CHAPTER I

INTRODUCTION

1.1 Background

Forest is not only the largest natural resource in terms of spatial coverage but also an important means for their products such as fuelwood, fodder, timber and medicines to majority of the people. The conservation of forest resources may also help in diversification of wild life and biodiversity. The fuelwood from the forest products is a major source of energy for majority of the rural people.

Fuelwood is primarily used for cooking and heating. The forests are the only sources that have received heavy pressure as a result of meeting ever increasing demand of fuelwood. Forests, which are main resource of biomass energy, have already been exploited beyond their sustainable capacity and are becoming relatively scarce (Katuwal and Bohara 2009). As more than 80 % of the energy needs in rural area are met by fuelwood, thus exerting immense pressure on the forest resources of the country with negative impacts on biodiversity conservation (WECS 2006). The biomass consumption has vast implications both for deterioration of natural resources which has been home to large number of wild flora and fauna.

Alternatives to wood and biomass based energy is unrealistic to the large majority of households in the near future as well. In this scenario, efforts and initiatives geared towards a sustainable alternative energy program seems crucial as a mitigating measure for the harmful effects derived from the excessive use of natural resources for energy (Thapa and KC 2009). Promotion of alternative energy has been a major component of biodiversity conservation, as it reduces human pressure in the park and buffer zone forests. It is a widely recognized fact that in order to reduce biotic pressure from forests it is important to identify, establish and develop alternatives to the biomass resources (Badola 1998). This can be done either by widening people's range of choices by increasing their income thus reducing their need to over exploit forests (Leach 1994), or by providing specific alternatives to forest resources such as biogas (Badola 1995).

With the on-going destruction of forests due to overuse and degradation, scarcity of wood has become increasingly common in Asia. Since livestock such as cattle, buffalo, sheep, and goat are common in villages of the developing countries, animal dung is the most easily available and abundant biomass for fuel and the burning of dung is common in rural areas. Cow dung has been used as both fertilizer and fuel in many countries around the world for centuries (Hall and Moss 1983).

To mitigate the excessive use of forest resources as energy alternative sources of rural domestic energy such as crop residues, animal dung, fuelwood, biogas, kerosene, sun and wind power can have significant role. Substitution from fuelwood to alternative sources can reduce pressure on natural forests. In addition, more wide-spread use of improved stoves, biogas, and other improved end-use technologies like briquettes and biofuels through reduced energy input requirements also has the potential to reduce pressure on forest resources (Heltberg *et al.* 2000).

Energy is undoubtedly a fundamental means for meeting the needs of daily life support system and developmental activities. Nepal's energy supply is primarily based on three sectors; traditional, commercial and renewable. Traditional energy sources are the primary sources of energy in the rural area of Nepal. It shows that rural Nepal has better options and potential for the development of renewable energy. Therefore, wise use of existing resources may have minimum environmental impacts. Among various renewable energy technologies, biogas energy is emerging as the major contributor in the current renewable energy resources development. The development of biogas technology is a milestone in the overall development of rural areas (Bhandari and Thapa 2011).

It is imperative to expand alternate and renewable resources for energy. Among all renewable resources the availability of biogas is de-centralized within the Terai and mid hills. Almost all rural households have animals and agro wastes to produce bioenergy at household level. Biomass bonds almost 15 % energy consumptions worldwide subsequently sharing 38 % in developing countries (Bhattaracharya and Abdul 2002, Amjid *et al.* 2011). The need for affordable, clean and renewable energy to enhance sustainable development has been reiterated recently by the World Energy Council (2006) and the UN Commission on Sustainable Development (2007).

Nepal, one of the least developed countries, is characterized by very low per capita energy consumption. Because of a lack of other commercial sources of energy, the country relies heavily on traditional fuel source, especially fuelwood. In order to solve the energy problem in rural areas, the country initiated production and distribution of several renewable energy technologies. Among several technologies, biogas has been proved to be viable and emerged as a promising technology. It has been one of the most successful models for the production of clean, environmental friendly, cost effective source of energy and has multiple benefits (Katuwal and Bohara 2009).

1.1.1 Energy Status of Nepal

Energy has been becoming a basic tool for development. Developing countries like Nepal face dilemmas regarding environmental protection due to their heavy dependency on biomass and fossil fuel. Per capita consumption of primary energy in Nepal is estimated to be fifteen gigajoules (GJ) in 2006 (MOF 2007/2008). Nepal relies heavily on traditional energy resources, as no significant deposits of fossil fuel are available. The major energy resource of Nepal, in terms of consumption, consists of biomass, hydroelectricity, petroleum products, natural gas and coal reserve. Nepal has a huge potential for hydropower production, but this remains mostly untapped.

Fuelwood is the biggest energy resources in Nepal providing about 77 % of the total energy demand in the year 2008/09. Other sources of biomasses are agricultural residues and animal dung which contribute about 4 % and 6 %, respectively. Share of petroleum fuels in the total energy system is about 8 %. This share is somehow similar with the past few years. Other sources of commercial energy are coal and electricity, both of which contribute about 4 % in the total energy. The overall energy consumption of Nepal is mainly dominated by the use of traditional non commercial forms of energy such as fuelwood, agricultural residues and animal waste. The share of traditional biomass resources, commercial energy resources and renewable energy resources are 87 %, 12 % and 1 %, respectively. The share of traditional fuel is decreased from 91 % in 1995/96 to 88 % in 2004/05 and to 87 % in 2008/09. The remaining 13 % of energy consumed is through commercial sources (Petroleum fuels, Coal and Electricity) and renewable supply (ADB/ICIMOD 2006, WECS 2006, and WECS 2010).

Total energy consumption in the year 2008/09 was about 9.3 million tonnes of oil equivalent (401 million GJ) out of which 87 % were derived from traditional resources, 12 % from commercial sources and less than 1 % from the alternative sources (WECS 2010).

1.1.2 Alternative Energy and Biogas in Nepal

The available sources of renewable energy in Nepal are water, sun, wind, biomass, hot spring and so on. These renewable energy sources are un-interruptible and infinitely available due to their widespread complementary technologies, which can accommodate the country's need of diverse supply. Besides, these energy sources are environmentally friendly as they have very little or no negative impact on green house gases (GHGs), landscape, climate, physical and topographical environment. Because of which significant effort has been put for the production of more cleaner and sustainable form of Renewable Energy Technologies (RETs). Biogas has emerged as a promising technology and proved to be one of the most successful models among several other RETs in Nepal (BSP 2009).

The estimated total technical potential of biogas plants is about 1.9 million plants, of which 1000000 plants are thought to be economically viable. As of December 2008/09, more than 200000 biogas plants of varying capacities (4, 6, 8, 10, 15 and 20 m^3) have been installed (BSP 2010). There is a huge potential for biomass technologies like improved cooking stoves (ICS), beehive briquettes, briquetting mechanism and gasifier. More than 331000 ICS have been so far installed through various government and non-government organizations. Till 2008/09, there were about 1977 micro-hydro (including pico-hydro) electrification schemes installed in various part of the country with the total installed capacity of about 13.9 MW (WECS 2010).

Biogas, as a simple, effective and eco-friendly technology is a good contributor in the energy sector in Nepal, which helps in conserving forest and associated habitat and ecology. Biogas is not a new invention, and was used as early as around 10 BC in Assyria for heating baths. While international interests in these uses have been most noticeable in the technical and developing communities in the last 15-20 years, serious development efforts in this field began about 50 years ago in Asia. The history of biogas in Nepal goes back to 1955, when Late Father B. R. Saubolle, a Belgian School Teacher at St. Xavier's School, Godavari in Kathmandu, built a demonstration plant of used oil drum (Ghimire 2000). After the establishment of BSP, the pace of biogas plant installation has increased in an accelerating rate. It is reported that as of March 2009, a total of 201247 biogas plants have already been installed in about 71 districts of Nepal (BSP 2009).

1.1.3 Ecological Benefits of Alternative Energy

Alternative energy, a sustainable renewable energy, has positive environmental impacts at local, national and global levels. From a national perspective, alternative energy systems have helped to reduce the pressure on forests. Biogas fuel helps to reduce greenhouse gas emissions by displacing the consumption of agricultural residues and kerosene.

Different alternative energy sources to replace or reduce fuelwood use such as back-boilers, kerosene depots, small hydropower plants, solar water heaters, have been installed in Mountain areas; and biogas, electricity, improved cook stoves, and solar power in the Terai. Studies show that these have reduced fuelwood consumption and thereby increased conservation of forests and biodiversity (Wells and Brandon 1992, Lama and Lipp 1994). Biogas provides an alternative renewable energy source, which has the potential to significantly reduce pressure on forest, soil and associated terrestrial ecosystems (Agoramoorthy and Hsu 2008).

With the installation of biogas systems, the annual reduction of fuelwood per HH is 2 tonnes. Following the assumption that 32.7 metric tonnes of fuelwood is harvested per hectare per annum, the national impact of using biogas on the protection of forest is as follows: using 111000 systems, there is a protection of 6790 ha of forest land and a total of 9 million trees. Furthermore, the operational biogas systems are estimated to displace the use of 222 thousand tones of fuelwood, 3.6 million litres of kerosene and replace chemical fertilizers with 189 thousand tonnes of bio-fertilizer annually (Mendis 2005). The savings in fuelwood help to slow the rate of deforestation in rural Nepal, while the savings from kerosene and fertilizer reduce ecological and economic pressure.

1.1.4 Biogas and Global Warming Mitigation Potential

Although greenhouse gases (GHGs) like carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) occur naturally in the atmosphere, human activities have changed their atmospheric concentrations leading to global warming and other environmental consequences. Cost-effective technologies are available that can stem GHG emissions growth by recovering methane and using it as a renewable energy source. The most common of these technologies are anaerobic digesters (Cornejo and Wilkie 2010). Global warming poses one of the major environmental challenges and the need to establish technologies that mitigate GHGs and adverse impacts of climate change is a must. Biogas technology may provide an opportunity for global warming mitigation through replacing fuelwood (for cooking), kerosene (for lighting and cooking), chemical fertilizers (with bio slurry) and saving trees from deforestation (Pathak *et al.* 2009)

1.2 Statement of Problems

In a country like Nepal, where sustainable economic growth is necessary and population growth is high, energy demand will continue to rise in the years to come. Energy consumption patterns and the rise in demand, their sources, and ways in which they are harnessed and utilized have implications for the environment and natural resources, which ultimately affect overall development. Fuelwood extraction is the major threat to the forests in the Himalayan country Nepal, where majority of the energy needed for households comes from fuelwood. As a result, the percentage cover of forest is declining day by day from 45.5 % in 1964 to 29 % in 1994 (Acharya and Dangi 2009). Forests are habitat to large number of flora and fauna, but the high fuelwood consumption has exerted immense pressure on forest resources. In order to enhance the conservation activities and preserve the biodiversity, programs promoting alternative energy need to be implemented, that reduce pressure on forest resource. The forest conservation might be possible through involving communities towards adoption of alternative sources of energy. It is necessary to assess the contribution and effectiveness of those measures in conservation of biodiversity. This study assesses the contribution of biogas in reducing fuelwood consumption and thus reflects its role in easing ecological stress. Thus the study attempts to reflect the linkage between biogas use and ecological stress.

1.3 Research Questions

The study was based on following research questions:

i. Is there significance different in fuelwood, kerosene and fertilizer consumption among households with and without biogas?
ii. What is the global warming mitigation potential of biogas in the study area?

1.4 Objectives of the Study

The general objective of the research is to study the role of biogas in easing ecological stress in Buffer Zones of Suklaphanta Wildlife Reserve.

The specific objectives of the study are:

i. To assess the role of biogas in forest area protection and compare fuelwood, kerosene and fertilizer consumption among households with and without biogas.
ii. To study people perception on biogas and its relation to forest conservation.
iii. To estimate the global warming mitigation potential of biogas.

1.5 Scope of the Study

Wood harvest can have detrimental effects on the structure and function of park and buffer zone forests, yet alternatives to wood and biomass-based energy are not available for most households. A sustainable alternative energy program is crucial to mitigate the harmful effects of excessive use of wood for energy. Promotion of alternative energy has been a major component of biodiversity conservation, because it reduces human pressure in the park and buffer zone forests.

Several studies such as Omer and Fadalla (2003), Prasertsan and Sajjakulnukit (2006) and Yu *et al.* (2008) discuss potential of biomass energy as an alternate source of energy and review the ecological, social, cultural and economic impacts of biogas technology. Many studies have also addressed different types of benefits of biogas such as health, education, employment generation, reduction in fuelwood consumption etc. However, this research does not explicitly quantify these benefits.

CHAPTER II

LITERATURE REVIEW

MoFSC (1988) has clearly focused on the necessity of alternative energy sources although the combined impact of energy saving stoves and solar panel plants can probably not reduce fuelwood needs by more than 15 % during the period of Master Plan 1988-2010.

According to Wells and Brandon (1992), Lama and Lipp (1994) and DNPWC (1999) biomass and forest resources are the important sources of household energy all over the world. About half of the world's households, mainly in developing countries use fuelwood. Different alternative energy sources to replace or reduce fuelwood use such as back-boilers, kerosene depots, small hydropower plants, solar water heaters, have been installed in Mountain areas of Nepal; and biogas, electricity, improved cook stoves, and solar power in the Terai. Studies show that these have reduced fuelwood consumption and thereby promoting increased conservation of forests and biodiversity.

Devkota (1993) explained that, an improved cooking stove is an alternate and efficient energy tool which uses the fuelwood efficiently. It was revealed that the use of improved cooking stoves could reduce the fuelwood requirement by at least 28 % compared to the traditional stoves. In addition, it has benefit of reducing health risks. The uses of improved cooking stoves conserve heat and reduce heat dissipation with minimal waste. It was reported that 30-50 % fuelwood could be saved through the proper use of improved stoves.

According to CMS (1996), slurry from one kilogram digested dung can yield up to an extra 0.5 kg nitrogen compared to fresh manure. Sasse (1988) estimated the N: P: K content in the bio-slurry as 2.7:1.9:2.2 respectively.

Report published by WECS (1998) states uncontrolled access to and use of forest resources at many places are leading to forest degradation in Nepal. The forest fuelwood meets about eighty one percent of the total fuel consumption.

According to Mendis and van Nes (1999), emission coefficients for non sustainable fuelwood and kerosene are 1.50 tons CO_2e per ton and 2.50 tons CO_2e per 1000 lt of kerosene. Based on these emission factors, a rural household with biogas reduces about 4.50 tons CO_2 being released in to the atmosphere each year. In other words, every biogas system in Nepal avoids nearly 4.50 tons of carbon emissions per year by reducing the use of fuelwood in the kitchen.

According to the Biogas User's Survey carried out by BSP (2000) for 600 biogas users and 600 non-users, four percent more non-biogas users have respiratory diseases than those who own biogas plants. Qualitative information from various household surveys carried out by BSP has revealed that problems like respiratory illness, eye infection, asthma and lung problems have decreased after installing a biogas plant. Similarly, those who had problems like asthma, eye infections and lung problems found that their problems had decreased after displacing dirtier fuels with biogas.

According to Heltberg *et al.* (2000), fuelwood collection and consumption are intricately linked to natural resource management. There is a two-way relationship between fuelwood collection and deforestation. On the one hand, demand for fuelwood from commons and forests cause resource degradation to the extent that collection exceeds sustainable yield. Forest degradation, on the other hand, leads to a situation of fuelwood scarcity. In addition, there are a number of other adverse consequences of forest degradation, including loss of biodiversity, deterioration of watershed management functions, release of carbon dioxide into the atmosphere, and soil erosion.

According to Omer (2002), renewable energy technologies such as solar, wind, etc. become more important since they are local resources, and also provide a near infinite source of energy. A new renewable fuels program in Sudan aims to improve environmental standards while making better use of domestic resources, providing an economic stimulus to the rural economy, and reducing CO_2 emissions. Biogas technology cannot only provide fuel, but is also important for the comprehensive utilization of biomass forestry, animal husbandry, fishery, protecting the environment, realizing agricultural recycling, as well as improving the sanitary conditions, in rural areas.

According to Shrestha *et al.* (2003), the biogas plants of sizes 4, 6 and 8 cu.m mitigate about 3, 4 and 5 tonnes of carbon dioxide, respectively per plant per year in the hills.

According to Starke (2004), in developing countries, wood is traditionally the main source of fuel for rural people who live adjacent to forest areas. About 2.50 billion people, mostly in Asia, use fuelwood or other biomass collected from forest for energy.

Winrock and Eco Securities (2004) has estimated that with the installation of biogas systems, the annual reduction of fuelwood was two tonnes per household and this provided an equivalent protection of 6790 hectares of forest per year through 11395 operational biogas plants. And the available carbon reduction per year per plant from the displacement of fuelwood, agricultural residues, dung and kerosene is nearly 4.60 tonnes of carbon equivalent.

According to DNPWC/PCP/UNDP (2004), Suklaphanta Wildlife Reserve and its buffer zone have 17899 households with 11639 households demanding 5-15 bhari fuelwood/month/HH. There is immense pressure on the nearby forest, and to reduce this pressure use of different alternative energy has been promoted.

Li *et al.* (2005) has reported that bio-slurry use can solve problems of soil degradation in areas where earlier dung has been used as a burning fuel and can also mean that less artificial fertilizer have to be bought which bring revenue to the household.

According to ADB/ICIMOD (2006), the forest conservation and sustainable development are only possible through involving communities towards alternative source of energy. As the need for fuelwood is a major cause of deforestation in Nepal, biogas helps conserve forest cover directly. Moreover, collecting fuelwood is one of the most toilsome tasks for rural women, often taking several hours per day.

Replacing wood with biogas has enabled many women to learn how to read and write, as they have finally got enough spare time to attend literacy classes.

According to BSP (2006), biogas (which is actually methane) - is also known as natural gas that can be used for cooking in a gas stove. Access to biogas saves huge amounts of fuelwood. With over 168613 plants installed under the SNV/BSP programme at the end of fiscal year 2006/07, of which 97 percent are operational displace the use of 328 thousand tonnes of fuelwood, 5.20 million litres of kerosene and replace chemical fertilizers with 280 thousand tonnes of bio-fertilizer annually and save approximately 1850 ha of forest annually.

According to Devkota (2007), biogas plant having size of 6 cu.m displace the use of three tonnes of fuelwood or 38 litres of kerosene annually and reduces 4.90 tonnes of carbon dioxide equivalent per year.

According to NTNC (2007), studies have revealed that the household consumption of fuelwood has been significantly reduced by 45 %-55 % after the installation of biogas plant.

In their research, Purohit and Kandpal (2007) have mentioned that biogas technology is being seriously promoted as an important option to meet the growing energy demand of rural areas in developing countries.

Fan *et al.* (2007) has mentioned that the household-size biogas digesters are estimated to reduce the rural use of fuelwood by 2 t per family, or 15.20 to 106 t/year, while also providing compost used as an excellent soil conditioner. In many forested rural areas, there is excessive fuelwood harvesting, which along with commercial timber extraction is contributing to deforestation, soil erosion, threats to biodiversity, and other problems.

Pei-dong *et al.* (2007) in their study have stated that in 2005, in China, large and medium scale biogas projects reduced emissions of CO_2 from 0.54 to 1.51 million tons/yr and CH_4 from 0.025 to 0.072 million tons CO_2e/yr.

Initially, it was estimated that each biogas system would reduce as high as 7.40 tonnes of GHG but the rate was capped at 4.99 tonnes of GHG per year per system due to limitation of a Small Scale Methodology of CDM (AEPC 2008).

According to Katuwal and Bohara (2009), biogas provides economic benefit to the country through reduced deforestation and carbon trading. In addition, by reducing green house gas emission, the technology helps in mitigating global warming and climate change. Thus biogas is a renewable, sustainable and clean source of energy.

Changa *et al.* (2011) has stated that in order to achieve sustainable development, comprehensive utilizations of renewable resources, efficient energy production and the reduction of energy consumption have become our major tasks. Bioenergy (biomass energy), derived from plant or animal sources, is an alternative clean energy with great potential for energy conservation. Biogas, referred as the gas produced by microbial degradation of organic matter through anaerobic process, is an efficient method to convert biomass into energy for cooking, heating, fueling, power generation and various purposes.

CHAPTER III

MATERIALS AND METHODS

According to specific tasks and anticipated outputs, the methodology of this research was designed to comprise of four major parts literature review, individual interview, collective discussions, and on-site survey. All tasks were completed by December, 2010. Interviews were conducted in 192 households to record data on perspectives on biogas plants, impact of biogas plants on local ecology, usage of forest fuelwood, chemical fertilizer, and kerosene among households with and without biogas use. Although a total of 3259 biogas plants have been built in the sampled Buffer Zones of SWR as of 2010 (BSP 2010), data on 96 biogas plants only (24 from each block) constructed after 2005 were included in the analysis.

3.1 Study Area

Shuklaphalta Wildlife Reserve (SWR) that lies in Kanchanpur district of the Far Western Development Region of Nepal was selected as the study area. SWR lies at 80^0 25' E and 28^0 35' N. It was officially declared as a wildlife reserve in 1976 although it was protected since 1965 as a Royal Sikar (Hunting Reserve). It lies in the flood plains of the Mahakali River with an area of 305 km^2. The Syali River forms the eastern boundary of this Reserve. The Reserve shares a common boundary with the Indian state of Uttar Pradesh in the South and West that formed by the Mahakali River, which is a major tributary of the Ganges. The northern boundary of the reserve comprises of forest and cultivated land.

The present study was confined at SWR and its buffer zone circumscribing 6 VDCs namely Suda, Beldandi, Piplari, Jhalari, Chandani, Dodhara and one municipality, the Mahendranagar Municipality. The buffer zone of the SWR in the Kanchanpur district has six different land use categories including agricultural land (69.98 %), forest (20.25 %), grassland (1.68 %), shrub land (0.93 %) and water bodies (7.16 %) covering an area of 152 km^2 (DNPWC 2003). The mean monthly minimum temperature varies from 10 to 12^o C in winter, gradually rising to 17^oC in the spring and 26^o C in the summer. In February and March, the maximum temperature rises up to 22^{o} C to 25^{o} C. Precipitation ranges from 1000 mm to 2000 mm. Over 90 % of the annual precipitation is during the Monsoon between June and September (DNPWC 2004).

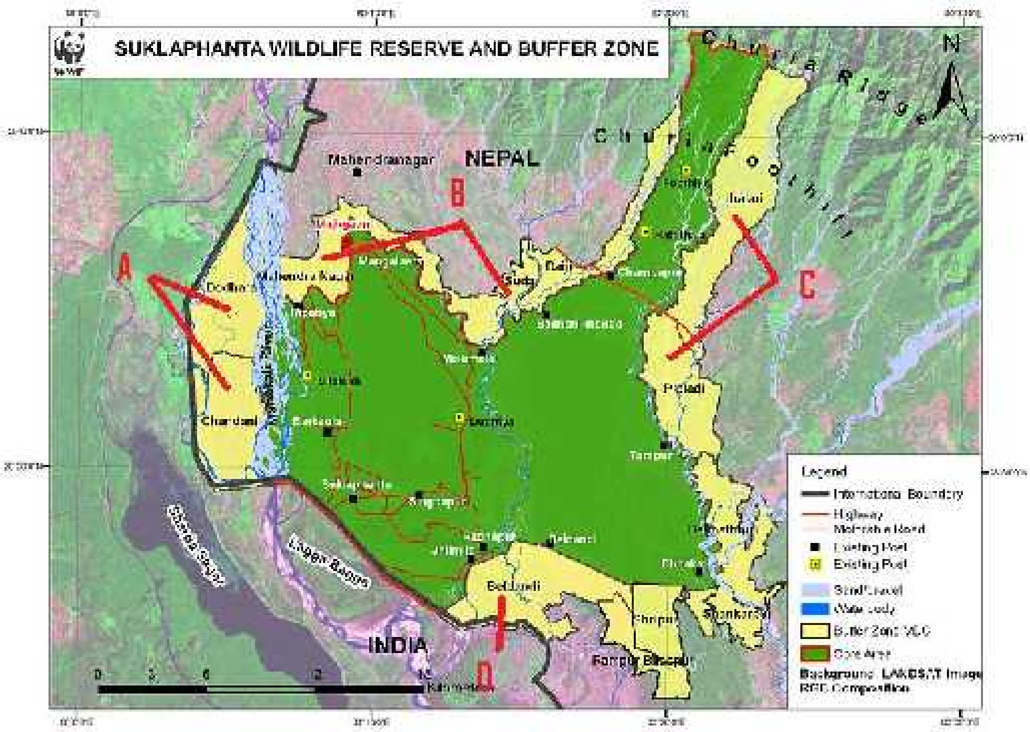

Fig 3.1: Study Areas Marked as A, B, C and D (Map Source: WWF Nepal)

The aquatic and terrestrial habitats of SWR contained more than 665 plant species belonging to 43 genera and 118 families, which makes the SWR as the highly species rich area, reported for any given PAs in Terai. The diverse wildlife habitats of SWR ranges from climax Sal forest to wet grassland and support more than 43 mammal species, including Royal Bengal tiger *(Panthera tigris)*, one horned rhinoceros *(Rhinoceros unicornis)*, wild elephant *(Elephas maximus)*, swamp deer *(Cervus duvauceli)*; 349 species of birds representing 54 families. Of these, 7 species are globally threatened. They are swamp francolin *(Francolinus gularis)*, bengal florican *(Houbaropsis bengalensi)*, sarus crane *(Grus antigone)*, white rumped vulture *(Gyps bengalensis)*, slender-billed vulture *(Gyps tenuirostris)* and lesser adjutant *(Leptoptilos javanicus)* (DNPWC/PCP/UNDP, 2004).

3.2 Desk Study

Required relevant reports, previous studies and procedure were reviewed and analyzed.

3.3 Research Design

3.3.1 Sampling Site Selection

From study point of view the wildlife reserve and its buffer zone were divided into four blocks; North, South, East and West. Chandani – Dodhara from West, Mahendra Nagar and Suda from North, Pipladi and Jhalari from East and Beldandi from South (marked as A, B, C and D, respectively as in Fig 3.1) were selected for the study. In order to generate reliable and valid data and minimize random error, probability technique, simple random sampling was applied.

3.3.2 Data Collection

Household Survey

It is very essential for collecting quantitative data especially to know the actual status of energy consumption, type of energy they rely on and to collect information based on biogas. The household survey included social variables like demography, occupation, caste, class and education. The questionnaire was pre-tested before the main survey with small focus group assembled to discuss their reactions to questionnaire prior to detail survey. At least 15 % households using biogas as source of energy were selected for this study.

Since extra questionnaires and sample size are often required to reduce response bias, an additional of 10 % reserve samples were considered by assuming the probability of incomplete and unrealistic samples, which was taken out at final analysis.

Group Interview and Activities

Focus Group Discussion (FGD) on people's perception on biogas and its impact on biodiversity and forest was done with local inhabitants, buffer zone management committee and wildlife reserve officials.

Key Informants Survey

It was another important technique for the data collection in this survey, conducted during field study. Enquiring who the key informants are and seeking them out to solicit relevant information. Key informants like past and incumbent executive members of CFUGs, BZMCs, elderly people, and teachers related to the field of this study was enquired and seeking them out, they were interviewed using key informants interview schedule as a tool of this technique.

Observation

The information was also collected by the application of non-participant method. Biogas plants of each household selected in sample was visited and observed. The data were recorded while observing the household environment, condition of biogas plant, number of cattle reared, site of slurry output and its utilization during household study.

3.4 Data Analysis

Both quantitative and qualitative data were analyzed through standard technique available and applicable statistical tools were used for this research. MS- Excel computer program was extensively used.

The equivalent forest area saved was estimated based on the study of Winrock and Eco Securities (2004) on Impact of Biogas on Forest. The estimated number of trees saved through potential biogas plants was based on the estimation of an annual saving of 11.6 trees per biogas plant (Devkota 2007).

For statistical analysis online Z-test calculator (Joosse 2011) was used:

$$Z = \frac{(\bar{X}_1 - \bar{X}_2)}{\sqrt{\frac{\sigma_1{}^2}{n_1} + \frac{\sigma_2{}^2}{n_2}}}$$

Where, $\bar{X}_1$= mean of sample 1 and $\bar{X}_2$= mean of sample 2

σ_1= standard deviation of sample 1 and σ_2 standard deviation of sample 2

n_1 = number of sample 1 and n_2 = number of sample 2

3.5 Calculation of Global Warming Mitigation Potential (GMP)

Global warming mitigation potential of biogas plant was calculated considering five factors as shown in the following equation.

GMP (CO_2 equiv.) = GWP of CO_2 emission reduction from kerosene and fuelwood savings + GWP of CH_4 emission reduction from fuelwood saving + GWP of CO_2 emission reduction from N, P and K fertilizer production + GWP of N_2O emission reduction from N fertilizer application – GWP of CH_4 leakage from biogas digester.

(Source: Pathak *et al.* 2009)

Calculation formula for project CH_4 emissions per plant size per year = m^3 biogas production × % methane concentration in biogas × 0.71 kg/m^3 × 10 % × 21 tCO^2eq/tCH_4. (Source: UNFCC 2006)

CHAPTER IV

RESULTS

4.1 Average Family Size

The table 4.1 shows the average family size among household with biogas and households without biogas, which was not similar. The average family size was less in households with biogas of Magendranagar-Suda and Chandani-Dodhara; whereas this was opposite in households of Jhalari-Piplari and Beldandi.

Table 4.1: Average Family Size in HHs with and without Biogas

Site	HHs without biogas	HHs with biogas
M.Nagar-Suda	6.50	6.02
Chadani-Dodhara	7.14	7.08
Jhalari-Piplari	7.00	7.47
Beldadi	6.70	6.87

4.2 Average Number of Cattle

The average cattle size was more in households with biogas as compared to households without biogas (table 4.2). As the feed for biogas plants are provided from the animal dung, biogas using households reared more cattle.

Table 4.2: Average Number of Cattle in HHs with and without Biogas

Site	HHs without biogas	HHs with biogas
M.Nagar-Suda	2.10	3.20
Chadani-Dodhara	4.10	5.00
Jhalari-Piplari	4.40	4.52
Beldadi	4.40	4.87

4.3 Sources of Fuelwood

The source of fuelwood varies from private land, community forest and reserve forest to other secondary sources like river (Fig 4.1). Majority of the respondents collect fuelwood from private land and reserve forest; whereas less respondents collect fuelwood from community forest.

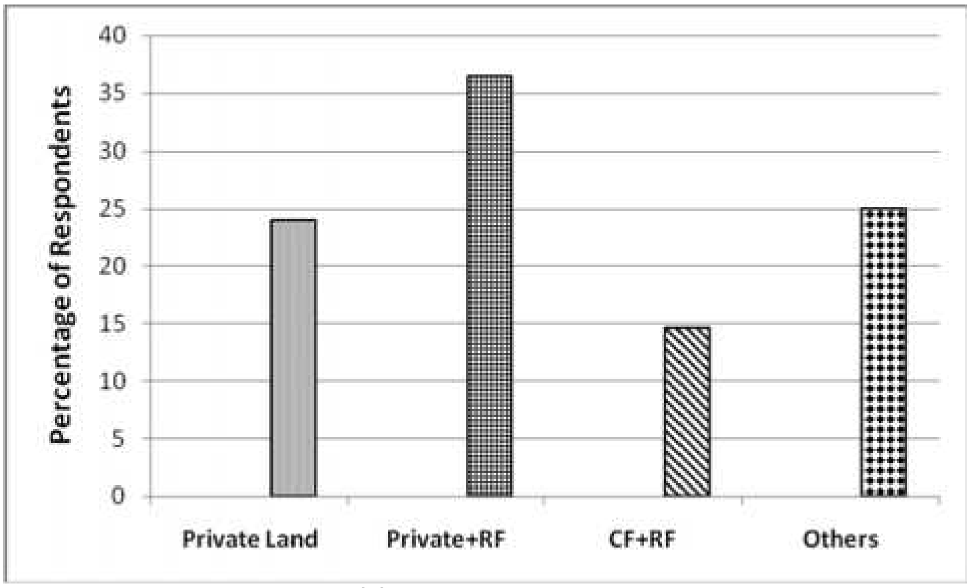

Fig 4.1: Sources of fuelwood within study area

4.4 Average Fuelwood Consumption in kg/HH/year among HHs with and without Biogas

The average fuelwood consumption among the four study sites vary between biogas users and non biogas users. The fuelwood consumption was highest among households without biogas of Piplari-Jhalari which was about 3569.34 kg/HH/year; whereas the least was that of Mahendranagar-Suda (fig 4.2). The average change in percentage of fuelwood consumption compared to biogas and non-biogas households is 62.84 in Beldandi. The average use of fuelwood in the households without biogas was 3006.81$\pm$338.50 kg/HH/year and with biogas was 1265.62$\pm$191.53 kg/HH/year ($Z = 43.86$, $p < 0.0001$), which showed a significant reduction in fuel wood consumption as source of energy.

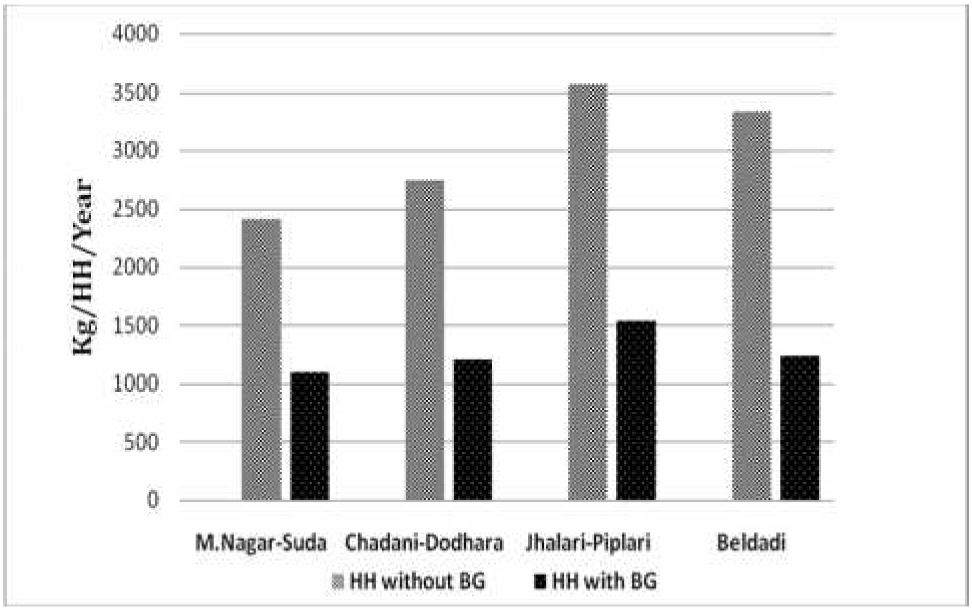

Fig 4.2: Average fuelwood consumption in kg/HH/year among HHs with and without biogas

4.5 Average Kerosene Consumption in lt/HH/year among HHs with and without Biogas

The average kerosene consumption among households with biogas and without biogas has also decreased (fig 4.3). The average kerosene consumption in lt/HH/year in households with biogas was 25.02, 26.44, 17.33 and 15.69 respectively in Mahendranagar-Suda, Chandani-Dodhara, Jhalari-Piplari and Beldandi.

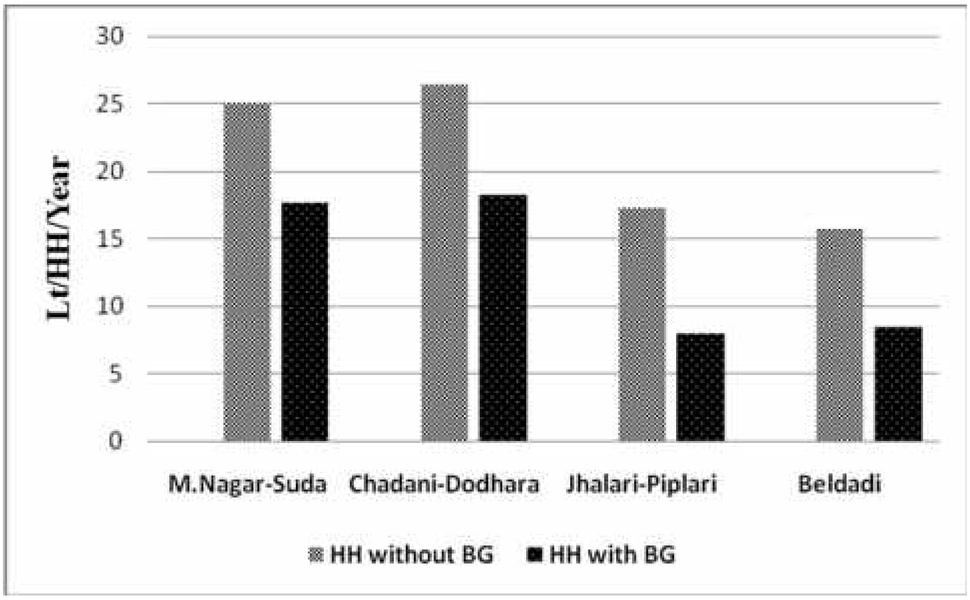

Fig 4.3: Average kerosene consumption in lt/HH/year among HHs with and without biogas

Whereas the kerosene consumption when compared among HHs with and without biogas, it was lesser by 29.33 % to 53.8 % in HHs with biogas. Furthermore, the average usage of kerosene was also significantly reduced by almost 39.81 % from 21.20±1.56 lt/HH/year to 13.25±1.17 lt/HH/year (Z= 39.94, p<0.0001).

4.6 Average Fertilizer Consumption in kg/Ha/year among HHs with and without Biogas

The difference in consumption of chemical fertilizer among the HHs with biogas and those without biogas was very less. The average percentage change in chemical fertilizer use was 16.8, 9.1, 11.1 and 8.6 respectively in Mahendranagar-Suda, Chandani-Dodhara, Piplari-Jhalari and Beldandi (fig. 4.4). The consumption of another factor, chemical fertilizer, analyzed as one of the indicators for easing ecological stress was more in HHs with biogas (144.08±6.33 kg/Ha/year) compared to households without biogas (127.82±6.05 kg/Ha/year).

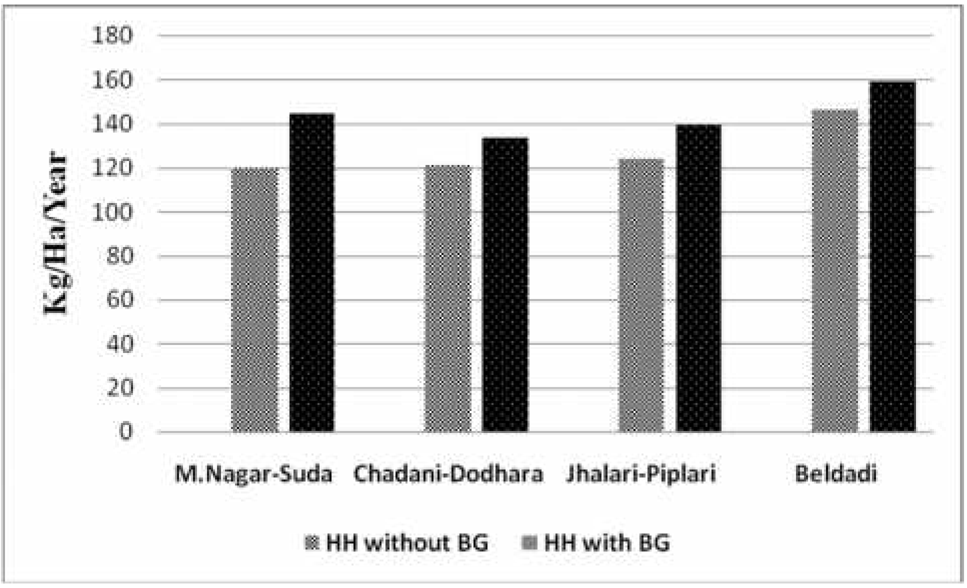

Fig 4.4: Average fertilizer consumption in kg/Ha/year among HHs with and without biogas

4.7 Equivalent Forest Area Protected

The biogas plants help to reduce the consumption of fuelwood as major source of energy. After the installation of biogas plants the annual average saving of fuelwood was 1.74 tonnes/HH/year (Table 8 of Annexes). Similarly, the equivalent forest area protected from the saving of fuelwood was 0.05 ha/biogas plant/year. Thus, the biogas plants reduce the consumption of fuelwood and protect the forest. From the study it was estimated that the surveyed biogas plants have potentiality to save about 1113 tress per year (Table 9 of Annexes). This helps in conservation of habitat of flora and fauna and associated biodiversity.

4.8 People Perception

4.8.1 Perception on Role of Biogas in Forest Conservation

People perception on role of biogas in conservation of forest has also been assessed. According to which 67 % of the respondents (fig. 4.5) has perceived that after the installation of biogas in the buffer zone there has been increase in the number of wild animals in the reserve and there has been improvement in the forest status of the reserve. Even after promotion of alternative source of energy 24 % of the respondents have perceived it to be decreasing,

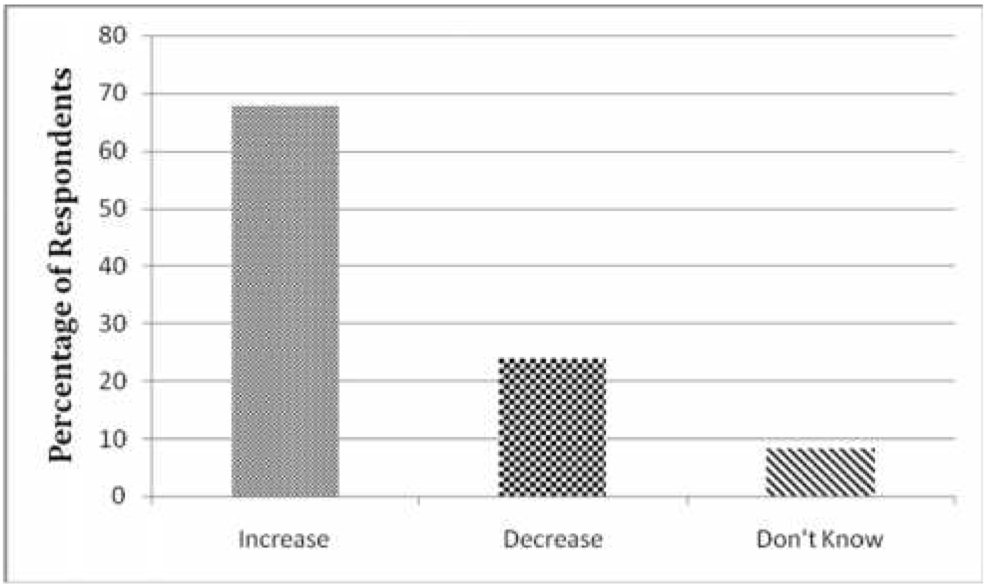

Fig 4.5: People perception on role of biogas in forest conservation

4.8.2 Perception on Biogas use and Level of Satisfaction

Fig 4.6 describes about the people perception towards use of biogas and level of satisfaction. All the respondents who has installed biogas has benefited in various terms such as time and money saving; heath and sanitation improvement. About 80 % of the respondents who has installed biogas in their household are fully satisfied with the plant whereas about 20 % of them are partially satisfied.

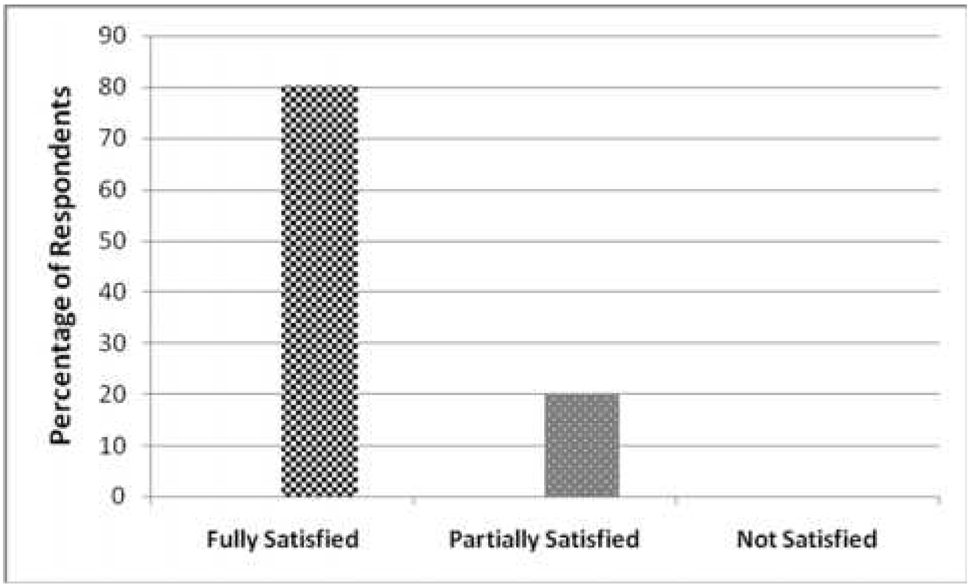

Fig 4.6: People perception on biogas use and level of satisfaction

4.9. Calculation of Global Warming Mitigation Potential (GMP)

Biogas plants in the study area with average of 4.30 cattle producing 4730 kg dung produces 2365 m^3 of biogas per annum. This amount of biogas, when compared with households without biogas substitutes 2029 kg of fuelwood and 9.33 lt of kerosene, the global warming potential (GWP) of which were 3879 and 22.50 kg CO_2 equivalent. Biogas slurry generated by the biogas plant was 1829 kg C which in "theory" could substitute 66, 52 and 38 kg N, P and K fertilizer respectively. The GWP for producing equivalent amount of chemical fertilizer would have been 247 kg CO_2 equivalent. Moreover, application of 66 kg N fertilizer in soil emits 0.46 kg N_2O-N with the GWP of 143 kg CO_2 equivalent. But in present study, biogas slurry generated by the biogas has not been able to reduce the use of chemical fertilizer, so the GWP of chemical fertilizer has been discarded. The sampled biogas plant leaks methane of 100.70 kg CO_2 equivalent and contributes to the global warming. The GMP of each biogas plant was calculated as 1787 kg CO_2 equiv./year. Whereas, GMP of the biogas plant, if there has been reduction in chemical fertilizer consumption would have been 2034 kg CO_2 equiv./year.

CHAPTER V

DISCUSSION

Excessive use of fuelwood in rural areas was known to cause forest decline in many developing countries and it was reported to account for nearly 54 % of all global harvests annually with a direct role in forest loss (Osei 1993). In Nepal, rural consumption of fuelwood accounts for nearly 80 % with demand exceeding supply. Communities that live in remote parts of the country rely in forest resources, with majority of them using biomass as major source of energy (ADB/ICIMOD 2006, WECS 2010). If the intensity of deforestation in the country increases in the future, the implementation of biogas plants in rural areas could certainly save enormous amount forest trees and biodiversity. Fuelwood collected from forest areas still serve as the main fuel consumed in Nepal and peoples' dependency on fuelwood is major setback for local biodiversity due to the unsustainable removal of natural forest vegetation.

5.1. Fuelwood, Kerosene and Chemical Fertilizer Consumption

There has been considerable reduction in fuelwood consumption among the households with and without biogas. Before the establishment of biogas, locals used to depend on the fuelwood collected from reserve forest and private land as well. The result showed that after the installation of biogas the fuelwood collection trend has decreased. The average fuelwood consumption in each household without biogas was 3006.81 kg/HH/year. Whereas the fuelwood consumption among households with biogas was 1265.62 kg/HH/year. The average reduction in fuelwood consumption among households with and without biogas was 57.545 %, which is more when compared to 45 %-55 % (NTNC 2007). The fuelwood consumption was high in Piplari-Jhalari as the cattle size was high and the area is adjacent to SWR because of which locals have high accessibility to fuelwood collection.

Biogas produces organic fertilizer that is high in Nitrogen, Potassium and Phosphorous contents. This organic form of fertilizer can be used in farmlands as an alternative to chemical fertilizers. It has been estimated that there is an annual saving of 4329 tonnes nitrogen, 2109 tonnes phosphorous and 4329 tonnes potassium due to installation of biogas (Gautam *et al.* 2007) .The use of chemical fertilizer in kg/ha/year was slightly more in case of households with biogas (144.08) than without biogas (127.82). The result is similar to Bhattarai (2006), according to which use is more in case of biogas HHs (97.1) than in non use (94.09). The difference is not comparable to the study by Agoramoorthy and Hsu (2008) in India and Gautam *et al.* (2007) in Nepal. Even after the biogas plants were installed, the need for chemical fertilizers was not reduced and people were seen using the chemical fertilizer. If organic slurry is used as natural fertilizer for crop, it enhances top soil health in agricultural areas, promote terrestrial ecosystem and ease ecological stress. As the bio slurry is in liquid form locals find difficulty in transporting the manure to their farmland, instead they prefer to use chemical fertilizer. At the same time due to lack of awareness there is also a wrong notion that the fertility value of manure gets decreased after being fed to the biogas plant, because of which also farmers are using chemical fertilizer in extra quantity along with the slurry.

Kerosene is widely used in Nepal for cooking and lighting purpose. Due to installation of biogas plants, the use of kerosene has been reduced by almost 7.70 million litres per annum in Nepal (BSP 2006). The study showed both households with and without biogas use kerosene. The average kerosene consumption in the VDCs was 13.25 litres per year for households with biogas and 21.20 litres per year for households without biogas. This shows in the study area, biogas has been able to contribute in considerable amount in reducing kerosene consumption. Which is less compared to study by Devkota (2007) and Agoramoorthy and Hsu (2008), according which each biogas plant of 6 cu.m displaces 38 litres and 37 litres of kerosene annually respectively. The average number of cattle is more in households with biogas (4.39) as compared to those not having biogas (3.75). If it is possible to install the biogas plants in those HHs as well they could contribute to some extent in reducing the pressure for fuelwood collection; which in turn could help in conserving forest and associated habitat of flora and fauna.

5.2. Forest Area Protection

In the study area, each biogas plant saved about 1.74 tonnes of fuelwood annually and 0.05 ha of forest per year which was comparable to an annual saving of two tonnes of fuelwood per household and 0.06 ha of forest per biogas plant as studied by Winrock and Eco Securities (2004) and CMS (2007). This was less when compared to the displacement of three tonnes of fuelwood by a biogas plant (Devkota 2007).

5.2. People's Perception on Biogas

Majority of the respondents (> 80 %) has perceived that biogas plants has in some way contributed in the conservation of forest as they believed after the promotion of biogas in the buffer zones, there has been decrease in deforestation. Biogas, being an eco-friendly technology, safeguards local biodiversity, ecological and forest resources. Due to less efficient performance of biogas during winter season and irregular availability of feeding material, about 20 % of the respondents are partially satisfied with the technology. Whereas, majority of the respondents (80 %) are fully satisfied with the use of biogas as source of energy as it helped to reduce the drudgery associated with fuelwood collection, saved cooking time, improved kitchen environment and reduce health problems.

5.3. Global Warming Mitigation Potential

There is a scientific consensus that global warming poses one of the major environmental challenges and the bulk of the so-called GHGs originate from fossil fuel consumption (Peidong *et al.* 2007). Biogas technology has been able to reduce the emission of GHGs. To start with, biogas generation by a family size biogas plant (6 cu.m), operated with dung produced by cattle, commonly reared in a household, was calculated using the relationship of 0.50 m^3 biogas/kg dry dung (Khendelwal and Mahdi 1986). From the study area the GMP of each biogas plant was calculated as 1787 kg CO_2 equiv. /year. This is comparable to that of Pokharel and Munakarmi (2003), which mentions that a 6 cubic meter biogas plant avoids 2.59 tonnes of CO_2/HH through saving of fuelwood and kerosene. But the result is less compared to 6 tonnes CO_2 per plant per year (Shrestha *et al.* 2003), 4.50 tonnes (Mendis and van Nes 1999), 4.90 tonnes (Devkota 2007), 4.60 tonnes of carbon equivalent (Winrock and Eco Securities 2004), 7.80 tonnes (Aryal 2007), 4.99 tonnes (AEPC 2008) of

Nepal, 9667 kg CO_2 equiv. (Pathak *et al.* 2009) of India. So far biogas has been viewed as an alternate energy source but it can play a major role in mitigating global warming by substituting cooking fuel and chemical fertilizer. Despite the concerted efforts by governments its adoption has not been very high because of high up-front investment cost of constructing a biogas plant.

CHAPTER VI

CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

Based on the results of the study it could be concluded that in buffer zones of Suklaphanta Wildlife Reserve:

- The consumption of fuelwood and kerosene was significantly reduced by 57.54 and 39.81 %, respectively when compared among HHs with and without biogas.
- Equivalent protection of forest area was calculated as 0.053 ha/BG/year
- Chemical fertilizer consumption trend is more in households with biogas.
- The global warming mitigation potential of each biogas plant was calculated as 1787 kg CO_2 equiv./year.
- Biogas has been able to reduce ecological pressure in terms of reduction of fuelwood and kerosene consumption only.

6.2. Recommendations

For General Public

- There is a need to minimize use or supplement traditional energy supply systems installed in household level by alternative forms of renewable energy like biogas.
- ICS could be a suitable RET for people who cannot afford to install biogas.

For Policy Makers and Concerned Authorities

- Villagers should be made aware about the fertility value of bio-slurry and also the best methods of utilizations of slurry in farm.
- Modern efficient designs of biogas stoves should be introduced and distributed in the rural areas which work efficiently in all seasons.
- Beside the biogas, the potentiality for installment of ICS has to be assessed which could also reduce the annual fuelwood consumption.
- More researches should be focused on the biogas and awareness programme should be implemented in grass root level for disseminating the knowledge about benefits of biogas plants in employment generation and gender issue also.

ANNEXES

Table 1: Average Fuelwood Consumption in kg

Site	HH without Biogas	HH with Biogas	% Reduction
M.Nagar-Suda	2412.8	1094.4	54.64
Chadani-Dodhara	2747.2	1209.6	55.9
Jhalari-Piplari	3569.34	1540	56.8
Beldadi	3337.5	1240	62.84

Source: Field Survey 2010

Table 2: Average Kerosene Consumption in lt

Site	HH without Biogas	HH with Biogas	% Reduction
M.Nagar-Suda	25.02	17.68	29.33
ChadaniDodhara	26.44	18.28	30.33
Jhalari-Piplari	17.33	8	53.8
Beldadi	15.69	8.49	45.8

Source: Field Survey 2010

Table 3: Average Fertilizer Consumption in kg

Site	HH without Biogas	HH with Biogas	% Change
M.Nagar-Suda	120.24	144.56	16.8
ChadaniDodhara	121.04	133.2	9.1
Jhalari-Piplari	123.86	139.34	11.1
Beldadi	146.2	159.04	8.6

Source: Field Survey 2010

Table 4: Sources of Fuelwood

Sources	Percentage of Respondents
Private Land	23.95
Private+ RF	36.45
CF+RF	14.58
Others	25

Source: Field Survey 2010

Table 5: People Perception on Role of biogas in Forest Conservation

Perception	No of HH	% of Respondents
Increased	130	67.7
Decreased	46	23.95
Don't Know	16	8.33

Source: Field Survey 2010

Table 6: People Perception on Biogas and Level of Satisfaction

Perception	No of HH	% of Respondents
Fully Satisfied	77	80.20
Partially Satisfied	19	19.79
Not Satisfied	0	0

Source: Field Survey 2010

Table 7: Impact of Biogas on Forest

Particulars	**Nepal**
Total Number of systems installed	111,395
Annual Fuelwood saving (tonnes of fuelwood per HH per yr)	2
Total Fuelwood saving (million tonnes of fuelwood)	222,790
Equivalent Forest area Protection (ha)	6,790

Source: Winrock and Eco Securities 2004

Table 8: Equivalent Forest Area Protected

Particulars	**Nepal**
Total Number of systems sampled	96
Annual Fuelwood saving (tonnes of fuelwood per HH per yr)	1.74 (3006-1265 kg/HH/yr)
Total Fuelwood saving (million tonnes of fuelwood)	176.04
Equivalent Forest area Protection (ha)	0.05

Source: Field Survey 2010

Table 9: Total Number of Trees Saved

No. of Biogas Plants	Trees saved per biogas plant	Total No. of Trees saved per year
96	11.6	1113

Source: Field Survey 2010

Table 10: Average Fuelwood, Kerosene and Chemical Fertilizer Consumption

Parameters / Site	**Fuelwood in kg/HH/year (Mean+SD)**		**Kerosene in lt/HH/year (Mean+SD)**		**Fertilizer in kg/ha/year (Mean+SD)**	
	NBG HH	**BG HH**	**NBG HH**	**BG HH**	**NBG HH**	**BG HH**
Mahendranagar-Suda	2412.8+412.59	1094.4+271.75	25.02+1.86	17.68+1.33	120.24+5.52	144.56+7.83
Chandani-Dodhara	2747.2+301.65	1209.6+174.58	26.24+1.68	18.28+1.64	121.04+6.51	133.2+6.48
Beldani	3337.5+346.24	1240+162.53	15.62+1.12	8.49+0.94	146.20+5.88	159.04+4.48
Piplari-Jhalari	3569.34+293.55	1540+157.28	17.33+1.60	8+0.80	123.86+6.29	139.34+6.54
Mean + SD	3006.81+338.50	1265.62+191.53	21.20+1.56	13.25+1.17	127.82+6.05	144.08+6.33

Source: Field Survey 2010

Table 11**:** Coefficients used for calculation of Global warming mitigating potential of biogas plant

Parameter	Conversion Factor
CO_2 emission from kerosene burning (kg l−1*)*	2.41
CO_2 emission from firewood burning (kg kg−1	1.83
CH_4 emission from firewood burning (g kg−1*)*	3.9
Annual dung production per cattle (kg dry wt.)	1,100
Biogas production from cattle dung (m3 kg−1 dry wt.)	0.5
Methane content in biogas (%)	60
C content in slurry (kg kg−1 dry wt.)	0.4
N content in slurry (kg kg−1 dry wt.)	0.014
P content in slurry (kg kg−1 dry wt.)	0.011
K content in slurry (kg kg−1 dry wt.)	0.008
CO_2 emission for N fertilizer production (kg kg−1*)*	1.3
CO_2 emission for P fertilizer production (kg kg−1*)*	0.2
CO_2 emission for K fertilizer production (kg kg−1*)*	0.2
N_2O-N emission from N fertilizer application (kg kg−1*)*	0.007
Methane leakage from biogas plants (% of production)	10
GWP of CO_2 (kg CO_2 equiv. kg−1*)*	1
GWP of CH_4 (kg CO_2 equiv. kg−1	21
GWP of N_2O (kg CO_2 equiv. kg−1*)*	310

Source: Pathak *et al.* 2009

Questionnaire for Assessing Role of Biogas in Easing Ecological Stress

Sample Number: Date:

Interviewed by: GPS Location:

A. Household Information

1. Name of the Respondent: Sex:

2. Address: District: VDC: Ward No:
Village/Tole:

3. Education: illiterate, pre primary, primary, secondary, higher secondary, university

4. Occupation: Agriculture, Government Job, Private Job, Business, Wage labour, Other (specify)……….

5. Family Size:

S.N.	Name	Sex	Age	Education	Occupation	Income per month
1						
2						
3						
4						

6. Land Ownership

Type of land	Tenure type	Unit(Bigha/ kathha	Qty	Cost/unit(in Rs)

7. Livestock Number:

Livestock	Adult	Young
Cow/ox		
Buffalo		
Goat/sheep		
Others		

B. Information on Energy use

1. What are Source of Energy at your Home?

S.N	Types of energy	Yes/ No
1	Firewood	
2	Dung cake	
3	Agriculture residue	
4	Bio gas	
5	Kerosene	
6	Electricity	
7	LP Gas	
8	Other (specify)	

2. Which of the following Alternative Energy Technology do you have?

S.N.	**Energy technology**	**Yes/No**
1.	Traditional cooking stove (TCS)	
2.	Improved cooking stove (ICS)	
3.	Biogas (*Gobar* gas)	
4.	PV Solar Home system (PVSHS)	
5.	Others (Specify)	

3. Non Biogas User:

Fuel wood (Bhari/month)	Kerosene (Litre/month)	Fertilizers (Kg/Ha/year)

4. Biogas User:

Installed date: Capacity (cb.m):

No of livestock needed to operate biogas plant:

Attached with toilet: Yes….. No…..

Fuel wood (Bhari/month)		Kerosene (Litre/month)		Fertilizers (Kg/Ha/year)	
Before	After	Before	After	Before	After

5. Is Gas Produced from the Plant is Sufficient to Cook Food for your Family?

a. Yes b. No

6. If No, from where do you fulfill the Extra Energy Requirements?

7. What motivated you to opt for the Alternative Energy Program and this Particular Device?

SN	**Reason**	**Yes/No**
1	High subsidy rate	
2	Peer motivation	
3	Scarcity of fuel woods	
4	Health benefits	
6	Others	

8. Perception towards Biogas:

Factors	**Yes/No**
Fuelwood Reduction	
Improve in Kitchen Environment	
Time Save in Cooking	

Financial Benefit	
Gas Sufficient for all Season	

Problems	Device Used
❑ Eye problems	❑ Biogas
❑ Dizziness	
❑ Chest pain	
❑ Cough	
❑ Insect manifestation	
❑ Others	

Fully Satisfied : if respondent says Yes for five factors

Partially Satisfied: if respondent says No for any one factor

Not Satisfied: if respondent says No for all five factor

9. Do you suffer from any Ailments from use of the Devices provided through the Alternative Energy Program?

C. Other Information

1. Where do you collect your Fuelwood from?

CF Government Forest Private Forest Own Land Others (specify)

2. Fuelwood use:

Fuelwood uses	Consumed per month
Cooking	
Preparation of animal feed	
Preparation of alcohol	

Space heating	
Water heating	
others	

3. Is the Fuelwood collected Sufficient?

Yes No

4. Condition of Forest before and after use of Biogas?

Improved Not Improved Don’t know

5. If improved, is it because of?

Decreased Consumption Afforestation Program

Rules, policy adopted Others

6. Which Species of Wildlife has become Common in this Area?

7. How do you say?

Sign Direct Obs Sound Increase in conflict Rate

8. Is it because of increase in Forest Density?

Yes No

➢

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