive expenditures, all else being equal. On the contrary, the positive coefficient on the THIN variable indicates that it is positively correlated with the dependent variable meaning that as THIN increases, a farmer would be more likely to invest in defensive measures. The marginal effect of THIN implies that a one unit increase in the ratio of the total number of days/nights spent patrolling by the total amount of all agricultural land under cultivation is likely to increase the defensive expenditures of a farmer by 19.04 NR, all else being equal. The dummy variable, MBOTH, is also positively correlated with the dependent variable while the marginal effect implies that a farmer that experienced daily and/or weekly rhino sightings during the monsoon would increase his/her spending on defensive expenditures by 195.80 NR relative to the base case (a farmer that does not experience daily and/or weekly rhino sightings during the monsoon). Lastly, the overall statistical fit of the model was quite good as indicated by the R^2_{ANOVA} value of 0.2653 and the R^2_{DECOMP} value of 0.4304.

Table 6: Estimated coefficients, p-values and model statistics for Models 5 & 6

Explanatory Variables	Model 5		Model 6		Expected Sign
	Coefficient	P-value	Coefficient	P-value	
Constant	40.5224	0.9084	723.7343	0.1308	~
SPILLAVG	-5.7749	0.0033***	-6.1667	0.0013***	+/-
THIN	68.7007	0.0003***	197.7292	0.0000***	+
INCOME	0.0003	0.8437	-0.0018	0.2957	+
MBOTH	706.4100	0.0001***	607.0451	0.0007***	+
THINSQ	~		-4.7752	0.0001***	-
DIST	~		-254.8941	0.0423**	-
CULTAREA	~		6.2989	0.0129**	+
AGE	~		-11.3536	0.0711*	-
SCHOOL	~		-0.0869	0.9968	+/-
Model Statistics	~		~		~
Log L	-716.8810		-701.5310		~
R^2_{ANOVA}	0.2653		0.4688		~
R^2_{DECOMP}	0.4304		0.4325		~

Note: N = 244
* P = < 0.1 (90%), ** = P < 0.05 (95%), *** = P < 0.01 (99%)

Table 7: Marginal effects of the independent variables for Models 5 & 6

Explanatory Variables	Model 5	Model 6
SPILLAVG	-1.6007	-1.5536
THIN	19.0423	48.6133
INCOME	0.0001	-0.0005
MBOTH	195.8014	152.9404
DIST	~	-64.2186
CULTAREA	~	1.5870
AGE	~	-2.8605
SCHOOL	~	-0.0212

The estimation results for Model 6 show that all explanatory variables possess the expected sign. The coefficients for SPILLVDC, THIN, THINSQ, and MBOTH are all significant at the 1% level. The coefficients for DIST and CULTAREA are significant at the 5% level while the coefficient for AGE is significant at the 10% level. Lastly, the coefficients on the INCOME and SCHOOL variables are both insignificant. With reference to the variables that are significant, the negative coefficient on the SPILLAVG variable indicates that it is negatively correlated to the dependent variable while its marginal effect implies that a one unit increase in a farmer's SPILLAVG would result in a 1.55 NR decrease in defensive expenditures, all else being equal. Similarly, DIST is also negatively correlated to DE with the marginal effect of DIST implying that moving a distance of one kilometer away from the CNP boundary would result in a 64.22 NR decrease in defensive expenditures, all else being equal. The THINSQ variable is also negatively correlated with the dependent variable, while the marginal effect of a one unit increase in THINSQ would decrease a farmer's investment in defensive expenditures by 1.20 NR, all else being equal. Finally, AGE is also negatively correlated to the dependent variable meaning that an increase in age of one year yields a 2.86 NR decrease in defensive expenditures, all else being equal.

From the opposite perspective, the positive coefficient on the THIN variable indicates that it is positively correlated to the dependent variable meaning that as THIN increases, a farmer would be more likely to invest in defensive measures. The marginal effect of THIN implies that a one unit increase in the ratio of the total number of days/nights spent patrolling by the total amount of all agricultural land under cultivation is likely to increase the defensive expenditures of a farmer by 49.82 NR, all else being equal. Likewise, CULTAREA is positively correlated with DE while the marginal effect of a one unit (katha) increase in the amount of agricultural land under cultivation provides an estimated increase in defensive expenditures by 1.59 NR, all else being equal. The dummy variable, MBOTH, is also positively correlated with the dependent variable while the marginal effect implies that a farmer that experienced daily and/or weekly rhino sightings during the monsoon would increase his/her spending on defensive expenditures by 152.94 NR relative to the base case (a farmer that does not experience daily and/or weekly rhino sightings during the monsoon). Lastly, the overall statistical fit of the model was quite good as indicated by the R^2_{ANOVA} value of 0.4688 and the R^2_{DECOMP} value of 0.4325.

6.2 Discussion

The models presented in this study provide important insight into the factors that are hypothesized to influence the decision of a farmer residing near CNP to invest in defensive measures. With the exception of Model 1, all models produced very similar results to one another and on the whole, they all performed extremely well. Of the main factors considered, the frequency of rhino sightings during the monsoon (MBOTH) represented a suitable proxy for the threat level faced by farmers as it was consistently positive and highly significant. Intuitively, a higher frequency of sightings equates to a higher threat level, and consequently, farmers responded by investing in defensive measures. Of interest is the fact that sightings during the winter were more common than during the monsoon, but the coefficient on this variable was not significant. One possible explanation is that although rice is the most common crop planted in Chitwan district (and accordingly, is raided by rhinos most frequently), wheat, a winter crop, is the most preferred crop for rhinos (Uprety, 1995). As a result of this preference, many farmers do not plant wheat and often leave their fields fallow during the winter season. However, despite the relatively low quantity of wheat cultivation, rhinos will often spend a considerable amount of time wandering from farm to farm to find and raid wheat (Uprety, 1995), thereby increasing the overall number of sightings. Concomitantly, near the end of the winter season, large tracts of grasslands within CNP are burnt by farmers through controlled burns. Considering that rhinos are grazers, burning large plots of land essentially reduces the availability of food found within the park, prompting rhinos to exit the park in search of alternate food sources, and once again, has the effect of increasing the frequency of sightings.

The distance between an individual farm and CNP (DIST) was a consistently negative and significant influence towards the decision of a farmer to implement defensive measures.

However, given the overwhelming amount of literature (Hill, 1997; Kharel, 1997; Naughton-Treves, 1998; Hill, 2000) that confirms how distance between a farm and a protected area is the primary factor that places farmers at risk to crop damages from wildlife, I expected this variable to have an even stronger influence on the dependent variable. Additionally, studies conducted in CNP (see Sharma, 1990; Uprety, 1995) report that most crop damages from the rhino occur within 1 km of the park border. Moreover, my field visit to the communities surrounding CNP confirmed this finding as farmers situated adjacent to the boundary repeatedly reported a drastically higher frequency of crop damages from the rhino compared to farmers located farther away from the park boundary. A central point discussed by Hill (1997) however, is that absolute distance itself is not overly important. Of more importance is that farms located farther away from a park boundary are typically buffered by neighboring farms situated between that farm and the border. Thus, it is unlikely that an animal would traverse through several farms to raid a farm located farther away from the boundary. Hill (1997) reported that those farmers who do not experience crop damages typically have two farms located between them and any forest cover. This result was confirmed numerous times during discussions with local farmers during my field visit who repeatedly reported that defensive measures employed by their neighbors located between them and the CNP boundary played an instrumental role in protecting their own crops. In effect, this latter point provided the impetus for excluding observations from VDC #1 (Ratnanagar) from the study sample as every farmer interviewed in that VDC confirmed that buffering farms resulted in no reported crop damages from the rhino.

The thinning variable (THIN) was designed to capture the influence that patrolling per unit of cultivated land had on the dependent variable and as anticipated, it was consistently positive and highly significant. A reoccurring theme throughout the crop damage literature (see Sekhar, 1998 and Nyhus et al., 2000) was that patrolling was the most common method of crop protection largely due to the minimal if any, financial investment involved. Further, Sitati & Walpole (2006) reported that a combination of patrolling and implementing passive barriers were more effective than simply implementing passive barriers alone. The positive and highly significant complimentary relationship between THIN and DE indicates that farmers appear to be aware of the benefit of concurrently investing in defensive measures and patrolling their fields, and do not substitute one for the other.

The SPILLAVG variable was motivated by the work of Murdoch & Sandler (1982) and was created in an attempt to explain whether the decision of a farmer to implement defensive measures is influenced by the defensive action employed by neighboring farmers. Both models that contained the SPILLAVG variable revealed that it was highly significant and negatively correlated to DE, implying that as SPILLAVG (the total amount of rupees that a VDC spends on defensive measures) increases, the corresponding farmer would be less likely to invest in defensive measures him/herself. In effect, when VDC wide defensive measures increase, an individual farmer will feel sufficiently protected from this additional effort and opt to not invest in personal defensive measures. With reference to the theory of alliances and in conjunction with Murdoch & Sandler (1982), this finding essentially confirms that farmers are free-riding on the defensive effort of neighboring farmers and in turn, are receiving a ‘spill-in’ benefit in the form of crop protection. It therefore appears that defensive effort can be viewed as a public good that is jointly consumed by various farmers simultaneously, where only one (or a few) farmer(s) constructs the defensive measure but many farmers obtain the benefits. Thus, the presence of the public good creates a market failure whereby an incentive is created for certain farmers to free-ride which ultimately leads to a suboptimal result being achieved. In this instance, the suboptimal result refers to an inefficient VDC wide investment in defensive measures. In essence, the farmer providing the defensive effort is not obtaining all the benefits of the public good that he/she has provided, and thus, his/her incentive to continue to supply the good might be insufficient. To ensure that the optimal or efficient quantity of the public good is provided, all users of the good must contribute to the cost of implementing/maintaining it. For farmers residing near CNP, this would require that those farmers who obtain the benefits of the defensive measure, yet do not bear the costs of the measure itself, compensate the farmer responsible for implementing/maintaining (i.e. provide a cash incentive or voluntary labour). Without this compensation measure, the suboptimal amount of defensive effort will continue to be provided.

A common opinion of farmers residing near protected areas is that crop protection is the responsibility of wildlife agencies (Osborn & Parker, 2003). Typically however, farmers are responsible for implementing their own defensive measures to combat crop damages from raiding species and often receive little, if any aid from the government. Such was the case in CNP in 2003-2004 (when the household survey was conducted) where local inhabitants were accountable for their own crop protection. However, in response to escalating crop damages from rhinos and the occasional wild elephant, coupled with local needs and desires for more action on the part of the government, an electric fence was constructed in 2008 that surrounds the majority of the buffer zone of CNP. Discussions with farmers that reside in nearby villages revealed that the electric fence had essentially reduced crop damages from the rhino to nothing and that, at least in the short term, the issue had been solved. In addition to a reduction in crop damages, farmers reported that rhino sightings that were once a daily occurrence were also substantially reduced. Many described how immediately after the fence was constructed, they witnessed rhinos cautiously approach the fence, receive a shock from the current and then simply return to the park. Several weeks after it was implemented, virtually no rhinos were attempting to by-pass the electric fence as they were essentially conditioned from the current. Generally, all farmers were extremely content with the fence and grateful that the government took the initiative to remedy the issue of rhino induced crop damages.

The fence itself is a joint product of the buffer zone committee, the Nepalese government (who received some funding from international donors) and the inhabitants of villages that surround CNP. The buffer zone committee and the government supply the requisite materials (wire, posts, etc…) to the farmers who are responsible for the maintenance of the fence on a voluntary basis. As discussed by Osborn & Parker, (2003) the failure to maintain a deteriorating fence is often the demise of internationally funded fencing projects. In many instances, the ownership and accompanying responsibilities of the fence are poorly communicated to the farmers resulting in a dilapidated fence. On the contrary, the situation in communities around CNP appeared to be well coordinated and efficient, as farmers assumed responsibility for fence maintenance. Moreover, the farmers realized that it is in the best interest of both the community and to themselves to immediately fix any problems associated with the operation of the fence. While it remains to be seen whether this successful operation will persist, in the meantime, it is nonetheless a positive example of community cohesion.

While the implementation of the electric fence at CNP has been viewed as an overwhelming success, for several reasons it should not be viewed as a silver bullet for solving the problem of crop damages. First, while the fence has succeeded in eliminating virtually all crop damages from rhinos, it has proved to be of little deterrence to other crop raiding species. Farmers reported that deer leap over the fence, wild boar dig underneath it and monkeys simply climb nearby trees to hurdle it. Consistent with the literature, Osborn & Parker (2003) reported that electric fences are only effective at preventing crop raiding from large mega fauna species such as rhinos and occasionally, elephants. Second, conflicting views exist from modern conservation officials as to whether fences should separate wildlife from human communities, as doing so essentially hems the animals within the boundary of the park and thus, restricts their traditional movement and decreases the amount of habitat available to them (O’Connell- Rodwell, et al., 2000; Hayward & Kerley, 2009). In turn, this reduces the park’s carrying capacity of the animal in question, resulting in the viewpoint that fences represent an anti-conservation initiative (Hayward & Kerley, 2009). Third, considering that CNP borders India to the south and that there is no electric fence in this region, the electric fence around CNP may simply be redistributing rhino crop raids to unguarded Indian farms. This aforementioned situation was hypothesized by O’Connell- Rodwell, et al., (2000) who believed that an electric fence constructed in one village in rural Namibia was simply deflecting elephants to neighboring villages that had previously experienced very minimal elephant damages.

Chapter 7: Policy Implications and Conclusions

7.1 Policy Implications

Presently, crop damages from wildlife in communities surrounding CNP represent a formidable barrier to improving the park-people relations in the region. One possible approach to remedy this contentious situation is for policy makers to gain a better understanding of the factors that influence the decisions made by farmers with respect to defensive measures. Although factors such as the distance a farm is located to the CNP boundary could be affected by national/regional policy initiatives (i.e. ensure that all farms are located at least 5 km from the border), this is highly unlikely due to the centuries long occupation of this territory. There are however, a number of factors that can be influenced by policies at the national/regional level in order to help reduce the amount of crop damages inflicted on farmer's fields. I hope the information presented here will assist conservation managers to evaluate and create more specific conservation and policy recommendations in the CNP region.

The most important result obtained from this study is the finding that farmers residing near CNP are free-riding on the defensive effort of neighboring farmers and in turn, are receiving a 'spill-in' benefit in the form of crop protection. This result proposes that defensive effort can be viewed as a public good that is jointly consumed by various farmers simultaneously, where only one farmer constructs the defensive measure but many farmers obtain the benefits. One caveat to this finding however, is the overwhelming importance of the specific location of a farm relative to one's neighbors, which in turn, suggests a necessity for cooperation amongst farmers. As reported by Hill (1997) and confirmed numerous times during discussions with local farmers during my field visit, it is evident that those farmers who are buffered by neighboring farms are essentially shielded from crop raiding animals and in turn, are receiving a ‘spill-in’ benefit in the form of crop protection.

It remains unclear, however, whether a farmer who does not implement defensive measures who resides directly adjacent to the CNP boundary and whose neighbors have invested in defensive measures, also receives a ‘spill-in’ crop protection benefit. As previously discussed, this benefit would be obtained if the approaching rhino encountered the neighbor’s fence and was sufficiently deterred from invading the farmer’s unguarded field. Conversely, if this rhino is simply deflected into the farmer’s unprotected field the defensive measure of the neighbor is essentially causing a ‘spill-out’ cost to the farmer. If the latter situation prevails over the former, it is in the best interest of the farmer who does not invest in defensive measures to collaborate with his/her neighbor over the implementation of defensive measures in order to prevent future crop damages from occurring. In fact, evidence presented by Sitati & Walpole (2006) has suggested that certain crop damage mitigation strategies simply displace raiding animals to nearby farms indicating that such strategies will not succeed in lowering the overall amount of crop damages if cooperation within and between farmers and communities does not occur.

In spite of the fact that the implementation of the electric fence has all but eliminated crop damages from the rhino, it is still paramount that farmers act collectively both to ensure that the fence remains robust and operational and to reduce crop damages from other wild animals. As described in section 6.2, a lack of communication and responsibility towards fence maintenance on behalf of the farmers can ultimately result in the demise of the fencing project. Thus, wildlife officials and the buffer zone committee must continue to work alongside farmers to ensure that farmers stay dedicated to any necessary fence maintenance and that they remain fully aware that regular upkeep is their responsibility. A possible challenge with perpetual fence maintenance is how to ensure that an equal allocation of time and effort between all beneficiaries is devoted to fence maintenance as opposed to a few farmers shouldering the majority of the burden. Achieving equality in fence maintenance, however, may prove to be a difficult task depending on how the criteria for attaining equality are devised. For instance, should those who benefit the most from the electric fence devote the most time and effort towards maintenance and if so, given the public good nature of the fence, how would benefits be determined? Given this difficulty, it is of the utmost importance that resource managers select a very simple and effective fence maintenance strategy that is build on equality. Such a strategy could be as basic as creating a rotating maintenance schedule amongst the farmers who simply take their turn engaging in maintenance duties when required.

Additionally, wildlife managers and the buffer zone committee must continue to work in tandem with farmers to create new strategies and enhance existing ones designed to reduce crop damages in the region. While in theory this may sound obvious and simple to accomplish, it has proven to be very challenging in the field. For instance, O'Connell- Rodwell, et al., (2000) found that one of the largest misconceptions regarding community based natural resource management schemes (CBNRMS) is the assumption that modern rural communities operate as a cohesive group, especially given all of the recent changes in traditional village life in the past several decades. Thus, it is of the utmost importance that appropriate strategies created to foster community wide cooperation to combat crop damages are not only designed and implemented, but are constantly monitored to ensure their long-term effectiveness. Lastly, considering that it is no longer acceptable to exclude local residents living in the vicinity of protected areas from planning decisions (McLean & Straede, 2003), every effort must be made to ensure that locals play an integral role in the development of regional policies.

While the implementation of the electric fence has certainly altered the defensive measure landscape at CNP, this study has nonetheless provided numerous insights into the crop damage/defensive measure quandary that exists in and around protected areas throughout the world that do not have an electric fence. Of primary importance from a public policy standpoint is to address the market failure arising from the public good aspect of defensive effort and the associated free-riding which ultimately leads to a suboptimal investment in defensive measures. Numerous avenues exist to resolve this pervasive problem. First, because the private sector is typically unable to produce the efficient amount of a public good, government intervention is required. A common method to ensure that the optimal or efficient quantity of the public good is provided in the private sector is for the government to subsidize the public good. In the context of the crop damage/defensive measure quandary, the government would need to provide subsidies to those farmers who supply the defensive measures. The government subsidy (typically a cash incentive) ensures that the farmer who supplies the defensive effort obtains the true market value, or complete benefit, of providing the public good. In essence, the subsidy corrects the market failure by filling the inequity gap suffered by the defensive effort supplier and in turn, provides the necessary incentive for the supplier to continue to provide the efficient quantity of the public good for the benefit of all.

In practice, implementing a subsidy program in the field is relatively simple. Prior to issuing any subsidies, policy makers would first need to identify those farmers responsible for supplying defensive effort. Once these farmers are identified, an appropriate payment scheme would need to be designed which guarantees that these farmers are being appropriately compensated for their efforts. In addition to simply subsidizing those farmers who supply defensive effort however, of paramount importance is to ensure that all farmers residing along the boundary of a protected area invest in a certain level of defensive effort. As the principle point of exit from the park/entry to agricultural fields for prospective crop-raiding animals, it is vital that farmers bordering the boundary invest in defensive measures not only to protect their personal crops, but also the crops of farmers located inland from the park border. Thus, policy makers would also have to identify those farmers living along a protected area boundary that do not invest in defensive measures and devise an appropriate subsidy package for that group of farmers.

A secondary approach to correct the market failure arising from the public good nature of defensive effort is for the farmers who free-ride on the defensive effort of others to directly compensate the suppliers. This compensation could come in the form of a cash incentive, but would more likely involve a payment of voluntary labor from the free-riding farmer (i.e. assist with construction/maintenance of the defensive measure). In effect, this form of compensation is essentially a subsidy, but rather than the government providing the payment, the onus would be on the farmers who benefit from the defensive effort. In reality, such a scheme would be difficult to implement as identifying both the beneficiaries of other farmers' defensive effort and the degree to which they benefit would undoubtedly prove challenging. For instance, what quantity of labor would a free-riding farmer who is buffered by three farms be expected to contribute as opposed to a farmer that is only buffered by two farms? Clearly, programs where the recipient of the public good is responsible for paying the subsidy must be considered very cautiously as a high degree of subjectivity is involved.

A third approach to address market failure is direct government intervention. As opposed to subsidizing the farmers who engage in defensive effort, the government could directly intervene and provide the public good, or defensive effort, themselves. For instance, if the government decided that constructing a fence that surrounds a protected area was the most desired type of defensive measure for a particular region, direct intervention would entail that they are responsible for supplying the materials and constructing the fence. Irrespective of which party provides the necessary compensation to rectify the market failure, rewarding the farmers who implement defensive measures is critical to ensuring that the optimal amount of defensive effort will be provided.

It should be mentioned that prior to addressing the market failure arising from the public good aspect of defensive effort, policy makers need to account for the carrying capacity of the animal in question. Installing an anthropocentrically oriented defensive measure that is strictly designed to reduce crop damages may have adverse affects on the population of the species and therefore, may ultimately reduce the protected area’s carrying capacity.

Although this is not a direct policy implication *per se*, it is worth mentioning that while investing in defensive measures to protect crops from wild animals addresses one of the symptoms of park-people conflict, it does not address the underlying cause, which is increasing levels of human settlement and crop cultivation within traditional wildlife ranges. Furthermore, successful crop protection strategies may actually create a perverse incentive as a farmer may feel immune to crop damages, and thus, be more inclined to increase cultivation in wildlife ranges. For defensive measures designed to protect farms to provide a long-term solution to park-people conflict, it is vital that they be accompanied by suitable land use planning and incentives to ensure that traditional wildlife habitat is protected in perpetuity.

7.2 Future Research

While this study has provided important insight regarding whether farmers base their decision to invest in defensive measures on the defensive effort of neighboring farmers (the SPILLAVG variable), an avenue to strengthen the SPILLAVG variable exists. Specifically, this variable was constructed by summing the total investment in defensive expenditures of all farmers at the VDC level as opposed to the ward level. However, considering that wards are smaller than VDCs in terms of the number of households they contain, constructing the SPILLAVG variable by ward would capture the defensive expenditures of households located in very close proximity to one another rather than households that are within the same VDC, but perhaps not necessarily located in the immediate vicinity of each other. Such a variable would provide additional and more powerful insight into whether farmers base their decision to invest in defensive measures on the defensive effort of neighboring farmers. The data employed for this study did not allow for ward level analysis because the majority of interviewed farmers within several wards did not invest in defensive measures. As a result, although it was possible to construct a SPILLAVG variable for such a ward, the variable would have very little meaning as the majority of farmers would have an identical SPILLAVG variable to one another.

A re-occurring theme throughout this study was the overwhelming importance of not only the distance between an individual farm and the CNP boundary, but the specific location of a farm in relation to both the boundary and neighboring farms. Thus, in addition to simply having a DIST variable that accounts for the distance between a farm and the park border, the inclusion of a unique LOCATION variable that incorporates a farm's location relative to both neighboring farms and the park boundary would significantly strengthen research in this field. In essence, a LOCATION variable would possess the ability to capture elements of farm location that this study was unable to. The following list is a set of recommendations and information that is suggested in order to create a LOCATION variable:

1. If a farmer is located directly adjacent to the park boundary;
2. If a farmer is not located directly adjacent to the park boundary, how many farms are situated between his/her farm and the nearest point of the boundary (i.e. how many farms buffer the farm in question?);
3. The total investment in defensive expenditures per farmer; and
4. Use Global Positioning System (GPS) to plot the exact location of a farmer.

The collection of this aforementioned information and the associated construction of a LOCATION variable could be used to more accurately determine how the defensive measures implemented by one farmer impact the decision of a neighboring farmer to invest in defensive effort. Further, a LOCATION variable could conclusively determine whether a farmer who does not implement defensive measures who resides directly adjacent to the CNP boundary and whose neighbors have invested in defensive measures receives a 'spill-in' benefit or a 'spill-out' cost as a result of his/her neighbors defensive effort.

This study has also provided the foundation for integrating the crop damage/defensive measure quandary within the context of the theory of alliances. A central component of this project was adapting and applying the economic model developed by Murdoch & Sandler (1982) which is rooted in the theory of alliances to the basic defensive measure model. As summarized in appendix 1, many additional models grounded in the theory of alliances exist that may possibly be applied to the crop damage/defensive measure quandary. For instance, while many models of alliances have computed alliance wide defense levels by simply summing the allies' expenditures, Conybeare, Murdoch & Sandler (1994) analyze how the ally with the smallest defense level, called the 'weakest link', and not the sum of all allies, determines alliance capabilities. Such a model, along with many others, could easily be adapted to the crop damage/defensive measure situation presented in not only this study, but other studies related to this subject matter as well. Additionally, due in large part to the attack on the World Trade Center on September 11, 2001, Sandler has published numerous articles pertaining to the modern-day threat of terrorism (see Sandler & Enders, 2004; Rosendorff & Sandler, 2005). This body of literature could also be adapted to the crop damage/defensive measure quandary where the rhino (or another crop raiding species) notionally plays the role of 'terrorist'.

Another area of future research could be to advance the existing literature on crop damages in Asia. Presently, the vast majority of the crop damage/defensive measure literature is centered on Africa (De Boer & Baquete, 1998; Naughton-Treves, 1998; Gillingham & Lee, 2003) with an overwhelming focus on elephant induced damages. Conversely, crop raiding by wildlife in Asia has yet to be extensively studied, while the majority of research that has been conducted is dedicated to either Asian elephants (Nyhus et al., 2000; Williams et al., 2001) or is based in India (Sekhar, 1998; Rao et al., 2002). As such, there is a dearth of information pertaining to crop raiding from, among other species, one-horned Indian rhinos both in India and Nepal. While the information obtained from crop damage studies on elephants for example, contributes to a growing body of important literature, it is often difficult to directly extrapolate the results from such research to different crop raiding species or to other parts of the world. In particular, it is especially challenging to extrapolate crop damage research pertaining to elephants to other species as elephants are renowned both for their enormous size and intelligence. These characteristics require that unique methods for deterring crop raiding from elephants must be implemented, and that such strategies will only be marginally useful when considering different species of wildlife. Thus, there exists a great need for more research on crop raiding from other species, in particular, the one-horned Indian rhino. All of these advancements in research could greatly contribute to policy making at the local, regional, and national levels to help reduce park-people conflicts and preserve rhinos.

7.3 Final Conclusion

This study looked into a centuries old quandary that exists in the Chitwan District of Nepal – the problem of crop damages caused by the one-horned Indian rhinoceros and how farmers respond to these damages – and did so from a unique perspective. Unlike any other preceding research, this study attempted to understand the factors that are hypothesized to influence the decision of a farmer residing in communities adjacent to Chitwan National Park (CNP) to invest in defensive measures to combat rhino induced crop damages using econometric models.

Considering that crop damages are viewed as one of the most serious problems hindering the relationship between humans and rhinos in the Chitwan District and that rhinos are an endangered species in Nepal, it is important to remedy this contentious situation. By gaining a better understanding of why farmers invest in defensive measures, resource managers will have an enhanced ability to create more effective environmental conservation strategies and policy recommendations in the CNP region.

Another unique aspect of this study entailed the application of the theory of alliances to the crop damage/defensive measure predicament. The theory of alliances itself was first studied in the mid-1960's and was originally applied to military partnerships with a specific focus on the North Atlantic Treaty Organization (NATO). One feature of this application was an analysis of whether the total quantity of resources that any NATO ally invested towards alliance wide defensive effort was influenced by the defensive expenditures of the other allies. For the purpose of this study however, the extension of the theory was applied to the crop damage/defensive measure quandary that exists in communities surrounding CNP to determine if farmers base their decision to implement defensive measures on the defensive action of neighboring farmers. To accomplish the latter, an economic model developed by Murdoch and Sandler (1982) that is rooted in the theory of alliances was adapted and applied to the basic defensive measures model.

In order to empirically estimate both the basic defensive measures model and the model rooted in the theory of alliances, a Tobit model – a type of regression method – was used. The Tobit was used because the dependent variable, the total monetary cost invested in defensive measures, is cross-sectional data which cannot be negative and contains a large number of zeroes. The independent variables were split into two categories: risk factors and demographic factors. The risk factors included: i) the distance a farmer is located from the CNP boundary, ii) the total amount of agricultural land under cultivation, iii) the frequency of daily and weekly rhino sightings by a farmer during the monsoon season, and iv) the ratio of the total number of days/nights spent patrolling by the total amount of all agricultural land under cultivation. The demographic factors included: i) total income per farmer, ii) the age of a respondent, and iii) the number of schooling years completed by a respondent. Additionally, the average investment in defensive measures by a farmer by VDC is a variable unique to the models influenced by the theory of alliances. Coefficients on all of the explanatory variables had the expected signs, and all non-demographic variables were significant.

The results of this study conclude that many factors contribute to the decision of a farmer to invest in defensive measures. With reference to the theory of alliances, when defensive measures within a Village Development Committee (VDC) increase, it appears as though an individual farmer feels sufficiently protected from this additional effort and opts to free-ride on the defensive effort of neighboring farmers instead of investing in personal defensive measures. As previously discussed however, one caveat to this finding is the overwhelming importance of the specific location of a farm relative to one's neighbors, which in turn, suggests a necessity for cooperation amongst farmers when implementing defensive measures.

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Appendices

Appendix 1: A select review of economic models pertaining to the theory of alliances

1) Murdoch, J.C., & Sandler, T. (1982). A theoretical and empirical analysis of NATO. *The Journal of Conflict Resolution, 26*(2), 237-263.

Summary: This article improves and refines the joint product model so that it can better analyze nuclear war alliances. In particular, the refined model demonstrates that allies' responses to defense spillovers depend upon the consumption relationship (i.e., complementarity or substitutability) as well as the allies' income responsiveness (i.e., complementarity or substitutability) of the jointly produced defense outputs. Previous studies have shown that responses to spill-ins only depend upon income responsiveness and that, in most situations, spill-ins cause allies to cut defense expenditures. In contrast, the model presented below indicates that when the jointly produced outputs are complementary, allies may increase their defense expenditures in response to spill-ins.

The Empirical Model: The following model assumes a linear functional form;

$$ME_j = \sigma_j + \beta_{1j}\ WEALTH_j + \beta_{2j}\ THIN_j + \beta_{3j}\ SPILL_j + \beta_{4j}\ STRAT + e_j$$

Where: ME stands for an allies military expenditures; WEALTH is measured by an allies GDP; Thinning (THIN) is proxied by the ratio of an ally's military personnel to its exposed border (such a measure attempts to depict the potential density of the ally's armed forces along it's exposed perimeter); Spill-ins (SPILL) are indicated by net NATO expenditures in which the ally's own defense expenditures are subtracted from NATO's total expenditures. Finally, the relative strategic strength (STRAT) of NATO is expressed by the ratio of U.S long range missiles and bombers to USSR long range missiles and bombers. STRAT is a proxy for both the external threat faced by NATO and the relative size of its strategic forces. As the size of the STRAT measure increases, external threat declines. Of note is that the country subscript for STRAT has been omitted as it is the same for each country. The subscript j corresponds to the country under consideration, e_j represents the vector of random disturbances, $\beta_{1j}\ldots\ \beta_{4j}$ are the unknown slope coefficients and σ_j is the constant.

2) Sandler, T., & Murdoch, J.C. (1990). Nash-Cournot or Lindahl behavior? An empirical test for the NATO allies. *The Quarterly Journal of Economics, 105*(4), 875-894.

Summary: This paper derives reduced-form estimating equations to distinguish between a Nash-Cournot and a Lindahl allocation process within a group that provides itself with a pure public good, which is non-rival in consumption and non-excludable in its benefits. There are at least two standard procedures for estimating the demand for a public good. One method derives its demand equations from maximizing a representative individual's utility function subject to the relevant budget constraint and to the constancy of the other individuals' public good contributions (i.e., the Nash-Cournot zero conjectural variation constraint). A second method examines the maximization problem of a median voter, often identified by median income, when determining the demand equation for the public good.

The Empirical Models: The statistical model representing the Nash-Cournot joint-product demand relationship is estimated using a log-linear specification:

$$\ln NATO_t = \beta_{io} + \beta_{i1} \ln FULLINC_{it} + \beta_{i2} \ln SPILL_{it} + \beta_{i3} \ln THREAT_t + e^{N}_{it}$$

Where: subscript i denotes the country and subscript t indicates the year. $NATO_t$ measures the public good contribution by ally I; $SPILL_{it}$ represents all other allies public good contributions; $FULLINC_{it}$ corresponds to full income and is equal to $FULLINC_{it} = GDP_{it} + SPILL_{it}$ where GDP_{it} represents an ally's gross domestic product and where the addition of GDP_{it} and $SPILL_{it}$ is consistent with the neutrality theorem. Finally, $THREAT_t$ equals the military expenditures of the Soviet Union.

If the Lindahl allocation process is the characterization for the NATO alliance, the statistical Lindahl model appears as follows:

$$\ln NATO_t = \sigma_{io} + \sigma_{i1} \ln GDP_{it} + \sigma_{i2} \ln SHARE_{it} + \sigma_{i2} \ln THREAT_t + e^{L}_{it}$$

Where: Once again, $NATO_t$ measures the public good contribution by ally i; GDP_{it} represents the GDP of ally i; and $SHARE_{it}$ is $ME_{it}/NATO_t$ where ME_{it} denotes the military expenditures of ally i.

3) Gonzalez, R.A., & Mehay, S.L. (1991). Burden sharing in the NATO alliance: an empirical test of alternative views. *Public Choice, 68*, 107-116.

Summary: The authors designed an empirical model to test two competing hypotheses concerning the behavior of NATO allies. The first hypothesis predicts that free-riding behavior will lead to unequal burden sharing with the larger nations shouldering a disproportionate share. The alternative hypothesis predicts that cooperation among alliance members and complementarity among weapons systems will combine to prevent the results predicted by the first hypothesis.

The Empirical Model: The empirical model is specified in log-linear form.

$$\ln (m_{it}) = \sigma_0 + \beta_1 \ln n_{it} + \beta_2 \ln y_{it} + \Sigma_k b_k x_k$$

Where: m_i denotes defense spending by ally i, the population share is $n_{it} = N_{it}/(\Sigma_i N_i)_t$, and the income share variable, Y_{it}, is calculated as the ratio of ally i's per capita income to the mean per capita income of the group in year t. That is, $Y_{it} = Y_{it}/Y_t$, where $Y_t = (\Sigma_i GNP_i)_t / (\Sigma_i N_i)_t$. Although it did not specifically mention what it is in the paper, I assume that $\Sigma_k b_k x_k$ is the sum of all ally's other characteristics that influence defense spending choices.

Unique to this model:

- Population is included: This variable is included because it represents the lives to be protected by defense provisions
- Threat level is omitted: This variable is omitted because when examining defense spending shares of allies, they all face a common threat
- Spillover variable is not included: This variable is omitted because the model examines spending shares as opposed to spending levels of allies

4) Conybeare, J.A.C., Murdoch, J.C., & Sandler, T. (1994). Alternative collective goods models of military alliances: theory and empirics. *Economic Inquiry (XXXII)*, 525-542.

Summary: Previous collective good models of alliances have computed alliance wide defense levels by simply summing the allies' expenditures. However, the appropriate manner for aggregating defense efforts among allies may depend on geographical, strategic and technological determinants. For example, the defense efforts of the weakest ally along a front may determine the strength of the allies' defenses, since the enemy's ability to penetrate behind the front hinges on the weakest fortification. In consequence, the minimal defense level of the allies, and not the sum, determines alliance capabilities.

In essence, this paper looks at three different methods of aggregating allies military expenditures to determine alliance wide defense levels. Three procedures – summation, weakest link, and best shot – are examined. The authors also devise an empirical procedure to test between the weakest link and best shot models of alliances, and employ this procedure on four military alliances to determine whether their alternative aggregation functions are more appropriate than summation.

The Empirical Model: The empirical model is specified in linear form.

The first part of the model looks at the non-weakest link allies defense activity under a weakest link technology.

$$\mathrm{DEF}_t = \beta_0 + \beta_1\,\mathrm{INC}_t + \beta_2\,\mathrm{WEAK}_t + \beta_3\,\mathrm{THREAT}_t + e_t$$

Where: DEF_t denotes annual defense activity for a non weakest-link ally; INC_t represents annual income; WEAK_t stands for the defense activity of the weakest link ally within a particular alliance; and THREAT_t measures the annual defense activity of the ally's enemy.

The weakest link ally's defense demand is now specified:

$$\mathrm{WEAK}_t = \beta_0 + \beta_1\,\mathrm{INC}_t + \beta_3\,\mathrm{THREAT}_t + e_t$$

Together, these two models define a recursive system of equations and the unknown parameters can be estimated using OLS

Similarily, linear empirical models can be specified for best shot alliances, with the new term (BS) denoting the defense activity of the best-shot ally.

$$\mathrm{DEF}_t = \sigma_0 + \sigma_1\,\mathrm{INC}_t + \sigma_2\,\mathrm{BS}_t + \sigma_3\,\mathrm{THREAT}_t + e_t$$

The best shot ally's defense demand is now specified:

$$BS_t = \sigma_0 + \sigma_1\ INC_t + \sigma_3\ THREAT_t + e_t$$

Once again, these latter two models define a recursive system of equations and the unknown parameters can be estimated using OLS.

Of importance is the recognition that the authors do not want to specify an alliance as either weakest link or best shot a priori. Rather, they wish to distinguish between the two paradigms empirically. Their approach is to first examine the best shot and weakest link nations in each alliance. They accomplish this by estimating two unrestricted models; first,

$$WEAK_t = \alpha_{10} + \alpha_{11}\ INC_t + \alpha_{12}\ BS_t + \alpha_{13}\ THREAT_t + e_t$$

And second,

$$BS_t = \alpha_{20} + \alpha_{21}\ INC_t + \alpha_{22}\ WEAK_t + \alpha_{23}\ THREAT_t + e_t$$

Then, empirical evidence of a weakest-link alliance occurs when $\alpha_{12} = 0$ and $\alpha_{22} \neq 0$. Similarily, evidence of a best shot alliance is when $\alpha_{22} = 0$ and $\alpha_{12} \neq 0$.

Lastly, an unrestricted model with both the best shot and weakest link variables entered as independent variables can be used to test the alternative restrictions. Therefore, with

$$DEF_t = \alpha_0 + \alpha_1\ INC_t + \alpha_2\ BS_t + \alpha_3\ WEAK_t + \alpha_4\ THREAT_t + e_t$$

as the unrestricted model, evidence of weakest link behaviour is found when $\alpha_2 = 0$ and $\alpha_3 \neq 0$. On the other hand, $\alpha_2 \neq 0$ and $\alpha_3 = 0$ provides evidence in favor of best shot.

5) Oneal, J.R., & Deihl, P.F. (1994). The theory of collective action and NATO defense burdens: new empirical tests. *Political Research Quarterly, 47*(2), 373-396.

Summary: Mancur Olson's theory of collective action centered around the tendency for the largest and most powerful ally (the USA in NATO) to provide the brunt of the public good produced by the alliance. Since the mid 1970's however, Todd Sandler and his associates have argued that the good NATO supplied was not purely public. Emphasis on the ability to defend territory, rather than deter war - a change clearly implied by the strategy of flexible response - is said to have made Olson's analysis inadequate because defense is an impure public good for which the allies are partly rival. Other authors also note that the allies' armed forces serve purely private, national interests. Thus, a joint-product model incorporating pure public, impure public (or mixed), and private benefits is needed to explain the allies' allocation of resources to the military. In this study, the authors re-evaluate the ability of the theory of collective action and its extension, the joint-product model, to explain NATO defense burdens.

The Empirical Model:

$$\text{BURDEN}_{it} = \beta_o + \beta_1\,\text{SIZE}_{it} + \beta_2\,\text{SUMMX}_{it} + \beta_3\,\text{PRIVDISP}_{it} + \beta_4\,\text{SOVBURD}_t + \beta_5{*}\text{II}_i$$

Where: BURDEN_{it} is the defense burden (military expenditures/GDP) of nation i in year t; SIZE_{it} is the relative economic size (GDP_i/sum of NATO countries GDPs) of nation i in year t; SUMMX_{it} is the normalized sum of the military expenditures of bordering NATO allies (MX1 + MX2 +.... + MXj/sum of NATO MXs) for nation i in year t; PRIVDISP_{it} is the number of militarized disputes not involving the Soviet Union or its allies over the previous five years for nation i in year t; SOVBURD_t is Soviet military expenditures/GDP for year t; and II_i is the Interdependence Index, the number of memberships in European regional organizations for nation i.

Explanation of independent variables:

a) SUMMX: A measure of the geographical distribution of NATO's military capabilities that indicates the incentive to cooperate in creating forces for the actual defense of territory. A larger value signifies that the Soviet threat is being met to a greater degree by local (European) efforts, making a defensive strategy more feasible. When SUMMX is small, on the other hand, defense is less practical; the Soviet threat is being countered primarily by extended deterrence from the United States.

b) PRIVDISP: Scholars agree that private interests affect nations allocations to the military and the authors incorporate this into the model by measuring each allies involvement in conflicts not associated with the cold war. To accomplish this, they look at the number of ‘militarized interstate disputes’ of each NATO country.