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Economic Benefits of Management Options for Kho Hong Hill, South Thailand

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Saowalak Roongtawanreongsri

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EXECUTIVE SUMMARY

Like other threatened forest areas around the world, almost half of the forest areas in Kho Hong Hill (KHH) in Songkhla Province, South Thailand have been deforested. Deforestation in KHH is primarily due to population increase, urbanization, and the continuous conversion of forest areas into rubber plantations. This research determined the net economic benefits of three forest resource management strategies to help inform stakeholders of the most economically efficient management option for KHH.

The study was done in three parts as follows: a) construction of three resource management strategies for KHH; b) selection of environmental variables and valuation of the ecosystem services from KHH; and c) cost-benefit analysis (CBA) of the three management options. The three forest management strategies were developed using information derived from interviews and discussions with relevant KHH stakeholders. The management scenarios developed include: a) Scenario I is the Base Case or the business-as-usual (BAU) scenario; b) Scenario II or the establishment of protected areas to preserve the remaining forest areas in KHH; and c) Scenario III, in which forest restoration/rehabilitation initiatives are implemented to increase the forest areas in KHH.

Six ecosystem services were selected as the environmental variables for this study: a) the provision of timber, b) carbon dioxide (CO_2) sequestration, c) oxygen (O_2) generation, d) water supply, e) flood control, and f) biodiversity. Market valuation was used to estimate the values of provision of timber, CO_2 sequestration, O_2 generation, water supply, and flood control. The value transfer approach was used to determine the value of the service derived from KHH biodiversity.

Based on 2011 figures, the ecosystem services from KHH provide the following benefits per hectare per annum: timber value of THB 632,974 (USD 23,089), CO_2 sequestration value of THB 12,618 (USD 406), O_2 generation value of THB 108,518 (USD 3,496), and biodiversity value of THB 163,836 (USD 5,277). The values for water supply and the damage cost from floods were calculated through simulation models. The resulting values cannot be reported in a yearly basis as the figures varied every year. However, the values of the latter two ecosystem services were higher than the others.

Lastly, CBA was performed for all three management scenarios, with a projection period spanning 25 years. Results showed that under Scenario I the annual benefits from the ecosystem services from KHH would turn negative from Year 15 onward. Meanwhile, both Scenario II and Scenario III yielded positive net present values (NPV). These CBA results imply that further deforestation of KHH will result in social losses in the long run. Thus, stakeholders must address the condition of KHH as early as now while the benefits can still be secured. The study has also shown that by just preserving the existing forest areas in KHH—thus, preventing further deforestation—positive NPVs can still be reaped throughout the 25-year period. Forest management through reforestation can yield higher NPVs than preserving the existing forest areas; albeit, the former involves higher management costs.

The study recommends that rubber farmers be encouraged to re-convert their rubber plantations into forest areas. Implementing a payment for ecosystem services (PES) mechanism is also encouraged to motivate rubber farmers to reforest. However, further studies are needed to establish an effective PES system for KHH. In the long term, plans should include defining the sustainable use of forest products, formulating public policy and regulations to guarantee sustainable use, determining and implementing a systematic monitoring strategy, and promoting the conservation of local species for the next generation.

1.0 INTRODUCTION

1.1 The Research Problem

Ecosystems provide valuable services to humans through their natural functions. Ecosystem services encompass the delivery, provision, production, protection, or maintenance of a set of goods and services (tangible or intangible) that people perceive to be important (Chee 2004). Forest ecosystems, in particular, play an important role in providing humans with resources and in supporting the environment's systemic functions. The tangible goods and services from forests include timber, non-timber products, water supply, medicine, tourism, biomass, and nutrition, among others. On the other hand, the intangible forest services include provision of clean air and oxygen, regulation of the atmospheric abundance of CO_2 (Murray 2000; Stinson and Freedman 2000), assimilation of wastes, recreation and aesthetic benefits, educational opportunities, and spiritual enrichment (Tong *et al.* 2007). Accordingly, deforestation—which can threaten the environment's ecological life support systems—has detrimental effects to a nation's economy as well as to human welfare (USDA 2007).

Kho Hong Hill (KHH) is the last forest area closest to Hat Yai City, the famous urbanized area in the east coast of lower south Thailand. KHH provides ecosystem services to the 157,682 residents of Hat Yai Municipality and to the 67,892 people living within 3 km from KHH. Previous studies have shown that KHH forest is still fertile, with its primary forest areas still intact (Roongtawanreongsri *et al.* 2012; Ployninpetch 2012). The benefits of the ecosystem support system from KHH are recognized among biologists in the Prince of Songkhla University (PSU) as it provides O_2, sequesters CO_2, and serves as a source of water supply for downstream communities. Moreover, the forest is home to many wild animals and plants—some of which are endangered such as the slow loris and malasian giant ant found only in fertile areas—and temporary homes for other species such as plain-pouched hornbill. Biodiversity is one of the greatest benefits from this forest.

Climate change, pollution, over-exploitation, and land use change are some of the drivers of ecosystem loss, as well as resource challenges associated with globalization and urbanization (USDA 2010). Like other threatened forest areas around the world, almost 40% of KHH forest has been deforested. Accordingly, the deforestation in KHH is primarily due to population increase, urbanization, and the continuous conversion of forest areas in KHH into rubber plantations. Recently, the issue of deforestation in KHH has become a critical concern among stakeholders as the ecosystem services it provides have become compromised. The effects of environmental degradation have become apparent such as occurrences of floods in areas that didn't use to get flooded, soil erosion, drought during the dry season, and loss of wildlife, among others.

Because ecosystem services are usually viewed as free benefits to society or "public goods" that lack a formal market, these natural assets are not included in society's balance sheet; their critical contributions are often overlooked in the public, corporate, and individual decision-making processes. When forests are undervalued, they become susceptible to development pressures and conversion. Accordingly, recognizing forest ecosystems as natural assets with economic and social values can help promote conservation and more responsible decision-making (USDA 2010).

A preliminary survey conducted in the local communities living within 3 km from the center of KHH revealed that the local residents do not appreciate the ecological value of this forest. Compared to the tangible benefits gained from rubber farming, most of the ecological benefits from KHH are intangible and immeasurable, thus the local communities do not perceive any benefits from the forest. The weak institutional arrangement, particularly on who governs over the forest, further worsens this problem. KHH land users claim that they have customary rights over the land they use since their ancestors have occupied the same land before any encroachment laws were established in the forest. As such, due to weak law enforcement, some people have illegally encroached into the KHH forest areas.

Recognizing the gravity of the deforestation problem in KHH as well as the importance of the ecosystem services that the forest provides, the PSU academic community initiated the project "Help Conserve Kho Hong Hill" to help protect and conserve the hill's forest areas. The University formally established the project, and a working committee was created to lead the forest restoration and conservation efforts. Accordingly, the committee developed a strategic process with three principal components as follows: a) development and implementation of integrated research projects; b) developing and establishing an alliance network; and c) promoting public campaigns (Figure 1).

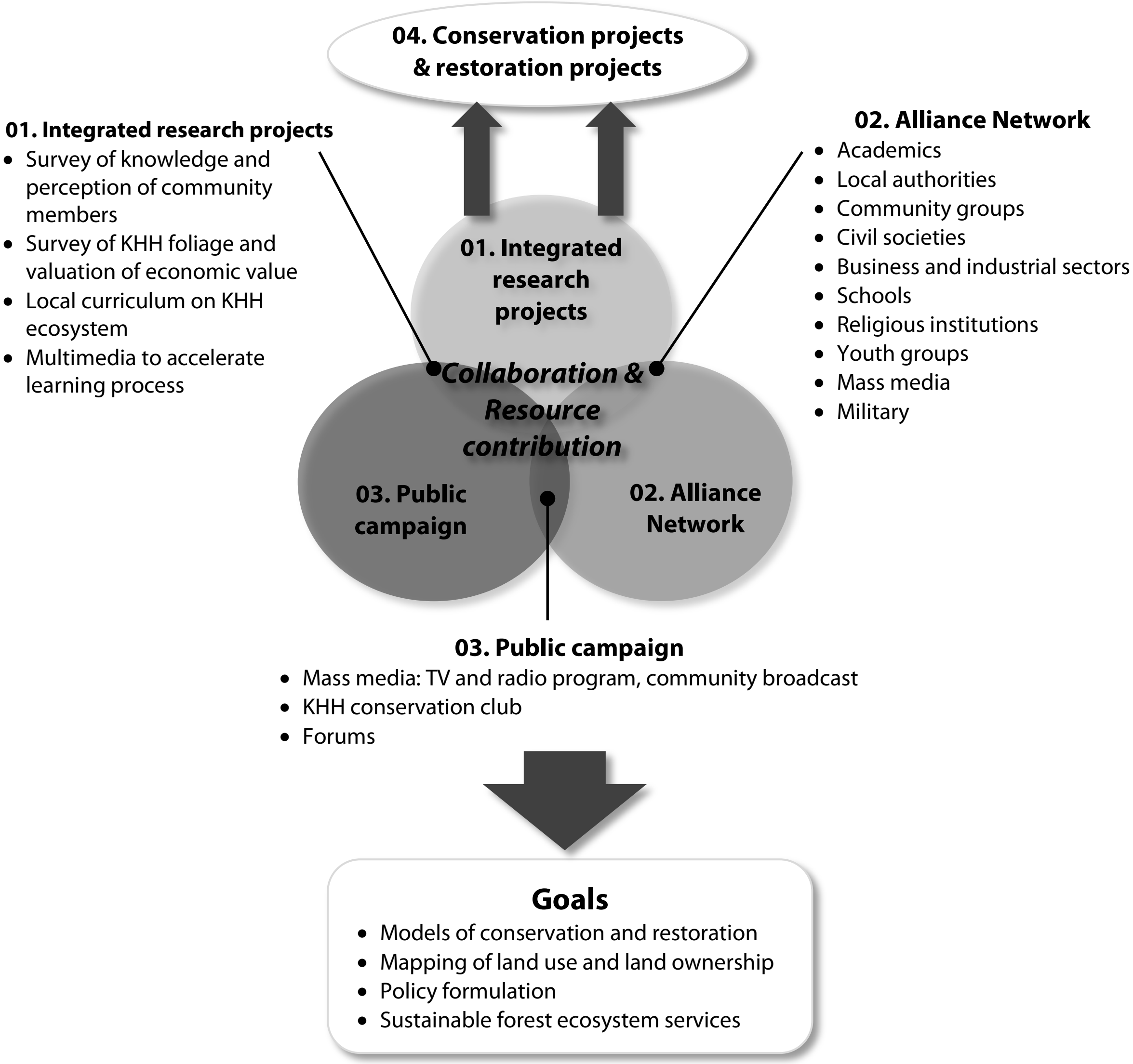

Figure 1. Major components of the integrated strategy for Kho Hong Hill conservation and restoration

From 2009 to present, the committee initiated public awareness campaigns in Songkhla province, and built alliances with various groups including the people of Hat Yai City. Moreover, a curriculum on the conservation and preservation of KHH was developed and subsequently integrated into the curriculum of six primary schools and three secondary schools in Hat Yai City. Numerous learning events were also organized at KHH communities to educate the local people about the ecological value and importance of KHH. Likewise, local authorities, government agencies, the business sector, students, and the community people were given the opportunity to participate in many different learning events.

One of the main goals of the project is to achieve sustainable use of KHH ecosystem services. Since KHH is one of the last intact urban forests in Songkhla province, it must be conserved and restored to preserve its ecological integrity and promote the well-being of the people in Hat Yai City and nearby communities. Thus, implementing the best forest management strategy for KHH will help in its conservation and preservation. Moreover, presenting the tangible benefits from implementing such strategies will also help promote the social gains reaped from preserving and conserving KHH forest ecosystems.

This study determined the values of KHH's ecosystem services and compared the economic net benefits of three management strategies for KHH. The results of this study can help decision makers in their environmental management initiatives, particularly if forest restoration programs are to be developed and implemented to complement the rubber farming activities and other changing land uses. Incentives or compensation management schemes may have to be implemented in order to restore the forest areas that have been encroached by present occupants, or to motivate other landowners near KHH to re-convert their lands back into forests. Some concerned residents have even suggested expropriating the lands from their present occupants in order to preserve the ecosystem services that the forest provides.

As such, to reverse the loss and degradation of KHH's ecosystem services, economic and financial motivations must include a conservation objective, and the value of ecosystem services needs to be incorporated into any decision-making (USDA 2010). This research determined the net economic benefits of three management strategies for KHH so as to inform stakeholders of the most economically efficient option. Specifically, this study aimed to:

1. determine the economic values of some of the ecosystem services from KHH, namely, the provision of timber, freshwater supply, CO_2 sequestration, flood protection, O_2 generation, and biodiversity;
2. examine three forest management scenarios for KHH, including the status quo;
3. conduct a cost-benefit analysis of the different forest management strategies for KHH using the values of the ecosystem services estimated in Objective 1;
4. compare the management options in terms of their maximum social gains; and
5. use the results and implications of this study in the policy development of Kho Hong Municipality, Hat Yai Municipality, and Thung Yai Tambon Authority Organization.

1.2 Research Questions

1. What are the three forest management options possible for KHH? To which KHH areas will each management option apply? What land uses are possible for each management option?
2. What are the economic values of the ecosystem services (i.e., provision of timber, freshwater supply, CO_2 sequestration, flood protection, O_2 generation, and biodiversity) provided by KHH under the different management options?
3. What are the net present values (NPV) of these ecosystem services under each management option?
4. Which management option is most beneficial to the Hat Yai people and to society in general?
5. How can the results of this study help the agencies involved in managing KHH (i.e., Kho Hong Municipality, Hat Yai Municipality, and Thung Yai Tambon Authority Organization) in their policy- and decision-making?

1.3 Study Area

KHH is located in Hat Yai District , Songkhla Province in southern Thailand. KHH is an evergreen forest with a combination of dry and moist forests that grow both deciduous and non-deciduous plants. Thus, organic matter grows throughout the year. Nutrient cycle and energy flow within the forest are high. As the forest is humid due to months of precipitation during the wet season, the growth and performance of the bacteria and microorganisms in the forest are enhanced such that dried leaves, branches, and other forest residues naturally decompose within a year. The nutrients are then recycled back into the soil and absorbed by the trees. Figure 2 shows some of the plant species and characteristics found in KHH.

The length of the ridge of KHH from north to south is 6.75 km, with its highest point measuring 371 m above sea level (Figure 3). Its total land area is approximately 1,212.42 ha. About 699.70 ha (57.71%) of KHH still remain as primary and secondary forests whereas 441.18 ha (36.40%) have already been converted into rubber plantations (Table 1 and Figures 3 and 4).

Figure 2. Forest structure of Kho Hong Hill

Table 1. Forest area and other encroachments in Kho Hong Hill

Type	Area (rai)	Area (ha)	Percentage
Forest	4,373.14	699.70	57.71
Rubber	2,757.35	441.18	36.39
Land with no cover	342.29	54.77	4.52
Buildings	104.82	16.77	1.38
Total	7,577.60	1,212.42	100.00

Figure 3. Views of Kho Hong Hill

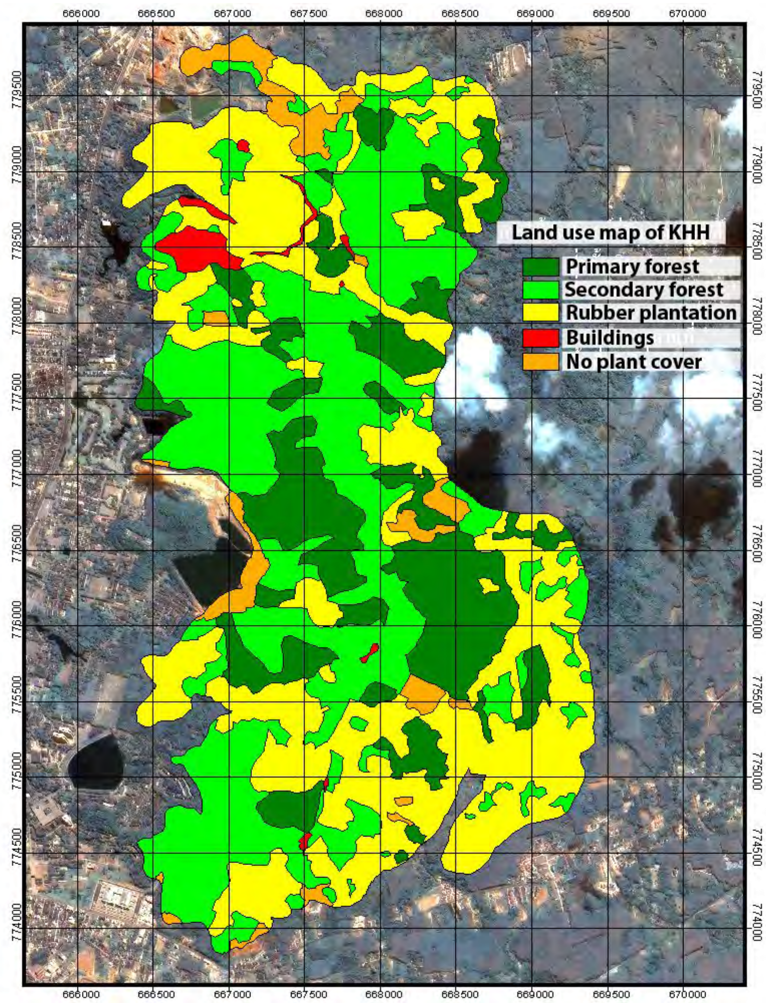

Figure 4. GIS map of Kho Hong Hill land use

2.0 LITERATURE REVIEW

To make sound decisions in favor of sustainable resource use, the total economic value of natural resources and the environment should be included in policy analysis. The total economic value of the environment—or the social gains—is the summation of direct use, indirect use, and non-use values of the environment. In environmental valuation, however, the challenge often lies on the non-market valuation, particularly on the indirect economic benefits gained from the environment and non-use value.

This chapter documents literature relevant to the research project. It starts with the concept of ecosystem services followed by a discussion of the methods used for valuing ecosystem services. The latter part of this chapter focuses on how ecosystem services can be incorporated into decision-making with the use of the economic cost-benefit analysis tool.

2.1 Ecosystem Services

The concept of ecosystem services is largely documented by the Millennium Ecosystem Assessment (MA), which is an organization implemented from 2001 to 2005 that aimed to assess the consequences of ecosystem change on human well-being, and to establish the scientific basis for implementing the needed actions to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being (MA 2005a, b).

Ecosystem services are commonly defined as the benefits people obtain from ecosystems (USDA 2010). They are the processes through which natural ecosystems—and the plants, animals, and microbes that live in those environments—sustain human life. Ecosystem services include the provision of goods such as timber and fibers, medicines, and fuels. Ecosystem services also include the provision of life-supporting activities like filtering water and recycling all kinds of wastes. However, the natural services that have purified water and air, supported the growth and reproduction of food plants, controlled pests, and even moderated the weather and its impacts are declining rapidly. Land clearing for agriculture, industry, and mining for economic development have adversely affected ecosystems worldwide. As habitats become fragmented, the services that these natural systems provide become less effective (Tawna 2010).

Ecosystem services can be categorized as follows (MA 2005a; Irwin, Ranganathan and Bateman 2007; USDA 2010):

- ***Provisioning Services*** or the provision of food, fresh water, fuel, fiber, genetic resources, natural medicine, pharmaceuticals, and other goods;
- ***Regulating Services*** such as air quality regulation, climate regulation, water regulation, erosion regulation, water purification and water treatment, and disease regulation, pest regulation as well as pollination, and natural hazard regulation;
- ***Supporting Services*** such as soil formation, photosynthesis, and nutrient cycling; and
- ***Cultural Services*** such as educational, aesthetic, cultural heritage, spiritual values, and recreation and tourism.

2.2 Valuing Ecosystem Services

Valuation is necessary in establishing markets and institutions that promote the efficient and sustainable use of ecosystem services (Abel *et al.* 2003). When resource managers make decisions, they are heavily influenced by the ecosystem services entering the markets; as a result, the non-marketed benefits are often lost or degraded. Many ecosystem services, such as the purification of water, regulation of floods, or provision of aesthetic benefits, do not pass through the markets. Therefore, the benefits they provide to society are largely unrecorded; only a portion of the total benefits provided by an ecosystem makes their way into statistics, and many of these are misattributed. For example, the water regulation benefits of wetlands do not appear as benefits of wetlands but as higher profits in water-using sectors.

Moreover, for ecosystem services that do not pass through the markets, people have insufficient incentive to invest in environmental conservation (although in some cases, common property management systems provide such incentives). Even when individuals are aware of the services provided by an ecosystem, they are neither compensated for providing these services nor penalized for reducing them. These non-marketed benefits are often high and sometimes more valuable than the marketed benefits (MA 2005b).

The economic value of an ecosystem good or service consists of both use and non-use values. *Use values* comprise of either direct or indirect uses. Direct uses involve some form of direct physical interaction with the good or service. With ecosystem goods, direct use may be consumptive (e.g., hunting) or non-consumptive (e.g., bird watching). Indirect use involves ecosystem services that contribute to the quality of an ecosystem good or a produced good. *Non-use values* are what people value simply for the services' existence (Brown *et al.* 2007).

There are several valuation techniques to measure the values of ecosystem services. Stephen, Farber, and Wilson (2002) discussed the methods for valuing ecosystem services using exchange value (price), willingness to pay or to accept, and indirect means of assessing economic values. The latter includes avoided cost, replacement cost, factor income, travel cost, hedonic pricing, and contingent valuation. Brown *et al.* (2007), on the other hand, categorized four valuation methods as follows: household revealed preference methods (travel cost, hedonic, and averting behavior methods), stated preference methods (contingent valuation and attribute-based methods), production function methods, and replacement cost method. The first two methods focus on individual choices and preferences, whereas production function approaches are used to value inputs in the production of the marketed good. The replacement cost method computes the cost of replacing a lost environmental good or service, or conversely, the replacement cost avoided if the environmental good or service is preserved.

2.3 Some Previous Studies

Some of the studies on ecosystem services valuation include those of Anielski and Wilson (2005), Curtis (2004), Olewiler (2004), Tong *et al.* (2007), and Tianhong , Wenkai, and Zhenghan (2008). Discussed below, in chronological order, are a few of the valuation studies on forest ecosystem services.

Guo *et al.* (2001) estimated the annual economic value of some of the forest ecosystem services in the Xingshan County in China using simulation models and geographic information system (GIS). The authors assessed the values of three ecosystem services, namely, water conservation, soil conservation, and gas regulation.

The Millennium Ecosystem Assessment (2005b) reviewed some studies on the valuation of ecosystem services and reported that non-marketed benefits are often high and sometimes more valuable than the marketed benefits. For example, one of the most comprehensive studies to date which examined the marketed and non-marketed economic values associated with forests in eight Mediterranean countries found that timber and fuel wood generally accounted for less than a third of the total economic value in each country. The study further revealed the following:

1. For *water quality*. In 1998, the estimated NPVs in protecting the water quality of the 360-kilometer Catawba River in the United States for five years were estimated at USD 346 million.
2. For *water purification service of wetlands*. About half of the total economic value of the Danube River Floodplain in 1992 could be accounted for in its role as a nutrient sink.
3. For *native pollinators*. A study in Costa Rica found that forest-based pollinators increased coffee yields by 20% in the areas within 1 km of the forest (as well as increasing the quality of the coffee). Thus, from 2000 to 2003, pollination services from two forest fragments (of 46 ha and 111 ha) increased the income of a 1,100-hectare farm by USD 60,000/year, a value commensurate with expected revenues from competing land uses.
4. For *flood control*. Muthurajawela Marsh, a 3,100-hectare coastal peat bog in Sri Lanka, provides an estimated USD 5 million in annual benefits (USD 1,750/ha) due to its role in local flood control.
5. For *recreational benefits* of protected areas. The annual recreational value of the coral reefs of each of the six marine management areas in the Hawaiian Islands in 2003 ranged from USD 300,000 to USD 35 million.

Jim and Chen (2009) also reviewed several studies on the major ecosystem services provided by the urban forests in China, including microclimatic amelioration (mainly evapotranspiration-cooling effects), CO_2 sequestration, O_2 generation, removal of gaseous and particulate pollutants, recreational, and amenity.

Most studies have used cost-benefit analysis (CBA) as a tool for economic assessment, particularly when evaluating scenarios relating to Base Case or to ecosystem services. Moons (2002) conducted a CBA for a new forestland. Although the study did not compare different policy options as this research did, it used a similar methodology for evaluating forest benefits (i.e., identifying and monetizing benefits). The forest benefits included in Moons' (2002) study were the provision of timber, hunting, CO_2 fixation, non-use, and recreation benefits.

Kuosmanen and Kortelainen (2007) conducted a similar study although they proposed a new approach in environmental valuation using the environmental CBA framework. They based the framework on data envelopment analysis (DEA) and did not require any price estimation for the environmental impacts using traditional revealed or stated preference methods. They showed that DEA could be modified in the context of CBA by using absolute shadow prices instead of using the traditional relative prices.

Other studies that used CBA method include those done on the energy sector and coastal environment. Islas, Manzini, and Martinez (2002) conducted a study on Mexico's power sector and compared three different scenarios, which included the Base Case (using fuel oil), Official (introducing natural gas) and

Transition (incorporating renewable energy). Meanwhile, the study by Wiskerke *et al.* (2010) on biomass energy analyzed the economic feasibility of a sustainable smallholder bioenergy production in the eastern part of Shinyanga region in Tanzania under semi-arid conditions. Likewise, using CBA method, various management realignment scenarios were assessed in the Humber estuary in Northeast England, and then compared with the holding-the-line strategy (Turner *et al.* 2007). The CBA method was viewed as an integral component of a wider policy appraisal process within the integrated coastal management.

3.0 METHODOLOGY

3.1 Conceptual Framework

KHH provides a range of ecosystem services that are fundamental in improving the well-being (developmental goals) of the communities living within the vicinity of KHH. Accordingly, the way people use the environment affects ecosystems—positively or negatively—and will determine whether the impacts will result in social gains or losses. As such, to measure the extent of how humans manage the environment affects society, ecosystem services must be valued and then compared with the economic benefits under different management options.

As pointed out by Ranganathan *et al.* (2008, 3), "decision makers—including those whose goals and actions might not at first seem connected to ecosystems—need to examine the dependence and impacts of their goals on ecosystem services. Making decisions for policy implementation by taking ecosystem services into account can strengthen decisions." Accordingly, this study's framework follows the same principle. Decision makers must clearly weigh the costs and benefits of each developmental goal and then compare them with the social gains (Figure 5).

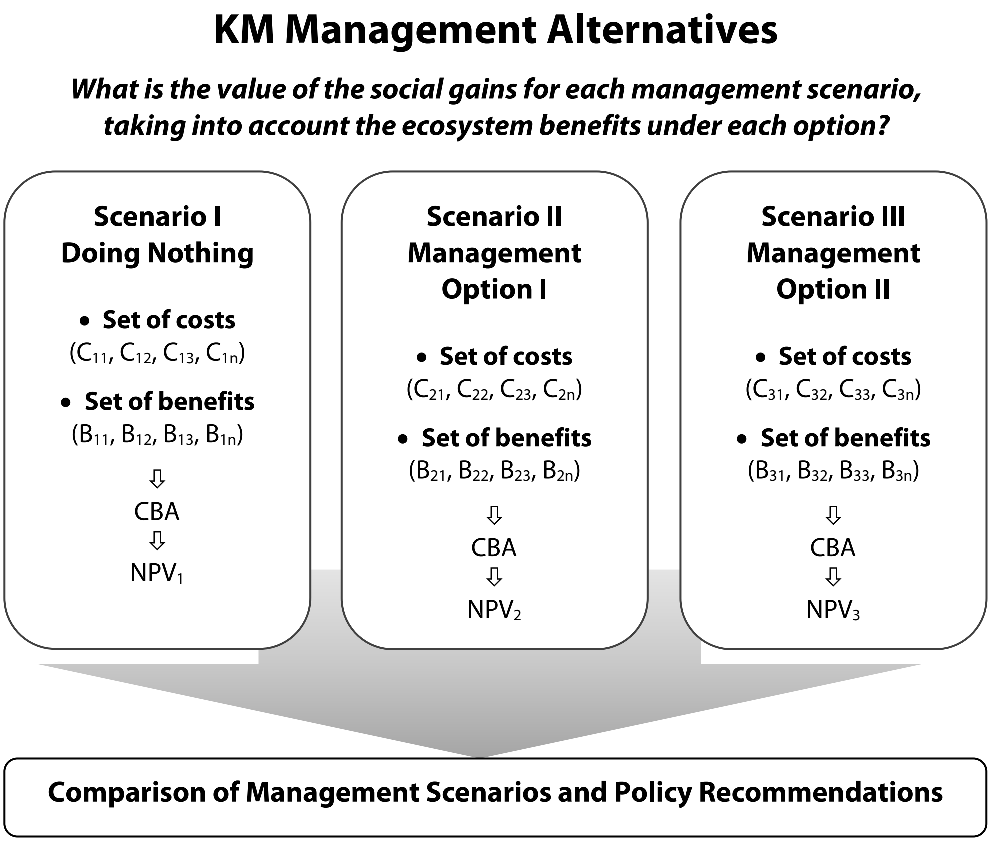

Figure 5. Conceptual framework of the research project

3.2 Incorporating Economic Value in Policy Analysis

Economic values that have been estimated through valuation methods can be used in a CBA. In the CBA, the economic benefits (i.e., the gains derived from the project) were compared with the economic costs and the losses or foregone benefits from the proposed project using the discounting method. This generated the present value. If the increased benefits exceed the costs, then the proposed project is considered to provide a net benefit to the community and improve economic efficiency (Gillespie, Clarke, and Mezzatesta 2005).

3.3 Constructing the Base Case and the Management Scenarios

Focused interviews (FI) and focus group discussions (FGD) were conducted among the various stakeholders in KHH in order to gather information relevant for the development of the three possible forest management scenarios (including the Base Case) for KHH.

The research team held a total of eight FGDs, which were conducted at various locations in KHH, namely: a) Ban PhruToNok, b) Ban Naidan in Thung Yai sub-district, c) Ban Kho Hong 1, d) Senanarong Military Base community, e) Ban NaiRai, f) Ban Thungri, g) Ban Thungdon, and h) PSU community in Kho Hong sub-district. FGD participants included the representatives from local communities living within the vicinity of KHH, local authorities associated with the forest management of KHH (i.e., government officials and representatives from non-government organizations), and the local business sector. Bryman (2001) prescribed that in order to cultivate a meaningful discussion, the number of participants for an FGD should range from 6-10 participants. Accordingly, 10 participants coming from various groups of stakeholders in KHH participated in each FGD. The participants were then asked about their opinions about the degrading environmental condition of KHH and their proposed management options.

On the other hand, academic experts on forest management from PSU were interviewed for their assessment of the deforestation problem in KHH as well as their recommendations on how to successfully manage the situation. Based on the information gathered from the FGDs and FIs, three forest management scenarios were developed.

3.4 Identifying and Screening Key Relevant Environmental Variables

The studies conducted by Olewiler (2004), Anielski and Wilson (2005), MA (2005a, b), Ranganathan *et al.* (2008), and Stenger, Harou, and Navrud (2009) extensively discussed the different types of ecosystem services, which this study used as a guide in identifying the KHH ecosystem services to be valued. However, only some of the ecosystem services that were initially considered for this study were selected for valuation due to resource constraints. For one, current data for some of the ecosystem services initially listed were unavailable. Likewise, valuing the parameters involved in some of the ecosystem services from KHH would prove to be too costly and impractical. Thus, only selected ecosystem services were valued in the current study (Table 2).

Table 2. Ecosystem services from Kho Hong Hill considered in the study

KHH ecosystem services	Beneficiaries/Boundary of services
Provisioning services	
Timber	Can be quantified and monetized, but people cannot use timber legally.
Freshwater supply	At present, KHH provides freshwater to communities downstream.
Regulating services	
CO_2 sequestration	CO_2 sequestration by KHH can benefit both the global and local communities.
O_2 generation	O_2 produced by KHH benefits local people and communities.
Flood control	People around KHH can benefit from this service.
Supporting services	
Habitat/Biodiversity	Beneficial to both local and global communities.

3.5 Estimating the Monetary Value of Kho Hong Hill Ecosystem Services

Where possible, primary data collected from the field study were used to estimate the values of KHH's ecosystem services. These services include the provision of timber, freshwater supply, O_2 generation, CO_2 sequestration, flood prevention, and biodiversity. On the other hand, secondary data collected from government documents, research reports, journal articles, statistical data, and case studies, among others, were used to provide context to the relevant environmental variables.

The ecosystem benefits and management costs for each scenario were estimated by monetizing the identified environmental variables. Table 3 presents the list of valuation methods used to estimate the ecosystem services from KHH.

Table 3. Valuation techniques used to estimate the ecosystem services considered in the study

KHH ecosystem services	Valuation techniques applied
Provisioning services	
Timber	Market approach
Freshwater supply	Market approach
Regulating services	
CO_2 sequestration	Market approach/Replacement cost approach
O_2 generation	Market approach/Replacement cost approach
Flood control	Market approach
Supporting services	
Habitat/Biodiversity	Value transfer

3.5.1 Timber value

Timber value was estimated using the data from an earlier study by Roongtawanreongsri *et al.* (2012). In the earlier study, the volume of timber was measured by tallying all the trees located within the sample plot (i.e., 1% of the total area of KHH), whereas data on timber prices were obtained from the Department of Forestry. With this information, the value of timber could already be calculated by multiplying the volume of timber by its prevailing price. To get the net benefit service, the cost of harvesting must be deducted from the obtained value. Note that timber value per area—assuming that forest productivity remains constant over time—must be considered in the CBA calculation only for the period when the forest was converted into a rubber plantation. Thus, timber value was derived using the equation

$$\text{Value of timber} = [\text{Volume of timber} \times \text{Price of timber}] - \text{Harvest cost} \quad (1)$$

3.5.2 CO_2 sequestration

CO_2 storage pertains to the accumulated CO_2 in the wood, branches, and soil in relation to the total age of the forest (i.e., primary forest or secondary forest). Accordingly, CO_2 sequestration can be defined as the capacity or rate by which the trees or plants in KHH can absorb CO_2 from the atmosphere in the span of one year.

Several methods can be used to assess the economic value of CO_2 sequestration. Guo *et al.* (2001) suggested three valuation methods, namely: a) through the formula of photosynthesis and respiration; b) the test and survey; and c) through a mathematical model. Guitart and Rodriguez (2010) evaluated the value of CO_2 fixing value using the alternative compensation value for silvicultural regimes. Anielski and Wilson (2005), on the other hand, suggested estimating the damage cost of climate change, carbon fee, replacement cost, carbon credit trading, and cost of timber income foregone in lieu of protecting the CO_2 stored in the forest ecosystem.

In this study, the authors used the trading price of carbon credits to calculate the value of CO_2 fixing. This way, the resulting values can easily be communicated to stakeholders as they are presented through clear and tangible information. Meanwhile, the sequestration rate was obtained through field experiment. The price of CO_2 was multiplied to the amount of CO_2 fixed by KHH, as in the following equation:

$$\textit{Value of } CO_2 \textit{ sequestration} = \textit{Total amount of carbon fixed} \times \textit{Price of } CO_2 \tag{2}$$

The rate of CO_2 sequestration and storage was estimated by using the data obtained from the field experiment conducted by the research team in KHH, and by applying the estimation method used by Yolasiğmas and Keleş (2009). In the field experiment, 15 plot samples in KHH were selected for evaluation. These plots served as representatives of primary forest (≥ 40 years of forest stand age), secondary forest (< 40 years of forest stand age), and rubber plantation.

3.5.3 O_2 generation

Similar to the way the value of CO_2 sequestration was estimated, O_2 provision can be determined by multiplying the quantity of O_2 provided by the forest by the price of the sold O_2, or by the replacement cost of generating O_2. Relevant studies which attempted to value O_2 generation service include those of Chen *et al.* (1998), Guo *et al.* (2001), Nowak, Hoehn, and Crane (2007), Tong *et al.* (2007), Jim and Chen (2009), Xi (2009), and Zhang *et al.* (2009).

Following the method used by Yolasiğmaz and Keleş (2009), the annual O_2 generation rate was obtained by multiplying the CO_2 absorption rate, which was calculated using Equation (2), by 1.2. The price of O_2 was then multiplied to the amount of O_2 generated by KHH, as in the following equation:

$$\textit{Value of } O_2 \textit{ provision} = \textit{Total amount of } O_2 \textit{ generated} \times \textit{Price of sold } O_2 \tag{3}$$

3.5.4 Source of water supply

KHH is the head watershed of Khlong Rian Canal below the catchment, which then flows to Songkhla Lake Basin. It also sustains the water supply requirements of Hat Yai City, particularly PSU and Senanarong Military Base. Without the water supply provided by KHH, these communities would need to find alternative sources to satisfy their requirements. Hence, they will have to connect their water pipes to the main pipeline of the municipality's waterworks authority. The municipality will also have to expand its water supply distribution coverage to cover these communities, which would entail capital input requirements from the government that could instead be used for other priority development projects. Therefore, the water conservation service that KHH provides is very important to Hat Yai City and to the nearby communities.

To calculate the amount of water provided by KHH, the Simple Hydrologic System Model was used. Data from Kho Hong Meteorological Station cites that the average annual rainfall in the area amounts to 2,825.9mm/year. Using the continuity equation, the amount of water flow can be calculated as follows:

$$\frac{dV}{dt} = A\frac{dd}{dt} = A \cdot i^{*} - Q \tag{4}$$

where: $V = A \cdot d$ = volume of water in the sub-catchment (m^3),
d = depth (m),
t = time (seconds),
A = surface of the water catchment area (m^2),
i^* = Excess rainfall [rainfall – (evaporation + infiltration)], and
Q = Rate of water flow out of sub-catchment (m^3/s).

The value of this ecosystem service can be assessed by estimating the water value held and released by KHH. This valuation technique has been applied in estimating the natural ecosystem processes in watersheds, specifically in providing clean drinking water (CAVSARTE 2005). CAVSARTE (2005) estimated that the value of clean water in a community due to the existence of forests amounts to USD 6-8 billion. As reviewed by Anielski and Wilson (2005), Sedell *et al.* (2000) used the same valuation technique to determine the value of the benefits gained from the water supplied by the forests for electricity generation, irrigation, and municipal use. Meanwhile, Guo *et al.* (2001) used the water balance method to evaluate the water storage ecosystem service provided by Xingshan County forest by calculating the value of the increase in water supplied to the communities. Other studies that valued the water storage ecosystem service from forests are by Xue and Tisdell (2000), Creedy and Wurzbacher (2001), and Tong *et al.* (2007).

In this analysis, the economic value of KHH service for water supply is based on the water held and released by the forest. Accordingly, the value can be calculated as follows:

$$\begin{aligned} \textit{Value of freshwater for municipal use} &= \textit{Amount of water held and released by KHH} \\ &\quad \times \textit{Price of water per unit} \end{aligned} \tag{5}$$

3.5.5 Flood control

KHH natural vegetation cover has high water storage capacity. However, for the past three years, some areas of the forest have been illegally converted for other uses (e.g., agriculture, rubber plantation, etc.). This has lessened the land's water storage capacity. As a result, flash floods have occurred in the area and may continue to occur should deforestation and land use change in KHH continue.

Using hydrological modeling, the volume and area flooded as well as the flood depth for each management scenario were simulated. The water balance study, conducted by the research engineering team, estimated the volume and depth of floodwater in a particular area. The model also figured the relationships among forest area, flood depth, and area flooded, and showed that the amount of runoff water increases as more of the forest areas are cleared. This would consequently flood the nearby communities. Accordingly, the damage cost corresponding with each land use change was estimated.

The flood control system for each of the three scenarios was likewise analyzed by developing a model that can show the characteristics of the flood, the location of the flooded area (which can be seen on a GIS map), and the depth and volume of the flood. On the GIS map, the flooded areas with similar depths were categorized as one zone. Three flood zones were identified for all three scenarios. Based on the identified zones, the number of households, business properties, and agricultural lands were then estimated. The average damage cost for each zone was calculated in relation to the zone's flood depth.

A total of 100 samples were examined. Subsequently, the average damage cost of flood at different flood depths and at different types of land use was estimated using the following equation:

$$\textit{Damage cost} = \sum_{i=1}^{n} D_{ij} \times A_i \tag{6}$$

where: D_i = average damage cost at land use category i at the corresponding flood depth,
i = land use categories,
j = flood depths,
n = number of damage categories, and
A = area of a land use category flooded.

3.5.6 Biodiversity

Due to time constraints, the research team was not able to estimate the benefits gained from the ecosystem services brought by KHH's biodiversity. Thus, the unit value transfer approach was used for this particular ecosystem service (this will be discussed in detail in Chapter 4). The adjusted benefit estimate *Bp* at the policy site can be calculated as:

$$B_p = B_s \left(\frac{Y_p}{Y_s}\right) \beta \tag{7}$$

where: B_s = the original benefit estimate from the study site,
Y_s and Y_p= the income levels at the study and policy site, respectively, and
β = the income elasticity of demand for the environmental good in question.

3.6 Conducting the Cost-Benefit Analysis

To derive the NPV of the Base Case Scenario and compare it with those under the two other management scenarios, all the environmental variables and their associated costs were incorporated into the CBA model using an Excel Program. The ecosystem services per area were entered into either the flow stream of benefit or cost per se. Therefore, the benefits would correspond to the number of the area of land use types (i.e., forest or rubber plantation). The results would then show which management option would yield the greatest benefit as measured in terms of NPV. Table 4 explains how the variables were considered in the CBA.

Table 4. Structure of the benefits from the ecosystem services considered in the cost-benefit analysis

Ecosystem service benefit	Benefit or cost corresponding to the type of land use in KHH [1]	
	Forest	Rubber
Timber	-	• Benefits gained from selling forest wood[2] • Release of CO_2 stored from harvested trees and from soil[2]
Water absorption	• Benefits gained from the water absorbed by the soil, which would be used by the people downstream all throughout the year	• Reduced benefit of water absorbed by forest
CO_2 sequestration	• Benefits gained from CO_2 sequestration at the rate of forest sequestration	• Benefits gained from CO_2 being sequestered by rubber plants • Release of CO_2 when the rubber trees reach their maximum age, and thus have to be harvested
Flood prevention	• Damage cost from floods	• Damage cost from the floods when forest areas get converted into rubber plantations
O_2 generation	• Benefits reaped from forest trees' provision of O_2	• Benefits gained from rubber trees' provision of O_2
Biodiversity	• Benefits reaped from forest biodiversity	-

[1]Benefits and costs are in terms of per area of land use.
[2]Only when the forest areas have been cut down to be transformed into rubber farms

4.0 VALUE OF ECOSYSTEM SERVICES

Six ecosystem services were evaluated: a) *provisioning service* of timber and b) freshwater supply; c) *regulating services* from CO_2 storage and sequestration, d) O_2 production, and e) flood prevention; and f) *supporting service* of biodiversity. The services were determined for both KHH forest and rubber plantation. The results of the evaluation became the basis for the CBA presented in the next section.

4.1 Timber Value

This study measured only the values of the forest product timber. Although KHH also provides other non-timber forest products, most of the beneficiaries are not dependent on them. Thus, the researchers no longer included non-timber forest products so as not to overestimate their actual values. However, note that if the potential total value of KHH is the one being estimated, then non-timber forest products should also be included in the valuation.

Timber concession has been prohibited in Thailand since 1989, thus current data on local timber prices were unavailable. Hence, this study used the prices of imported timber, which is categorized into two groups: Keruing group and other timber. On the other hand, the cost of harvest was based on the 1987 harvesting costs (when forest concession was still in effect) adjusted for inflation (i.e., 2011 Consumer Price Index [CPI]).

The KHH secondary forests used to consist mainly of rubber plantation; thus, there were numerous rubber trees in the sample plots. As the prevailing prices of rubber wood significantly differed from the price of "other timber," the timber located in the secondary forests was valued using the prices of rubber wood instead of the prices of "other" timber. Likewise, the volume of rubber wood was converted into kilograms so as to correspond with the typical monetary unit for selling prices, which is in Thai Baht per kilogram. Note that this estimation for timber value was used only when the forest area has been cleared and transformed into rubber farms. Accordingly, the total timber value was estimated at THB 632,974/ha (USD 23,089/ha).

4.2 CO_2 Storage and Sequestration

CO_2 sequestration can be categorized into two types. The first type happens when the CO_2 stored in the trees—or the accumulated carbon in the forest (in terms of the CO_2 stored in woods, leaves, roots, and soil)—are released back into the atmosphere when trees are cut down. This becomes a cost of deforestation. On the other hand, the second type comes in the form of a benefit, which happens when forests are kept intact to sequester the CO_2 in the atmosphere. This ecosystem service also holds true for rubber plantation because rubber trees can also sequester CO_2 in the atmosphere although at a much lower rate. Thus, CO_2 sequestration can still be considered as a benefit from rubber plantations.

The amount of CO_2 accumulated in KHH forest was estimated at 193.26 tC (tons of carbon). On the other hand, the annual CO_2 sequestration estimated from this study's field experiment amounted to 24.07 tC/ha per year. CO_2 prices from the Thailand Greenhouse Gas Management Organization (TGO) were used in this study to calculate the value of CO_2 sequestration since TGO is the official organization in Thailand that trades carbon. Table 5 presents the estimated values of CO_2 storage and annual CO_2 sequestration of KHH.

Table 5. Value of CO_2 storage service of Kho Hong Hill

Types of ecosystem	Carbon sapacity		CO_2 price (tC)	Value	
	CO_2 storage (t/ha)	Annual CO_2 sequestration (t/ha/year)		CO_2 storage (THB/ha)	Annual CO_2 sequestration (THB/ha/year)
Primary forest	218.55	17.01	EUR 12.30 or THB 524.32 (USD 16.89)	114,595	8,919
Secondary forest	167.97	31.13		88,068	16,317
Average of forest	193.26	24.07		101,331	12,618
Rubber plantation	100.79	7.12		52,847	3,738

Note: 1 EUR = 42.6276 THB

4.3 O_2 Generation

Similar to CO_2 storage and sequestration, O_2 production as an ecosystem service can be studied through field experiments. According to Yolasiğmaz and Keleş (2009), total biomass can be converted into O_2 production by multiplying the former by 1.2. Thus, on the average, a hectare of KHH forest area can generate about 46.61 tO_2 (tons of O_2) annually (Table 6). This figure is about 3.5 times higher than that of the rubber plantation, which is 13.39 tO_2/ha per year.

Table 6. O_2 production capacity of Kho Hong Hill from field study

Type of Ecosystem	O_2 Production (t/ha/year)	Price of O_2 (THB/tO_2)	Value (THB/ha/year)
Primary forest	39.1145	USD 74.31 or THB 2,328.11	91,063
Secondary forest	54.1101		125,975
Average of forest	46.6123		108,519
Rubber plantation	13.3934		31,181

The data on the price of O_2 from various literatures are limited and varying. However, there are a few studies that valued O_2 production as a forest ecosystem service, with most of them conducted in China's forest. Still, the prices of O_2 cited from these studies vary widely from one another. Xi (2009) used a lower price range with O_2 production from industrial cost amounting to CYN 40/tO_2 (USD 5.86/tO_2). Guo *et al.* (2001) used a higher price range, using an average cost for O_2 production amounting to CYN 377.64/tO_2 (USD 45.49/tO_2). This was close to what Hou (1994, as cited in Jim and Chen 2009) used, which amounted to CYN 369.70/tO_2 (USD 48.64/tO_2). Herzog (2003) cited O_2 prices ranging from USD 11-12/tO_2, USD 27/tO_2 (for O_2 production from large industrial gas supplier), USD 95/tO_2 (for O_2 production from coal gasification), to USD 180/tO_2 (O_2 production from pulverized coal). In Hat Yai, O_2 for medical purposes sells at THB 5,674/tO_2 (USD 181.17/tO_2).

For this study, the abovementioned O_2 prices were averaged to get the middle range price value of USD 74.33/tO_2 (1 USD = 31.32 THB). The same method of calculation applies to rubber farms as well.

4.4 Water Supply

KHH supplies water to the 11 water reservoirs of the nearby municipalities, with six of these reservoirs being serviced at full capacity. The six water reservoirs include those located in PSU, Senanarong1, Senanarong2, Hat Yai Park, SanjaoNaJa, and Namnoi.

The runoff water coming from the KHH sub-catchment area is enough to sustain the requirements of nearby communities in KHH. However, the simulation model showed that clearing more forest area would increase the volume of runoff water discharged from KHH, which could cause more floods.

The benefits gained from KHH come in the form of KHH's capacity to store water in the soil to regulate floods and the capacity to release the same to supply the water reservoirs. Appendix 1 enumerates the values of the benefits gained by the local communities from this ecosystem services under the three management scenarios.

Unlike in CO_2 sequestration and O_2 generation, the value of KHH's provision of water supply was no longer estimated for the rubber farms. It is known that rubber trees have low water storage capacity due to their shallow roots as they are usually seen to fall down when there is runoff water.

4.5 Damage from Floods

The damage costs from floods for each type of land use (at different flood depths) were calculated for each scenario. Costs from floods include damaged properties and household items, foregone income due to work suspension, cost of illnesses, and the cost of rehabilitation after the floods. Results from the survey data revealed that the average damage cost increases as flood depth increases.

Since the damage cost depends on flood depth, average damage cost per land use, and the area flooded (as explained in Chapter 3), the cost of damage varied from year to year (Appendix 2). However, note that the estimated damage cost was undervalued as the damage cost for other land use types (i.e., damage cost to infrastructure and agriculture) were not included in the analysis. This means that the net benefit of each scenario should be higher than the resulting figures in this study.

4.6 Biodiversity

Researchers from the PSU's Department of Biology have been conducting regular surveys and researches on KHH biodiversity since 1984. One particular study conducted from 1984 to 1986 discovered 37 species of plants belonging to 130 families of which 19 species were ferns, 90 species were dicotyledon, and 19 species were cotyledon (Help Conserve Kho Hong Hill Project 2012). Due to time limitation, the value of the ecosystem service from KHH biodiversity was not estimated by this study; instead, the value transfer approach was used for this service. Previous studies were reviewed regarding the valuation of services gained from biodiversity, with particular focus on those researches that studied ecosystems similar to KHH. Local studies such as theses and dissertations found in the National database were reviewed, but only a few studies were related to biodiversity. Moreover, most of the studies were focused on existence use rather than on biodiversity. The studies from other countries were more diverse, but those that examined an ecosystem similar to KHH were difficult to find.

According to Navrud and Bergland (2001), value transfer approach can be done by either a) basing the selected unit values from the estimates derived from one or a few valuation studies that have close similarities to the policy site of the present analysis, or b) basing the unit values on the average willingness-to-pay (WTP) estimates derived from many studies. The authors also suggested that the simple unit value transfer approach should not be used for countries with different income levels and costs of living. This is particularly true for KHH. Therefore, only unit transfer from within the country was considered in this study.

Several studies were considered for this approach. The studies conducted in Huai Kha Khaeng (Krasuaythong 2000), Thung Yai Naresuan (Naruchaikusol 2002), and Phu Khiew Wildlife Sanctuaries (Wiwatthanapornchai 2001) are well known and the surveys conducted in these studies were at the national level, so they could be used for benefit transfer. However, since the characteristics of the forests and the biodiversity present at these sites were significantly different from those in KHH, using the unit values from these studies might overvalue the benefits derived from KHH. Likewise, the study conducted in Doon Lam Phan (Satjapong 2000) was too local and the characteristics of the forest were also different from KHH; thus it could not be considered for this study.

The study done by Gumpoo (2002) in Pa Krad, a tropical forest in Nathawee District near Hat Yai in in Songkhla province was the one chosen as the basis for the value transfer approach. Although its biodiversity is not as abundant, the characteristics of the Pa Krad forest were more similar to KHH than the other forest sites studied in the literature reviewed. The study was chosen for two particular reasons: a) it was at the same scale as the present research, which is in the provincial scale since KHH is not known nationwide; and b) the contingent valuation method (CVM) survey was also done in Songkhla province, the same province as KHH. Moreover, the sample respondents in this study had similar characteristics as those in the present research. For these reasons, the study was chosen as the value transfer basis to prevent the uncertainty in the spatial and temporal benefit transfer from increasing (which can be quite large), which can happen when using the value transfer approach (Navrud and Bergland 2001).

The WTP estimates—or the existence value—for conserving the forest of Pa Krad was THB 128/person per year (USD 4.12/person per year). This figure was estimated in 2001 and thus had to be adjusted for inflation using the 2011 CPI. The adjusted figure was THB 159/person per year (USD 5.12/person per year). This amount was then transferred to reflect the value in the policy site, multiplying it by the ratio of the incomes at the policy and study sites. The resulting figure was further multiplied to the total population of the policy site.

There were three possible beneficiaries, namely: a) the Hat Yai populace only; b) the residents in the three districts around KHH (i.e., Hat Yai District, MuangSongkhla District, and Namom District); and c) the whole Songkhla province population. Accordingly, a conservative estimation was done using the three districts around KHH, as they are the direct recipients of the benefits gained from the biodiversity service. The estimation was conservative because KHH's biodiversity can be considered as a benefit to the whole Songkhla province since it is one of the few remaining fertile mountains left in the province. Moreover, the people at the Pa Krad case study site had an average income lower than that of the people in the three districts around KHH. In addition, the biodiversity and ecosystem services from Pa Krad were less appreciated compared to KHH. Thus, the WTP used in this study may be undervalued. The value estimates for the three possible beneficiaries are shown in Table 7.

Table 7. Value of Kho Hong Hill biodiversity

Scale of beneficiaries	Average WTP (THB/person/year)	Total population	Value (THB/ha/year)
Hat Yai district only	159	374,891	111,606
Three districts adjacent to KHH		560,336	163,837
Songkhla province		1,357,023	326,251

Note: These values are considered undervalued.

The summary of all the estimated values for the ecosystem services from KHH is shown in Table 8. Results show that water absorption had the highest value among all the other services, excluding timber value. Although not seen in Table 8, the damage cost from flood (resulting from the reduced water absorption capacity of KHH) was also the highest.

Table 8. Summary of all ecosystem service values of Kho Hong Hill

Ecosystem services	Value at current stage (THB/ha/year)	Notes
From intact forest		
Timber	632,974	Entered into CBA only when the forest is cleared
CO_2 sequestration	12,618	Annual benefit
CO_2 storage	47,983	Entered into CBA only when the forest is cleared
O_2 generation	108,518	Annual benefit
Water absorption by forest (THB/ha for a one-year period)	118,954,045	Value was for the first year only (See Appendix 1 for the remaining values)
Flood prevention (THB/ha for a one-year period)	-	Different in each year for each scenario (See Appendix 2)
Biodiversity	163,836	Annual benefit
From rubber plantation		
CO_2 sequestration	3,738	Annual benefit
O_2 generation	31,181	Annual benefit

Note: Rubber farms do not generate significant volume of water or biodiversity, and thus were not estimated.

This has very important implications. If KHH forest is lost, then a) the communities around the area may experience increased occurrences of floods due to the excessive runoff water coming from KHH which can damage properties and infrastructures; and b) communities will have reduced water supply during the dry season because the forest will absorb less water.

Excluding timber value, the ecosystem service from KHH biodiversity had the second highest value (Table 8), even though the figure was undervalued as earlier explained. The value of O_2 generation was higher than the value of CO_2 sequestration due to the higher price of substituted O_2. All the values from forest ecosystem services were higher than that of from rubber farms.

The resulting values of these six ecosystem services were then used for the CBA of the three proposed management options. The construction of each case and their results are reported in the next section.

5.0 COST-BENEFIT ANALYSIS OF THE MANAGEMENT OPTIONS

5.1 Development of Management Scenarios

The information gathered from the surveys, FIs, and FGDs conducted among the stakeholders were used to develop the three proposed management options.

5.1.1 Suggested options from community people

The research team conducted eight FGDs in various locations around KHH, namely, Ban PhruToNok and Ban Naidan in Thung Yai Sub-district, Ban Kho Hong 1, Senanarong Military Base, Ban NaiRai, Ban Thungri, Ban Thungdon, and PSU in Kho Hong Sub-district). The results are summarized below.

Resources in KHH. According to the respondents, informants, and FGD participants, KHH used to be very fertile with various animal species (e.g., barking deer, gibbon, mouse deer, fishing cat, python, king cobra, birds of many kinds, and different kinds of fishes) inhabiting the forest. At present, many species are no longer or seldom seen, which implies that they may be already lost or decreasing in number since humans have started to invade the forest.

Utilization of KHH resources. People used to gather fruits and vegetables in KHH for consumption. At present, KHH land serves as a site for rubber plantations, building sites, religious centers, military base, residential areas, and as a tourist destination.

Land entitlement. Even before laws on land rights and ownership were issued in 1977, local people have already been occupying the KHH highlands and thus, they have ancestral rights over them. Most of the ancestral forestlands in KHH are held from generation to generation although no land titles were issued. However, in the lowlands where utilization is prominent, land rights and land ownership are issued.

Water use. There are several waterways in KHH. At present, water still flows into these waterways, but the amount of water have significantly decreased over the years, especially during the dry season. Currently, KHH remains the major source of water supply for PSU, the Buddhist Meditation Center, and the military base.

Locals also reported that the water path in KHH has changed resulting from the construction of a 1,600 m^2 television network station at the top of the hill. This infrastructure has also damaged the natural water source, thereby contributing to the decreased volume of water produced.

In the past, water flowed all throughout the year, as evidenced by the waterfalls located in the military base that used to attract local tourists all year round. Now, the water only flows from the falls during the rainy season. The people from Ban Phru To Nok, a village within the vicinity of KHH, have even reported that they have started to experience water shortages, which never used to happen before.

Aside from the decreased water supply, the respondents also mentioned incidences of flash floods during the rainy season, which have become more severe as more forest areas are cleared.

Cultural value. KHH also holds cultural value to the local communities. Legends of buried treasures, gods and goddesses living in the mountain, and other local myths have been told from generation to generation. Accordingly, the local people celebrate these beliefs by performing traditional spiritual rites such as the *Great Groom and Little Groom,* which is performed in the mountain.

Problems in KHH. From the community people's perspective, the destruction of KHH is due to deforestation, illegal encroachment, conversion of forest into rubber farms or agricultural lands, and construction of buildings. Likewise, inconsistent and inequitable land governance occurs such that influential and wealthy politicians can acquire land rights, whereas the common people are not granted with the same. The impacts of deforestation include loss of landscape, desertification, floods, drought, and landslides.

Possible suggestions for managing KHH. Based on the results of the survey and group discussions, the following are recommended as possible solutions to the problems in KHH: a) increased cooperation among government offices tasked with forest resource management; b) strict law enforcement; c) land title mapping; d) opening the area as a learning resource; e) encouraging land owners to participate in conservation projects; f) conducting awareness campaigns about forest conservation in nearby schools and local communities; g) forest restoration through tree planting initiatives in the deforested areas; and h) strengthening the Help Conserve KHH Project.

Respondents also noted that in order to persuade landowners to switch to agro-forestry, they should be given a monetary incentive to conserve the forest, which can equal to the amount of their foregone income if they use their land for agriculture or as a rubber plantation. Another option suggested was through ecotourism promotion so that landowners can be compensated for not using their land for rubber farming.

5.1.2 Suggested options from academic experts

Experts from PSU, the most relevant academic institution in KHH, were interviewed to gain their assessment on the KHH situation. In summary, all the academic experts believed that KHH forest would continue to decline if no intervention is introduced. Their recommended forest management initiatives were similar to those of the local community. Establishing protected areas was also considered as an option.

From the FGDs and FIs conducted, the management options are summarized as follows:

a. Establishing protected areas in KHH to preserve the remaining forest areas;
b. Conducting environmental education activities to raise stakeholders' awareness on the current plight of KHH;
c. Encouraging participation among stakeholders, particularly the local communities and government agencies involved in forest resource management;
d. Re-enforcing laws;
e. Restoration/rehabilitation by replanting or by practicing agro-forestry; and
f. Registering KHH for carbon market.

Only a few of the options can effectively and immediately save KHH from being further degraded. Although environmental education, public participation, cooperation among government offices, and law enforcement are critical in conserving KHH, these initiatives will take some time to take effect. The remaining forest areas in KHH may already have been converted for other land uses before the proposed initiatives can make an impact. Besides, the Help Conserve Kho Hong Hill has already implemented awareness campaigns and initiatives to encourage forest conservation since 2009. Likewise, re-enforcing laws and regulations is a continuous process that needs to be complemented with other options that can yield immediate impacts.

On the other hand, registering KHH forest for carbon market requires KHH to comply with certain requirements for registration. In particular, KHH must have a) an area that has never been forested for the past 50 years or b) an area that has not been converted for other uses from 1989 onward. Although KHH forest is more than 50 years old, parcels of its land have been steadily converted into rubber plantations. Therefore, KHH does not qualify for carbon market.

Considering all of these, KHH needs a more concrete management plan in order to sustain the ecosystem services it provides local communities. The other two remaining options—establishing protected areas and restoring the forest—are the most feasible among all the other management options proposed.

5.2 The Scenarios

Most stakeholders agree that if interventions are not introduced, KHH forest areas will certainly be converted for other land uses, particularly for rubber plantation. Accordingly, this became the base case scenario (status quo or business-as-usual). The deforestation rate was projected in terms of the current trend in the conversion of forest areas into rubber plantation, which was at 14.30 ha/year.

Based on the proposed alternatives, the following scenarios were developed:

a. Scenario I or the base case scenario, in which land use change is pegged at their usual rate;
b. Scenario II, in which KHH is declared as a protected area; and
c. Scenario III, in which the forest is rehabilitated to its primary stage, with or without payment for ecosystem services (PES) to owners who practice agro-forestry, replanting forest trees in rubber farms, or keeping trees (not rubber trees) for carbon market.

5.2.1 Scenario I: Base case scenario

The first scenario was the base case or the business-as-usual (BAU), in which no intervention is introduced. It was developed using information obtained from local representatives living nearby the forest, and using statistical data on population growth and forest reduction area.

Most of the stakeholders agreed that the situation in KHH would continue to worsen unless interventions are implemented. Therefore, the base case depicts a scenario, in which KHH will suffer further deforestation at the current rate of 16.68 ha/year and rubber farms will continue to propagate at the current rate of 14.30 ha/year.

5.2.2 Scenario II: Establishing a protected area

This option is already being explored by the government, thus KHH forests may be included as part of the Greater Songkhla Lake Basin Protected Area. There have been some discussions with the Office of Natural Resources and Environmental Policy and Planning to bring KHH into the agenda of protected area (PA) establishment. With this option, all current land use activities in KHH will have to stop; thus, the forest area can no longer be converted for other land uses. This implies that the 666.35 ha of remaining forest and 469.78 ha of rubber farms will be maintained.

Management cost includes the cost of PA establishment, including a budget for the maintenance, operations, and overhead expenditures of government agencies tasked to manage and monitor the forest once it has been declared as a PA.

5.2.3 Scenario III: Rehabilitating forest from rubber plantation area

This scenario proposes to introduce and promote a management scheme that will convert rubber plantations back into its natural state as a native forest. According to the Help Conserve KHH Project, this may be the most effective option for managing KHH. Thus, the Project has committed to inform and educate people about restoring KHH, as well as support and monitor the conservation efforts being implemented in the area. This option can be implemented through:

a. ***Farmers' voluntary actions.*** The Help Conserve KHH Project considers this as an alternative because all rubber farms in KHH are basically illegal. Had the laws governing the area been strictly implemented, rubber farmers would have been penalized. Since that is not the case, their motivation would be to cooperate with the government in the form of restoring the forest.

b. ***Fund raising.*** Funds can be raised to buy back these rubber plantations from its present owners and rehabilitate it as a conservation area.

The forest can be restored in different ways. It can be left alone so it can naturally regenerate on its own, native species can be replanted, the local communities can switch to agro-forestry, or any of these methods can be combined together. Replanting trees would yield a faster forest regeneration rate than natural regeneration. This scenario also assumes that the whole KHH will eventually return to its natural condition as a 100% forest area at a reforestation rate of 10% (of the total area of rubber plantations) per year. Rehabilitation costs include the costs in building and maintaining seedling nurseries, replanting, labor, and transportation, among others.

The same variables were used to evaluate and predict the possible impacts of each scenario on KHH's current condition. A planning period of 25 years was assumed as the development phase. The next section discusses the variables used, namely, the ecosystem services applied to all of three scenarios.

5.3 Conducting Cost-Benefit Analysis

5.3.1 Variables for cost-benefit analysis of Scenario I

In this BAU scenario, KHH forest areas would continue to decline (at the rate of 16.68 ha/year) to be replaced by rubber farms (at the rate of 14.30 ha/year). Considering this, the ecosystem services provided by the forest are expected to decline every year. These services include CO_2 sequestration, O_2 generation, and biodiversity. However, since rubber farms also provide ecosystem services and are expected to increase over the next 25 years, these services would also have values, although they would be significantly less than that of the forest.

CO_2 sequestration and O_2 generation were the considered ecosystem services from rubber farms. Biodiversity services coming from rubber farms are far less than the forest's; thus it is not usually considered as an ecosystem function of rubber farms. The same holds true for the water absorption service provided by rubber farms.

The greatest benefit gained from rubber farms is in its provision of rubber, which can be translated into income from selling latex rubber. Due to this tangible benefit, the local people become motivated to convert forest areas into rubber plantations. Accordingly, the income gained from rubber farming would be entered into the cost-benefit stream after Year 7, which is the period when latex can already be collected.

Another benefit in this scenario is the provision of timber, which is gained when forests are cleared to be converted into rubber farms.

On the other hand, the costs in Scenario I are in the form of foregone benefits from losing the forest (through the services that should have been otherwise rendered to society, but was lost due to land use change) and the cost of rubber farming. Another cost item is the CO_2 released from trees when they are harvested, which is assumed to be about 40% of the total CO_2 stored in the wood. The rest of the carbon stored in the litter, floor plants, poles, and soil are counted as the CO_2 released back into the environment, which consequently increases the level of CO_2 in the atmosphere. Table 9 shows the cost and benefit items appearing in the CBA flow.

Table 9. Example of Scenario I: Base case

Items	Year 1	Year 2	Year 3	…	Year 24	Year 25
Area of forest (in ha)	666.35	649.67	632.99	…	282.74	266.06
Area of rubber plantation (in ha)	469.78	484.09	498.39	…	798.78	813.08
Cost						
• **Management cost**	0	0	0	…	0	0
• **Cost of rubber farming**	Cost of rubber farming at the age of rubber farms per hectare per year					
• **Loss of ecosystem service benefit (foregone benefits from losing forest)**						
Loss of annual CO_2 sequestration capacity	The annual CO_2 sequestration of forest per hectare × area of forest cut × price of CO_2					
CO_2 released into the atmosphere when trees are harvested	The CO_2 stored in wood and other parts of the forest per hectare × area of forest cleared × price of CO_2					
Loss of O_2 generation	O_2 supplied per hectare forest × area of forest cleared × price of O_2					
Water supply	Predicted total amount of water loss for each year × price of water					
Foregone benefit from biodiversity	Foregone benefit from biodiversity service per unit area of forest × area of forest cleared					
Damage cost of floods	Predicted total depth of flood water for each scenario × damage cost					
Benefits						
• **Benefits from converting forest areas into rubber plantations**						
Harvested timber value	Timber value × area of forest cleared					
Latex rubber	For present rubber plantation = net revenue of rubber sold For newly planted = net revenue would happen seven years after rubber tree has been planted					
• **Benefits from intact forest**						
Value of annual CO_2 sequestration	Amount of CO_2 sequestered by forest per hectare × area of forest intact × price of CO_2					
Value of O_2 generation	Amount of O_2 generated per hectare of forest × area of forest intact x price of O_2					
Value of water supply	Amount of water supplied by forest × price of water					
Value of biodiversity	Value of biodiversity per unit of forest area × area of forest					
• **Benefits from intact rubber farms**						
CO_2 sequestration	Amount of CO_2 sequestered by rubber farm per hectare × area of rubber farm × price of CO_2					
O_2 generation	O_2 supplied by rubber × area of rubber farm × price of O_2					

Other assumptions in this scenario include the following:

a. The rate of forest reduction and rubber plantation is linear using current data available.

b. Benefits from timber are considered only when the trees have been cut.

c. Rubber production only starts at Year 8. The ecosystem services from rubber trees include CO_2 sequestration and O_2 generation, with consideration to the capacity of rubber trees to provide these services.

d. The average age of rubber farms is 21 years.

e. The CO_2 released from harvested forest products include the CO_2 stored in the wood, poles, litter, shrubs, and soil. Only 40% of the CO_2 from the wood is released into the atmosphere.

5.3.2 Variables for cost-benefit analysis of Scenario II

In this scenario, the forest areas and area of rubber farms are fixed at their current conditions, which are at 666.35 ha and 469.78 ha, respectively. For the whole analysis, the ecosystem services from forest and rubber farms would stay at their current levels. These figures are constant for all services.

The costs for this scenario include the cost of establishing the PAs (i.e., documentation and processing costs), cost of raising awareness and of organizing forums with stakeholders to gain their support and participation, and monitoring costs. The cost of rubber farming was also included in the analysis, as the existing rubber plantations would still continue operating. Table 10 shows the cost and benefit items present in the CBA flow.

Table 10. Example of Scenario II: Protected area options

Items	Year 1	Year 2	Year 3	…	Year 24	Year 25
Area of forest (in ha)	666.35	666.35	666.35	…	666.35	666.35
Area of rubber plantation (in ha)	469.78	469.78	469.78	…	469.78	469.78
Costs						
• **Management cost**	Establish-ment cost	Monitor-ing cost	Monitor-ing cost	…	Monitor-ing cost	Monitor-ing cost
• **Cost of rubber farming**	Cost of rubber farming at the age of rubber farms per hectare per year					
• **Damage from flood**	Predicted total depth of flood water for this scenario × damage cost					
Benefits						
• **Benefits from intact forest**						
Value of annual CO_2 sequestration	Amount of CO_2 sequestration by forest per hectare × area of forest intact × price of CO_2					
Value of O_2 provider	Amount of O_2 provided per hectare of forest × area of forest intact x price of O_2					
Value of water supply	Amount of water supplied by forest × price of water					
Value of biodiversity	Value of biodiversity per unit of forest area × area of forest					
• **Benefits from intact rubber farms**						
Latex rubber	For present rubber plantation = net revenue of rubber sold					
CO_2 sequestration	Amount of CO_2 sequestered by rubber farm per hectare × area of rubber farm × price of CO_2					
O_2 generation	O_2 supplied by rubber farms × area of rubber farm × price of O_2					

Assumptions in this scenario include the following:

a. Establishing PAs in KHH preserves the current land uses; thus, further deforestation will no longer be possible.

b. The costs involved in establishing PAs include preparation cost (mostly cost of study) and monitoring cost. Data on preparation cost were derived from related literature. The monitoring cost was assumed to be 10% of the study cost for each year.

5.3.3 Variables for cost-benefit analysis of Scenario III

In this scenario, the area of forest increases while that of the rubber farms decreases due to reforestation. As the rate of forest restoration is difficult to estimate, this study based its estimate on the goal of Help Conserve Kho Hong Hill Project in 2012, which was to restore about 32 ha of forest area. Hence, the restoration rate was set at approximately 10% of the total area of current rubber farms (Case B). Since this figure may be too optimistic, a more realistic (lower) figure was defined for sensitivity analysis, and was set at the rate of the current conversion from forest to rubber farms (Case A).

The values of the ecosystem services from restored forest areas largely depend on when the land has been reforested. Some studies argue that it would take more than 100 years for any deforested area to return to its natural state of primary forest (Uhl *et al.* 1988; Blay 2002). Some argue a shorter duration of less than 40 years (Magnusson et al. 1999; Lebrija-Trejos *et al.* 2010; d'Oliveira *et al.* 2011). Other studies have also cited that from field inventory, deforested areas need more than 40 years after abandonment to fully recover (Hughes *et al.* 1999; Aide *et al.* 2000; Chinea 2002). This study agrees with the latter figure, as evidenced by the situation in KHH; after 40 years of abandoning rubber plantations, forest areas were able to recover although not to its original state as a primary forest.

Therefore, the ecosystem services provided by recovering forests are assumed to be initially slow. Aide *et al.* (2000) studied the structural characteristics of natural regeneration with no intervention and found that abandoned areas can rapidly become CO_2 sinks and sequester about 2.5 tC/ha per year. d'Oliveria and Ribas (2011) found that recruitment rate for understory plants in term of biomass is 0.4% per year. However, figures from KHH field experiment showed that CO_2 grows in understory plants at a rate of 0.2967 tC/ha per year. Adding this amount to the current rubber sequestration rate, the amount resulted in a rate of 7.3687 tC/ha per year. This figure is within the middle range of the figures cited by Aide *et al.* (2000) and d'Oliveria and Ribas (2011). To take a conservative analysis, this study used this rate for the 25-year analysis period. This implies that the value used in this study is underestimated.

The costs in this scenario include restoration expenses, specifically the costs for building nurseries, labor, and seedlings. Since Case A is voluntary, there is no additional cost. In Case B, in which restoration rate is expected to be fast, a market mechanism may be needed to accelerate restoration. Rubber farmers may be paid with either the full value of the land or half of its value in exchange for agreeing to restore the forest. The two different prices were then analyzed to determine their feasibility. Table 11 shows the cost and benefit items present in the CBA flow.

Assumptions in this scenario include the following:

a. KHH forest can fully recover to its original primary forest state after 40 years.

b. CO_2 sequestration from restored rubber farms grows at a rate of 7.3687 tC/ha year. O_2 generation is based on this figure, multiplied by 1.2 as in other cases.

c. There are two cases of reforestation. The first case is when the forest is restored at a rate equal to the rate of reduction, which is 16.68 ha/year. This estimation seems most possible. However, if interventions are implemented, such as purchasing rubber farms for reforestation purposes, then restoration rate is estimated at the rate of 10% of rubber area per annum.

d. There are two ways by which rubber farms can be purchased for reforestation. First is by paying the full value of the land, which is at THB 2,500,000/ha (USD 80,530/ha). The second is by paying for half of the total land value. Note that these payments are just monetary incentives for rubber growers, such that they would relinquish their holdings, and not considered as real opportunity costs.

e. With this management option, rubber farmers do not lose all of their income—only a part of it—from producing latex rubber because rubber can still be harvested considering the reforestation would be gradual (either at a rate of 16.68ha/year or 10% of the total area of rubber farm per annum). In the analysis, however, this benefit would no longer be included in order to estimate a value that is within the lower bound of the estimation. If the net benefit still turns out to be positive, then the actual value of this ecosystem service would be higher than what would be estimated in this study.

Table 11. Example of Scenario III: Rehabilitation/forest restoration options

Items	Year 1	Year 2	Year 3	…	Year 24	Year 25
Area of forest (in ha)	666.35	713.32	760.30	…	1157.50	1157.50
Area of rubber plantation (in ha)	469.78	422.81	375.83	…	0	0
Costs						
• **Purchasing of land**	Land price × area of land restored each year (only in Case B)					
• **Cost of restoration**	Cost of nursery and seedlings, and labor cost for restoration					
• **Cost of rubber farming**	Cost of rubber farming at the age of rubber farms per hectare per year					
• **Ecosystem service losses (foregone benefits from losing forest)**						
Damage cost from floods	Predicted total depth of flood water for this scenario × damage cost					
Benefits						
• **Benefits from intact forest**						
Value of annual CO_2 sequestration	Amount of CO_2 sequestered by the forest per hectare × area of forest intact × price of CO_2					
Value of O_2 generation	Amount of O_2 provided per hectare of forest × area of forest intact × price of O_2					
Value of water supply	Amount of water supplied by forest × price of water					
Value of biodiversity	Value of biodiversity per unit of forest area × area of forest					
• **Benefits from intact rubber plantation**						
CO_2 sequestration	Amount of CO_2 sequestration by rubber farm per hectare × area of rubber farm × price of CO_2					
O_2 provider	O_2 supplied by rubber × area of rubber farm × price of O_2					
Latex rubber	For present rubber plantation = net revenue of rubber sold					

5.4 Results of the Cost-Benefit Analysis

All scenarios were analyzed and the values of ecosystem services were estimated for a 25-year period to match the cycle of rubber farms.

5.4.1 Results of Scenario I

Although rubber farms generate high financial gains for rubber farmers, results of the CBA showed that social gains from rubber farms are low. In this case, the annual net benefit started to reach the negative mark in Year 15 onward. In a long-term situation when a higher discount rate is used but the NPV does not decline, it means that the net benefit would decrease in the future years unless something is done to remedy the situation. This shows that actions should be taken to preserve the forest ecosystem services from KHH to protect the well-being of the people around KHH.

Table 12. Results of the cost-benefit analysis of Scenario I

Discount rate	Net present value (THB)	Benefit cost ratio	Annual equivalent benefit (THB)
1%	60,784,334	1.00	607,842
2%	130,528,481	1.02	2,610,568
3%	183,935,062	1.03	5,518,051
4%	224,531,610	1.05	8,981,263
5%	255,071,853	1.06	12,753,592
6%	277,710,718	1.08	16,662,642
7%	294,138,461	1.09	20,589,691

5.4.2 Results of Scenario II

When the current land uses are maintained, the NPVs of the net benefits were positive for all discount rate levels, with benefit cost ratios over 2. This implies that if KHH forest is established as a PA, thereby prohibiting any more land use change, then the social gains would have a net benefit value of more than THB 2.3 billion (USD 74,087,197) (if the discount rate is at 7%) for the next 25 years (Table 13).

Table 13. Results of the cost-benefit analysis of Scenario II

Discount rate	Net present value (THB)	Benefit cost ratio	Annual equivalent benefit (THB)
1%	4,548,691,971	2.880	45,486,919
2%	4,023,692,477	2.878	80,473,849
3%	3,581,714,446	2.874	107,451,432
4%	3,207,653,492	2.870	128,306,139
5%	2,889,404,643	2.867	144,470,231
6%	2,617,227,284	2.864	157,033,636
7%	2,383,251,622	2.861	166,827,612

5.4.3 Results of Scenario III

CBA results show that at any discount rate level, the NPVs were positive for all cases. This implies that social gains from forest restoration far exceed the cost. The NPVs in Case A (voluntary case) was lower than the NPVs in Case B (payment options). This is because the rate of conservation was lower in the former, thus the benefits generated from the forest was gained more gradually than that of Case B. In summary, the faster the rubber farms are converted back into forests, the greater the benefits will be.

Comparing within the same rate of restoration (Case B), it was found that the amount of payment affects the NPVs. Results indicate that the higher the financial incentives given to rubber farm owners are, the less social gains will be reaped. The details of NPVs are shown in Table 14.

Table 14. Results of the cost-benefit analysis of Scenario III

	Discount rate	Net present value (THB)	Benefit cost ratio	Annual equivalent benefit (THB)
Case A	1%	5,666,960,203	3.52	56,669,601
	2%	4,975,243,925	3.48	99,504,877
	3%	4,395,466,924	3.45	131,864,007
	4%	3,907,004,334	3.42	156,280,172
	5%	3,493,360,286	3.39	174,668,013
	6%	3,141,288,730	3.36	188,477,323
	7%	2,840,111,000	3.33	198,807,769
Case B Purchasing at a price equal to the total land value	1%	5,029,490,834	2.07	50,294,907
	2%	4,379,783,815	2.05	87,595,675
	3%	3,835,386,731	2.03	115,061,601
	4%	3,377,040,814	2.01	135,081,631
	5%	2,989,311,362	1.98	149,465,567
	6%	2,659,779,319	1.96	159,586,758
	7%	2,378,412,682	1.94	166,488,887
Case B Purchasing at a price equal to half of the total land value	1%	6,322,756,976	2.86	63,227,569
	2%	5,526,260,077	2.83	110,525,200
	3%	4,857,939,295	2.79	145,738,178
	4%	4,294,416,476	2.76	171,776,658
	5%	3,816,950,306	2.73	190,847,514
	6%	3,410,456,557	2.70	204,627,392
	7%	3,062,746,242	2.67	214,392,236

5.4.4 Comparison of the three scenarios

Scenario I had the lowest NPV, whereas Scenario III had the highest. Specifically, Scenario III Case B had the highest NPV, in which restoration rate was pegged at 10% (of the total area of rubber plantations) per annum, and incentive payment to rubber farmers was half of the total land value. Scenario II (establishing protected areas) resulted in NPVs within the middle range of Scenarios I and III, specifically when the discount rate level is low.

The same trend resulted for the values of the annual benefits. Scenario II had the highest benefit-cost ratio, as the costs in this scenario were lower than that in Scenario III. However, Scenario III Cases A and B had higher net benefits than that in Scenario II.

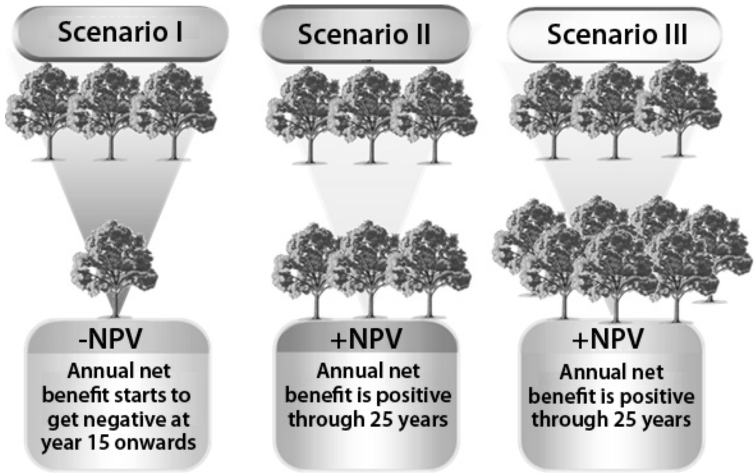

Figure 6. Summary of the cost-benefit analysis of the three scenarios

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Research Conclusion

Intangible benefits are often taken for granted whereas the tangible ones are more appreciated. As with the case of KHH, people put more value on the tangible benefits, such as the financial gains from selling forest products, than on the intangible benefits provided by the forest. Thus, forests are cleared and converted into rubber plantations or agricultural lands without realizing that the losses would be far greater than the gains. These are some of the considerations that are often overlooked in the normal decision-making process.

The resulting NPVs of this study have shown that the long-term economic viability of KHH is at risk considering the current rate of deforestation. Although financial returns are assured for private individuals (i.e., rubber farmers) when forest lands are converted into rubber plantations, the social gains are low, which implies that it is actually not economically feasible to convert forest lands into rubber plantations. Thus, further deforestation of KHH should be prevented.

All three scenarios considered in the study yielded positive NPVs; however, there were differences in each case. For the first scenario (BAU), although the resulting NPVs were positive at KHH's current condition, the values are seen to decline and will eventually turn negative (within 15 years) unless KHH is managed differently. On the other hand, the scenario that proposed establishing PAs in KHH to preserve the remaining forest yielded positive NPVs all throughout the 25-year period of analysis. This suggests a better management strategy than the current one being implemented in KHH. The best management strategy, however, is to preserve the remaining forest and, at the same time, restore areas that have already been deforested. The latter two management strategies both yielded high net benefits.

The results of this study also showed that social gains are greater if the reforestation rate is higher, and that giving financial incentives to rubber farmers so that the rubber plantations can be restored into forest areas is economically viable.

Note that the services evaluated in this study are only a part of the total ecosystem services provided by KHH. For example, services like tourism, prevention of soil erosion, soil fertility, pollination, and microclimate regulation are not accounted for. These services are more difficult to evaluate because of their complex nature; evaluating them will require a longer research period, more rigorous examination, physical data, and a deeper understanding of the systems involved.

It would be worthwhile to further analyze the proposed management options. Table 15 compares the advantages and disadvantages of each management scheme. It is clear that to go BAU—and thus maintain the current forest management approach in KHH—would be detrimental in the long run. As previously mentioned, the annual net benefit under the BAU scenario will turn negative from Year 15 onward. Accordingly, stakeholders should take action before such condition happens.

Table 15. Comparative analysis of the three management options

Criteria	Scenario I Business-as-usual	Scenario II Protected area	Scenario III Restoration Case A	 Restoration Case B
Economic feasibility	Positive NPV but annual net benefit turns negative from Year 15 onward	Positive NPV	Positive NPV	Positive NPV
Implementation cost (Present value at 7% discount rate)	None	THB 3,077,137 (USD 99,120)	THB 6,217,656 (USD 200,282)	***Case B1:*** THB 1,298,856,998 (USD 41,838,554) ***Case B2:*** THB 658,124,699 (USD 21,199,397)
Impact on communities/ acceptance	• No impact on rubber farmers; however, they are illegal farmers • Other people (e.g., people in Hat Yai, PSU, media, business sector) may not be receptive	• No impact on present rubber farmers, but may create inequity between present and prospective rubber farmers • Other communities may be receptive	Current rubber farmers will lose some of their income, as the rate of latex collection will no longer be at full capacity.	No impact on current rubber farmers as they are financially compensated.
Political acceptance	Government is in the position to enforce the law to deal with illegal encroachment.	Local politicians may lose their political support from rubber farm owners.	Local politicians may lose their political support from rubber farm owners.	Local politicians may not lose support as rubber farmers are financially compensated
Management possibility	Status quo	Possible and easily implementable	Voluntary participation of rubber farmers in the reforestation efforts is uncertain	Implementation may be a challenge as KHH lands are not legally owned by present occupants and may raise inequity between present and prospective rubber farmers.
Enforceability	Laws on encroachment are not strictly enforced; thus, many violate the law.	Enforcement should be strictly implemented	No enforcement needed since it is voluntary	No enforcement needed because the management is based on cooperation.

Establishing PAs in KHH is highly plausible, and is now being examined by academic experts from PSU. The process to achieve this would be rigorous but necessary. This would include conducting detailed data collection on the areas to be protected. To this extent, researchers from PSU have already substantially accomplished this task.

The next phase is to build a consensus among the stakeholders, especially the landowners, about the initiative to declare PAs in KHH. Conducting public consultations and dialogues with the local communities will help achieve this goal. Likewise, implementing information campaigns and organizing learning events to educate the local communities about the importance of preserving KHH forest and its economic value can help make people appreciate KHH better. At present, the Help Conserve Kho Hong Hill Project has been implementing this kind of activities, and is now gaining support from the communities.

Converting rubber farms into areas for reforestation can be challenging. However, this remains to be the primary goal of the Help Conserve Kho Hong Hill Project team—to conserve KHH and establish it as a suburban forest for the benefit of the people dwelling around it. Accordingly, the Project aims to recruit rubber farmers and convince them to volunteer their lands as demonstration sites for reforestation. With this initiative, together with other efforts like the implementation of information campaigns, public consultations, and learning events, the Project team hopes to encourage more rubber farmers to participate in the reforestation program. To succeed in this objective would save on costs and would make it easier to implement the complementary forest management strategies.

It is possible to accelerate the rate of restoration by giving financial incentives to the current rubber farm owners. However, several factors must be considered in this strategy. Implementing this would raise serious issues. For instance, why should rubber farmers be given financial incentives to reforest their lands when, in the first place, clearing them violates the law? If this strategy is to be implemented, will it encourage more violation in order to be paid in the future? Where will the funds to finance this incentive scheme come from? These issues underscore the need to further study the most feasible method of implementing the incentive scheme, which is already beyond the scope of this study.

6.2 Policy Recommendations

This section introduces a four-item policy recommendation, which is arranged in order of their priority. Depending on the availability of resources, some of the items can be implemented in parallel with the other recommendations to achieve maximum results. In general, all of the recommendations will help maintain the economic viability of KHH ecosystem services.

6.2.1 Preventing further deforestation

1. ***Preventing further deforestation.*** Programs must be developed and implemented to prevent KHH forest areas from being further converted and used for other purposes. Otherwise, the annual net benefits gained from KHH will turn negative in the long run as the damage cost from deforestation will exceed the benefits. Accordingly, forest conservation can be achieved by strictly enforcing existing environmental laws and policies and by raising the awareness of stakeholders through local environmental education.

    - ***Local authorities*** (i.e., Kho Hong Municipality, Hat Yai Municipality, and Thung Yai Tambon Authority Organization) must strictly enforce environmental laws and penalize violators in order to discourage others from further clearing the forest.

    - ***Academic institutions and the local government*** must help in the awareness campaigns by communicating science-based information to the communities.

2. ***Protection of existing forests.*** Instituting PAs in KHH is a practical management option. It has relatively low implementation cost, and can yield positive NPVs. Accordingly, the following preparatory courses of action must be done to be able to implement this management strategy:

    - ***Characterization and profiling of KHH forest area.*** Local authorities, communities, or organizations can propose for the establishment of PAs in KHH. Accordingly, studies to profile and characterize

KHH in terms of its social relevance, current physical condition and problems, and future threats must be conducted. PSU researchers have already conducted studies on the area; thus, related literatures on KHH are already available and can be used. Experts from the University can also serve as the lead proponents in implementing the research activities.

- ***Organizing public consultations and hearings.*** Participation from local stakeholders is very critical to establish PAs in KHH because this would mean that some of the land uses in the area will be regulated. Therefore, the local people need to understand the importance of the regulations in order to gain their compliance. Experts from PSU, together with the local authorities, should again take the lead on enlisting the participation of community leaders, community people, and other stakeholders. The local authorities can also help by providing the necessary resources for implementing such activities.

- ***Defining PA regulations.*** All stakeholders should participate in defining suitable regulations within the PAs. This step can be done during the public consultations and hearings.

- ***Submission of PA requirements to the Committee on Environmental Protected Area for approval of the application.*** Either PSU or local authorities can undertake this step.

- ***Declaration of PA.*** This step is under the jurisdiction of the Committee on Environmental Protected Area.

- ***Monitoring***. This should involve all stakeholders' participation—local communities, media, schools, business, organizations, local government agencies, and local authorities. The existing network of the Help Conserve Kho Hong Hill Project can also be recruited for this task. Meanwhile, the local government must strictly monitor people's compliance—and accordingly impose penalties on violators—to the rules and regulations that come with declaring PAs in KHH.

6.2.2 Reforestation

There are several ways to restore forest, some of which may be through the following (Blay 2002):

1. ***Through natural succession.*** Without any additional intervention, restoring KHH forest through natural succession would take longer. However, considering that simply maintaining the present forest areas in KHH can already yield high NPVs, this method may already be sufficient to restore KHH to its natural primary forest condition.

2. ***Through enrichment planting***. This forest restoration method introduces valuable plant species into degraded forests without eliminating those that are already thriving. Accordingly, the Help Conserve Kho Hong Hill Project promotes this method.

3. ***Through agro-forestry.*** This is another method that the Help Conserve Kho Hong Hill Project considers to be highly suitable for KHH. With this method, the present landowners can still enjoy the benefits from agriculture, the forest can flourish, and the local people can reap the benefits given by the forests.

As discussed in previous chapters, rubber farms can be converted into areas for reforestation through a) rubber farmers' voluntary participation and b) by giving them financial incentives.

1. ***Voluntary participation***. For rubber farmers to relinquish the lands they use for harvesting latex rubber and subsequently return them to the government for reforestation would require some critical inputs as follows:

    - Convincing them of the real benefits of rehabilitating KHH forest using concrete data and examples;

    - Demonstrating the benefits of agro-forestry; and

    - Educating rubber farmers on the costs of deforestation and on the benefits of reforestation. Accordingly, this would require presenting a comparative analysis that is understandable to rubber farmers, such as using tangible figures in presenting the costs and benefits. Such initiative can be spearheaded by experts from PSU through participatory action researches.

2. ***Accelerating reforestation through financial incentives.*** As earlier presented in this study, the faster that rubber farms are converted back into forest areas, the higher the benefits will be. Therefore, a payment scheme may be catalytic for this purpose.

   In the CBA, the strategy that was proposed was to pay rubber farmers in exchange for using the rubber plantations for reforestation purposes. However, this strategy may have some drawbacks. As such, instead of purchasing the land from rubber farmers, a strategy can be used that would incentivize farmers and landowners into keeping the forest environment suitable for yielding ecosystem services sustainably. This strategy is also known as the payment for ecosystem services (PES) mechanism. Figure 8 illustrates a PES mechanism for KHH, as adapted from Pagiola *et al.* (2004).

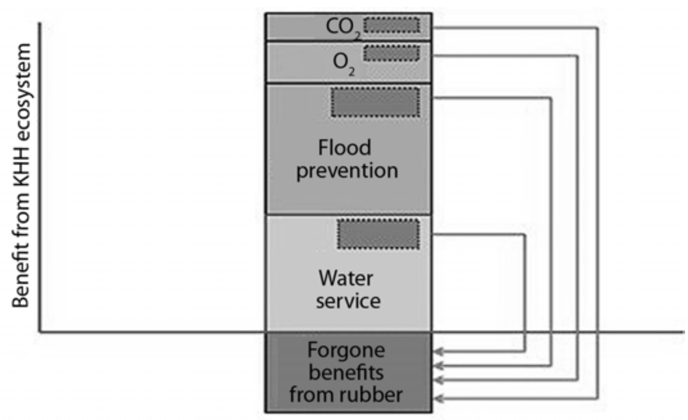

Figure 7. Payment for ecosystem services mechanism for Kho Hong Hill
Source: Pagiola *et al.* 2004

The following are some suggestions for the implementation of the PES mechanism:

- KHH water consumers—namely those from PSU and Sennarong Military Base—should pay a certain amount of fee to KHH farmers and landowners in exchange for their efforts in conserving the forest. In Figure 7, this fee represents the foregone benefits from rubber farming. However, the amount and collection system for this service need to be further studied.

- Likewise, the communities vulnerable to floods should also give compensation to those who conserve KHH forest. Similarly, the implementation of this PES mechanism needs to be further studied.

6.2.3 Securing long-term benefits

Implementing a total ban on the consumption of any forest product in KHH (e.g., timber, medicinal plants, wild flowers, etc.) would translate to loss of livelihood for some KHH locals. However, unregulated harvesting of the same would also be detrimental to KHH. To encourage local communities to conserve the forest, they should be allowed to harvest forest products at an appropriate volume. The recommendations are as follows:

- Studies to determine the sustainable amount of forest products for consumption should be prioritized. This would help encourage the local people to live sustainably with the forest.
- Policies and regulations that encourage the sustainable use of KHH should be formulated through a participatory process.
- The locals should establish a monitoring and surveillance system in KHH. The benefits they gain from their sustainable use of forest resources should be incentives enough for them to help protect it.

6.2.4 Ecosystem services expansion

Since time immemorial, the local communities near KHH have benefited from the ecosystem services provided by the forest. Thus, it is only fair that the locals conserve it for the enjoyment of next generations. Accordingly, the following are some recommendations for the redistribution of such benefits:

1. ***Conservation of local species***. By propagating native plants, KHH biodiversity can be conserved. Moreover, it will help raise people's awareness on the value of the local species in KHH. Other conservation initiatives include:
   - Encouraging locals to plant native plant species, thereby discouraging them from harvesting plants from the forest.
   - Promoting the use of native plants for landscaping public areas like city parks, schools, institutions, government offices, and residential areas.
   - Supporting local species that are planted from home, not from forest, like wild flowers in decorating buildings.
2. ***Development of a seed bank*** that will grow seedlings from KHH, particularly those plant species that are valuable, rare, or with great commercial values.
3. ***Establishing KHH as an ecotourism destination that showcases different life species in the mountains.*** Educational programs, scientific researches, and ecotourism should be developed systematically so that people can learn about the KHH ecosystem. This will help change the locals' perception and attitude toward KHH. As more people learn to appreciate the value of KHH, the easier it will be to encourage participation toward its conservation.

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APPENDIX 1. Study on Water Supply and Water Absorption

(All data is from the simulated models using primary data from KHH field study)

Water balance in Scenario I

Year	Water runoff flow (m^3/yr)	Water absorption (m^3/yr)	Value of water absorption (THB/year)
2011	11,509,034	9,820,935	118,954,042
2012	11,626,880	9,575,120	115,976,660
2013	11,744,728	9,329,306	112,999,279
2014	11,862,577	9,083,491	110,021,898
2015	11,980,424	8,837,676	107,044,517
2016	12,098,272	8,591,861	104,067,135
2017	12,216,119	8,346,047	101,089,766
2018	12,333,966	8,100,232	98,112,385
2019	12,451,813	7,854,418	95,135,004
2020	12,569,661	7,608,602	92,157,610
2021	12,687,508	7,362,787	89,180,229
2022	12,805,354	7,116,973	86,202,860
2023	12,923,203	6,871,157	83,225,467
2024	13,041,051	6,625,344	80,248,110
2025	13,158,897	6,379,530	77,270,728
2026	13,276,744	6,133,715	74,293,347
2027	13,394,592	5,887,899	71,315,954
2028	13,512,440	5,642,085	68,338,585
2029	13,630,287	5,396,270	65,361,203
2030	13,748,135	5,150,455	62,383,822
2031	13,865,981	4,904,641	59,406,441
2032	13,983,827	4,658,827	56,429,072
2033	14,101,677	4,413,011	53,451,678
2034	14,219,524	4,167,196	50,474,297
2035	14,337,371	3,921,382	47,496,928

Water balance in Scenario II

Year	Water runoff flow (m^3/yr)	Water absorption (m^3/yr)	Value of water absorption (THB/year)
2011-2035	11,509,034	9,820,936	118,954,045

Note: The water supply is the same every year since this scenario assumes that the area of forest and rubber farms stay the same.

Water balance in Scenario III

Year	Case A			Case B		
	Water runoff flow (m^3/yr)	Water absorption (m^3/yr)	Value of water absorption (THB/year)	Water runoff flow (m^3/yr)	Water absorption (m^3/yr)	Value of water absorption (THB/year)
2011	11,509,034	9,820,936	118,954,045	11,509,034	9,820,936	118,954,045
2012	11,403,684	10,066,749	121,931,414	11,212,294	10,513,327	127,340,492
2013	11,298,335	10,312,566	124,908,819	10,915,554	11,205,718	135,726,939
2014	11,192,985	10,558,379	127,886,176	10,618,816	11,898,110	144,113,385
2015	11,087,637	10,804,194	130,863,557	10,322,076	12,590,501	152,499,832
2016	10,982,287	11,050,009	133,840,937	10,025,337	13,282,892	160,886,278
2017	10,876,940	11,295,823	136,818,318	9,728,601	13,975,284	169,272,725
2018	10,771,588	11,541,637	139,795,687	9,431,860	14,667,676	177,659,183
2019	10,666,240	11,787,452	142,773,068	9,135,120	15,360,066	186,045,618
2020	10,560,891	12,033,268	145,750,461	8,838,380	16,052,459	194,432,077
2021	10,455,542	12,279,082	148,727,829	8,541,643	16,744,850	202,818,523
2022	10,350,192	12,524,896	151,705,210	7,997,620	17,437,240	211,204,957
2023	10,244,844	12,770,711	154,682,591	7,947,404	17,700,874	214,398,162
2024	10,139,494	13,016,526	157,659,972	7,830,797	17,964,507	217,591,366
2025	10,034,146	13,262,340	160,637,341	7,714,190	18,228,141	220,784,570
2026	9,928,797	13,508,156	163,614,734	7,597,583	18,491,774	223,977,774
2027	9,823,447	13,753,971	166,592,114	7,480,976	18,755,407	227,170,979
2028	9,718,098	13,999,785	169,569,495	7,364,369	19,019,041	230,364,183
2029	9,612,749	14,245,599	172,546,864	7,247,762	19,282,674	233,557,387
2030	9,507,400	14,491,414	175,524,245	7,131,155	19,546,307	236,750,591
2031	9,402,052	14,737,228	178,501,614	7,014,548	19,809,941	239,943,796
2032	9,296,701	14,983,044	181,479,006	6,897,941	20,073,574	243,137,000
2033	9,191,353	15,228,858	184,456,387	6,781,334	20,337,207	246,330,204
2034	9,086,003	15,474,673	187,433,768	6,664,727	20,600,841	249,523,408
2035	13,154,244	15,720,487	190,411,137	6,548,120	20,864,474	252,716,612

APPENDIX 2. Study on Flood Damage

(All data is from the simulated models using primary data from KHH field study)

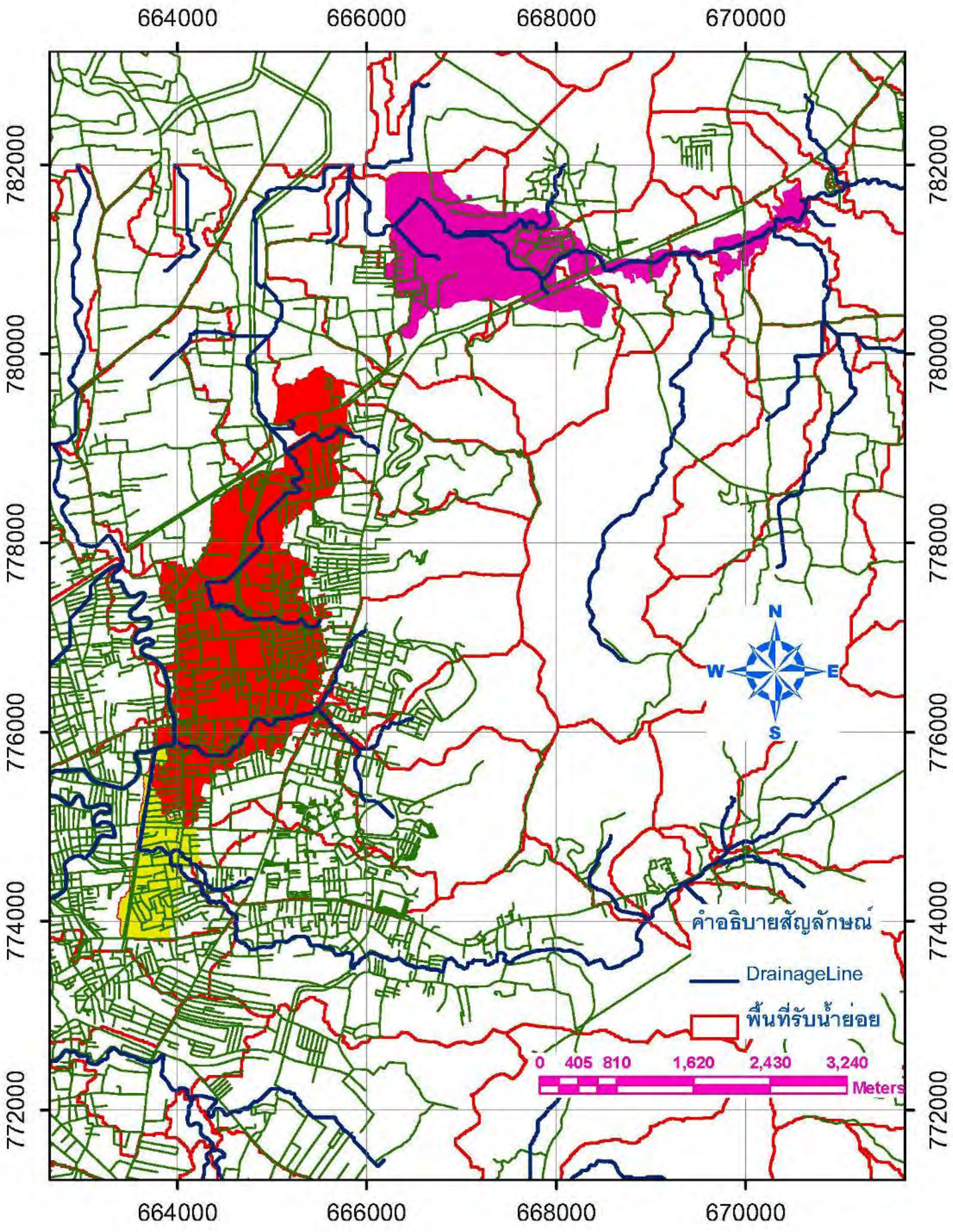
Area of flooding according to different scenarios

Year	Case	Zone	Flood depth	Area (m^2)	Area (rai)	Area (ha)
2011-2017	1	1	1.20	4,863,203.830	3,039.50	486.32
2018-2032	1	1	1.30	4,953,606.121	3,096.00	495.36
2033-2035	1	1	1.35	4,993,202.666	3,120.75	499.32
2011-2027	1	2	0.65	2,677,277.271	1,673.30	267.73
2028-2035	1	2	0.75	2,770,944.035	1,731.84	277.09
2011-2024	1	3	0.60	770,943.804	481.84	77.09
2025-2035	1	3	0.80	829,938.061	518.71	82.99
2011-2035	2	1	1.20	4,863,203.830	3,039.50	486.32
2011-2035	2	2	0.65	2,677,277.271	1,673.30	267.73
2011-2035	2	3	0.60	770,943.804	481.84	77.09
2011-2031	3A	1	1.20	4,863,203.830	3,039.50	486.32
2032-2035	3A	1	1.15	4,804,437.628	3,002.77	480.44
2011-2027	3A	2	0.65	2,677,277.271	1,673.30	267.73
2028-2035	3A	2	0.60	2,633,618.600	1,646.01	263.36
2011-2027	3A	3	0.60	770,943.804	481.84	77.09
2028-2035	3A	3	0.55	757,314.309	473.32	75.73
2011-2019	3B	1	1.20	4,863,203.830	3,039.50	486.32
2020-2022	3B	1	1.10	4,757,014.247	2,973.13	475.70
2011-2016	3B	2	0.65	2,677,277.271	1,673.30	267.73
2017-2022	3B	2	0.55	2,596,586.557	1,622.87	259.66
2011-2019	3B	3	0.60	770,943.804	481.84	77.09
2020-2022	3B	3	0.50	741,181.591	463.24	74.12

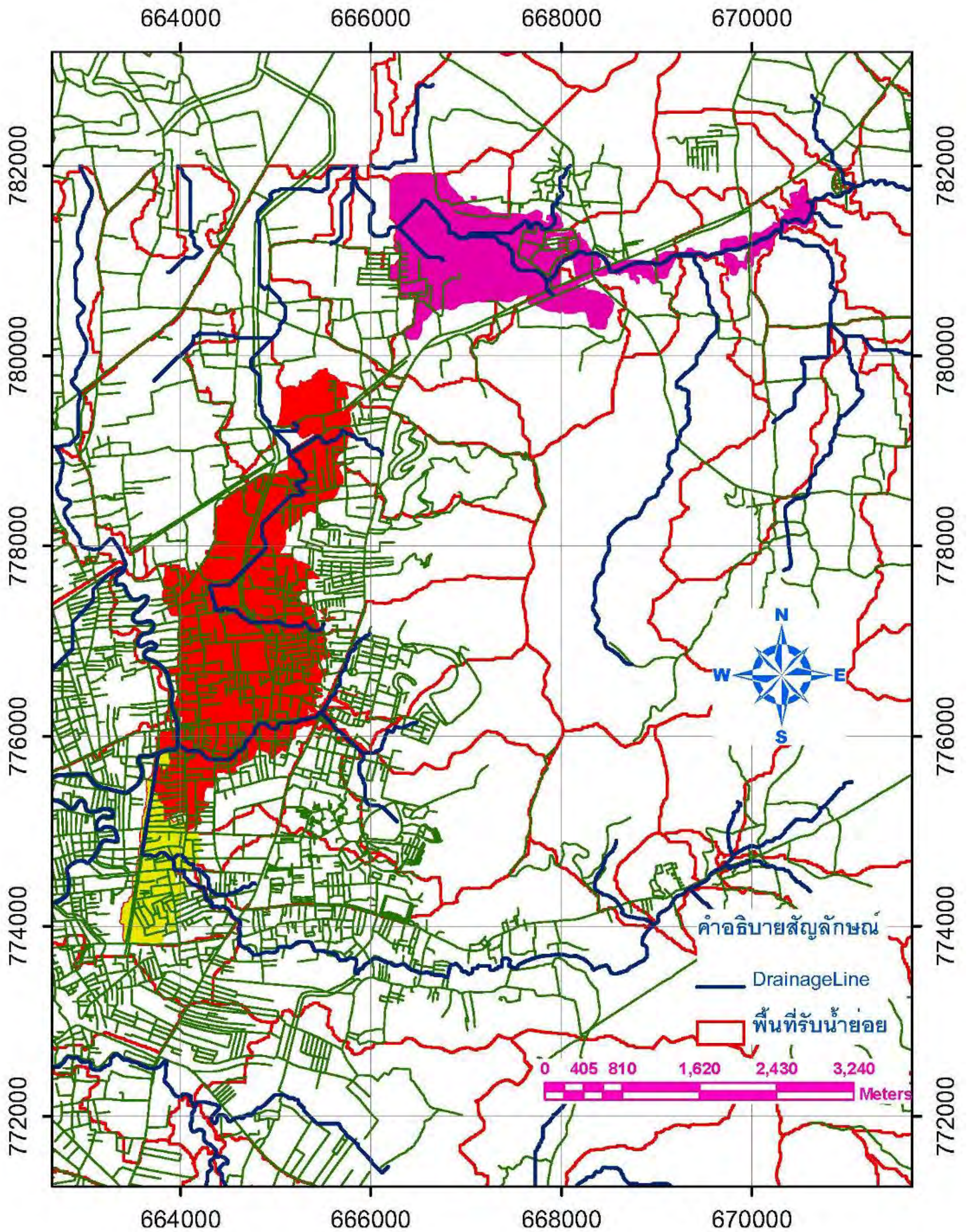
Total flooding area by land use type

Year	Area flooded according to type of land use (ha)			
	Residential area	Business	Agriculture	Total
2011-2017	157.41	58.36	269.23	484.99
2018-2032	161.17	59.44	274.23	494.85
2033-2035	161.93	59.92	276.42	498.27
2011-2027	6.26	32.13	148.21	186.60
2028-2035	8.30	33.25	153.40	194.95
2011-2024	46.32	9.25	42.68	98.25
2025-2035	48.48	9.96	45.95	104.38
2011-2035	157.41	58.36	269.23	484.99
2011-2035	6.26	32.13	148.21	186.60
2011-2035	46.32	9.25	42.68	98.25
2011-2031	157.41	58.36	269.23	484.99
2032-2035	156.57	57.65	265.97	480.20
2011-2027	6.26	32.13	148.21	186.60
2028-2035	6.18	31.60	145.80	183.58
2011-2027	46.32	9.25	42.68	98.25
2028-2035	46.13	9.09	41.92	97.14
2011-2019	157.41	58.36	269.23	484.99
2020-2022	155.53	57.08	263.35	475.97
2011-2016	6.26	32.13	148.21	186.60
2017-2022	5.95	31.16	143.75	180.86
2011-2019	46.32	9.25	42.68	98.25
2020-2022	44.85	8.89	41.03	94.77

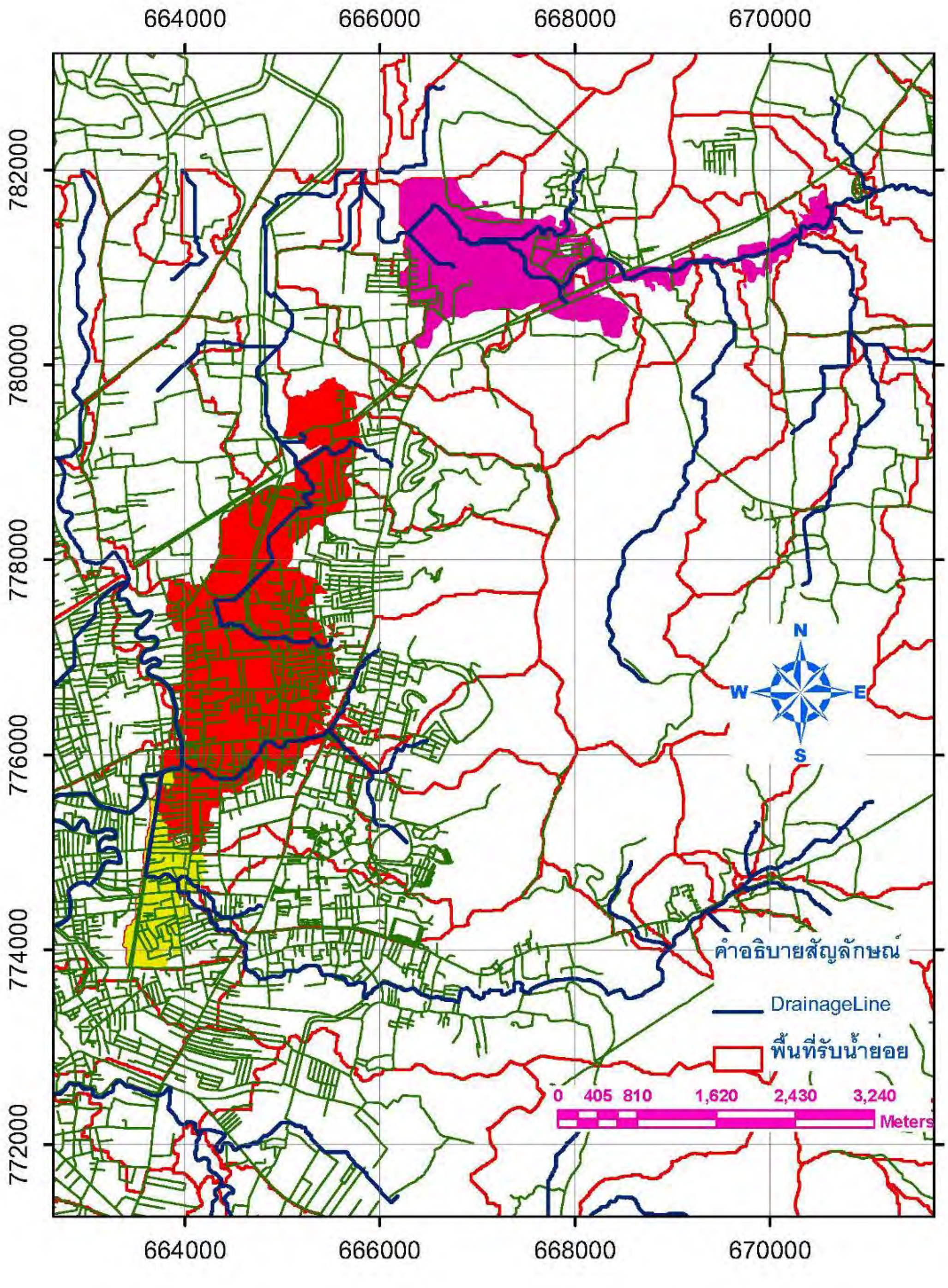
Note: This study does not consider the damage from agricultural area due to limited information, time and resources. The value of flood damage is thus underestimated.



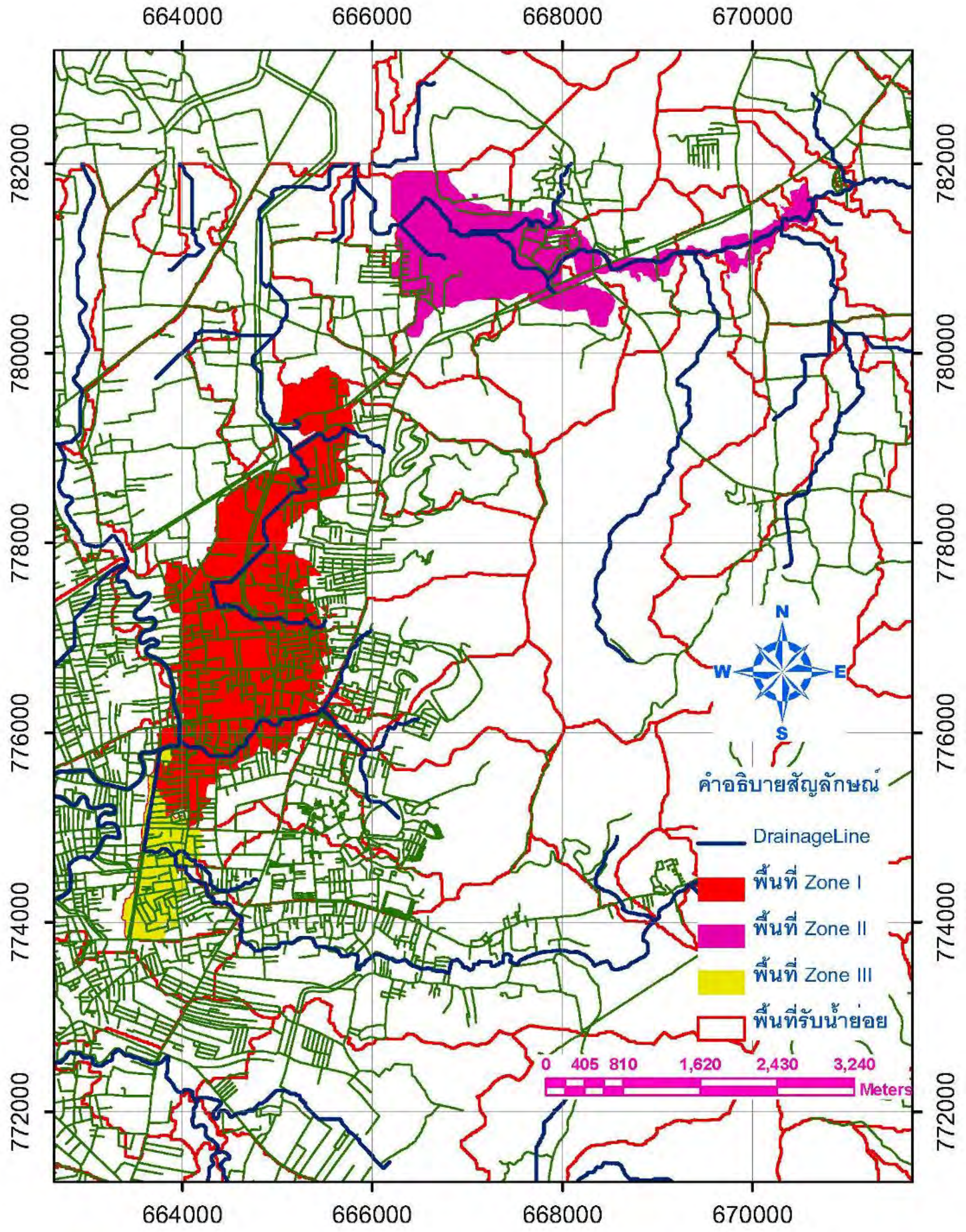
Flooding area in Scenario I



Flooding area in Scenario II



Flooding area in Scenario III Case A



Flooding area in Scenario III Case B

Damage cost by land use type

Flood depth in buildings (m)	Damage cost per household (THB/0.22 ha/day)	
	Residence	Business
0-0.50	3,999.58	2,236.82
0.51-1.0	3,643.12	5,040.02
1.01-1.50	7,387.54	3,638.42
1.51-2.0	5,943.66	3,638.42
2.01-2.50	5,943.66	5,017.25
2.50	34,345.99	9,338.49

Value from flood damage in Scenario I

Year	Zone 1	Zone 1	Zone 1	Zone 2	Zone 2	Zone 3	Zone 3	Total damage value
2011	68,759,570.68	0.00	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2012	68,759,570.68	0.00	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2013	68,759,570.68	0.00	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2014	68,759,570.68	0.00	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2015	68,759,570.68	0.00	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2016	68,759,570.68	0.00	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2017	68,759,570.68	0.00	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2018	0.00	70,347,949.84	0.00	9,236,057.96	0.00	10,768,066.06	0.00	90,352,073.86
2019	0.00	70,347,949.84	0.00	9,236,057.96	0.00	10,768,066.06	0.00	90,352,073.86
2020	0.00	70,347,949.84	0.00	9,236,057.96	0.00	10,768,066.06	0.00	90,352,073.86
2021	0.00	70,347,949.84	0.00	9,236,057.96	0.00	10,768,066.06	0.00	90,352,073.86
2022	0.00	70,347,949.84	0.00	9,236,057.96	0.00	10,768,066.06	0.00	90,352,073.86
2023	0.00	70,347,949.84	0.00	9,236,057.96	0.00	10,768,066.06	0.00	90,352,073.86
2024	0.00	70,347,949.84	0.00	9,236,057.96	0.00	10,768,066.06	0.00	90,352,073.86
2025	0.00	70,347,949.84	0.00	9,236,057.96	0.00	0.00	11,340,025.29	90,924,033.09
2026	0.00	70,347,949.84	0.00	9,236,057.96	0.00	0.00	11,340,025.29	90,924,033.09
2027	0.00	70,347,949.84	0.00	9,236,057.96	0.00	0.00	11,340,025.29	90,924,033.09
2028	0.00	70,347,949.84	0.00	0.00	9,890,452.95	0.00	11,340,025.29	91,578,428.08
2029	0.00	70,347,949.84	0.00	0.00	9,890,452.95	0.00	11,340,025.29	91,578,428.08
2030	0.00	70,347,949.84	0.00	0.00	9,890,452.95	0.00	11,340,025.29	91,578,428.08
2031	0.00	70,347,949.84	0.00	0.00	9,890,452.95	0.00	11,340,025.29	91,578,428.08
2032	0.00	70,347,949.84	0.00	0.00	9,890,452.95	0.00	11,340,025.29	91,578,428.08
2033	0.00	0.00	70,713,055.25	0.00	9,890,452.95	0.00	11,340,025.29	91,943,533.49
2034	0.00	0.00	70,713,055.25	0.00	9,890,452.95	0.00	11,340,025.29	91,943,533.49
2035	0.00	0.00	70,713,055.25	0.00	9,890,452.95	0.00	11,340,025.29	91,943,533.49

Value from flood damage in Scenario II

Year	Zone 1	Zone 2	Zone 3	Total damage value
2011	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2012	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2013	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2014	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2015	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2016	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2017	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2018	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2019	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2020	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2021	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2022	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2023	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2024	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2025	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2026	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2027	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2028	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2029	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2030	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2031	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2032	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2033	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2034	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70
2035	68,759,570.68	9,236,057.96	10,768,066.06	88,763,694.70

Value from flood damage in Scenario III Case A

Year	Zone 1	Zone 1	Zone 2	Zone 2	Zone 3	Zone 3	Total damage value
2011	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2012	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2013	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2014	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2015	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2016	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2017	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2018	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2019	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2020	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2021	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2022	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2023	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2024	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2025	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2026	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2027	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2028	68,759,570.68	0.00	0.00	9,088,941.71	0.00	10,692,661.56	88,541,173.95
2029	68,759,570.68	0.00	0.00	9,088,941.71	0.00	10,692,661.56	88,541,173.95
2030	68,759,570.68	0.00	0.00	9,088,941.71	0.00	10,692,661.56	88,541,173.95
2031	68,759,570.68	0.00	0.00	9,088,941.71	0.00	10,692,661.56	88,541,173.95
2032	0.00	68,321,577.21	0.00	9,088,941.71	0.00	10,692,661.56	88,103,180.48
2033	0.00	68,321,577.21	0.00	9,088,941.71	0.00	10,692,661.56	88,103,180.48
2034	0.00	68,321,577.21	0.00	9,088,941.71	0.00	10,692,661.56	88,103,180.48
2035	0.00	68,321,577.21	0.00	9,088,941.71	0.00	10,692,661.56	88,103,180.48

Value from flood damage in Scenario III Case B

Year	Zone 1	Zone 1	Zone 2	Zone 2	Zone 3	Zone 3	Total damage value
2011	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2012	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2013	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2014	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2015	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2016	68,759,570.68	0.00	9,236,057.96	0.00	10,768,066.06	0.00	88,763,694.70
2017	68,759,570.68	0.00	0.00	8,936,523.98	10,768,066.06	0.00	88,464,160.72
2018	68,759,570.68	0.00	0.00	8,936,523.98	10,768,066.06	0.00	88,464,160.72
2019	68,759,570.68	0.00	0.00	8,936,523.98	10,768,066.06	0.00	88,464,160.72
2020	0.00	67,835,106.25	0.00	8,936,523.98	0.00	10,410,828.65	87,182,458.88
2021	0.00	67,835,106.25	0.00	8,936,523.98	0.00	10,410,828.65	87,182,458.88
2022	0.00	67,835,106.25	0.00	8,936,523.98	0.00	10,410,828.65	87,182,458.88
2023	0.00	67,835,106.25	0.00	8,936,523.98	0.00	10,410,828.65	87,182,458.88
2024	0.00	67,835,106.25	0.00	8,936,523.98	0.00	10,410,828.65	87,182,458.88
2025	0.00	67,835,106.25	0.00	8,936,523.98	0.00	10,410,828.65	87,182,458.88
2026	0.00	67,835,106.25	0.00	8,936,523.98	0.00	10,410,828.65	87,182,458.88
2027	0.00	67,835,106.25	0.00	8,936,523.98	0.00	10,410,828.65	87,182,458.88
2028	0.00	67,835,106.25	0.00	8,936,523.98	0.00	10,410,828.65	87,182,458.88
2029	0.00	67,835,106.25	0.00	8,936,523.98	0.00	10,410,828.65	87,182,458.88
2030	0.00	67,835,106.25	0.00	8,936,523.98	0.00	10,410,828.65	87,182,458.88
2031	0.00	67,835,106.25	0.00	8,936,523.98	0.00	10,410,828.65	87,182,458.88
2032	0.00	67,835,106.25	0.00	8,936,523.98	0.00	10,410,828.65	87,182,458.88
2033	0.00	67,835,106.25	0.00	8,936,523.98	0.00	10,410,828.65	87,182,458.88
2034	0.00	67,835,106.25	0.00	8,936,523.98	0.00	10,410,828.65	87,182,458.88
2035	0.00	67,835,106.25	0.00	8,936,523.98	0.00	10,410,828.65	87,182,458.88

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