Doctoral Thesis

Estimation of Carbon Emission Reductions and Costs for Reducing Local Dependency on Fuelwood Consumption in Cambodia

by

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Abstract

Tropical deforestation was responsible for the release of 1 PgC yr^{-1} or about 6-17% of global carbon emissions. Deforestation is caused by many drivers and fuelwood extraction is an important driver of tropical deforestation and forest degradation in developing countries. This is because approximately 2.7 billion people or 40% of the global population rely on wood biomass to meet their residential needs of energy predominantly for daily cooking. Excessive consumption of fuelwood through the common use of three-stone cooking stove by forest-dependent community and burning of wood for protecting animal from insects have contributed to tropical deforestation and related carbon emissions in developing countries. Introducing more efficient cookstoves and the use of mosquito nets for insects' protection can reduce excessive consumption of fuelwood while improving local livelihood of forest-dependent community and reducing deforestation and related carbon emissions. Until recently, there is no study on potential carbon emissions and reductions from substitution of common practices with the use of improved cooking stoves and mosquito nets. Assessing carbon emissions and reductions through this substitution also contributes to the development of carbon accounting system necessary for developing countries to benefit from the carbon-based financial incentives REDD+ scheme of the United Nations Framework Convention on Climate Change.

Using a community located in Phnom Tbeng forest area in Cambodia as a case study, this study assessed fuelwood dependency quantitatively via random surveys of 105 households and to project potential carbon emission reductions

realized by the substitution of three-stone stoves with improved cooking stoves and the use of mosquito nets instead of wood burning to protect animals. During the fieldwork, heads of households were targeted because of their main roles in daily family management. To perform cost effective analysis, three discounted rates were used to assess project development and implementation costs in terms of carbon prices for the substitution three-stone stove with improved cookstoves and the use of mosquito nets. Field surveys suggested that approximately 98% of the households collected firewood from nearby forests and used it as fuelwood for cooking, with the remaining 2% using both charcoal and fuelwood for this purpose. All respondents used the three-stone cooking stove for cooking. On average, fuelwood consumption was 2.0 ± 0.1 Mg $household^{-1}$ yr^{-1} (± refers to Confidence Interval of 90%) for daily cooking, corresponding to 3.8 ± 0.2 $MgCO_2$ of emissions. Burning wood for protecting cattle from insect consumed 4.3 ± 0.2 Mg $household^{-1}$ yr^{-1} or 7.9 ± 0.3 $MgCO_2$ of emissions.

Using results from the field surveys, population growth was projected for a period of 10 years between 2015 and 2024. Modeling suggests that households in the study site increased from 13,261 families in 2015 to 23,379 in 2024 based on the annual population growth rate of 6.3% in 2010. As population grows, more fuelwood consumption also increases and so do the carbon emissions. Carbon emissions from cooking and boiling water increase from 49,872 $MgCO_2$ to 87,923 $MgCO_2$, whereas emissions from burning fuelwood for protection against insects increase from 94,003 to 165,724 $MgCO_2$. In total, carbon emissions from cooking, boiling, and burning fuelwood for protection against insects were estimated at 673,082 $MgCO_2$ and 1,268,676 $MgCO_2$, respectively for the 10-year modeling period. Total carbon emissions under the baseline scenario or in the absence of project activities were estimated at 1,941,759 $MgCO_2$ over a 10-year period. To reduce these emissions, two project scenarios were compared. Under project scenario 1, Three Stone Stove has switched to Traditional Lao Stove with 43.11% of fuelwood saved. Second, project scenario 2 affords 64% of fuelwood saving by switching from Three Stone Stove to New Lao Stove. Under both scenarios, introduction of mosquito nets to replace burning fuelwood for protection against insects has been implemented. Carbon emissions were estimated at 847,475 $MgCO_2$ and 706,801 $MgCO_2$ respectively under project scenario 1 and scenario 2, respectively for the 10-year modeling period. Therefore, by using improved cookstoves and mosquito nets to protect cattle, carbon emissions can be reduced up to 1.1 $TgCO_2$ for the whole study site, corresponding to the avoidance of 6,187-6,983 ha of tropical forests from being cleared.

Substitution of conventional cookstoves with improved cookstoves and the use of mosquito nets instead of fuelwood burning could result in using less fuelwood for the same amount of energy needed and thereby result in reduction of carbon emissions and deforestation. To realize this substitution, approximately US$ 15–25 $MgCO_2^{-1}$ is needed depending on discount rates and amounts of emission reduction. These carbon prices are greater than carbon price traded in 2014, when average carbon price was just US$ 4.9 $MgCO_2^{-1}$, suggesting that carbon-based financial incentives alone is not attractive unless carbon price is set at the minimum level or financial support is provided to fill the gap. Carbon price is affected by the international agreement on climate change mitigation targets because it is driven by demand and supply. Carbon price is likely to increase after the 22nd Conference of the Parties to the UNFCCC, which is scheduled in 2016 when world leaders will agree to decide on emission reduction targets. In addition to reducing carbon emissions, substitution of cookstoves and mosquito nets will have direct impacts on the livelihoods of forest-dependent communities and on forest protection. Therefore, financial incentives under voluntary and mandatory schemes are needed to materialize this substitution.

Models developed in this study could be useful tools for carbon accounting through the use of improved cookstoves and mosquito nets. To improve accuracy of the models, field surveys according to seasonal variation are needed because households conduct daily activities by seasons.

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Chapter 1

Introduction

1.1 Background

Natural forests are habitat to more than half of terrestrial plant and animal species (Hassan et al. 2005). Ecologically, forests control erosion from landslides (Dymond et al. 2006) being wind and flood protection (Evans 2009) and benef ts to water quality. Furthermore, forests provide timber for construction, wood for fuel and other uses (FA-RGC 2009) and variety of essential goods from non-timber products such as rattan, medicines, resins, leaves and fruits, all of them contribute to livelihoods (Chan and Sarthi, 2002; FA-RGC 2009; DANIDA-SCW 2006; Scherr et al., 2004; Bhatt 2005). Forests are important sources of income and subsistence use for 1.2 billion of rural population (FAO 2006; FAO 2007; Scherr et al. 2004). With regard to climate change, forests are considered as a huge carbon pool that is playing very important role through carbon sequestration (Carnus et al. 2003; Rudel et al. 2005).

Unfortunately, tropical forests have lost about 13 million ha of forests area annually (FAO 2005) and many million hectares more have been logged and degraded annually for multiple purposes. Rapid population growth coupled with rapid economic development in tropical countries in the last few decades have brought these forests under risk because a large area in these forests were being overexploited and cleared for resettlement and agricultural expansion (Kaimowitz and Angelson 1998; Geist and Lambin 2001; Revington 1992; FAO

2003). Simultaneously, the capacity of tropical forest to provide these services is reduced each year by deforestation (Lambin et al. 2003) as well as by degradation principally due to uncontrolled logging (Gaston et al. 1998; Asner et al. 2009; FAO 2006; Tacconi 2007) and fires (Nepstad et al. 1999; Siegert et al. 2001). Data for 2000–2009 suggest that land use change (mostly from tropical deforestation) was responsible for the release of 1.1–2.7 $PgC\ yr^{-1}$ or about 40 billion tonnes of CO_2 (Friedlingstein et al. 2010; Pan et al. 2011). As the plants and soil of tropical forests hold an immense amount of global carbon and rich in biodiversity, tropical deforestation will continue to have direct effect on global environment and it is a threat to life worldwide because deforestation has led to the so-called "Climate Change" (IPCC 2001; Bolin and Sukumar 2002).

To deal with climate change resulting from forest loss, international agreement has promoted REDD+ scheme (Reducing Emissions from Deforestation and Forest Degradation, sustainable forest management, conservation of forest carbon stock and enhancement of forest carbon stock) at the 13th conference of the parties (COP13) in 2007 to the United Nations Framework Convention on Climate Change (UNFCCC). Two year later, REDD+ was increasing attractive and widely recognized after Copenhagen Accord adopted at the COP15 in December 2009. The REDD+ scheme had become the common terms referring to a scheme that provides financial compensation to developing countries for protecting their forests and particularly ensuring benefits are shared with the poor people. REDD+ has quickly become a widely accepted, although the payment system and measurement of carbon emission reductions are technically complex. Obviously, carbon emission reductions could be achieved if appropriate compensation mechanisms can be created. Compensation could only be possible if the amount of reduced emissions through appropriate intervention actions can be quantified. Until recently, there is no global carbon accounting system that is applicable for any specific forest in any country (Angelsen 2008). Particularly, no study of carbon emission reductions and the cost of REDD+ project implementation for forest management at local level has been developed for Cambodia. As REDD+ projects are commonly implemented at the local level (project level) in developing countries where forests have been deforested and degraded, community forest in Cambodia was selected as study site.

Cambodia is one of the countries in the Southeast Asia with the high deforestation rates. Annual deforestation rate was estimated at 0.7% between 1993 and 2003 (Sasaki 2006) and 0.8% between 2002 and 2010 (FA 2011). Addressing the deforestation is difficult due to the complexity of drivers of deforestation and forest degradation. According to Ty et al. (2011), the main drivers of deforestation in Cambodia are illegal logging, land conversion for agriculture, land encroachment, fuelwood consumption, lack of sustainable forest management capacity and lack of financial incentives to conserve forests, as well as timber demand from other countries. Recent study by Chhun (2015) showed similarity to that of Ty el al. (2011). Chhun (2015) found that drivers of deforestation and forest degradation include conversion forest to large scale agro-cropping and mining (large scale economic land concession under 10,000 ha, economic land concession under 1,000 ha and mining concession), conversion forest to settlement and farmland (social land concession, conversion forest to settlement and farmland through Government directive 001 policy, illegal forest land conversion & illegal forest land speculation at household scale), conversion forest to large scale infrastructure development (hydropower dam construction and electricity consumption, road construction), forest concession and local coupe & annual coup, illegal logging, fuelwood harvesting and forest fire. Starting in the 1990s, as a result of rapid economic growth and fragile environmental regulations, 60% of the country was leased to private timber industry, which led to widespread deforestation and forest degradation (Poffenberger 2009). Land speculation driven by high prices has also contributed to accelerated forest clearing in recent years (Poffenberger and Smith 2009). In particular, economic land concessions for production of rubber, sugarcane, cassava and more recently biofuel crops have led to substantial deforestation and displacement of forest dependent populations (Poffenberger 2009). Forest degradation is also caused by unsustainable fuelwood collection and charcoal production. The latter is more damaging as it requires green wood and in some regions is more profitable than agriculture (WB 2011). Due to lack of alternative energy sources, wood is the primary energy sources for most rural and some urban households in Cambodia. Uncontrolled logging has also resulted in forest degradation. Uncontrolled logging was driven by the regional demand for wood. In recent years, industrial round wood production in Cambodia has increasingly supplied the region's wood product manufacturing centers in Viet Nam and China (Katsigris et al. 2004). To address the drivers of deforestation, the Royal Government of Cambodia expresses its strong commitment to continue forest reform by providing land tenure, strengthening law enforcement, enhance capacity building of forest officers and encouragement of forest community's participation. However, successfully addressing these drivers still remains a great challenge because Cambodia still lacks of financial means and technical capacity.

From 1994 to 1997, Cambodia established a logging concession system whereby the Government granted 36 forest concessions covering closed to 7 million ha, or approximately 70% of the forest area (Chhun 2015). Due to poor management and regulatory control of the logging concessions resulted in the Cambodian Government decision to issue a logging suspension in January 2002 for all forest concessions. Some forest concessions were cancelled, while other concessions were designated as protected forests. Currently there are approximately 3.3 million ha of forest still under valid concession licenses, though these are not harvesting timber (Chhun 2015). The Forestry Administration and the Ministry of Agriculture, Forestry and Fisheries (Cambodia) manage the allocation of forest areas for annual forest coupe for bidding that is open to private companies. The Government only had one coupe permit for 2012 within production forests in Cambodia, thus forming an insignificant portion of the current timber supply, and the timber will used domestically. The most timber production is obtained from land clearing activities in economic land concession areas under the jurisdiction of the Ministry of Environment and the Ministry of Agriculture, Forestry and Fisheries (Cambodia).

Economic land concessions have been granted as means to economic development in Cambodia since the 1990s. The 2001 Land Law formalized the legal framework for granting concessions for economic purposes. An economic land concession is a long term renting agreement that allows the beneficiary to clear land in order to develop industrial agriculture. According to the Land Law (2001), economic land concessions are granted for a period of 99 years on the state-owned forests. Large scale economic land concession area is limited to 10,000 hectares. The economic land concessions have been granted for activities that include large-scale plantations, animal husbandry and building factories to process agricultural products (ODC 2014). Data published by UNEP (2010) indicated that Cambodia has over 160 economic land concessions, located mostly in the Northeast and Southwest regions, covering an area of 1,777,000 ha, or 10% of total land area. In 2015, 301 economic land concessions were granted covering 2,116,067 ha of forest land, this lead to widespread forest clearance in some areas. Available information of Ministry of Agriculture, Forestry and Fisheries (Cambodia) showed that from 1996 to 2013 the Ministry of Agriculture, Forestry and Fisheries (Cambodia) granted 121 economic land concession covering 1,230,364 ha of forest in 17 provinces, in which 39 local companies covered 609,377 ha, and 82 international companies covered 620,987 ha. Of these, rubber, palm oil, cashew nut, cassava, was planted and cattle raised on 135,322 ha. In the same report it was indicated that among 82 international companies, 34 are Vietnamese owned companies, 25 Chinese owned companies, 7 Korean owned companies, 4 Thai owned companies, and the remainder are Indian, Singapore, US, Australia, and Russian owned companies (MAFF 2013). These figures represent only economic land concessions in Ministry of Agriculture, Forestry and Fisheries (Cambodia) jurisdictional areas. According to information published by the Ministry of Environment (Cambodia) on the total land surface exploited in natural protected areas in 2011, the total protected land surface was 3,143,763 ha. Of this, 322,113 ha were used for rubber plantations, 172,731 ha for other agro-industrial crops, 38,831 ha for mining exploration, 89,359 ha for eco-tourism and 4,593 ha for hydro-power. In other words, 20% of all Cambodian protected areas (627,627 hectares) were exploited for timber in 2012 (OHCHR 2012). Official data from Ministry of Environment (Cambodia) indicates that forest land inside Protected Area (PA) has been granted to 87 economic land concessions, which covers a total area of 482,543 ha.

A part of economy land concession, Cambodia has several large-scale hydropower projects under development that induce forest loss in the reservoir. Recent government records on log production indicate that only a small portion of the total timber supply volume originates from hydropower projects. Forestry Administration and Open Development Cambodia both showed roughly 8,000 m^3 of timber harvested from three dams constructed in 2012, and Forestry Administration 2012 data show that 11 dams constructed in that period covered 305,250 ha of forest land. Road building projects also cause forest loss in some provincial area. Major road building programs are stimulating economic development but they have been criticized for the inadequacy of their social and environmental safeguards. The new road construction itself strongly correlates with deforestation and induced illegal logging or land encroachment for settlements that emerge alongside the road.

Fuelwood consumption is an important driver of deforestation and forest degradation caused by unsustainable use of wood products for daily livelihood. Wood is commonly used by local people for daily cooking and livelihood of local people. Energy from the fuelwood in the rural area accounted for 80% of national energy consumption in Cambodia (UNEP 2010). UNDP forecasted that wood derived fuels will remain the main source of cooking energy in rural areas until 2030 (UNDP 2008). Fuelwood consumption remains the significant driver of deforestation and forest degradation because almost 100% of Cambodian population lives in rural area use fuelwood for daily energy need. Based on Cambodian Socio-economic Survey 1998 reported that 91.2% of Cambodians use fuelwood and another 5.1% use charcoal (NIS 1999) for cooking, lighting, charcoal and palm sugar producing. According to the draft Cambodia energy sector strategy in 2013, despite importation of energy resources such as fossil fuels, natural gas and coal from others countries, over 84% of the primary energy come from fuelwood for household consumption. The majority of rural Cambodians generally cook daily food with traditional method such as three-stones-cooking stoves that lead to excessive fuelwood consumption and related carbon emissions. In addition to cooking, recent study of San et al. (2013) suggested that wood is not used only for cooking and boiling but also burning to protect animal from insect. Burning fuelwood to produce smoke to protect the animals against insects is usually conducted at the night time, especially in the rainy reason. Therefore, wood consumption is intensely used within six months in rainy season and lower in the dry season. This practice has consumed excessive fuelwood. Per capita wood consumption in Cambodia was estimated at 0.66 m3 person-1 year-1 (World Bank et al. 1996). As Cambodian population continues to grow, and more demand for wood is expected to increase. Cambodia recognizes that supply of non-electricity energy sources for domestic applications like cooking and heating are also critical in the rural areas. There are some potential sources of alternative energy such as LPG, electricity, wind energy, solar energy or hydro energy but this utilization has restricted by the payment capacity of the household. Since using improved cook stove and mosquito net is cheaper than other alternatives, while financial incentives could be achieved under Clean Development Mechanisms (CDM) of the Kyoto Protocol, the REDD+ scheme of the UNFCCC, and other voluntary carbon offsetting standards for reducing emissions from forestation and forest degradation. There is a huge potential that using improved cook stove and mosquito net can reduce dependency on forests and therefore can result in reducing deforestation and carbon emissions.

1.2 Statement of Research Problems

According to the International Energy Agency, 2.7 billion people or 40% of the global population rely on the use of biomass to meet their residential energy needs, predominantly cooking (IEA 2006; IEA 2010). Fuelwood extraction from forests has become one of the major drivers of deforestation and forest degradation in developing countries that led to huge carbon emissions. Until recently, fuelwood and charcoal have been the most common sources of cooking and heating energy for rural population in Southeast Asia especially in Cambodia because alternatives to fuelwood for cooking and heating are generally expensive and rarely available (Geres 2007; Ty et al. 2011). Depending on the location, 50% or more of fuelwood is collected from natural forests in Cambodia

(CCCO 2003). Firewood and charcoal are often considered as conventional fuels, yet they remain the dominant source of cooking energy in Cambodia, even in the cities. The World Bank (2009) reported in 2009 that over 90% of Cambodian population use firewood and charcoal, and that with increasing population, dependence on fuelwood has contributed to deforestation and forest degradation. Although Cambodia has set a goal of providing an electricity grid to 70% of households by 2030 (Kunthy 2012), there is still a long way to reaching this goal, and rural electricity prices are higher than urban prices due to lack of access to national grid. A fuelwood-saving solution is critically needed to reduce the massive collection of fuelwood for energy. With recently increasing interest in reducing deforestation under the REDD+ scheme, an improved cookstove (hereafter, ICS) project is seen as an ideal method for reducing fuelwood consumption with easy-to-use technologies for forest-dependent communities. In addition to emission reductions through the adoption of ICS, avoiding the burning of wood for protecting domestic cattle from insects can also result in huge emission reduction. At night, Cambodian's rural people generally burn fuelwood for several hours to protect their cattle and such burning results in huge carbon emissions. Several studies on fuelwood consumption have been conducted in different parts of Cambodia. FAO (1998) studied the fuelwood consumption rate and fuelwood distribution system in Phnom Penh. In the same year, Gorse (1998) conducted research on fuelwood energy supply, trading and demand in the whole province of Kampong Chhnang, Cambodia. Top et al. (2003) studied fuelwood consumption rates and f ow in Kampong Thom Province, Cambodia and Top et al. (2004) conducted further research on variation in fuelwood consumption patterns in response to forest availability in the same province. Kong (2007) investigated fuelwood and charcoal demand in Kampong Speu Province and f ow in Phnom Penh. Mansvelt et al. (2008) conducted a survey to estimate the total fuelwood use for cooking by households in Phnom Penh and to examine supply characteristics at the main production area in Kompong Speu Province. UNDP (2008) released a report about residential energy demand in rural areas in Kampong Speu and Svay Rieng Province, Cambodia. Recent study of San et al (2013) reported that there are 4 types of fuelwood consumption namely cooking, boiling water, preparing animal feed and protecting cattle. San et al. (2013) proposed to use improved cooking stoves for reducing fuelwood consumption from cooking, boiling water and preparing animal feed, whereas Ty et al. (2011) proposed to use mosquito nets instead of burning fuelwood to protect cattle. The use of improved cooking stoves and mosquito nets will not only reduce wood collection from the forests but it also improves human and animal health, the latter resulting in more livestock production from health animals (FAO 2013). Until now, some studies had examined forestry issues in Cambodia (Kim Phat et al. 1998; 1999; 2000; 2001; 2002; 2004;Kim et al. 2005; 2006; 2008) but only a handful of studies had focused on carbon emissions from deforestation and forest degradation (Sasaki 2006; 2010; 2013; Ty et al. 2011). However, there is no specific study on potential carbon emissions, emission reductions and carbon price from the use of improved cooking stoves and mosquito nets in order to analyze the possibility of developing carbon project in Cambodia. While financial incentives under Clean Development Mechanisms (CDM) of the Kyoto Protocol, the REDD+ scheme of the UNFCCC, and other voluntary carbon offsetting standards are available from reducing deforestation and forest degradation, the study on estimation of carbon emissions, emission reductions, carbon credits and carbon price from using improve cooking stoves and the use of mosquito nets is important for carbon project developers and host country to achieve sustainable forest management. Moreover, Cambodia lacks of long term supporting finance for policy implementation and ground implementation in forestry sector. The royal government of Cambodia collected $15.83 million from the forestry sector in 2013 but only a small amount of budget returned to support the forestry sector. The data from the Technical Working Group on Forestry Reform presented in 2014 indicated that $21.58 million was invested in the implementation of National Forest Programme. Of this however, 98.64% was invested by donors and NGO partners, and only 1.36% by the government (Chhun 2015). Thus it is observed that a lack of domestic financial reinvestment in the forestry sector lead to ineffective field implementation activities addressing negative drivers of deforestation and forest degradation. Another crucial problem is the lack of current capacity of staffs who are working in Ministry of Environment and Ministry of Agriculture, Forestry and Fisheries which strongly affects forest management in Cambodia. According to Forestry Administration data from 2015, the government employs only 1,361 Forestry Administration officers in managing permanent forest estate and production forest of an estimated 9 million ha. Moreover, only 915 field rangers manage about 3 million ha of 23 protected areas (Chhun 2015). Compare to forest area, Cambodia are very short of field rangers to manage the forest. Thus, local communities play a critical part in forest protection and forest law enforcement. While revenue from carbon sales under REDD+ from ICS and mosquito net project could be achieved, these revenue will be used to pay for forest communities to participate forest protection and patrolling the forest to avoid illegal logging or preventing forest fires. The carbon project under REDD+ will help to address both environmental degradation and poverty reduction simultaneously. The study will not only estimate carbon emission reductions and carbon credits from using ICS and Mosquito net but then the study will analyze the carbon price of this project when payment for forest protection was given to forest communities.

1.3 Research Questions

The study would like to answer the following questions:

- What are the drivers of deforestation and forest degradation in forest dependent community?
- What is the relationship between forest resources to household in forest community?
- What are impact of fuelwood consumption on forest dependent community and forest management?
- What are potential of voluntary carbon market (through carbon incentives) on the sustainable management of forest and in reducing poverty in the forest dependent community?

1.4 Study Objectives

The general objectives of this study are to observe the drivers of deforestation and forest degradation, forest dependency, fuelwood consumption and its efficiency in forestry community. Furthermore, this study assesses other alternative sources and analyses how REDD+ (Reducing Emission from deforestation and forest degradation) can be emerged to achieve sustainable management of forest and in reducing poverty. This study also discusses a benefit-sharing mechanism and recommendations that could result in reducing deforestation and forest degradation driven by unsustainable extraction of fuelwood. Specific objectives of this study are:

- To assess the fuelwood consumption of household in forest dependent community.
- To project future consumption of fuelwood and its carbon emissions with business as usual scenario and with intervention action scenario. The time frame for the assessment is the 10 years between 2015 and 2024, corresponding to approximately one crediting period for a verified CDM project (Geres 2007).
- To estimate carbon emission reductions and carbon credits in the event that the use of conventional cookstoves is substituted by the use of more efficient cookstoves and burning fuelwood is prevented by the introduction of the mosquito nets to protect cattle.
- To estimate the range of carbon prices required for implementing the use of improved cookstoves and mosquito nets under REDD+ scheme.

1.5 Structure of the Dissertation

This thesis consists of six chapters.

Chapter 1 provides the overall introduction on the important of forest, tropical deforestation and forest degradation, carbon emissions and impact of fuelwood consumption on forest management. This chapter further elaborates upon the problem statement, the research objectives and thesis outline for this study.

Chapter 2 describes about literature reviews of global effort to reduce deforestation and forest degradation, analyze the opportunity of carbon market and development of REDD+ in the past and present. Furthermore it provides description of forest resources and the use of fuelwood in Cambodia. It also gives the reason why fuelwood efficiency is crucial to reduce deforestation and forest degradation in rural area of Cambodia.

Chapter 3 explains the research methods and materials used to collect field data and to develop carbon accounting system under REDD+ scheme by substitution of three stones stoves to ICS and use mosquito nets for insect protection. This chapter consists of information of research site such as socioeconomic condition; forest types and forest cover changes in study site. It will summarize detail about the equations used to estimate baseline emissions, project emissions, carbon emission reductions, carbon credits and carbon prices for 10 years timeframe.

Chapter 4 shows the results of this study including carbon emissions from cooking, boiling and animal protection, emission reductions and carbon credits under project scenario. It will discuss about some parameters that could affect the results of this research. The cost and benefit of this project also introduces in the last page of this chapter.

Chapter 5 proposes policy framework for REDD+ implementation in Cambodia to reduce deforestation and forest degradation from fuelwood consumption.

Chapter 6 draws the important of this carbon accounting system for estimating emissions reduction. This chapter will provide conclusions of the major research findings and personal highlights on theoretical and societal relevance of this study.

Chapter 2

Literature Reviews

2.1 Deforestation and Forest Degradation and Carbon Emissions

Forests play a huge role in the carbon cycle on our planet. When deforestation and forest degradation occur, not only does carbon absorption cease, but also the carbon stored in the trees is released into the atmosphere as CO2 if the wood is burned or even if it is left to rot after the deforestation process. Until now, global forests are continuing to decline at an alarming rate with annual rate at 13 million ha (FAO 2005). Second to energy sector, land use change (mostly from tropical deforestation) was recognized as a main source of global carbon emission that leads to global warming. In terms of carbon emissions, the data between 2000-2009 suggest that it is responsible the release of 1.1–2.7 PgC yr^{-1} or about 40 billion tonnes of CO_2 (Friedlingstein et al. 2010; Pan et al. 2011) (1 PgC (petagram of carbon) = 10^{15} gC, or 1 billion metric tons C, or 3.67 billion metric tons CO_2), due to the massive release of CO_2 that had been captured and stored in the trees. This emissions account for 13.7% to 27.5% of the 8.0 PgC of global emissions. In addition, emissions from forest degradation also account for a high proportion of global carbon emissions (Hoghton 2003). With regard to degradation, at least 392 million ha, or 20% of the total area of humid tropical forests, were logged during 2000-2005, and about 50% of standing humid tropical forests retained 50% or less cover as of 2005 (Asner et al. 2009).

2.2 Drivers of Deforestation and Forest Degradation

Drivers of deforestation and deforestation derive from economic development, population growth, political instability and governance failures, wildf res as well as the uncontrolled and often illegal logging mostly in tropical forests (Hembery et al. 2007; Meyfroidt and Lambin 2008). There are direct anthropogenic drivers of tropical deforestation, such as clearing for agriculture, as well as road construction, market forces, and government policies. Tropical forest losses from anthropogenic causes can be exacerbated by natural events, such as drought and fire. There are direct drivers from agriculture, including shifting cultivation and small-scale and large-scale permanent agriculture; and wood extraction, including logging and fuelwood harvests. Some literatures have identified the drivers of tropical deforestation and forest degradation in several categories. (Hosonuma et al. 2012) identified commercial and subsistence agriculture, mining, infrastructure extension and urban expansion as direct drivers of deforestation; while activities such as logging, uncontrolled fires, livestock grazing in forests, and fuel wood collection and charcoal production are considered to be drivers of forest degradation. Based on this synthesis of nationally reported data, agriculture is estimated to be the proximate driver for around 80% of deforestation worldwide which is in line with estimates provided by Geist and Lambin (2002), and Gibbs et al. (2010) for the 1980s and 1990s. More recently, it is shown that commercial actors play a larger and increasing role in the expansion of agriculture into forests and for many countries commercial agriculture is dominant over subsistence agriculture (Boucher et al.

2011) in particular in the Amazon region and Southeast Asia. Agribusinesses are increasingly producing for international markets (cattle ranching, soybean farming and oil palm plantations) were identified as main drivers of post-1990 deforestation (Rudel et al. 2009; Boucher et al. 2011). Mining plays a larger role in Africa and (sub) tropical Asia than in Latin America. Urban expansion is most significant in (sub) tropical Asia, perhaps due to the large population growth (De Fries et al. 2010). Timber and logging activities account for more than 70% of total degradation in Latin America and (sub) tropical Asia, while Fuel wood collection and charcoal production is the main degradation driver for the African continent, (sub)tropical Asia and Latin America (Kissinger et al 2012).

In Cambodia, deforestation and forest degradation is still significant with annual forest loss of 0.8% between 2002 and 2010 (FA 2011). The ongoing forest changes occurring throughout Cambodia have severe implications to the sustainability of natural resources (DANIDA-SCW 2006) which is influenced by many factors such as employment and land use options in rural areas, land tenure arrangements and enforcement, accessibility and infrastructure, market integration, unsustainable and illegal logging practices, institutional weaknesses, corruption, and the macro-policy context (McKenney and Prom 2002). In Cambodia, the main factors contributing to deforestation and forest degradation include commercial logging, illegal logging (both large and small scale), fuelwood collection, shifting cultivation and the settlement of new villages (DANIDA- SCW 2006; McKenney and Prom 2002; ClFOR 2007) inappropriate resource use, uncertain resource tenure and rapid population growth (Ly and Lao 2004). Another study found that the main drivers of deforestation and forest degradation in Cambodia are illegal logging, land conversion from agricultural encroachment, fuel wood consumption, lack of sustainable forest management capacity, and lack of financial incentives to conserve forests, as well as timber demand from other countries (Ty et. 2011). Poverty combined with population growth has put further burden on forest management because local people are continue to overexploit the forest resources even more. In rural areas of developing countries in particular, energy consumption from fuelwood has caused a series of environmental and economic problems. About 2.5 billion people in developing countries rely on traditional and low-tech uses of biomass to meet their residential energy needs, predominantly cooking. On current trends, this number will increase to 2.7 billion by 2030 (IEA 2006). Global fuelwood consumption in 2000 reached 2.3 billion m^3; accounting for roughly 60% of all the wood harvested that year. For the group of developing countries this proportion rises to 80% (Trosserro 2002). This is to say, energy from fuelwood consumption is one of the major drivers of deforestation and forest degradation in developing countries.

2.3 Fuelwood Consumption in Cambodia

Over 84% of Cambodians live in rural areas depend on forests resources for both consumption and income generation (DANIDA-SCW 2006). Fuelwood are the most common sources of energy for the majority of the population in the Kingdom of Cambodia. Firewood and charcoal are often referred to as traditional fuels, yet they remain the dominant source of energy for cooking within the domestic sector, and are used extensively by industry and services. Based on Cambodian Socio-economic Survey 1998 reported that, 91.2% of Cambodians use fuelwood and another 5.1% use charcoal (NIS 1999) for cooking, lighting, charcoal and palm sugar producing and etc. Majority of rural Cambodians are still cooking with traditional method such as three stones cooking stoves. This practice has consumed excessive fuelwood. Therefore, when fuelwood is harvested at a rate exceeding natural growth and inefficient conversion technologies are used, negative environmental and socio-economic impacts, such as fuelwood shortages, natural forests degradation and net GHG emissions arise (Arnold et al. 2003).. According to Cambodian Climate Change Office, about 50% of fuelwood is derived from natural forest (CCCO 2003). This percentage can be inferred that, Cambodian natural forests are in high pressure to be deforested. Therefore, the study is a positive step in estimating the amount of fuelwood extracted from natural forest in order to predict whether the way of harvesting the natural forest is sustainable or not, and the information on forest dependency in the rural area is known.

San et al. (2013) found that wood is primarily used for daily cooking and boiling water, preparing animal feed in addition to burning to protect animal from insect. Burning fuelwood to produce smoke to protect the animals against insects is always conducted at the night time. Since the number of insect are increasing during rainy season. Therefore, wood consumption is intensely used within six months in rainy season and lower in the dry season. This practice has consumed excessive fuelwood, therefore result in forest degradation. There are several studies on fuelwood consumption have been conducted in different parts of Cambodia such as FAO (1998), Gorse (1998), Top et al. (2003, 2004), Kong (2007), Mansvelt et al. (2008) and UNDP (2008). But none of these studies have researched on carbon emissions, emission reductions and carbon credits from using improved cook stoves and mosquito nets under REDD+ scheme.

2.4 REDD+ and Fuelwood Consumption

Financial incentives for reducing carbon emissions in developing countries are available under Clean Development Mechanisms (CDM) of the Kyoto Protocol, the REDD+ scheme of the UNFCCC, and other voluntary carbon offsetting standards. REDD+ is seen as the best scheme for forest management and local livelihood improvement in developing countries. REDD+ refers to Reducing Emissions from Deforestation and forest Degradation, conservation of carbon stocks, sustainable management of forests and enhancement of forest carbon stocks in developing countries. REDD+ is a global initiative designed to pay groups or countries for protecting their forests and reducing emissions of greenhouse gas pollutants, especially CO_2. It aims to reduce net emissions on a global scale. If it succeeds, it could help protect the world's forests as carbon reservoirs and maximize their potential for slowing down and reducing the impact of climate change. REDD+ is recognized as a way to address environmental degradation and encourage enhancement of forest carbon stocks by assigning an economic value to forests in the international climate regime. Many developing and developed countries see REDD+ as a positive way to contribute to global mitigation efforts. However, REDD+ is also a highly technical and rapidly evolving subject, and many developing countries require support to develop national frameworks and negotiate effective modalities and processes within the agreement under the United Nations Framework Convention on Climate Change (UNFCCC). Since fuelwood extraction for household energy consumption is one of major drivers of deforestation and forest degradation, REDD+ is an ideal tool to reduce this driver. Improved cookstove (hereafter, ICS) project is seen as an ideal method for reducing fuelwood consumption with easy-to-use technologies for forest-dependent communities. In addition to emission reductions through the adoption of ICS, avoiding the burning of wood for protecting domestic cattle from insects can also result in huge emission reductions. The use of ICS and mosquito net are expected to achieve huge carbon emission reductions, carbon credits and reduce the fuelwood dependency.

Among the ongoing projects, ICS projects have attracted increasing attention from carbon developers. In recent years, ICS projects have been successfully implemented in Africa and Southeast Asia. According to the UNFCCC registry (PoA Registry 2015), ICS projects generally claim emission reductions between 1 and 5 $MgCO_{2e}$ per ICS, as example ICS project in Nepal and Haiti has claimed emission reduction approximately 1.9 and 2.5 $MgCO_{2e}$ per ICS, respectively. This change depends mainly on fuelwood consumption in a baseline scenario (a scenario occurs in the absence of project activities) and the efficiency of ICS projects. With these carbon-based incentives and given that most of the Cambodian population depends heavily on fuelwood and charcoal for daily energy needs but still uses inefficient cookstoves, in particular the high-fuelwood-consuming three-stone stove and huge emissions from burning wood to protect animal, large carbon emissions remain to be assessed and at the same time huge carbon emission reductions could be achieved if the project is appropriately implemented. Therefore, there is a great potential that REDD+ mechanism can effectively improve local livelihood and protect the forest through their financial incentives.

Energy is the most basic material demand for human existence and development. Energy consumption level is used as the criteria to indicate the economic and social development level of a certain region. Energy demand has also become a critical factor driving to resource exploitation and environmental change. In rural areas of developing countries in particular, energy consumption has caused a series of environmental and economic problems. There are complex and numerous links between energy and poverty. Shortage of energy severely restricts the improvement of people's living standard. At the same time, the rapid growth of total energy consumption causes serious environmental problems (Chen et al. 2006) because excessive consumption of biomass energy has resulted in degradation of forest and grass vegetation, accelerated soil erosion, and changed ecosystem substance cycles. Furthermore, burning of biomass and coal has caused massive CO_2 and SO_2 emissions, resulting in atmospheric pollution (Zhang et al. 2005). Indoor air pollution from household energy use is also a leading environmental health risk because indoor smoke in particular produces obvious impact on the health of women and children (Jin et al. 2006).

Energy supply and demand is widely and closely connected to eco-social development and environmental protection in developing countries. The demand for rural energy in developing countries is continuously increasing, while the energy consumption structure only changes gradually along with population growth and improvement of household living level. These increases impact on the ecological environment, causing shifts in the energy consumption behavior of households and government policies.

About 2.5 billion people in developing countries rely on traditional and low-tech uses of biomass to meet their residential energy needs, predominantly cooking. On current trends, this number will increase to 2.7 billion by 2030 (IEA 2006). Global fuelwood consumption in 2000 reached 2.3 billion m^3; accounting for roughly 60% of all the wood harvested that year. For the group of developing countries this proportion rises to 80% (Trosserro 2002). This is to say, energy is the main application of woody biomass worldwide.

In Cambodia, fuelwood are the most common sources of energy for the majority of the population. Fuelwood and charcoal are often referred to as traditional fuels, yet they remain the dominant source of energy for cooking within the domestic sector, and are used extensively by industry and services. Based on Cambodian Socio-economic Survey 1998 reported that, 91.2% of Cambodians use firewood and another 5.1% use charcoal (NIS 1999). About 50% of fuelwood is derived from natural forest (CCCO, 2003). When fuelwood is harvested at a rate exceeding natural growth and inefficient conversion technologies are used, negative environmental and socio-economic impacts, such as fuelwood shortages, natural forests degradation and net GHG emissions arise. According to Cambodian Climate Change Office, about 50% of fuelwood is derived from natural forest (CCCO 2003). This percentage can be inferred that, Cambodian natural forests are in high pressure to be deforested. Therefore, the study is a positive step in estimating the amount of fuelwood extracted from natural forest in order to predict whether the way of harvesting the natural forest is sustainable or not, and the information on forest dependency in the rural area is known.

Cambodian people especially in rural areas rely mainly on fuelwood for cooking, lighting, charcoal and palm sugar producing and etc. Approximately 91.2% of Cambodians use firewood and another 5.1% use charcoal (NIS 1999). Although fuelwood extraction for residential purposes is not a major cause of deforestation, tree removal is likely to occur in localized areas, as for example in large and growing pre-urban areas (Arnold et al. 2006). Moreover, wood removal for fuel only at a low but constant rate may have negative impacts on the structure of natural forests (Arnold et al. 2003). The Royal Government of Cambodia (RGC) recognizes that supply of non-electricity energy sources for domestic applications like cooking and heating (for instance, biomass and solar) are also critical in the rural areas. Recently The Royal Government of Cambodia (RGC) has formulated a national energy sector policy, its objectives being to provide a secure, reliable, environmentally safe, and sustainable energy supply from various forms, at reasonable and affordable price, in order to address the population needs as well as the economic development needs of the Kingdom. In order to cope with the new policy of RGC, the comparison of fuelwood energy and the alternative energy sources in term of cost-benefit analysis, and assessment of energy potential from agricultural residues are required.

Chapter 3

Study Methods and Materials

3.1 Forest Resources Revolution in Cambodia

Cambodia located in Southeast Asia that is rich in tropical monsoon forests resources. Forest resources are one of nation's most valuable natural assets, as most vulnerable people are critically dependent on forest products to support their livelihood. The forests of Cambodia provided essential materials such as food, construction materials, cooking fuel, resins, vines and rattans, wild fruits and vegetables, livestock fodder, and medicines which in some cases they are used to generate income as well (McKenney and Prom 2002; Chan and Sarthi 2002; Scherr et al. 2004). The forests are not only provide raw materials and food, but they are very important to ecological functions such as ecosystem preservation, biodiversity conservation and protection of soil and water resources (CIFOR 2007; CBNRML 2005; McKenney and Prom 2002) and potential for the development of ecotourism (DANIDA-SCW 2006) and others opportunities for socio-economic development of the country (CIFOR 2007; Lic 2004).

The country has a total area of 181,035 square kilometers and population of 14.9 million people (MoP 2010) covering 10.4 million ha of forests cover or 57.07% of the country's total land area in 2010 (FA 2011). There are three major types of forest in Cambodia namely evergreen, semi-evergreen and deciduous forests with forest area of 3.5 million ha, 1.3 million ha and 4.5 million ha respectively. Other forests consist of 1.1 million ha including inundated and mangrove forests, bamboo, plantation and pine forests. In the late 1960s, forest cover in Cambodia was 13.2 million ha or 73% of total land area (Tran and Kol 1987) but forest area has undergone a substantial decline to 10.4 million ha in 2010 equivalent to 57.07% of total land area (DFW 1998; FA 2011) due to logging and forest clearing during the civil wars, clearing for economy land concessions and dams, unsustainable exploitation of forests for fuelwood consumption, rapid expansion of urban area, and increasing population (Table 1).

Table 1 Forest cover statistic 2010

No	Forest Types	Area (ha)	Percentage (%)
1	Evergreen forest	3,499,185	19
2	Semi-evergreen forest	1,274,789	7
3	Deciduous forest	4,481,214	25
4	Other forest	1,108,600	6
	Total	10,363,789	57
5	Non Forest	7,796,885	43
	Grand total	18,160,674	100

During Vietnam War in the late 1960s, large area of forest in the eastern parts of Cambodia was bombed during US military campaign against Vietnam communists. Moreover, during civil war 1970-1979, there was the clearance of hundred thousands of hectares of forests for resettlement of displaced people. Although large-scale logging was not carried out during 1979-1989, some thousands of hectares of forests were cleared along the border and military cantonment for so-called safety protection. Since the 1991 Paris Peace Accord totally ending the civil war in Cambodia, government changed its policy toward free market-oriented economy that lead national and international logging companies began their activities. Almost all the highly valued forests were logged intensively at highly unsustainable logging rates. Just before and during the election campaigns in 1993 and 1998 there was widespread corruption, collusion on illegal logging throughout the country (Global Witness 1996; 1997; 1998; 1999). Even though, forest concession was introduced in 1993 (WB et al. 1996), illegal logging and overexploitation were still observed taking place both concession and non-concession areas (Kim Phat et al. 2001).

Until recently, forest resources have increasingly come under pressure due to the rapid national economic development, population growth, uses of forest resources by local people, insufficient governance of forests and the highly increasing price of valuable timber species that lead to illegal logging. As seen in Fig. 1, Cambodia is a country that has a rich bio-diversity, including an array of diverse organisms and multiple benefits from forest resources that many poor people living in the countryside about 90% depend on for their livelihood; this makes forests more important resources for poverty reduction and economic development in Cambodia. Forestry Administration has played an important role for sustainable forest management in Cambodia but yet it is not adequately dealt.

The lacks of financial and technical supports are the big problem to address with deforestation in Cambodia as well as others developing countries.

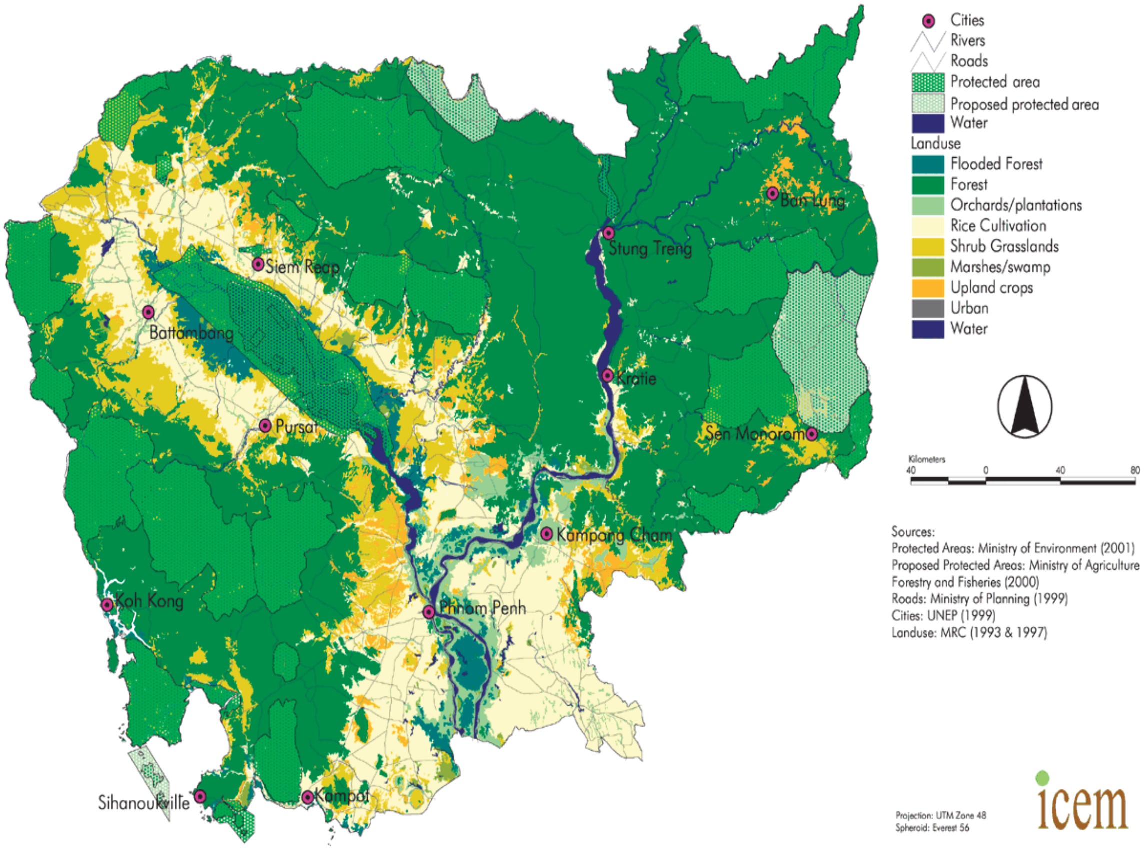


Fig. 1 Cambodian forest map

Source: Ministry of Agriculture, Forestry and Fisheries (2000)

Recently study suggested that annual deforestation rate was estimated at 0.7% between 1993 and 2003 (Sasaki 2006) and 0.8% between 2002 and 2010 (FA 2011). Deforestation has posed challenges for Cambodia for decades. Dealing with deforestation is not an easy assignment for the government due to the complexity of drivers of deforestation and forest degradation. The main drivers of deforestation and forest degradation are illegal logging, land conversion from agricultural encroachment, fuelwood consumption, lack of sustainable forest management capacity, and lack of financial incentives to conserve forests, as well as timber demand from other countries (Ty et al. 2011). Fuelwood consumption is considered one of the main drivers because the majority of Cambodian people still depend on fuelwood extracted from natural forest in the great extent. To reduce deforestation and ensure sustainable management of forests, Cambodia needs financial and technical help. Thus, REDD+ is a good mechanism for Cambodia to achieve sustainable forest management, improve livelihood of local people and halt deforestation while also delivering climate change mitigation benefits (Poffenberger 2009).

3.2 Study Site

As REDD+ projects are commonly implemented at the local level (project level) in developing countries where forests have been deforested and degraded, forests in Cambodia was selected as study case in order to develop carbon accounting system that could estimate carbon emission reductions for financial compensation. This compensation can be achievable, unless the estimation emission reductions, carbon credit can be quantified under REDD+ scheme, whereas carbon price need to be estimated for decision making on feasibility of project implementation. The study sites were in the foot of Phom Tbeng forest in Preah Vihear province in the northern part of Cambodia namely Phnom Tbeng forests (Fig. 3). Field surveys were conducted in three villages: Bak Kam (total population was 749 persons in 2010), Sethakech (775 persons), and Moha Phal (814 persons). These villages are located the Chhean Mukh commune, Tbeng

Meanchey distict, Preah Vihear Province (Fig. 2). These three villages are the closest villages to Phnom Tbeng forest and the villagers depend almost entirely on fuelwood collection for energy use. Therefore, they were selected as our study site. Owing to resource scarcity, poverty, and population growth, collection of forest and non-timber forest products is an almost daily activity for generating income. Fuelwood collection is particularly important for this community because fuelwood is the only source of cooking energy and burning for animal protection against insect. As the forest area declines, the future availability of fuelwood is uncertain unless better methods of using fuelwood are made available.

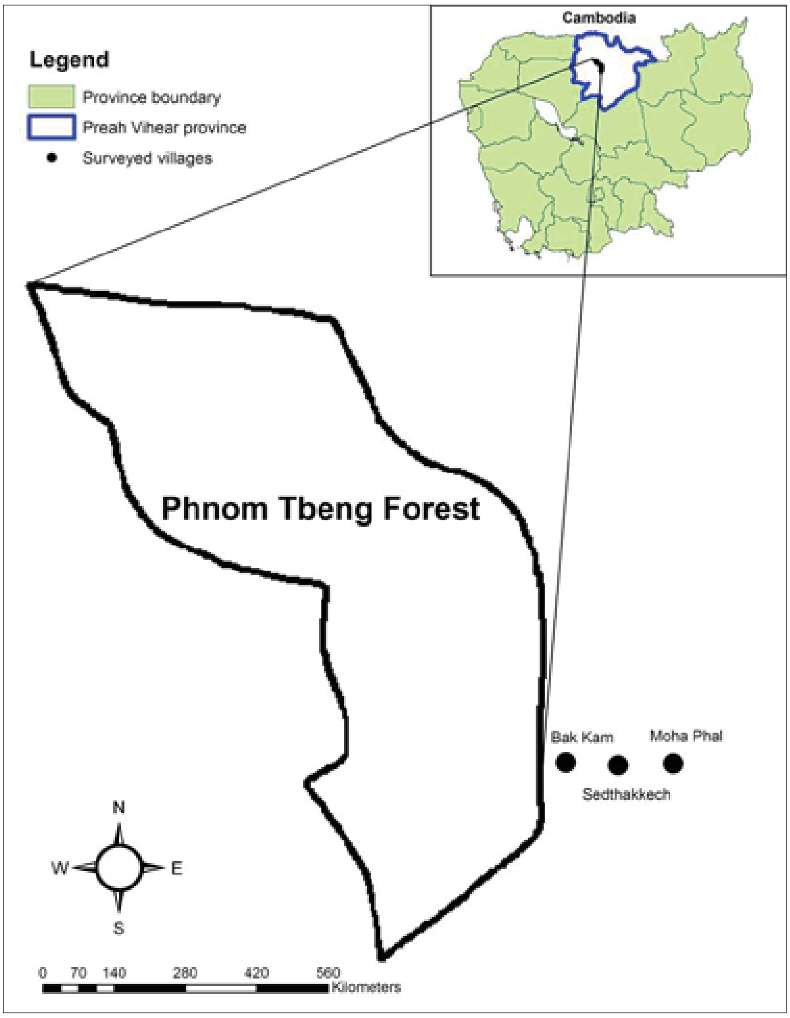


Fig. 2 Location of study site in Phnom Tbeng forest

Note: no fixed boundary for Phnom Tbeng forest was available at the time of writing this paper. It was considered as protected forest by forestry administration but there was no official decree from Cambodian government to recognize it as such.

Fig. 3 The footage's view of Phnom Tbeng forest

3.2.1 Socioeconomic Condition of Local People in Phnom Tbeng Forest Community

Understanding socio-economic values of forests in Cambodia are important for designing appropriate interventions which less harm to local communities' livelihood and contribute to reducing carbon emissions from deforestation and forest degradation in Cambodia. Socio-economic survey tools provide a means of improving understanding of local resource management systems, resource use and the relative importance of resources for households and villages. The study area is located in the poorest provinces in Cambodia namely Preah Vihear, experiencing a high rate of deforestation, and majority of the rural poor live on an income below US $3 day^{-1} (WB 2011). Up to 15% of the total provincial population has access to a power supply from an independent power producer (IPP), in comparison with only 4% in the study site. Almost all 9,700 households around Phnom Tbeng forest in Preah Vihear province are farmers who depend entirely on agriculture and forest resources for living. Population has increased about 6.3% annually from 2007 to 2010 (NCDD 2010). Education services are generally improved but data limitation suggests that percentage of children (age 6-11) attending school varied from one commune to another. School attendance rate ranges from less than 1% in Pong Ro commune to more than 50% in the rest of communes.

The main occupation of villagers in the entire village is farming followed by collection of forest and non-forest products. The highest educational level is in high school. No health center was found in the studied villages but there were few mobile doctors available for treating villagers in various locations. Rainfall is the only source of water for their farming because irrigation system is very poor in the villages. Water supply for household consumption comes from well. Some villagers can access to battery light as source of their electricity because electricity grid is still unavailable. Infrastructure has been gradually developed for most of the villages in terms of physical access to the village (Fig. 4), except in

Srei Sronos village where accessible road is not available. Accessibility to Srei Sronos village is possible only through paddy field. The houses in each of village are traditionally built close to each other. This practice is still adopted for security and social reasons of the villagers.

Fig. 4 Road access to villages in Phnom Tbeng forest community

Each household owns cropping land (from 2 to 5 ha) except in Srobal village where most of the families own less than 2 ha of land. None of families in the five villages own more than 5 ha of cropping land. Official land title for agricultural land in this area was not yet granted by the central government and this practice is still common in other parts of Cambodia. Farmers in the studied villages and in neighboring villages obtained their legitimate land tenure from the local authorities i.e. village chief and commune councils. Official tenure is not yet a concern of the villagers since villagers mutually recognize their respective lands and protect their lands from outsiders. It is also possible for villagers to sell their land to others with recognition by village or commune level. The most important agricultural product is rice with average annual yield of 1,000 kg/ha to 3,000 kg/ha, which are the range of average yield in Cambodia (1,980 kg/ha) but lower than that in other countries in region.

Cattles (cow and buffalo) are main source of agricultural labor in most villages although some households use plowing machines. In general, the majority of the villagers have livestock such as pig, chicken and duck are in addition to cow and buffalo. On average, a family has 2-3 pigs or 5-8 chickens or 8-10 ducks. In terms of cattle, each family owns about 2-3 animals and they are main force for plowing the paddy field, transporting rice and performing other labor-intensive tasks. Meat from the livestock products is used for household consumption as food and in some cases, for sale. Livestock production in Cambodia accounted for 4.6% of GDP in 2006 (NIS 2007) and was the second most important source of protein intake after fish in Cambodia.

3.2.2 Forest Types and Forest Cover Changes of Phnom Tbeng Forest

According to its draft boundary, Phnom Tbeng forests have 43,041 ha approximately. There are four types of forests, namely evergreen forests, semi-evergreen forests, deciduous forests and others forests where forest community solely depends on for timber and non-timber forest products. It administratively spans over 11 communes and 4 districts (Tbeng Meanchey, Kulean, Chey Saen, Sangkom Thmei) and one municipality of Preah Vihear province. This forest is located at 100 to 530 m elevation approximately and has plateau geography. Edges of the plateau are very steep slopes and the top of the plateau large flat land is extended. In the steep slopes of edges, semi-evergreen forests seem to be dominant, while in the flat land on the top of the plateau evergreen forests look dominant. Although forests remain along the steep slopes of the mountain ranges, accessible forests are being threatened by clearing for agricultural cultivation, logging, and fuelwood collection.

Phnom Tbeng forest have classified into four types of forest which are different characteristics as following:

Evergreen forests: Evergreen forests are usually multi-storied forests where trees maintain their leaves during the whole year. They comprise the low land tropical rain forests, the hill evergreen forests and the dry evergreen forest and along streams and rivers.

Mixed or Semi-evergreen forests: Semi-evergreen forests contain variable percentages of evergreen and deciduous trees, the percentage of evergreen trees varying from 30% to 70%. Semi-evergreen forests continue to appear evergreen throughout the year, even when the percentage of deciduous trees is high.

Deciduous forests: Deciduous forests comprise dry mixed deciduous forests and Dry Dipterocarp forests. Deciduous forests drop their leaves more or less completely during the dry season. Human impact such as fire is usually much higher compared to other forest types. Dry Dipterocarp forests naturally have an open character. As undisturbed deciduous forests may have crown cover of only

40%, soil and grass may have a significant impact on reflections from these forests. As a result, it is difficult to separate deciduous forests from shrub land during the dry season.

Other forests: Other forests have small proportion compare to the total forest area in this study site. These forests include regrowth forests, stunted forests, inundated forests, plantation forests and bamboo forests.

During feasibility study, forest covers were processed by remote sensing technology and GIS. Images from satellite in different time series have been used in this study for estimating changes in forest cover data were selected in dry season in each time. After the fieldwork in 2011 and corporation with FA's local authority of Cambodia, Japan Forest Technology Association (JAFTA), historical of forest change rate between 2004 and 2009 has been found. According to JAFTA's forestland cover analysis, total forest area in this study site was 41,530 ha in 2004 and decreased to 41,038 ha in 2009 with an overall annual decrease rate of 0.24% (JAFTA's unpublished data). More specifically evergreen forest decreased 2.71%, semi-evergreen forest 2.09%, other forests 1.53% while deciduous forest increased 5.58% annually between 2004 and 2009 (Table 2). Based on historical data of forest area change in 2004 and 2009 from JAFTA, Chan et al. 2013 estimated forest change for modeling timeframe between 2012 and 2014 (30 years). The result suggested that with business as usual evergreen forests, semi-evergreen forests and other forests will decrease by deforestation and forest degradation forest such as clearing for land sales, conversion to crop land, conversion to settlements, fuel-wood gathering, annual forest fires induced to "clean" the land, hunter inducing forest fires, illegal logging for commercial on-sale from 11,902 ha to 5,573 ha; 10,216 ha to 5,933 ha and 3,288 ha to 2,209 ha respectively. Anyway, deciduous forest has been increasing by natural regrowth from 12,302 ha to 13,379 ha for 30 years estimation. Chan et al. 2013 estimated that if there is no project action to reduce drivers of deforestation and forest degradation in this area, forest would decrease 10,614 ha in 30 years or 354 ha per year.

Table 2 Forest cover changes by forest types in Phnom Tbeng forests 2004-2009

Forest type	2004		2009		Change rate/year 2004-2009
	Area (ha)	Percent	Area (ha)	Percent	
Evergreen	14,784	34.3%	12,778	29.7%	-2.71%
Semi-evergreen	12,075	28.1%	10,816	25.1%	-2.09%
Deciduous	10,954	25.5%	14,013	32.6%	5.58%
Other forest	3,716	8.6%	3,431	8.0%	-1.53%
Total forest	41,529	96.5%	41,038	95.3%	-0.24%
None forest	1,512	3.5%	2,003	4.7%	6.51%
Total Area	43,041	100.0%	43,041	100.0%	-

3.3. Survey Design and Data Collection on Fuelwood Consumption

Data and information of this survey design in order to understand the efficiency of fuelwood use, sources and quantity of fuelwood for household consumption, socio-economic information, energy use pattern and problems incurred from using biomass in the traditional cooking stove. The primary data on wood consumption is recorded in daily basis; then it was converted to annual consumption. Fuelwood consumption data will be used to estimate carbon emissions and related equations. There were few studies have surveyed on fuelwood consumption such as Geres (2007) and San et al. 2012 in Phnom Penh and Kompong Chhnang province respectively. Their studies were taken for comparison in Chapter 4 Results and Discussions.

Prior to fieldwork, meetings with local forest rangers were organized to discuss the questionnaire surveys and the expected outcomes. Accompanied by forest rangers, the research team visited various locations in the Phnom Tbeng forest to observe the daily activities of local households. Revised questionnaires were then discussed with experts from Royal Phnom Penh University and foresters of the Forestry Administration (a governmental institution) to finalize the questionnaires and locations for data collection. The questionnaires were translated into Khmer, a Cambodian language used by households in the study site. The questionnaires had three broad headings: background information of respondents, socioeconomic data (forest dependency), and household energy consumption (fuelwood use, types of cookstove, and cooking patterns). The questionnaires contained a mixture of open-ended and confined questions that were administered in face-to-face interviews. In terms of fuelwood use, all respondents were asked about their purposes of using fuelwood, types and number of cooking per day, and the weight of fuelwood use for each cooking. Since respondents were not able to estimate the weight of fuelwood use, we brought and used our scales to weight fuelwood during interview so as to minimize bias. To obtain reliable answers from the households, local foresters were not allowed to accompany the research team during the interviews. The interviews were conducted intentionally just before midday because this is the time when villagers are cooking. With this timing, the research team could observe the actual practice of using fuelwood for cooking energy and the types of cookstoves being used (Fig. 5).

Fig. 5 Cooking stove and fuelwood observation

Fig. 6 Household survey on fuelwood consumption

Villagers interviewed were heads of household responsible for cooking and even for fuelwood collection, with the aim of minimizing bias in the collected data. The household census was used as sampling frame and the respondents were chosen through a systematic random sampling method. A total of 105 randomly selected households (representing 517 family members) were interviewed in a week time from 4 to 10 April 2014. Because of the time and resource availability, members of the research group were divided into two teams; each team consists of one interviewer and one recorder (Fig. 6). To reduce disturbing households during their busy cooking time, we tried to minimize the duration of the interviews. Average time for interview of one household was approximately 20 minutes. Carbon emission factors, efficiency of cookstoves, population, and other data were based on secondary sources including the Forestry Administration of Cambodia, Groupe Energies Renouvelables, Environnement et Solidarités (Geres), Royal Phnom Penh University, National Committee for Sub-National Democratic Development, Forest Trends' Ecosystem Marketplace and Bloomberg New Energy Finance.

3.4. Cooking Stoves and Energy Efficiency

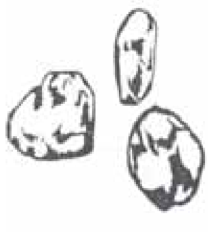
On the basis of our surveys, the majority of the population in the study site used three-stone stoves (TSS) for cooking, boiling water, and burning wood to generate smoke to protect their cattle against insects (Fig. 7). There are some reasons behind the use of three stone stoves. Villagers are poor and cannot afford new, energy-efficient stoves even though those stoves can save up to 60 percent on fuel. The other reason is three stone stove is easy make by combining three stones or bricks which can be collected in village and around their house, whereas the stove can be resized as the villager prefer. Previous studies have found that three-stone stoves consume more fuelwood than other cookstoves (Batchelor 1997; Kituyi et al. 2001; Turker and Kaygusuz 2001; WB 2009). Two types of cookstoves are more efficient with respect to fuelwood consumption for producing needed energy. They are the Traditional Lao Stove (TLS) and the New Lao Stove (NLS) (Table 3). Geres (2007) and World Bank (2009) reported that both Lao cookstoves have net savings of 43.1% and 64.0% of wood consumption, respectively, compared with the three-stone stove (TSS) (Table 3). Traditional Lao Stove (TLS) and the New Lao Stove (NLS) are made of baked clay and covered by mnetal, the different is the weight of New Lao Stove (NLS) (12 Kg) higher than Traditional Lao Stove (TLS) (3-8 Kg). The New Lao Stove (NLS) is more efficient than the Traditional Lao Stove (TLS) because of the following advantages;

- The low pot rests to prevent heat loss characterize the NLS. In addition, the pot rests are slanted at an incline to accommodate many sizes of pots.
- The NLS grating has 37 air holes, which are good for air circulation and induce more efficient fuel-burn. The grate thickness has also been improved for more durability.
- The NLS has an improved combustion chamber, which is higher than traditional cookstove and consumes less fuel wood.
- The NLS has improved insulation and a refractory liner to prevent heat loss.
- The NLS has a metal sheet body cover for durability.

The price of New Lao Stove (NLS) is little expensive (US $3.5–5), while Traditional Lao Stove (TLS) is only US $1.5. Assessments of carbon emissions from the use of fuelwood for cooking energy were performed for TSS, TLS, and NLS. The study will substitute three-stone stoves with the improved cooking stoves.

Fig. 7 Traditional use of three stone stoves by villagers in the study site

Table 3 Characteristics, efficiency and cost of individual cookstoves

Type of Stove	 Three-stone stove (TSS)	 Traditional Lao stove (TLS)	 New Lao stove (NLS)
Materials	Stones	Metal covered, baked clay	Metal covered, baked clay
Weight (Kg)	Varies	3–8	12

Height (cm)	Varies	Multi	30
Width (cm)	Varies	Multi	25.4
Length (cm)	Varies	Multi	25.4
Efficiency (%)	10	24	29
Energy saving (%)	No	43.1 Used in equation (6)	64.0 Used in equation (6)
Cost	Free	US $1.5	US $3.5–5

Source: http://www.cfsp.org.kh/ics_design.html

Furthermore, the study found that another source of fuelwood consumption is burning wood to protect animals from insects at night, an activity for which emissions cannot be reduced by ICS (Fig. 8). Regardless to where cattle are kept at night (with or without barn), villagers commonly burn tree stumps and tree trunk close to their cattle in order to generate smoke to prevent insects, particularly mosquito from biting. Since using stove for this activity is not possible, preventing the burning of fuelwood for protecting could be possible through cattle mosquito netting method (Fig. 9). There are various sizes of mosquito nets and the average price of one mosquito net is US$5 with 2 years effective lifetime (Erlanger et al. 2004). Given that TSS is the common daily practice in the study site, we considered TSS plus burning fuelwood for protecting cattle from insects (i.e. mosquitos) as baseline practice (activities in the absence of financial incentives). Under project scenario 1, TSS will be substituted by TLS and cattle mosquito nets are used to replace burning fuelwood against insects. Under project scenario 2, TSS will be substituted by

NLS and the use of cattle mosquito nets to replace burning fuelwood against insects. However, Ty et al. (2011) have introduced a method for protecting animals with mosquito net instead of burning fuelwood but no specific assessment have been conducted. To estimate project emissions from using mosquito net, Relative Impact Project (RPI) data of Ty el al. (2011) were used. These emissions will also be included in the whole assessment.

Fig. 8 Fuelwood burning to protect animal

Source: http://sylvanvideo.com/SylvanVideo1/Poverty_project_Chapter_8.html

Fig. 9 The use of mosquito net to protect animal

Source: http://sylvanvideo.com/SylvanVideo1/Poverty_project_Chapter_8.html

3.5. Estimation of Carbon Credits and Carbon Price

Two important element need to be estimated in order to calculate carbon credit and carbon price. The first one is baseline emissions and second is project emissions. Given that TSS is the common daily practice in the study site, we considered TSS plus burning fuelwood for protecting cattle from insects (i.e. mosquitos) as baseline practice (activities in the absence of financial incentives). This study provided two project scenarios for comparison. Under project scenario 1, TSS will be substituted by TLS and cattle mosquito nets are used to replace burning fuelwood against insects. Under project scenario 2, TSS will be substituted by NLS and the use of cattle mosquito nets to replace burning fuelwood against insects.

Carbon Credits (CC)

$$CC(t) = \left[CE_{Baseline}(t) - CE_{Project}(t)\right] \times [(1 - \text{Leakages})] \quad (1)$$

where,

- $CC(t)$ represents carbon credits ($MgCO_2$) obtained through project implementation.
- t indexes time steps.
- Leakages are carbon emissions outside project boundary being 15% (0.15) of emission reductions (Geres 2007). To analyze sensibility of emission reductions and leakages, another two rates of leakages were also analyzed: 5%, 20%. Leakages can be up to 40%, but it is too risky and the project would be unrealistic.
- $CE_{baseline}(t)$ represents carbon emissions under baseline ($MgCO_2$)
- $CE_{project}(t)$ represents carbon emissions under project ($MgCO_2$).

$CE_{baseline}$ (t) is derived as:

$$CE_{Baseline}(t) = CE\_CB(t) + CE\_AI(t) \quad (2)$$

where,

- CE_CB(t) represents carbon emissions from cooking and boiling for daily needs ($MgCO_2$).

- CE_AI(t) represents carbon emissions from burning wood for protection against insects ($MgCO_2$).

CE_CB(t) and CE_AI(t) are derived as:

$$CE\_CB(t) = CB \times HH(t) \times 0.5 \times 44/12 \quad (3)$$

$$CE_{AI(t)} = AI \times [HH(t) \times (1 - HH_{no\_cattle})] \times 0.5 \times 44/12 \quad (4)$$

where,

- CB is average fuelwood consumption for cooking and boiling per household per year (Mg yr^{-1}).
- AI is average fuelwood consumption for burning against insects per household per year (Mg yr^{-1}) taken as average of fuelwood consumption from 105 surveyed households.
- HH(t) represents the number of households at time *t*.
- HH_{no_cattle} represents household without cattle 10% (0.1) (NCDD 2010).
- 0.5 represents carbon content (conversion rate from wood to carbon).
- 44/12 is the ratio of the molecular weight of CO_2 to that of carbon.

HH(t) is derived as:

$$HH(t) = HH(0) \times e^{a \times t} \quad (5)$$

where,

- HH(0) represents the number of households in the Phnom Tbeng forest area at time t = 0.
- *a* is population growth rate with 6.3% (NCDD 2010).

- t is time step (year).

$CE_{project}(t)$ is derived as:

$$CE_{Project}(t) = [CE\_CB(t) \times (1 - NS)] + [CE\_AI(t) \times RPI(t)] \quad (6)$$

where,

- NS is net savings from ICS, 43.1% (0.431) (calculated from Geres data) by shifting from TSS to TLS (project 1), 64.0% (0.64) by shifting from TSS to NLS (project 2) (Geres 2007). 43.1% derived by 64.0% – 20.9% (20.9% is net saving from TLS to NLS) (Table 3).
- RPI(t) is relative project impact taken from Ty et al (2011). RPI(t) is derived from introducing mosquito nets rather than burning fuelwood to protect animals against insects.

Carbon price (CP)

Carbon price is the cost of project implementation per ton of CO_2. Carbon price in this study will be used to compare to carbon price in the real market to see whether project is feasible or not. If the price of carbon in actual market is lower than the projecting cost, it means this project is financially lost. On another way around, if price of carbon in actual market is higher than the projecting cost, it means this project is financially gained. Or if both carbon price are equal, there is neither profit nor loses.

$$CP = PV\_TC / \sum CC\,(t) \quad (7)$$

where,

- CP is carbon price at break-even point (US \$ $MgCO_2^{-1}$) where there is neither profit nor loses.
- PV_TC is present value of total costs between 2015 and 2024 (US \$).

PV_TC is derived as

$$PV\_TC = \sum[TC(t) \times (1 + r)^{-t}] \qquad (8)$$

where,

- TC(t) denotes total costs including Salary (rice), ICS costs, mosquito nets costs and transaction costs at time *t*. 30 kg of rice was given to household as monthly salary for their patrol works protect the forests. The reason that money is not given because there is concern over inappropriate use of money for other purposes that do not benefit their family. 30 kg of rice is provided every month as salary (1 kg of rice is valued at 1700 riels; World Food Program 2014), this 30 kg of rice is valued at US \$12.75 $month^{-1}$ or US \$153 yr^{-1} (US \$1 = 4,000 riels), equivalent to 12% of Cambodian GDP per capita (US \$1,108) (IMF 2014). It will be sufficient to feed two members per family. This is supported by the recent report published by the Ministry of Agriculture, Forestry and Fisheries of Cambodia, which reports that average rice consumption per capita is 13 kg $month^{-1}$. $Rice_{costs}(t)$ = 30 kg × 1700 riels × 12 × HH(t).ICS_{costs} refers to costs of giving one ICS to a household every two years. One ICS unit costs US \$1.5 under project 1 and US \$4 under project 2, ICS(t) = US \$1.5 × HH(t) (project 1); ICS(t) = US \$4 × HH(t) (project 2 Average cost of a mosquito net is US \$5 with 2 years lifetime (Erlanger et al. 2004), thus Mosquito net Cost(t) = US\$ 5 × HH(t) × [1- HH_{no_cattle}]. On the basis of the Geres ICS project, the total transaction cost is US \$1.37 million with carbon emission reduction of approximately 2.4 million $MgCO_2$, equivalent to US \$1.75 $MgCO_2^{-1}$; thus, $Transaction_{costs}(t)$ = US \$1.75 × CC(t). Camille and Jayant (2007) reported similar figures for transaction cost, ranging from US \$0.22 to \$2.48 $MgCO_2^{-1}$ under an energy efficiency project. In other reviews, transaction costs for a small-scale CDM project comprise registration fee (maximum US \$350,000) (MOE 2010), search and negotiation costs between US \$22,000 and US \$160,000, approval costs between US \$12,000 and US \$120,000, and monitoring costs between US \$5,000 and US \$270,000 (Michelowa et al. 2003; de Gouvello and Coto 2003; Krey 2004; EcoSecurities 2003).

- *r* denotes discount rate, with 5%, 10% and 15% assumed for financial comparison. The discount rates of 5-15% were used in our study with reference to the rates of economic growth in Cambodia over the last 10 years. The rates were between 6-13% except in 2009 when Cambodia effected by global economic crisis (WB 2015).

Chapter 4

Results and Discussions

4.1 General Information of Household

Approximately 95% of respondents were father and mother, who were in charge of fuelwood collection for daily cooking and warmth. The household samples were categorized into three different family sizes; small (1–4 persons), medium (5–7 persons), and large (>8 persons). Numbers of families are 44 (42%), 55 (52%), and 6 (6%) with average age 25, 28, and 30 respectively for small, medium, and large families (Table 4). Respondents reported that cropping was the most important source of livelihood, followed by forest and non-timber forest products, livestock, labor, and fishing. Our surveys suggested that forest and non-timber forest products were fuelwood for daily energy needs, timber for construction, resin tapping from large trees (Dipterocarps), rubber, wild meat, fruits and vegetables, rattan, and medicinal plants. Among 105 respondents, 30% of them owned 2-5 cattle per family. Cattle (cows and buffalo) are raised mainly for farm plowing to prepare soil for cropping, harvesting, and exporting crop products. Cattle provided important labor for daily household activities. Most medium and large families owned cropping land, 2–5 ha per family, whereas small families owned <2 ha of land. Land tenure was recognized by the village chief and commune councils. Recognition of land tenure by the central government is not a concern of villagers because the land they own at present is socially accepted by villagers and neighboring villages (Chan and Sasaki 2014).

Table 4 Household information in the study site

Family size	Number of families (households)	Males (persons)	Females (persons)	Average (persons)	Average age (years)
Small (1–4 people)	44 (42%)	12	32	3.5	37.2
Medium (5–7 people)	55 (52%)	17	38	5.7	41.3
Large (>8 people)	6 (6%)	4	2	8.7	47.3
Total	105 (100%)	33	72	4.9	39.9

4.1.1 Household Asset

In forest dependent community, villagers usually construct their houses using wood extract from forest. This common practice also results in deforestation and forest degradation. As seen in Fig. 10 of the survey, almost 100% of the house was made of wood. Overexploitation of forests for housing is likely to occur for many years since the demand of wood locally have dramatically increased by population growth and the shortage of wood supply from neighboring countries. About 90% of house's walls are made of wood followed by thatch (5%) and bamboo (5%). About three fourth of the respondents live in the house with zinc roof, another 19% with thatch roof and the rest 5% are roof made of fibro (Table 5). This information indicated that forest is an important source of materials for housing.

Table 5 Household materials

Wall			Roof		
Wood	Bamboo	Thatch	Zinc	Thatch/Leaves	Fibro
90%	5%	5%	76%	19%	5%

Fig. 10 House's structure of villager in Phnom Tbeng forest community

4.1.2 Sources of Livelihoods

Livelihood of communities is closely related to forest resources. Forest products are daily collected by communities for subsistence and generating income. Since villagers are poor and cannot effort energy such as LPG or electricity, fuelwood collection is the only option for living such as cooking and warming. The constant fuelwood extraction from forest has resulted in forest degradation. The study suggested that beside from forest product, their livelihood sources forest depend on laboring, cropping, livestock and fishing. We assessed these sources of livelihood with the following quote: very important, important, little important, not important and don't know. Since community is not homogenous, family has different sources of livelihoods, some of which are important while others are not so important. As seen in Fig. 11, forest products were viewed as very important or important by about 85% of respondents since forest products have been extracted for subsistence and cash income, followed by laboring at about 80% of respondents because they also relied on works from agricultural sector and logging services. Forest products were extracted include firewood, timber for construction, resin tapping, rubber, wild meat, fruits/vegetables, rattan, medical plants. These forest products are not only use in household, but they have been sold in local market to generate income. This also illustrates that forests play a very crucial part to livelihoods of this people since they provide employment opportunities and forest products. Almost one third of the respondents, livestock are very important for them as they help farming work, provide food and some cases for sale. In general, the four sources (cropping, livestock, forest products, and laboring) of livelihoods listed in the questions are important for most of the respondents (80%). Fishing is not viewed as important for livelihoods due to a couple of reasons. The first reason is the natural endowment of this region is not potential for fishing. Secondly, other sources, timber or laboring are more attractive and accessible to villagers.

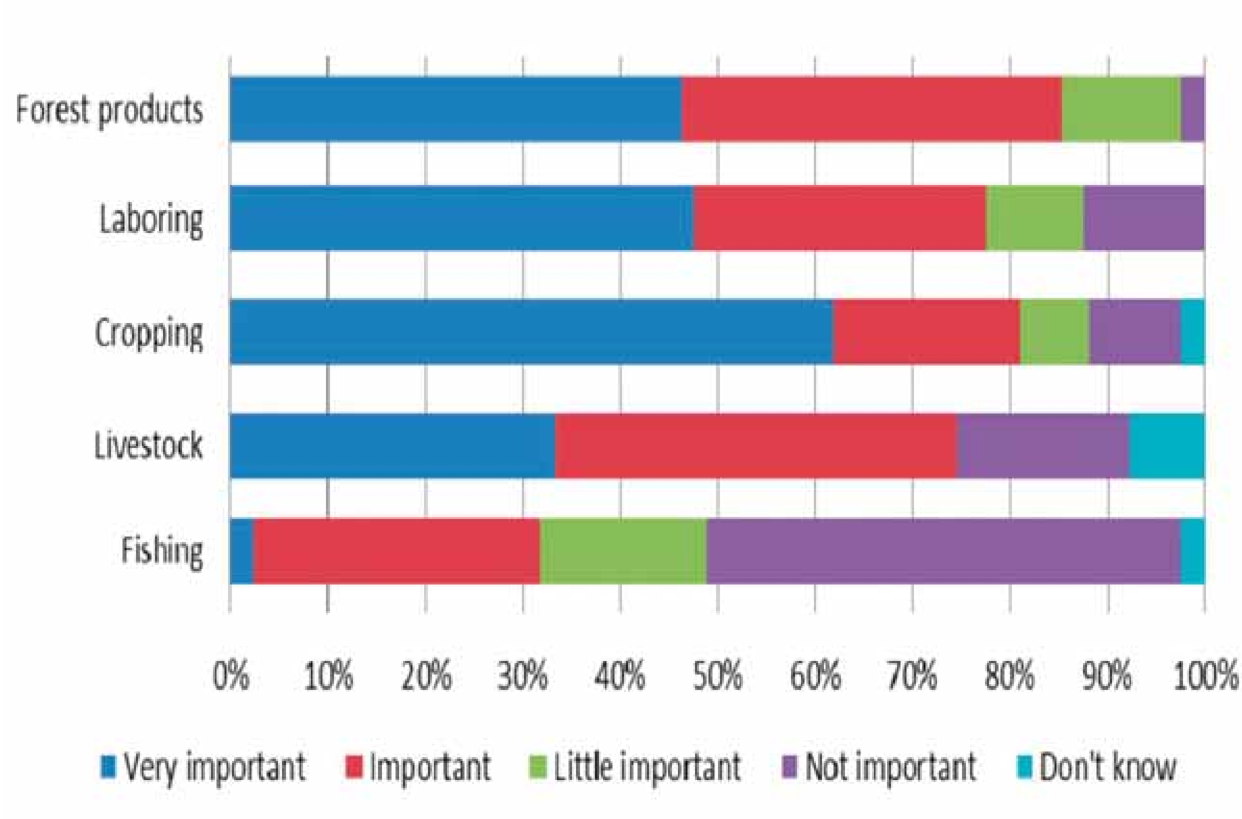


Fig. 11 Main livelihood sources of villagers

4.1.3 Contribution of Forest Products to Household Livelihoods

Generally forest products can provide both subsistence and cash income to households. Our surveys suggested that forest and non-forest products were extracted include firewood, timber for construction, resin tapping, rubber, wild meat, fruits/vegetables, rattan, medical plants and fishing ground. The Fig. 12 showed the variety of forest and non-forest products and their perceived importance to local people. The first important product from the forest was firewood (77% of respondents), timber for construction (20% of the respondents) and medical plants (3% of respondents). The products come to second, third and fourth important are rubber, rattan, resin tapping, fruits/vegetables, fishing ground and wild meat (Fig. 12). A study in Bangladesh revealed that contribution of forest to household livelihood is timber, firewood and wild NTFPs (bamboo, wild vegetables, sun grass, broom grass, game meat, bamboo shoots, medical plants and wild fruits). Most three important wild NTFPs for sale are bamboo, wild vegetables and broom grass with mean annual income from NTFPs was US$69.01 (Kar and Jacobson 2012) while NTFPs for sale in Cambodia are resins, honey and beeswax (US$78.9) (Kim 2008). Potential source of income in Cambodia derives from NTFPs are higher than in Bangladesh because villagers in Bangladesh depend more on daily wage labor (usually temporary or seasonal), and they collect NTFPs only when they don't have any wage labor in agriculture or another employment. Although this value is small but it represents amount of villagers' extra money. Moreover, most of the respondents also stated that forest doesn't only mean to livelihood but their social and cultural identity as well. Several studies were reported that poor households in tropic depend solely on forest resources (Arnold and Ruiz 2001; de Beer and McDermott 1996; Belcher and Schreckenberg 2007; Fu et al. 2009; Pimentel et al. 1997), which mean that if forests are still being deforested or degraded, it will put livelihood of local people at risk since a proportion of income and subsistence is related to forest-based activities.

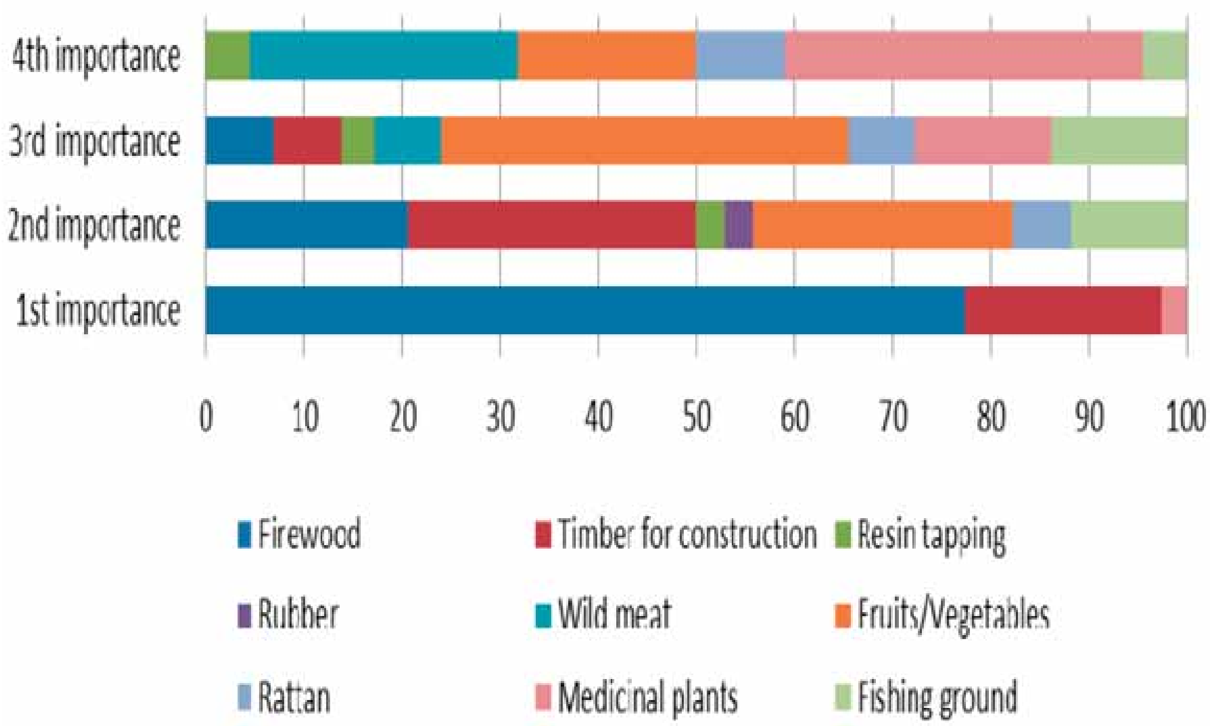


Fig.12 Important of different forest products to household livelihood

4.1.4 Identification of Drivers of Deforestation and Forest Degradation

The survey reveals that more than haft of the respondents (57%) used to cleared forest and some cases were taken place in recent year in average the size 1.2 ha per villagers. As trust between research team and respondents are limited because this is a sensitive question related to illegal logging. Therefore the cases of clearing forest may even be higher than this figure. As seen in Figure 13 the main cause of deforestation given by majority of the respondents is illegal logging (almost 70%) because of rapid increase in market demand of commercial timber, timber for house construction and firewood. Due to the inefficient of agriculture productivity, limited access to technology and seeking potential of agro-industrial, people need more land to cultivate their agriculture by clearing more forests for slush and burn cultivation and large plantation. In addition, the increasing in number of migrants and land speculation, forests are felled down to claim land for settlement and then would be later possible to be sold. There is not a serious problem to forest cause by forest fire as only 10% of the respondents mentioned fore fire to be second cause (Fig. 13). This also confirms from data in village key informant as forest fire is rarely occur in the Phnom Tbeng area. Logging for commercial purposes is compounded by local demands for house construction and fuelwood consumption is severely threat the Phnom Tbeng forest. There is no rule of management system established to regulate the use and access to forest of villagers in each of the visited villages. Phnom Tbeng forest is seen as common resources where everyone can access to and freely benefit from it. This situation of an open access encourages competition amongst different users rather than cooperation and lead to destruction practices.

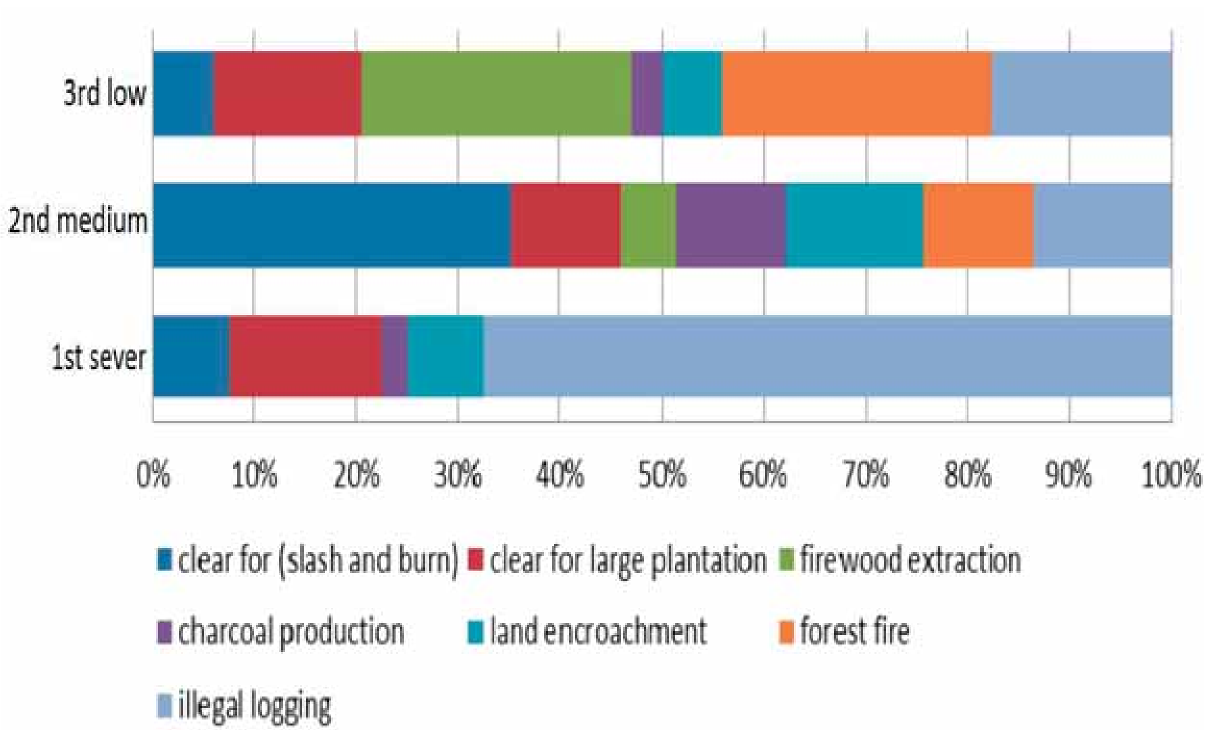


Fig.13 Drivers of deforestation and forest degradation in study site

Based on data analysis, drivers of deforestation and forest degradation are classified into illegal logging/timber extraction, forest clearing for large plantation, forest clearing for slush & burn, land encroachment, charcoal production, firewood extraction, and forest fire. The underlying causes for these drivers include limited livelihood options, weak implementation of the law, political instability and poor forestry governance. The findings in this study were similar to that found by Ty et al. 2011 where 10 drivers of deforestation were identified namely forest clearing for sales , conversion to cropland, conversion to settlements, fuel-wood gathering, forest fired induced to clean land, hunting inducing forest fires, illegal logging for commercial on sale, timber harvesting for local use, large economic land concessions and timber concession with a very small proportion. Not different to Cambodia, Lao has been facing similar activities that result in deforestation and forest degradation. Colin et al. (2011) identified 9 source activities as being responsible for deforestation and forest degradation: fire (human and natural induced), timber extraction (commercial/illegal logging and household consumption), pioneering shifting cultivation, agricultural expansion, forestry plantation, mining/hydropower/ infrastructure development and urban expansion.

4.2. Household Fuelwood Consumption and Fuelwood Collection

This study found that fuelwood extraction for household energy consumption was one of the major causes of deforestation and forest degradation in Phnom Tbeng forest along with illegal logging, clearing forest for slash-and-burn cultivation, clearing for large plantations, charcoal production, land encroachment, and forest fires in Phnom Tbeng forest. Among the 105 households interviewed, 98% used firewood to cook, boil water, prepare animal food, and burning wood to protect their cattle from insects such as mosquitoes. The remaining 2% used both charcoal and fuelwood. Respondents reported that 5 plant species are the most preferred for fuelwood collection namely Pchoek (*Shorea obtusa*), Trosek (*Peltophorum ferrugineum*), Tbeng (*Dipterocarpus obtusifolius*), Khlong (*Dipterocarpus tuberculatus*) and Sokram (*Xylia xylocarpa*). Respondents reported that old people are only able collect small wood or the branch (Fig. 14). While young people, they go for big three and then chop it into small pieces (Fig. 15 & 16). In some case, the big trees are used to make charcoal. There are similarities of drivers in Lao and Cambodia where fuelwood collection is considered as one of the main drivers of deforestation and forest degradation along with fire (human and natural induced), commercial/illegal logging, pioneering shifting cultivation, agricultural expansion, forestry plantation, mining/hydropower/ infrastructure development and urban expansion (Colin et al. 2011). FAO (2009) also suggested that in Sub-Saharan Africa fuelwood consumption will increase 34% from 2000–2020 due to the population growth and over reliant on biomass.

Fig.14 Small fuelwood collected and stored under villagers' house

Fig.15 Big trees have been cut into pieces easy for transportation

Fig.16 Wood has been chopped into small pieces as fuelwood

4.2.1 Fuelwood Consumption for Cooking and Boiling

The present study showed that the average household's fuelwood consumption for cooking was 3.23 ± 0.30 (± refers to 90% of confidence level), 3.73 ± 0.23, and 4.83 ± 0.50 kg day^{-1} $household^{-1}$ for small, medium, and large families, respectively. Boiling water consumption on average was 1.73 ± 0.60, 2.21 ± 0.15, and 2.66 ± 0.54 kg day^{-1} $household^{-1}$ for small, medium, and large families, respectively. As seen in Fig. 17, overall average fuelwood consumption for cooking and boiling water was 5.62 ± 0.27 kg day^{-1} $household^{-1}$ or CB = 2.05 ± 0.1 Mg yr^{-1} $household^{-1}$ (used in equation 3). Findings in this study were similar to that found by San et al (2012), average fuelwood consumption for cooking and boiling water per family per day is 5.21 ± 0.11 kg and 2.82 ± 0.11 kg respectively.

Another finding from Geres (2007) reported that household monthly fuelwood consumption was 37.64 kg or 0.44 Mg yr^{-1} in Phnom Penh. The figures in our study are higher. There are many possible reasons. One reason could be that Geres surveyed an area where villagers had already changed to Traditional Cookstoves and the water was clean, whereas in Preah Vihear province there is not enough safe water to drink or proper water storage, and water must be taken from lakes or wells and boiled. Family size is also another factor increasing fuelwood consumption. As seen in above statement, fuelwood consumption increases with family size. This relationship is consistent with the results of Miah et al. (2009) who found that family size influences the amount of fuelwood consumption per family.

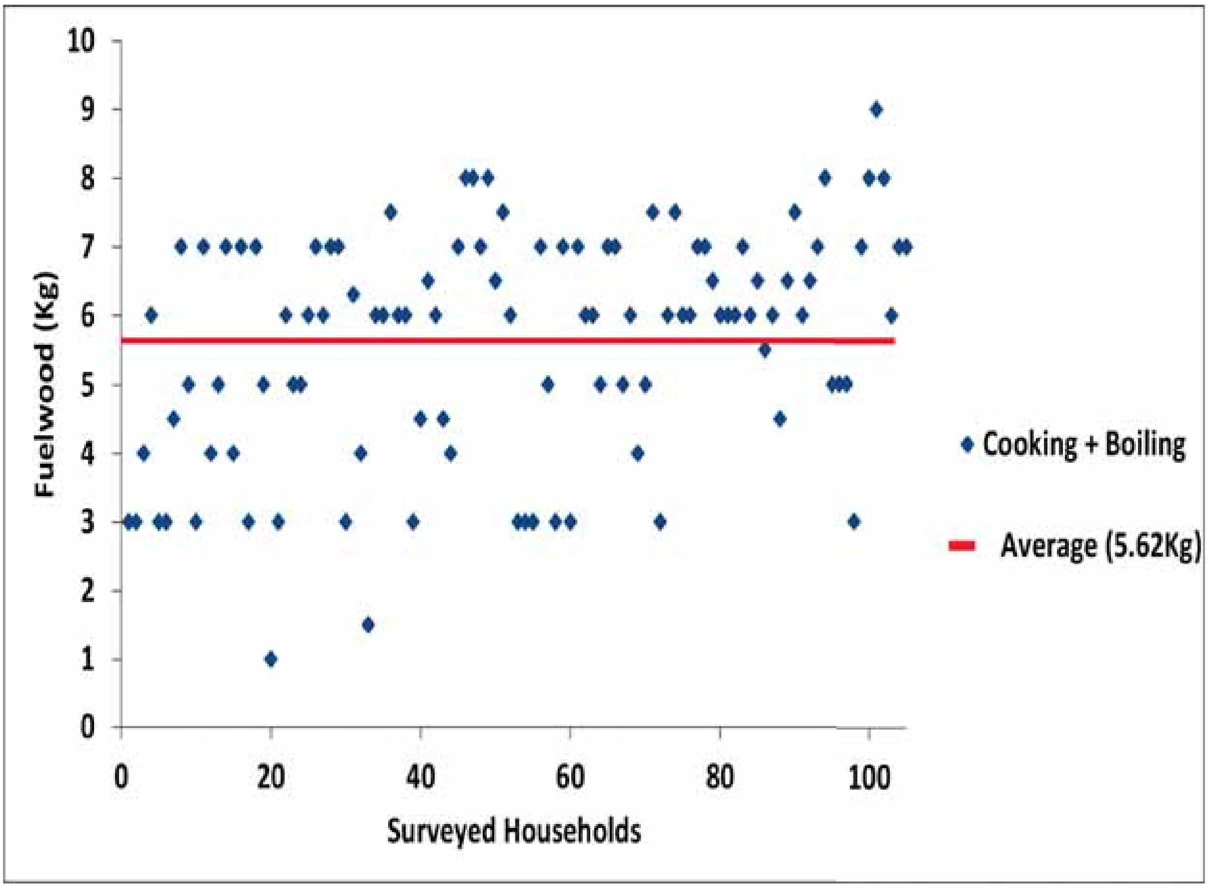


Fig. 17 Average fuelwood consumption of household for cooking and boiling per day

4.2.2 Fuelwood Consumption Against Insect

Livestock and cattle play an important role in livelihoods of villagers in Phnom Tbeng forest. The study found that villagers usually protect their animals by burning fuelwood to produce smoke for protection against insects at night, particularly during the rainy season. Households reported that they prefer to collect tree stumps rather than tree stems in the forest because stumps produce more smoke to protect their animals from insects. As the result of several hours of burning fuelwood, the average amount of fuelwood consumption is 11.77 ± 0.89 kg day^{-1} $household^{-1}$ or $AI = 4.29 \pm 0.18$ Mg yr^{-1} $household^{-1}$ (used in equation 4) for those who raise cattle (Fig. 18). This figure is double that for fuelwood consumption from cooking and boiling water. Thus, as fuelwood becomes increasingly scarce, an alternative method for reducing these emissions is immediately needed. Although emissions from burning fuelwood for protection against insects cannot be reduced by ICS because cookstoves are not required for these activities, Ty et al. (2011) introduced a new method of protecting cattle against insects with mosquito netting instead of burning fuelwood. This method could be introduced to our study areas as well, but training for the appropriate use of the method is important because villagers tend not to adopt the new method readily. Some local people stated that they prefer a combination of fuelwood and rice straw or rice husks that produces more smoke without cost. Although smoke can prevent insects from their animals, it can also cause health problems for villagers (Jin et al. 2006). Zhang et al. (2005) reported that excessive consumption of biomass energy has resulted in degradation of forest and grass vegetation, accelerated soil erosion, and changed ecosystem substance cycles. Burning of fuelwood and charcoal has caused massive CO_2 emissions, resulting in atmospheric pollution. Efficiency of end-used devices is useful information for policy makers and NGOs to pay attention on Fuelwood efficiency in rural area in order to help the poor.

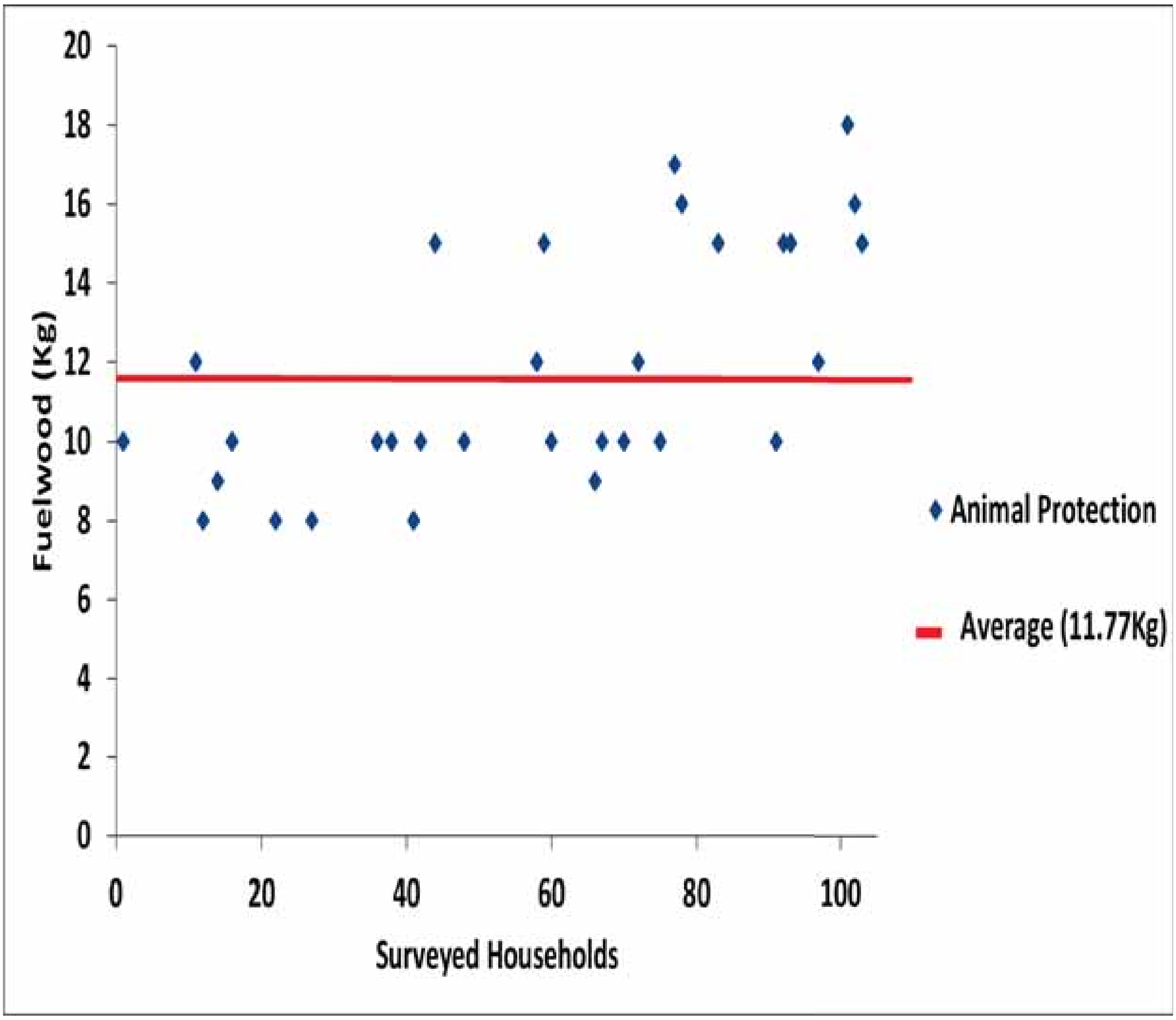


Fig. 18 Average fuelwood consumption of household against insect per day

4.3 Carbon Emissions, Emission Reductions and Carbon Credits

4.3.1 Carbon Emissions from Cooking/Boiling and Against Insect (Baseline Emissions)

Baseline emissions are the emissions under business as usual when there are no intervention actions. Therefore, villagers are still using traditional method for cooking and protecting their animal from insect. Our projection suggests that during the 10-year modeling period between 2015 and 2024 under baseline scenario, households in the study site increased from 13,261 families in 2015 to 23,379 in 2024 based on the annual population growth rate of 6.3% in 2010 (NCDD 2010) (Table 6). Chan et al. (2013) reported that without project activities to protect Phnom Tbeng forest, this forest is likely to decline 0.24% annually, suggesting that fuelwood increase due to forest growth is not sufficient to supply wood to local demand. Using the average fuelwood consumption from above section (CB = 2.05 ± 0.10 Mg $household^{-1}$ yr^{-1} and AI = 4.29 ± 0.18 Mg $household^{-1}$ yr^{-1}), thus baseline emissions in the full project area can be estimated. As seen in Table 6, carbon emissions from cooking and boiling water (CE_CB) increase from 49,872 $MgCO_2$ in 2015 to 87,923 $MgCO_2$ in 2024, whereas emissions from burning fuelwood for protection against insects (CE_AI) increase from 94,003 to 165,724 $MgCO_2$. In total, carbon emissions from cooking, boiling, and burning fuelwood for protection against insects were estimated at 673,082 $MgCO_2$ and 1,409,640 $MgCO_2$ respectively for the 10-year modeling period. Consequently, total carbon emissions under the baseline scenario or in the absence of project activities (emissions from cooking/boiling + against insect) were estimated at 1,941,759 $MgCO_2$ over a 10-year period or 194,176 $MgCO_2$ yr^{-1} (Table 6).

Table 6 Household growths, carbon emissions from cooking & boiling, against insect and baseline emissions

Year	Households	Cooking & Boiling CE_CB ($MgCO_2$)	Against Insect CE_AI ($MgCO_2$)	Baseline Emissions $CE_{baseline}$ ($MgCO_2$)
2015	13,261	49,872	94,003	143,875
2016	14,124	53,115	100,116	153,231
2017	15,042	56,569	106,626	163,195
2018	16,020	60,248	113,559	173,807
2019	17,062	64,165	120,944	185,109
2020	18,172	68,338	128,808	197,146
2021	19,353	72,782	137,184	209,966
2022	20,612	77,514	146,105	223,620
2023	21,952	82,555	155,606	238,161
2024	23,379	87,923	165,724	253,648
Total		673,082	1,268,676	1,941,759
Annual		67,308	126,868	194,176

4.3.2 Carbon Emission Reductions and Carbon Credits from using TSL and Mosquito Nets (Project 1)

To estimate emission reductions, two project scenarios have been introduced. Under project scenario 1, TSS has switched to TLS with 43.11% of fuelwood saved. Second, project scenario 2 affords 64% of fuelwood saving by switching from TSS to NLS. Under both scenarios, introduction of mosquito nets to replace burning fuelwood for protection against insects has been implemented. As seen in Table 10, carbon emissions under project scenario 1 were estimated at 847,475 $MgCO_2$ for the 10-year modeling period or 84,748 $MgCO_2$ yr^{-1} less than baseline emissions, whereas total leakages (15%) accounted for 164,142 $MgCO_2$ or 16,414 $MgCO_2$ yr^{-1}. Thus, the total carbon credits under project scenario 1 (CC1) were estimated at 930,141 $MgCO_2$ or 93,014 $MgCO_2$ yr^{-1}. These emission reductions are equivalent to 507,350 Mg of wood, corresponding to 6,187 ha of forest saved (this is based on average 1 hectare of forest in Asia contains 82 Mg of wood) (FAO 2000). Since leakages have direct impact on carbon credits, two more rates of leakages have been estimated. Leakages can be up to 40%, but this figure is unreality because the project would be too risky for project developers and buyers. Therefore, this study will discuss sensibility of carbon credits under rate 5% and 20%. As you can see in the Table 7, if the leakages are reduced to 5%, carbon credits can increase up to 1,039,569 $MgCO_2$. On contrary, carbon credits will be decreased down to 875,427 $MgCO_2$ when 20% of leakages are applied. These figures showed that the more leakages can be reduced, the more carbon credits can be achieved.

Table 7 Emission Reductions under Project Scenario 1

(BE = Baseline Emissions, PE = Project Emissions, ER =Emission Reductions, L = Leakages, CC = Carbon Credits)

Note: Unit is $MgCO_2$

Year	BE	PE	ER	L(15%)	CC	L(5%)	CC	L(20%)	CC
2015	143,875	122,380	21,495	3,224	18,271	1,075	20,420	4,299	17,196
2016	153,231	123,130	30,101	4,515	25,586	1,505	28,596	6,020	24,081
2017	163,195	107,466	55,729	8,359	47,370	2,786	52,943	11,146	44,583
2018	173,807	79,023	94,784	14,218	80,566	4,739	90,045	18,957	75,827
2019	185,109	71,705	113,405	17,011	96,394	5,670	107,734	22,681	90,724
2020	197,146	62,843	134,304	20,146	114,158	6,715	127,589	26,861	107,443
2021	209,966	66,380	143,586	21,538	122,048	7,179	136,407	28,717	114,869
2022	223,620	69,674	153,945	23,092	130,854	7,697	146,248	30,789	123,156
2023	238,161	72,804	165,357	24,803	140,553	8,268	157,089	33,071	132,285
2024	253,648	72,070	181,578	27,237	154,341	9,079	172,499	36,316	145,262
Total	1,941,759	847,475	1,094,283	164,142	930,141	54,714	1,039,569	218,857	875,427
Annual	194,176	84,748	109,428	16,414	93,014	5,471	103,957	21,886	87,543

4.3.3 Carbon Emission Reductions and Carbon Credits from using NSL and Mosquito Nets (Project 2)

Under project scenario 2, carbon emissions were estimated at 706,801 $MgCO_2$ for the 10-year modeling period or 70,680 $MgCO_2$ yr^{-1} lower than baseline emissions and project scenario 1, whereas total leakages (15%)

accounted for 185,244 $MgCO_2$ or 18,524 $MgCO_2 yr^{-1}$. Thus, total carbon credits under project scenario 2 (CC2) were estimated at 1,049,714 $MgCO_2$ or 104,971 $MgCO_2$ yr^{-1} (Table 8). These emission reductions are equivalent to 572,571 Mg of wood, corresponding to 6,983 ha of forest saved. The same as project 1, two more rates of leakages have been estimated. They are 5% and 20%. As you can see in the Table 11, if the leakages are reduced to 5%, carbon credits can increase up to 1,173,210 $MgCO_2$. On contrary, carbon credits will be decreased down to 987,966 $MgCO_2$ when 20% of leakages are applied. The first step suggested that project scenario 2 seems the better option for carbon project developers because carbon carbons can be achieved more than project scenario 1 nevertheless leakages are 5, 15 or 20%. However, to ensure which project is the best, comparison of carbon prices of the two projects and carbon price in actual market need to be performed. That analysis was discussed in the next section.

Table 8 Emission Reductions under Project Scenario 2

(BE = Baseline Emissions, PE = Project Emissions, ER =Emission Reductions, L = Leakages, CC = Carbon Credits)

Note: Unit is $MgCO_2$

Year	BE	PE	ER	L(15%)	CC	L(5%)	CC	L(20%)	CC
2015	143,875	111,957	31,918	4,788	27,131	1,596	30,322	6,384	25,535
2016	153,231	112,029	41,202	6,180	35,022	2,060	39,142	8,240	32,962
2017	163,195	95,643	67,552	10,133	57,419	3,378	64,175	13,510	54,042
2018	173,807	66,432	107,376	16,106	91,269	5,369	102,007	21,475	85,900
2019	185,109	58,294	126,815	19,022	107,793	6,341	120,474	25,363	101,452

2020	197,146	48,560	148,586	22,288	126,298	7,429	141,157	29,717	118,869
2021	209,966	51,169	158,797	23,820	134,978	7,940	150,857	31,759	127,038
2022	223,620	53,474	170,146	25,522	144,624	8,507	161,639	34,029	136,117
2023	238,161	55,550	182,611	27,392	155,219	9,131	173,480	36,522	146,088
2024	253,648	53,694	199,954	29,993	169,961	9,998	189,956	39,991	159,963
Total	1,941,759	706,801	1,234,957	185,244	1,049,714	61,748	1,173,210	246,991	987,966
Annual	194,176	70,680	123,496	18,524	104,971	6,175	117,321	24,699	98,797

As seen in Fig. 19, it clearly showed that project scenario 2 is the best option with carbon emissions is lower than those of project scenario 1 and the baseline scenario. This result suggested that one unit of ICS could reduce carbon emissions by approximately 1.4 ± 0.07 $MgCO_2\ yr^{-1}$ and 2 ± 0.09 $MgCO_2\ yr^{-1}$ respectively for project scenarios 1 and 2; whereas using mosquito net can reduce emissions 3.8 ± 0.18 $MgCO_2\ yr^{-1}$ for both project (90% confidence interval). However, the project scenario 2 appears to be the best option in term of carbon emission reductions, there are still discussion on total costs and carbon prices of both project scenarios in the next section.

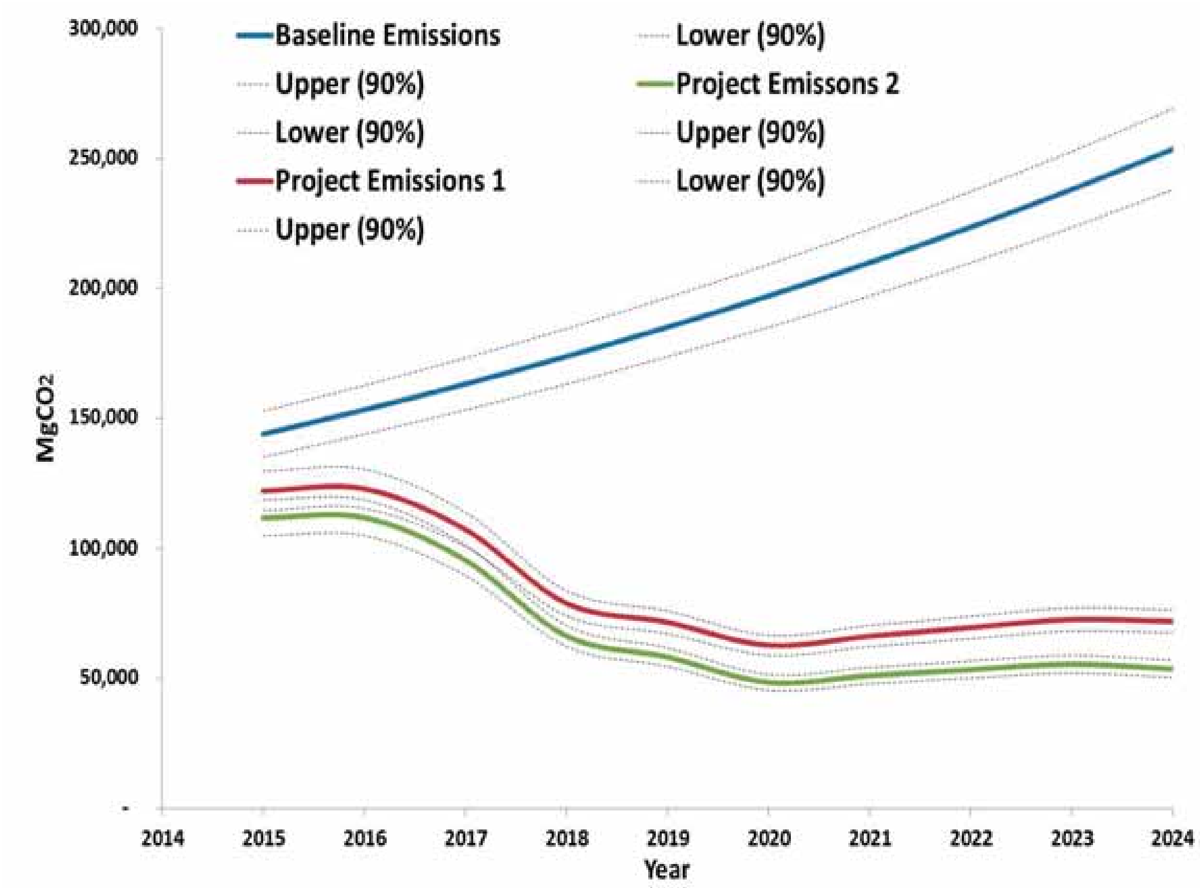


Fig. 19 Baseline emissions, project emissions 1 and project emissions 2

4.4. Carbon Price for Project Implementation

As mentioned in Chapter 3, carbon price is the cost of project implementation per ton of CO_2. Carbon price in this study will be used to compare to carbon price in the real market. It is important for project developers whether project is be implemented or not. If the price of carbon in actual market is lower than the projecting cost, it means this project is financially lost. On another way around, if price of carbon in actual market is higher than the projecting cost, it means this project is financially gained. Or if both carbon price are equal, there is neither profit nor loses. Owing to the uncertainty of future carbon agreements, carbon prices have fallen from €17 to €4 $MgCO_2^{-1}$ between 2010 and 2014 (Fig. 20).

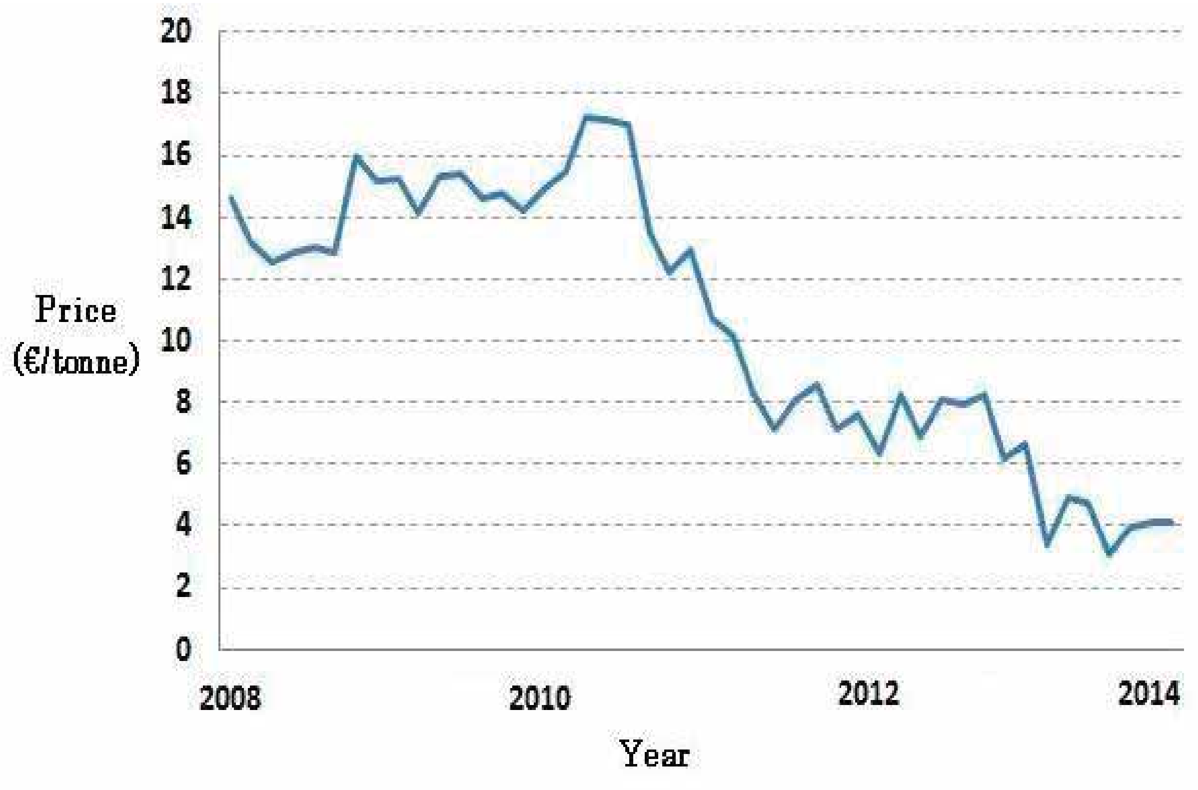


Fig. 20 Carbon price (2008-2014)

Source:http://www.investing.com/commodities/carbon-emissions-historical-data

This issue has become a concern to carbon project developers. If carbon is traded at the current price of US \$5 $MgCO_2^{-1}$ (mean carbon price in the voluntary carbon market was US \$4.9 $MgCO_2^{-1}$ as reported by Forest Trends' Ecosystem Marketplace (2014)), total revenue from carbon sales will be only US \$4.7 million or US \$0.47 million yr^{-1} and US \$5.2 million or US \$0.52 million yr^{-1} respectively, for project scenarios 1 and 2. To compare the carbon price of these 2 projects with the current carbon price in the actual market, three types of discount rate (5%, 10%, and 15%) were used to calculate the present value of total costs from 2015 to 2024, whereas three types of leakages have been applied to discuss the sensibility (5%, 15% and 20%). As seen in Table 9, total costs are much higher than total revenues at the current carbon price. Total costs comprised ICS costs (US $0.07–0.11 million under project 1), (US $0.19–0.28 million under project 2); salary (rice) (US $14.72–21.65 million under project 1), (US $14.72–21.65 million under project 2), mosquito nets costs (US $0.22–0.32 million under project 1), (US $0.22–0.32 million under project 2) and transaction costs (US $0.76–1.23 million under project 1), (US $0.88–1.40 million under project 2). As the result, total costs range from US $15.7 to 23.3 million under project 1 and US $16 to 23.6 million under project 2 for the 10-year time frame. This result clearly showed that the current carbon price in actual market (US $4.9 $MgCO_2^{-1}$) is insufficient to provide incentives for implementing these projects. On the basis of our study under 15% of leakages, the carbon prices should be at least from US $16.96 $MgCO_2^{-1}$ to US $25.05 under project 1 or from US $15.25 to US $22.52under project 2 at discount rates of 5%, 10%, and 15% respectively (Table 9). In case leakages are reduced to 5%, carbon price is cheaper (US $15.17 $MgCO_2^{-1}$ - US $22.41) under project 1 and (US $13.65 $MgCO_2^{-1}$ - US $20.15) under project 2. On contrary if leakages are increased to 20%, carbon price also increased (US $18.02 $MgCO_2^{-1}$ - US $26.61) under project 1 and (US $23.93 $MgCO_2^{-1}$ - US $16.20) under project 2. The result clearly showed that leakages have significant impact on carbon price. The more leakages can be reduced, the more carbon price can be decreased. Even though the leakages are 5%, the carbon price is still higher than the current carbon price. In this case, government subsidies are really needed to fill the gap of financial loss. However, there is still a high expectation that the carbon price will increase again after a new climate agreement is reached at the upcoming COP 22 in December 2016.

Table 9 Total costs and carbon price of project 1 and project 2

Description of Project 1	Present Value of Total Costs from 2015–2024 (US $)		
	5%	10%	15%
ICS_{costs}	105,362	87,767	74,901
Salary	21,647,718	17,619,913	14,715,200
Mosquito $nets_{costs}$	316,087	263,302	224,702
$Transaction_{costs}$	1,229,622	953,747	757,680
Total cost under project 1	23,298,788	18,924,729	15,772,481
Carbon Price under Project 1 (US $ $MgCO_2^{-1}$)			
Leakages (5%)	22.41	18.20	15.17
Leakages (15%)	25.05	20.35	16.96
Leakages (20%)	26.61	21.62	18.02
Description of Project 2	Present Value of Total Costs from 2015–2024 (US $)		
	5%	10%	15%
ICS_{costs}	280,966	234,046	199,735
Salary	21,647,718	17,619,913	14,715,200
Mosquito $nets_{costs}$	316,087	263,302	224,702
$Transaction_{costs}$	1,395,044	1,088,390	870,126
Total costs under project 2	23,639,815	19,205,651	16,009,763
Carbon Price under Project 2 (US $ $MgCO_2^{-1}$)			
Leakages (5%)	20.15	16.37	13.65
Leakages (15%)	22.52	18.30	15.25
Leakages (20%)	23.93	19.44	16.20

Chapter 5

Framework for Reducing Local Dependency on Fuelwood Consumption

This study suggested that huge carbon emission reductions could be achieved by using improved cook stoves and mosquito nets, which eventually will result in reducing deforestation and forest degradation in Phnom Tbeng forest. Carbon-based financial support may be available under the REDD+ scheme. However, only using improved cook stoves and mosquito nets would not be sufficient to reduce local dependency on fuelwood in Cambodia unless strategies are introduced. Three main strategies can be appropriate for reducing local dependency on fuelwood consumption (Fig. 21):

I. Strengthening Governance and Legal Issues

II. Sustainable Community Forest management

III. Poverty Alleviation

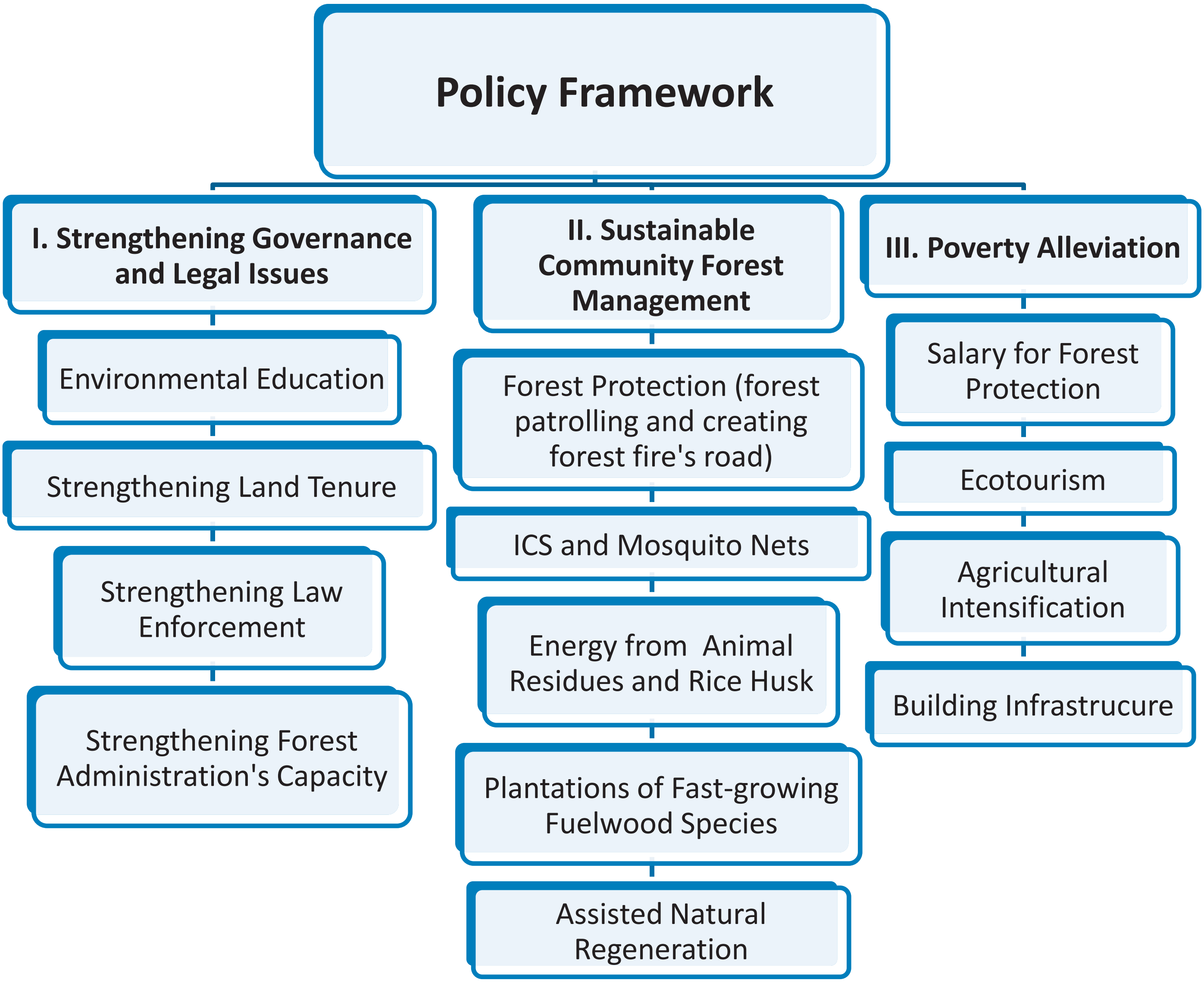


Fig. 21 Framework for reducing local dependency on fuelwood consumption

I. Strengthening Governance and Legal Issues

1. Environmental Education: Training course should provide to local people about the benefits of forests and the effect of deforestation on climate change as well as their livelihood. The lesson should teach them how to protect and use the forests in sustainable way.
2. Strengthening Land Tenure: Tenure right should be provided to indigenous

people or forest dependent communities as a mechanism for resolving conflicts over tenure right, self-forest protection and conserve cultural of indigenous people.

3. Strengthening Law Enforcement: Even though there are laws concerning forests in Cambodia, there are lack of enforcement and transparency. Thus, strengthening capacity building of Forestry Administration and local authorities as well as anti-corruption activities will help to reduce illegal logging.
4. Strengthening Forest Administration's Capacity: More training courses, technical and financial assistance should be provided not only at national level but to local forestry officers because they will be responsible to work closely on the field. Moreover they are the main actors to spread the knowledge to forest communities.

II. Sustainable Community Forest Management

1. Forest Protection (forest patrolling and creating forest fire road): To reduce illegal for commercial and charcoal production, participation of local forestry officers and forest communities are important to patrol forests weekly or monthly. During the patrolling, they can also create forest fire's road in order to avoid forest fires. As already mention in the study, salary should be given to household for these activities. This practice also implemented in Vietnam where villagers are given 200,000 dong and 15 kg of rice every month as income in exchange for protecting the forest (Mucahid et al. 2014).

2. ICS and Mosquito Nets: As the results from this study, using ICS and Mosquito nets can achieved huge carbon emissions reductions. Studies from San et al. (2013) and Ty et al. 2011 also recommended implementing these two activities because it will reduce local dependency on forest. In recent years, there are some successful project in Africa and Southeast Asia. According to the UNFCCC registry (PoA Registry 2015), ICS projects generally claim emission reductions between 1 and 5 $MgCO_{2e}$ per ICS, as example ICS project in Nepal and Haiti has claimed emission reduction approximately 1.9 and 2.5 $MgCO_{2e}$ per ICS, respectively. In 2006, GERES Cambodia (Groupe Energies Renouvelables, Environnement et Solidarités) was the 1st project developer to bring ICS project to the voluntary carbon market. The project avoided the emission of 1,464,625 tons of CO_{2e} (2003 to 2011) which represents more than 1,600,000 stoves sold on the Cambodian market. The project would not only reduce carbon emissions but also create many jobs from ICS and Mosquito nets production.
3. Energy from Animal Residues and Rice Husk: Cambodia's energy sector plays a crucial role in the country's continued development. However, Cambodia has no proven fossil fuel reserves and is almost completely dependent on imported diesel fuel for electricity production and other power applications. The demand for fossil fuel imports in Cambodia grew by an average 33% yr^{-1} from 1997 to 2000 and there is no sign of slowing of this trend (Samy 2004). Current energy prices in Cambodia may not be affordable for the poor. For this reason a majority of the population opts to use energy derived from biomass, particularly fuelwood from natural

forest for daily consumption (MIME 2004; Kunthy 2012). Investment in hydroelectric dams and solar panels is vital for reducing dependency on fuelwood but household payment capacity is still a big obstacle to forest community. Introducing alternative renewable energy sources such as biogas to rural areas will also reduce dependence on wood. Small-scale biogas production has proved to be one of the most promising renewable-energy technologies, having very low generation cost and being widely used for cooking and lighting in rural areas of India, China, and Nepal (Nijaguna 2002; Katuwal and Bohara 2009). Biogas is usually generated from agricultural residues, livestock dung and rice husk available around villages.

4. Plantation of Fast-growing Fuelwood Species: Even after the above actions have been implemented, wood demand is still increasing owing to population growth. Plantations of fast-growing fuelwood species such as Acacia spp. and Albizia spp., in non-forest areas would also be an ideal method for supplying local and outside demand.
5. Assisted Natural Regeneration: Most of the community forests of Cambodia are very degraded which strongly limits the potential of income generating activities for the communities to sustainably manage their forest resources. Local forestry officers should cooperate with forest communities to regenerate forests by natural or artificial means.

III. Poverty Alleviation

Poverty is the main reason of local people to commit illegal logging and over exploitation of forest resources. The lack of income and food securities of people living in rural area forces them to cut the trees in forests. However, strengthening governance, legal issues and sustainable community forest management can reduce some of drivers of deforestation and forest degradation; but it still not adequately dealt unless their livelihood has been improved at local level. Here are 4 methods proposed to tackle this problem:

1. Salary for Forest Protection: To reduce poverty and encourage forest community to participate in forest protection, salary should be given to household. As mentioned above, in Vietnam villagers are given 200,000 dong and 15 kg of rice every month as income in exchange for protecting the forest (Mucahid et al. 2014). But this study recommended giving salary as rice (30 kg), while cash are not given due to the concern of unappropriated use of money for other purposes that do not benefit their family.
2. Ecotourism: However salary was given, it would not be enough to feed the whole family; thus, creating jobs at a local level through factory or enterprise development, especially in the ecotourism sector, can provide sustainable income to villagers. They can switch their jobs from producing charcoal, an occupation that threatens forest resources, to working as guides or as sellers of forest and non-forest products. In 2000, Qingkou forest-dependent communities in China have been developed as eco-cultural tourism villages where local people can earn money from sales of entry tickets, cultural performances, guiding services, renting camping sites, and selling forest products (Gu et al. 2009). Local people can sell their services and local product from ecotourism. Ecotourism focuses on

forest ecosystems, waterfall, mountains and wild animals in order to generate revenues for local people, thereby discouraging them from deforestation. Instead, it could encourage them to protect the forests as well as environment.

3. Agricultural Intensification: Cambodian people depend on rain for planting rice, usually once a year. By providing new technology, know-how, good rice seeds and enough water supplies, farmers can plant rice 2 or 3 times per year. It leads to increase their productivity and surely increase their income.
4. Infrastructures: School, hospital, roads, bridges and irrigation system will help pushing economic development at local level. These will be important for long term and sustainable development. It will definitely contribute to reduce poverty and improve livelihood of rural people.

In terms of costs and carbon price in the current market, this project is financially unfeasible unless there are subsidies from government. The other problem is how to make project work and reduce the impact of fuelwood dependency in the project site. The agents of drivers of deforestation have to be identified in order to set up appropriate intervention actions. To deal with drivers of deforestation and forest degradation, participation of government forestry officers, local people, other stakeholders are crucial to implement the REDD+ project. Government forestry officers should provide capacity building on environmental education and related legal issues to community forestry. Poverty is the main reason of local people to commit illegal logging and over exploitation of forest resources. The lack of income and food securities of people living in rural area forces them to cut the trees in forests for more income. Based on the "Tragedy of Commons" of Hardin (1968), human population growth and the use of the earth's natural resources will eventually deplete all natural resources. Hardin (1968) pointed out that avoiding over exploitation of common resources can be solved by good management and human participation. Therefore participation from community forestry and local forestry officers is very important factor to conserve and protect the forest. There is a good example of Yakushima island of Japan, forest at one time has been logged (dating back at least to the early Edo period), but have been extensively replanted and reseeded since logging ended in the late 1960s, at which time a conservation regime was established. Then Yakushima forest has become natural World Heritage Site since 1993. However, more efforts are needed to build the capacity of communities to manage community resources. The community should be given technical and financial assistance in the management of forest. Moreover local forestry staffs should facilitate and empower communities on forest patrolling and increasing their knowledge on legal issues. These activities can be effective unless the local livelihood has been improved at local level. Reducing poverty and pushing economic development at local level can reduce dependency on fuelwood and will surely contribute to reduce drivers of deforestation and forest degradation.

Chapter 6

Conclusions

Rural households in the study area depend on fuelwood from forests as a primary energy source for multiple purposes including cooking, boiling water, animal protection against insects, and preparation of animal feed. Not only is fuelwood extracted for household consumption, but in some cases, trees have been cut for housing and producing charcoal for extra income. This common practice occurred throughout the forest area results in deforestation and forest degradation. Approximately 98% of the 105 sampled households were using fuelwood for daily consumption and 2% were using charcoal and fuelwood. Current energy structure consumption in study site is dominated by biomass which TSS are commonly used. The results clearly showed that wood consumption in rural area is higher than urban area. Overall average fuelwood consumption for cooking and boiling water was 5.62 ± 0.27 kg day^{-1} household^{-1} or 2.05 ± 0.1 Mg yr^{-1} household^{-1}. Fuelwood is also burned to generate smoke for protecting animals against insects. This practice accounted for 11.77 ± 0.89 kg day^{-1} household^{-1} or 4.29 ± 0.18 Mg yr^{-1} household^{-1}. The amount of fuelwood burning against insect is two times more than amount of fuelwood used for cooking and boiling because wood was burned several hours at night time. Using three stone stoves and burning wood against insect not only induced to forest loss and emitted massive carbon dioxide to atmosphere but it also results in negative health impacts, air pollution to human and animal. By using ICS and Mosquito net, it can save energy up 64% compare to three stone stoves and it surely improve health condition of human and animal. With less wood being use, the ICS and Mosquito net will helps to reduce the deforestation and illegal logging in Cambodia and eventually it reduces carbon emissions from wood burning. Households also spend less time to collect the fuelwood from forest. The time saved from fuelwood collection can be used to find another income opportunity. In addition, the ICS and Mosquito nets are manufactured locally, therefore when this project starts, there will be more demand in ICS and Mosquito nets. Thus new job opportunities will increase for the local communities in production, distribution and sales of the ICS and Mosquito nets.

Altogether, using improved cookstoves and mosquito nets can reduce carbon emissions up to 1,049,714 $MgCO_2$ for 10-year project or about US $5.2 million depending on carbon price. This study suggested that total revenues at the current carbon price are insufficient to implement the low-carbon project unless the carbon prices are in the minimum range of US $15–25 $MgCO_2^{-1}$ under 15% of leakages. To further decrease carbon price, drivers of leakages should be scientifically studied and reduce it impact accordingly. Carbon price is a crucial factor in carbon project development; therefore government subsidies are needed to fill the gap of financial lost to ensure that a carbon project is feasible. Even though ICS and mosquito nets are introduced, fast growing trees should be planted to supply local and outside demand. Other intervention should be taken in place such as community forestry capacity building, increasing participation of forest community and forest patrolling etc.

However this study suggested that this project has great potential of reducing carbon emissions, without sufficient financial incentives carbon project would not happen and therefore climate change will continue to threaten future development. Developing countries do not have an obligation to reduce their emissions, but have a right to pursue development and poverty reduction as national priorities. In Chapter 5, the study was not only proposed to introducing ICS and mosquito nets, others interventions should be followed in order to the impact of driver of fuelwood extraction such as planting fast-growing tree to supply wood demand, communities capacity building, participation of forest community and forestry officers, encouraging communities to protect and patrol the forest by providing incentives. Anyway, poverty is still the main reason of local people to commit illegal logging and over exploitation of forest resources. Reducing poverty by creating job at local level and paying the environmental services of forest is crucial for forest management and conservation. REDD+ implementation will determine its social and economic impacts on people, and a consideration of these impacts should be included early on in REDD+ implementation. REDD+ may generate substantial positive impacts but it may also lead to changes in resource management and access that will disproportionately affect the poor and those that are most vulnerable. Pursuing social objectives alongside REDD+ will not only make the process more equitable but it will also increase the likelihood and at the same time achieving carbon emission reductions goals. For example, increasing agricultural productivity can in some cases lead to reduced deforestation, and be a very powerful poverty reduction tool. Thus, a successful project should contribute to local livelihoods by both benefit sharing and technology transfer for long-term sustainable development.

Cambodia lacks of long term supporting finance for policy implementation and ground implementation and the number of staffs who are working in Ministry of Environment and Ministry of Agriculture, Forestry and Fisheries are still insufficient which result in ineffective field implementation activities addressing negative drivers of deforestation and forest degradation. Therefor revenue from carbon sales under REDD+ from ICS and mosquito net project could be used to pay to forest communities for forest protection such as patrolling the forest to avoid illegal logging or preventing forest fires. The main factor for rural household in selecting fuelwood for living is related to their livelihood income and how easily the fuelwood can be obtained. Environmental cost should be considered in REDD+ project. The reasons why the tradition energy structure exists are that most of households are poor, therefore not being able to pay consumption of electricity and fossil fuel and the households can't access to the electricity grid. Appropriate use of carbon revenue will help to achieve poverty reduction and reduce drivers of deforestation and forest degradation at local level for sustainable forest management.

Since REDD+ scheme is recognized as a way to address environmental degradation, encourage enhancement of forest carbon stocks and improve local livelihood by assigning an economic value to forests in the international climate regime. The results of the study provide good information to policy makers, Cambodian Government and some NGOs to make better decision on renewable energy promotion, forest conservation and management. Some countries in

Africa and Southeast Asia that are facing similar problem on fuelwood consumption extraction from forests can use the application and method of this study to apply in their respective countries. It could be useful tools to estimate carbon emission, emission reductions and carbon credits from this sector in forest dependent community.

Understanding socio-economic values of forests are important for designing appropriate interventions which less harm to local communities' livelihood and contribute to reducing carbon emissions from deforestation and forest degradation in Cambodia. Socio-economic survey tools provide a means of improving understanding of local resource management systems, resource use and the relative importance of resources for households and villages. However, due to the limitation of resource and time, the survey was conducted only one week in dry season. Further studies on collection and use of fuelwood by local people according to seasonal variations (i.e. two to four times of survey per year) to be conducted, thus it would improve accuracy of our research findings such as carbon emission reductions and prices. It is not easy to anticipate or measure all impacts of management actions on carbon and biodiversity, particularly as impacts can occur outside the area of management or leakages in the future, and they can also evolve over time. Impacts of REDD+ interventions are also likely to vary signif cantly across different forest types and landscape conditions. Therefore, caution and scientific study is needed when extrapolating management recommendations across different ecosystems for REDD+ remains a major priority for future research.

On negative perspective, REDD+ have been blamed for corruption and mismanagement of forest resources in developing countries. Successful implementation of the REDD+ projects require transparency, appropriate intervention policy and sustained political commitments from Annex 1 countries that provide financial and technological supports to developing countries and non-Annex one countries that will act as hosting and implementing countries. Capacity building toward hosting countries will also contribute to success of the REDD+ projects as the concept and implementation are new to them. Many developed and developing countries considered REDD+ scheme as a positive way to contribute to global mitigation efforts to address environmental degradation and at the same time reducing poverty by through carbon-based incentives. However, REDD+ is also a highly technical and rapidly evolving subject, and many developing countries require support to develop national frameworks and negotiate effective modalities and processes within the agreement under the United Nations Framework Convention on Climate Change (UNFCCC). There is still a high expectation that there is more demand in carbon again after a new climate agreement is reached at the upcoming COP 22 in December 2016. Therefore carbon price will increase by carbon market mechanism and consequently investments on carbon projects in developing countries will be attractive to project developers. With REDD+ scheme, fuelwood consumption for daily cooking energy and protecting local people's domestic animals could be reduced and so are the emissions from fuelwood consumption.

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Appendices

Appendix 1. Questionnaires for Household Survey (English)

Household Survey on Fuelwood Consumption in Phnom Tbeng Forest, Preah Vihear province, Cambodia

Hello. My name is ___________________I am a ______________ conducting a survey to understand fuelwood consumption. This survey is part of my doctoral research on fuelwood consumption of local people in the Phnom Tbeng forest. The main objective of the survey is to uncover how much energy from fuelwood is being used by local people. Your opinion and cooperation is very important for the successful completion of this study. There is no right or wrong answer to the questions; we only want your honest opinion. Your responses and your identity will be held strictly confidential.

Date of interview:	
Location:	
ID number:	

Section 1: Household's General Information

1. Name: ________________________ Age: ______ Gender: ☐ Male ☐ Female

2. Position in Family:

☐ Father ☐ Mother ☐ Child

☐ Grandparent ☐ Other (Specify): ________________________

3. Were you born here? ☐ Yes ☐ No

4. Where were you born?

Answer:

____

5. When did you settle here?
Answer:

____

6. How many people are living in your household, including yourself?
Answer:

____

7. What is the highest level of education in the household?

☐ No schooling ☐ Primary school ☐ Secondary school

☐ High school ☐ University ☐ Other (Specify): ________

8. The main material of the walls and roof of your house (Place a (√) mark).

Wall	**Roof**
1. Bamboo	1. Thatch/leaves
2. Wood	2. Tile
3. Zinc	3. Zinc
4. Thatch/leaves	4. Fibro
5. Brick/ cement	5. Concrete
6. Other (specify): ________	6. Other (specify): ________

Section 2: Socioeconomic Data, Forest Dependency and Drivers of Deforestation

9. I will now mention several practices that may contribute to your household's livelihood. Please indicate whether each of the following practices is very important, important or not important to your household's livelihood (Place a (√) mark).

	Very important	Important	Little important	Not important	Don't know
1. Cultivating crops					
2. Raising livestock					
3. Using resources from forests					
4. Laboring					
5. Fishing					

6. Other (specify): ___________________					

10. What are the four main products from the forests for your household use? (Let the respondent identify these before you ask him to rank)

Answer:

____

11. Please rank them from most important to fourth most important. (Place a (√) mark)

	1st	2nd	3rd	4th
1. Fuelwood				
2. Charcoal				
3. Timber for construction				
4. Resin tapping				
5. Rubber				
6. Wild meat				
7. Fruits/vegetables				
8. Rattan				
9. Spices/herbs				
10. Medicine				
11. Fishing				
12. Other (specify): ______________				

12. Do you feel that your surrounding forests are threatened by deforestation and forest degradation?

☐ Yes ☐ No ☐ Don't know

13. Please rank them from most important to third most important of deforestation and forest degradation. (Place a (√) mark)

	1st	2nd	3rd
1. Forest clearance for small-scale			

agriculture			
2. Forest clearance for Commercial Plantations			
3. Fuelwood			
4. Charcoal production			
5. Land encroachment			
6. Fires			
7. Illegal Logging			
8. Other (specify): ________________			

Section 3: Energy Consumption

14. Do you use electricity? ☐ Yes: How much per kWh? Answer: ________________

☐ No

15. Do you use chargeable battery? ☐ Yes: How often do you charge? _____ times, How much it costs per charge? __________

☐ No

16. Which types of energy you use for daily consumption?

☐ Dead fuelwood ☐ Fresh fuelwood ☐ Charcoal ☐ LPG

17. Where do you collect fuelwood?

Answer:

____

18. What purpose do you use fuelwood for daily consumption? How much fuelwood you use per day?

Purposes	Quantity of Fuelwood (Kg/day)
Cooking	
Boiling	
Protection against insect	
Other (specify): ___________________	

Duration of the interview: ____________ Minutes

Thank you very much for your cooperation and help!

Appendix 2. Questionnaires for Household Survey (Khmer)

ការស្ទង់ទិន្នន័យស្តីពីការប្រើប្រាស់អុសរបស់ប្រជាជននៅភ្នំត្បែង ខេត្តព្រះវិហារប្រទេសកម្ពុជា

ជំរាបសួរ។ ខ្ញុំបាទឈ្មោះ___________________ ខ្ញុំជា ______________ ធ្វើការស្ទង់ទិន្នន័យពីការប្រើប្រាស់អុសរបស់ប្រជាជនក្នុងតំបន់នេះ។ ការស្ទង់ទិន្នន័យនេះគឺជាផ្នែកមួយនៃការស្រាវជ្រាវថ្នាក់បណ្ឌិតរបស់ខ្ញុំនៅលើការប្រើប្រាស់អុសតាមបែបប្រពៃណីរបស់ប្រជាជនក្នុងតំបន់ជនបទ។ ការចូលរួមសហការរបស់អ្នកគឺមានសារៈសំខាន់ខ្លាំងណាស់សម្រាប់ការបញ្ចប់ដោយជោគជ័យនៃការសិក្សានេះ។យើងគ្រាន់តែចង់បានគំនិតស្មោះត្រង់របស់អ្នកប៉ុណ្ណោះ; នឹងមិនមានការចាប់កំហុសចំពោះការឆ្លើយនឹងសំណួរនេះទេ។ អត្តសញ្ញាណរបស់អ្នកនឹងត្រូវបានរក្សាទុកជាការសម្ងាត់បំផុត។

កាលបរិច្ឆេទនៃការសំភាសន៍:	
ទីតាំង:	
លេខសម្គាល់:	

ផ្នែកទី 1: ពត៌មានទូទៅរបស់គ្រួសារ

1. ឈ្មោះ: ___________________________ អាយុ: _______ ភេទ: ☐ ប្រុស ☐ ស្រី

2. តួនាទីក្នុងក្រុមគ្រួសារ:

☐ឪពុក ☐ម្តាយ ☐កូន

☐ជីដូនជីតា ☐ផ្សេងទៀត (បញ្ជាក់): ______________________________

3.តើអ្នកកើតនៅទីនេះ? ☐បាទ/ចា ☐ទេ

4. កន្លែងដែលអ្នកកើតនៅទីណា?

ចម្លើយ:____

5. តើអ្នកបានមករស់នៅទីនេះនៅពេលណា?

ចម្លើយ:____

6. ចំនួនសមាជិកនៅក្នុងគ្រួសាររបស់អ្នករួមបញ្ចូលទាំងខ្លួនអ្នកផ្ទាល់?

ចម្លើយ:____

7. កម្រិតសិក្សាខ្ពស់បំផុតនៅក្នុងគ្រួសារ?

☐ មិនមានការសិក្សា ☐ សាលាបឋមសិក្សា ☐ អនុវិទ្យាល័យ

☐ វិទ្យាល័យ ☐ សាកលវិទ្យាល័យ ☐ ផ្សេងទៀត (សូមបញ្ជាក់):____________

8. ធាតុផ្សំនៃផ្ទះរបស់អ្នក(ជញ្ជាំងនិងដំបូល) (√) ។

ជញ្ជាំង	ដំបូល
1. ឫស្សី	1. ស្បូវ
2. ឈើ	2. ក្បឿង
3. ស័ង្កសី	3. ស័ង្កសី

4. ស្បូវ	4. ហ្វីប្រ៊ូ
5. ឥដ្ឋ / ស៊ីម៉ងត៍	5. បេតុង
6. ផ្សេងទៀត (សូមបញ្ជាក់): ______________________	6. ផ្សេងទៀត (សូមបញ្ជាក់): ______________________

ផ្នែកទី 2: ទិន្នន័យសេដ្ឋកិច្ចគ្រួសារ ការអាស្រ័យផល និងមូលហេតុនៃការបំផ្លាញព្រៃឈើ

9. ឥឡូវនេះខ្ញុំនឹងអោយឧទាហរណ៍ជាច្រើនទាក់ទងនឹងការចិញ្ចឹមជីវិតរបស់គ្រួសាររបស់អ្នក។ សូមចង្អុលបង្ហាញថាតើការនៃការអនុវត្តដូចខាងក្រោមថាមួយណាសំខាន់ខ្លាំងជាងគេ (√) ។

	សំខាន់ខ្លាំងណាស់	សំខាន់	សំខាន់តិចតួច	មិនសំខាន់	មិនដឹង
1. ដំណាំបណ្តុះ					
2. ការចិញ្ចឹមសត្វ					
3. ការប្រើប្រាស់ធនធានពីព្រៃឈើ					
4. កំលាំងពលកម្ម					
5. ការនេសាទត្រី					
6. ផ្សេងទៀត (សូមបញ្ជាក់): ______________________					

10. ចូររៀបរាប់ផលដែលបានមកពីព្រៃឈើ៤ប្រភេទ។

ចម្លើយ:____

11.សូមចាត់ចំណាត់ថ្នាក់ផលដែលបានពីព្រៃឈើដូចខាងក្រោម។

	ទី1	ទី2	ទី3	ទី4
1. អុសដុត				
2. ធ្យូង				
3. សម្រាប់ការសាងសង់				
4. ជ័រ				
5. កៅស៊ូ				
6. សត្វព្រៃ				
7. ផ្លែឈើ / បន្លែ				
8. ផ្ដៅ				
9. គ្រឿងទេស				
10. ឱសថ				
11. ការនេសាទត្រី				
12. ផ្សេងទៀត (សូមបញ្ជាក់): ________________				

12. តើអ្នកគិតថាព្រៃឈើនៅតំបន់នេះរងការគំរាមកំហែងដោយការកាប់បំផ្លាញព្រៃឈើដែរទេ?

☐ បាទ/ចា ☐ ទេ ☐ មិនដឹង

13. បើមាន សូមចាត់ចំណាត់ថ្នាក់មូលហេតុនៃការបំផ្លាញព្រៃឈើដូចខាងក្រោម។

	ទី1	ទី2	ទី3
1. ការឆ្ការព្រៃសម្រាប់ធ្វើកសិកម្មខ្នាតតូច			

2. ការកាប់ព្រៃឈើសម្រាប់ដំណាំខ្នាតធំ			
3. អុសដុត			
4. ផលិតកម្មធ្យូង			
5. ការទន្ទ្រានយកដី			
6. ភ្លើងឆេះព្រៃ			
7. កាប់ឈើខុសច្បាប់			
8. ផ្សេងទៀត (សូមបញ្ជាក់): ____________			

ផ្នែកទី 3: ការប្រើប្រាស់ថាមពល

14. តើអ្នកប្រើអគ្គិសនីដែរទេ?

☐ បាទ/ចា: តើក្នុងមួយគីឡូវ៉ាត់ថ្លៃប៉ុន្មាន? ចម្លើយ: ____________________

☐ គ្មាន

15. តើអ្នកប្រើអាគុយដែរទេ?

☐ បាទ: រយៈពេលប៉ុន្មានសំរាប់សាកថ្មម្តង? ____________

តម្លៃសម្រាប់ការសាកថ្មម្តង? __________

☐ គ្មាន

16. ប្រភេទនៃថាមពលដែលអ្នកប្រើប្រាស់ជារៀងរាល់ថ្ងៃ?

☐ អុសងាប់ ☐អុសស្រស់ ☐ ធ្យូង ☐ ហ្គាស

17. តើអ្នកប្រមូលអុសពីកន្លែងណា?

ចម្លើយ:____

18. តើអ្នកប្រើអុសក្នុងគោលបំណងអ្វីខ្លះ? តើអ្នកប្រើក្នុងក្នុងបរិមាណប៉ុន្មានមួយថ្ងៃ?

គោលបំណង	បរិមាណអុស(Kg/ថ្ងៃ)
1. ចម្អិនអាហារ	
2. ដាំទឹក	
3. ការការពារប្រឆាំងនឹងសត្វល្អិត	
4. ផ្សេងទៀត (សូមបញ្ជាក់): ___________	

រយៈពេលនៃការសំភាសន៍: ______________ នាទី។ សូមអរគុណសម្រាប់ការសហការរបស់អ្នក!