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Assessment of Current Energy Consumption Practices, Carbon Emissions and Indoor Air Pollution in Samagaun, Manaslu Conservation Area, Nepal

Rajani Suwal [a*] and Siddhartha Bajra Bajracharya [b]

[a] Central Department of Environment Science, T.U., Kritipur, Nepal.

[b] National Trust for Nature Conservation, Khumaltar, Lalitpur, Nepal.

* Corresponding author: rajni.suwal@gmail.com

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Abstract

Nepal is one of the lowest energy consuming countries in the world. More than 85 percent of its total energy comes from traditional biomass energy such as forests, agricultural residues and by-products from crops. Due to increasing per capita energy consumption, natural resources are being depleted with heavy emissions of GHGs in the atmosphere, which causes global warming. The main objective of the study was to investigate current energy consumption practices, to estimate particulate matter and carbon emissions from current practices and to recommend the most suitable alternative energy technologies. The fieldwork was based on primary and secondary data with a design methodology. Firewood burning was found to be the major source of energy used for cooking purposes in Samagaun. The use of this traditional fuel has negative environmental implications, such as deforestation, indoor air pollution and it ultimately affects human health. The results show that traditional cooking stoves (TCS) are used more than improved cooking stoves (ICS). The total amount of firewood used per day by TCS is 2135 kg/day, and by ICS it is 349 kg/day. The average amount of firewood consumed by traditional and improved cooking stoves per day is 62.79 kg and 43.63 kg, respectively. The annual per capita firewood consumption of TCS and ICS is 4401.9 kg and 3266.7 kg, respectively. The calculation shows that per capita firewood consumption by TCS users is 1.3 times higher than that of ICS users. The annual per capita carbon emissions from TCS and ICS is 8055.47 kg CO_{2e} and 5978.15 kg CO_{2e}, respectively. This calculation shows that ICS emits 1.3 times less CO_2 into the atmosphere than the TCS. The average mean particulate concentration at normal atmospheric conditions for a traditional cooking stove was found to be 2866 μg/Nm^3 and for an improved cooking stove 1333 μg/Nm^3, both of which far exceed the national standard of 230 μg/m^3 TSP. Based on the study results, metallic improved cooking stoves could be recommended as the best alternative energy technology in the study area.

1. Introduction

Energy is the center of economic, environmental and development issues in today's world. Clean, efficient, affordable and reliable energy services are indispensable for global prosperity. Developing countries in particular need to expand access to reliable and modern energy services to reduce poverty and to improve the health of their citizens by increasing productivity, enhancing competiveness and promoting economic growth. Current global energy systems are inadequate to meet the needs of poor people and are jeopardizing the achievement of the Millennium Development Goals **[1]**.

About one billion people in Asia depend on biomass as their main source of energy **[2]**. Nepal is one of the highest traditional fuel consuming countries in Asia because of its high dependency on traditional biomass fuels, mostly firewood, and to limited extent charcoal, and crops and animal residues **[3]**. From the total energy requirements of the country, the rural areas account for 80 percent; energy that is mainly used for cooking **[4]**. The burning of fuel wood, dung cakes, straw and agricultural residue creates many hazardous particles. Since cooking is usually done indoors, it can lead to severe health problems **[5]**.

Nepal's energy resources are presently classified into three categories, namely the traditional, commercial and alternative or renewable energy, by **[6]** the National Planning Commission, 1995. Traditional energy resources include fuel wood from forests and tree resources, agricultural residues from agricultural crops and animal dung in the dry form. Energy resources coming under the commercial or business practices are grouped into commercial energy resources that particularly include coal, grid electricity and petroleum products. Biogas, solar power, wind and micro level hydropower are categorized as alternative energy resources in Nepal **[7]**. Exploring renewable energy resources and technologies, which could be used by rural people, is critical to changing this situation. Substituting fuel wood as an energy source with renewable energy would help to reduce deforestation and greenhouse gas emissions **[8]**.

In the early 1990s, the Research Centre for Applied Science and Technology modified stove design, creating a stove that can be built completely from cheap readily available local materials. These have been promoted by various organizations to complement these efforts. Alternative Energy Promotion Centre/Ministry of Science and Technology executed the National ICS Program with the support of the Energy Sector Assistance Program. In 1999, the National ICS Program was implemented in the middle hills of Nepal through experienced NGOs and GOs **[9]**.

The rural population in Nepal is highly dependent on traditional biofuel for heating and cooking. This form of energy, however, is a threat to the environment and the health of the population. The high dependence on traditional energy sources increases the demand of the energy accordingly **[10]**. However, the use of energy based on fossil fuels decreases their stock for major environmental degradation. A lack of practices that use Renewable energy technologies (RETs), depending on traditional energy resources and depleting forest resources, are also major causes of underdevelopment in the country and the main cause of the sudden energy crisis. People in many remote villages are deprived of clean energy supply, though finding a clean energy supply is not on their list of priorities.

Viewing these perspectives in the study area, this report has been prepared by conducting a survey to study current energy consumption practices in rural households, to estimate the particulates matter (PM) from current practices, to compute the carbon emissions from these practices and to recommend the most suitable renewable energy technologies.

2. Methodology

2.1 Study Area

The research was conducted in Samagaun (**Figure 1**), which lies in the Gorkha District. Its coordinates are 28°34'58.6"N, 84°38'28.2"E and it is at the height of 3390 m.a.s.l. It has an area of 333.09 km^2. Samagaun is surrounded by High Mountain and traversed by the Buddhi Gandaki River. The Sama Village Development Committee (VDC) is situated on the flat land and consists of two settlements i.e. Sama and Samdo. The bio-climatic zone varies from sub-tropical to nival with various ecosystems as micro-habitats. It has a total population of 604, of which 281 are male and 323 female, with 197 households according to CBS 2011 **[11]**. The ethnic group is found to be Bhotia which originates from Tibet, and they like to call themselves lama.

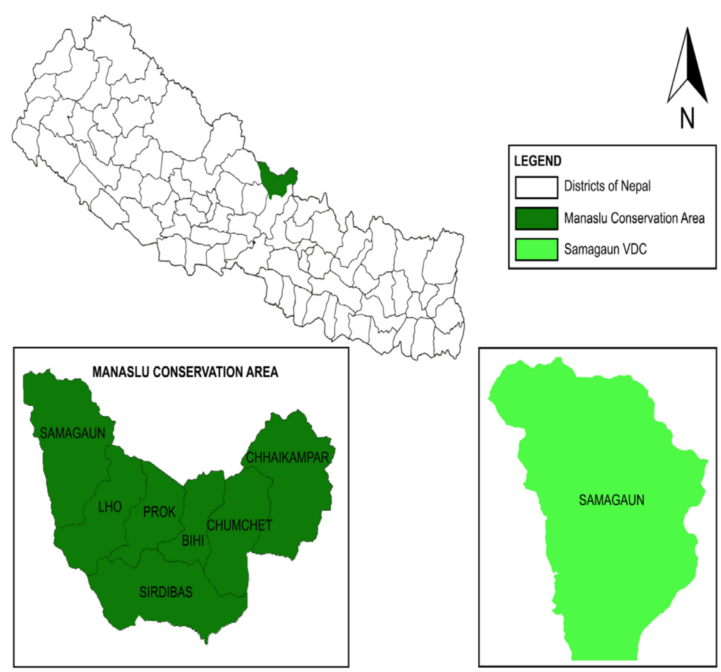

Figure 1: Map showing the study area

2.2 Data Collection

The field survey was conducted in May-June 2012. The structured questionnaire survey was conducted on a household level, with households possessing TCS and ICS. Both primary and secondary data were collected for the research study. First of all, the survey was designed and the questionnaire and interview schedule was developed. The data are of both quantitative and qualitative form. Qualitative data were collected through the questionnaire survey, focus group discussion, key informant interviews and observation, while the quantitative data were collected by measuring the indoor air pollution using the medium volume air sampler (Model no. APM 821, Envirotech Instruments Pvt. Ltd.).

2.3 Methods of data interpretation

The field data were analyzed using SPSS v.16 statistical tools, Correlation, t-test, Z-test, and Microsoft Excel to produce graphs and figures. To convert fuel wood reduction to greenhouse gas emission, 1 kg fuel wood burning is equivalent to 1.83 kg of CO_2 eqv. **[12]**. The average weight of one kg of fuel wood was determined by weighing each bundle of firewood from the sampled households with the help of a spring balance. To quantify the total amount of particulate matter in ambient air, a medium volume air sampler was used. The average concentration of particulate matter was calculated by step-by-step calculation of ambient particulate concentration **[13]**.

3. Results and Discussion

3.1 Types of cooking stove used

Out of 42 households, 81 percent used the traditional type of cooking stove and 19 percent used the improved type of cooking stove (**Figure 2**). Due to its remoteness the new technology of renewable energy has not reached this study area yet, and the traditional types of cooking stove remain dominant in number.

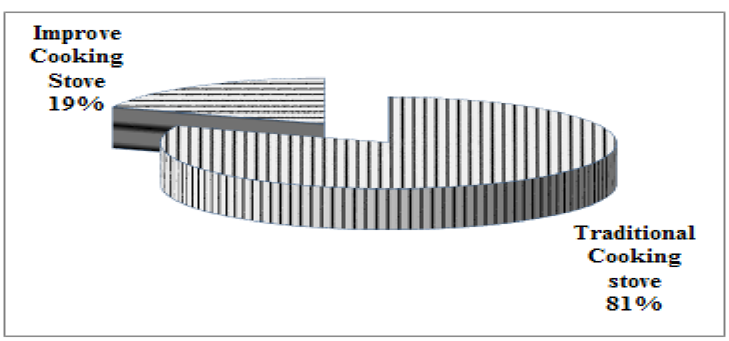

Figure 2: Types of cooking stove

3.2 Source of firewood

The source of firewood for all the respondents in Samagaun is from the protected forest area which is inside the Manaslu Conservation Area (MCA). Pangshar and Kermo are the two forests near Samagaun where inhabitants collect their daily domestic energy, only dry fodder and timber are allowed to be gathered rather than cutting down the trees. Mostly Betula utilis (Bhojpatra), Rhododendron campanulatum (Chimal) and Juniperus spp. (Dhupi) are found in the forest, which are used as the firewood for cooking purposes.

3.3 Firewood consumption

In Samagaun, the major energy source is firewood. The total energy consumption in the sampled households is 7668.6 kg/day. The average firewood consumption by TCS and ICS users per day was 62.7 kg/day and 43.63 kg/day, respectively. The per capita/year firewood consumption of TCS and ICS users was 4401.9 kg/person/year and 3266.7 kg/person/year, respectively (**Table 1**). The calculations show that per capita firewood consumption for a TCS user is 1.3 times more than for an ICS user. In the Sagarmatha National Park Buffer Zone (SNPBZ) the major energy sources are firewood 30%, kerosene 33%, dung 19% and liquefied petroleum gas 7.5% **[14]**.

The energy consumption of the study area is higher than the National annual per capita energy consumption of 15 GJ **[15]**. It is similar to the energy consumption scenario in Chekampar site in the MCA **[16]**. In this zone, winters are very cold and even in summer the temperature is not high with a mean annual temperature of 6 to 10°C **[17]**. Consequently, the people keep their stoves running for longer hours to keep their houses warm.

Table 1: Per capita firewood consumption

Type of stoves	Total no. of traditional cooking stove users (n)	Total amount of firewood used per day in kg (N)	Average firewood consumption per kg/day (N/n)	Per capita firewood consumption (kg/per person)	Per capita/ year firewood consumption (kg/per person/year)
Traditional(TCS)	34	2135	62.79	12.06	4401.9
Improved (ICS)	8	349	43.625	8.95	3266.75

Source: Field Survey 2012

The average firewood consumption by TCS and ICS users per day was 62.7 kg and 43.63 kg, respectively (**Table 1**). At a 5% level of significance (α = 0.05), the Z tabulated value is greater than the Z calculated value. It shows that there is no significant difference between the firewood consumption in TCS and ICS. (**Table 2**).

3.4 Carbon Emissions

The per capita/year carbon emissions from TCS and ICS were 8055.47 kg per capita/year and 5978.15 kg per capita/year, respectively.

The difference in the amount of carbon emitted by TCS over ICS was 2077.32 kg per capita/year (**Table 3**). This calculation shows that ICS emits 1.3 times less CO_2 into the atmospheric environment than TCS. The carbon emission is slightly similar to that of the Syafrubesi area (2190 kg/yr) as recorded in a study carried out by Silwal (2011) **[18]**. This might be due to the cold climate of the region and the lack of any other alternative sources of energy other than firewood taken from the nearby forest.

Table 2: Result of the z- test of firewood consumption between the TCS and ICS

Firewood consumption TCS (X_1) in kg	Firewood consumption in ICS (X_2) in kg	α	zcal. value	ztab. value
62.79	43.63	0.05	0.27	1.96

Table 3: Result of the z- test of firewood consumption between the TCS and ICS

Types of stove	Per capita/year in kg firewood consumption (kg/per person/year) (X)	Carbon emissions per capita/year in kg (X kg *1.83kg)	Difference in amount of Carbon emitted per capita/year in kg
Traditional (TCS)	4401.9	8055.47	2077.32
Improved (ICS)	3266.75	5978.15	

Source: Field Survey 2012

3.5 Indoor air pollution

As a result, the study reported higher 24 hour mean Indoor air pollutant (IAP) levels for ICS and TCS. It was found that with traditional cooking stoves the total suspended particles (TSP) were 2866 μg/Nm^3 and with improved cooking stoves the TSP were found at 1333 μg/Nm^3, both of which far exceed the National standard of 230 μg/m^3 TSP. The value of IAP is slightly less with a traditional stove and slightly higher with an improved stove as compared to **[19]**. The mean personal exposure to TSP with traditional (agena) and improved cooking stoves is 3.92 and 1.13 mg/m^3, respectively. Due to the lack of a chimney or other fume outlet with the traditional stove, these facilities emit fumes directly into the kitchen area which have a direct impact on human health.

A statistical analysis was carried out on the indoor air pollution measurements. At a 5% level of significance (α = 0.05), the t-tabulated value is less than the t- calculated value. It shows that there is a significant difference in total suspended particles between the TCS and ICS (**Table 4**).

3.6 Health problems from using firewood

From the people's perception, it was found that traditional cooking stoves have a significant negative effect on human health. From the questionnaires it was reported that 68% of respondents suffer from eye irritation, 16% of respondents reported that they have suffered from coughs, 11% reported that they suffer from asthma and 5% reported that they suffer from ARI, as shown in **Figure 3**. A study conducted by the Nepal Health Research Council **[20]** found that the prevalence of ARI among children aged below 5 was 38%. Mostly women and children are affected because they spend most of their time near the kitchen cooking food.

Table 4: Result of t- test of total suspended particles between the TCS and ICS

Mean particulate concentration of TCS (X_1)	Mean particulate concentration of ICS (X_2)	α	t cal. value	t tab. value
2866	1333	0.05	17.30	2.78

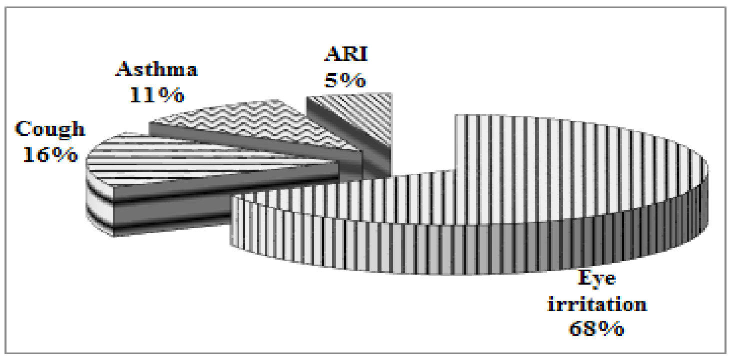

Figure 3: Types of cooking stove

3.7 Lighting energy sources

Out of 42 household, all 42 families have electricity and 13 households have both solar and grid connected electricity as shown in **Figure 4**. The supply of this electricity is from the local micro hydropower. The solar panels were donated by the Chinese government in 2010 (2067 B.S.) in a few numbers by lottery system.

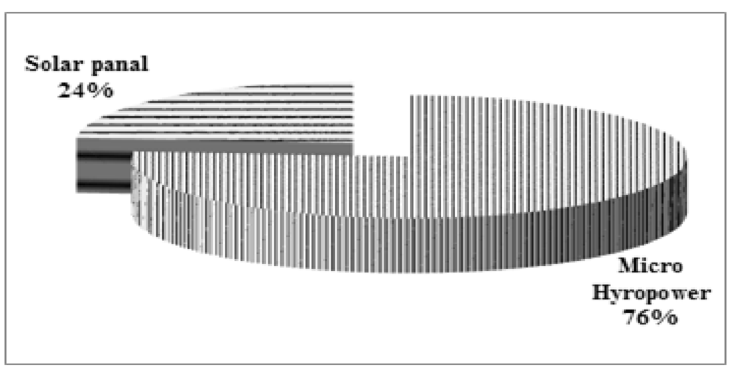

Figure 4: Lighting energy sources

3.8 Willingness of people to use alternative sources of energy

In the survey, 81% of respondents mention that they are open to alternative sources of energy. 64.8% of respondents are willing to use LPG, 20.9 % of respondents are willing to use Kerosene and 14.3% of respondents are willing to use ICS, as shown in **Figure 5**. They said that the main reason for using other sources of energy is the energy efficiency, ease of use and that these alternative sources do not create any health problems.

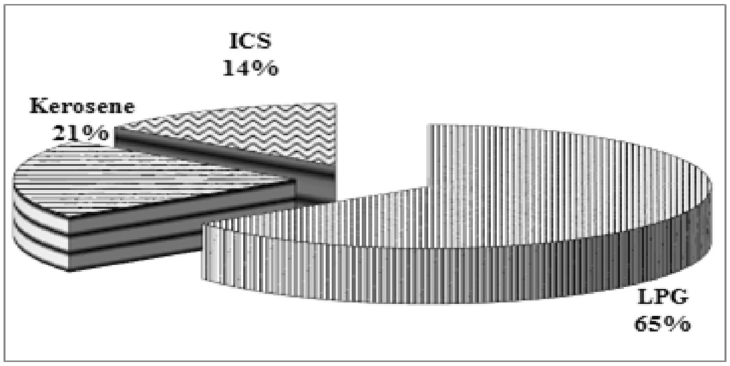

Figure 5: Willingness of people to use the alternative sources of energy

4. Findings and Conclusion

The energy consumption scenario in this area is comparable to the national level. Most people in the area are using biomass, especially fuel wood burnt in traditional cooking stoves. Firewood is the most prevalent source of energy for cooking purposes. Traditional cooking stoves are found to be dominant compared to improved cooking stoves. The use of efficient cooking stoves is decreasing due to a lack of proper knowledge. Grid electricity and solar systems for power generation are used to a lesser extent and almost all the households are using them only for lighting purposes. It was concluded that the total firewood consumption in the area is 7668.6 kg per year with 106.42 kg per capita per year. The per capita firewood consumption for TCS users was 1.3 times more in comparison to ICS users. The per capita/year carbon emission of TCS and ICS users is 8055.47 kg CO_{2e} per capita/year and 5978.15 kg CO_{2e} per capita/year, respectively. This calculation shows that ICS emits 1.3 times less CO_2 into the atmospheric environment than TCS. The average mean particulate concentration at normal atmospheric conditions for a traditional cooking stove was found to be 2866 μg/m^3 and for an improved cooking stove it was found to be 1333 μg/m^3, both of which far exceed the national standard of 230 μg/m^3 TSP. The study shows that TCS users are more vulnerable. Mostly women and children are facing indoor air pollution because they spend most of their time in the kitchen only. People are facing environmental problems like loss of biodiversity, destruction of wildlife habit, lack of grazing lands, health hazards and Glacial Lake Outburst Floods (GLOF). The study found that there was massive use of traditional forms of energy. Although the study results show that in the study region the use of traditional energy forms outweighs alternative energy sources, it was also proven that people are open to use these alternative energy sources such as LPG, Kerosene and ICS.

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