CO_2 and CH_4 Emission from Domestic Fuel and Livestock Keeping in Tarai and Bhawar in Nepal: A Household-level Analysis

Ram Asheshwar Mandal[1]*, Ishwar Chandra Dutta[2], Pramod Kumar Jha[3], Siddhi Bir Karmacharya[1], Bijay Kumar Yadav[4], and Roshan Raj Kafle[5]

[1]*Trichandra College, Ghantaghar, Kathmandu, Nepal*

[2]*Tribhuwan University Service Commission, Kirtipur, Kathmandu, Nepal*

[3]*Central Department of Botany, Kirtipur, Kathmandu, Nepal*

[4]*Department of Forests, Babarmahal, Kathmandu, Nepal*

[5]*Kathmandu Forestry College, Kathmandu, Nepal*

Abstract

The CO_2 and CH_4 are the major components of greenhouse gases and their quantification is essential to address the issues of Climate Change. The research objective is to assess the CO_2 and CH_4 emissions produced from domestic fuel consumption and livestock keeping respectively in Tarai (plain area) and Bhawar (foothills) and also evaluate and explore their management options. Two villages of Mahottari district were selected and altogether 138 households were sampled randomly after well-being rankings given as rich, medium and poor. The quantity of fuel consumption was recorded in the morning and evening for seven days during summer and winter seasons. The collected samples of fuel were dried in the laboratory. Moreover, a record of cattle keeping was taken from a participatory rural appraisal. Information on CH_4 emission management was gathered from experts and literature. The dry weight of fuel was converted into C and latter into CO_2 while CH_4 emission was calculated by using factors of IPCC. The estimated CO_2 and CH_4 emission were 14027.94 t and 318.24 t respectively which together can emit 21347.45 tCO_2 but managing CH_4 through installing biogas plants have the potential to reduce the gasses to about 9514.27 tCO_2 which can offer US$ 47568.35 of certified emission reduction in two villages.

Key words: Emission/ CO_2/ CH_4/ Livestock/ Fuel

1. Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) has a major global response to address the issues of climate change. Under, UNFCCC, the clean development mechanism, emission trading and joint implementation under the Kyoto protocol are one of the major actions while reducing emissions from deforestation and forest degradation (REDD) is another appropriate action. They have a target to reduce the green house gases by either extending forest areas or by reducing emissions (Skutsch and Laake, 2009).

There are various gases in green house gases (GHGs) but CO_2 and CH_4 are the key ones. The rate of growth of CO_2-equivalent emissions was much higher in the recent 10-year period of 1995-2004 (0.92 $GtCO_2$-eq yr^{-1}) than the period of 1970-1994 which was 0.43 $GtCO_2$-eq yr^{-1}. The CO_2 emissions from energy use between 2000 and 2030 are projected to grow by 40 to 110%. CH_4 is expected to cause 15 to 17% of the global warming over the next 50 years and about 0.2° C per decade for the next 20 years (Intergovernmental Panel on Climate Change (IPCC), 2006).

Global energy demand will grow by 35 %, as the world's population expands from about 7 billion people today to nearly 9 billion people by 2040, led by growth in Africa and India. About 2.4 billion people rely on traditional biomass, mainly for cooking and heating (International Energy Agency (IEA), 2002) and their livelihood is directly

*Corresponding author:
E-mail: ram.mandal@gmail.com

linked to livestock keeping which is a major source of CH_4 emission (Dherani et al., 2008). Rural populations in developing countries rely heavily on biomass burning as a primary source of energy (Yevich and Logan, 2003). The rural household energy consumption constitutes over 70% of the national energy use in Asian countries e.g. India, Pakistan, Myanmar and Bangladesh (Koopmans, 2005). Dung used as a biofuel is mainly used in Asia, e.g. India, Nepal and China (Yevich and Logan, 2003). In addition, livestock keeping is one of the major agricultural activities.

Fuel wood supplies almost 80 % the of total energy demand for consumption and has resulted in deforestation and forest degradation in Nepal. The energy consumption is growing by almost 3 % each year (Central Bureau of Statistics (CBS), 2011) in the country. About 2.7 million MT of dry livestock manure is estimated to be available for domestic energy use in Tarai (Pokharel, 1998; MoF, 2007). About 64 % of the population use firewood as the usual source of fuel for cooking followed by liquefied petroleum gas (LPG) (21.03 %), cow dung (10.38 %) and other materials (4.59 %). Not only that, more than 70% of people are reliant on livestock based agricultural work. As consequence there is a significant increase in CO_2 and CH_4 emission (CBS, 2012).

The climate change process driver is closely related to the sources of GHGs. Moreover, each country has to submit a national communication report periodically to the Conference of the Parties of the UNFCCC. It is necessary in both cases, to indicate that local level plans and actions quantify the CO_2 and CH_4 emissions. Obviously, research questions are raised like, what are the values of CO_2 and CH_4 emission by different socio- economic levels of rural communities living either near or far from forest resources; what are the major sources of CO_2 and CH_4 emission and what will be the appropriate options to manage them, locally. Thus, the research objectives are: i. to compare household level CO_2 emissions produced from burning of fuel; ii. to evaluate CH_4 emission from livestock keeping; iii. to explore the sources of CO_2 and CH_4 emission produced by the rural community and iv. to assess the management potentials to reduce the emission from these sources in Tarai and Bhawar. The study is limited to the emission from domestic fuel burning and cattle keeping only.

2. Materials and methodology

2.1 Research site

Maisthan village adjoins the forest, whilst Sahodawa village is farther away from the forest of Mahottari district, Nepal was selected for the study site (Figure 1) because no previous studies about quantification and comparison of the local level of emissions has been done yet. Moreover, selecting the former village is a good representation of the household domestic emission levels of rural people who have frequent access to national forest while the latter can show the quantity of emissions produced by local people who have very little access to the national forests and are normally dependant on their own private forests. This district lies in 26^o 36' to 28^o10' N and 85^o41' to 85^o 57' E. Tarai, Bhawar and Chure have tropical and subtropical climates. The temperature ranges between 20-45^o C and average annual rainfall has been recorded between 1100-3500 mm, however they vary each and every year.

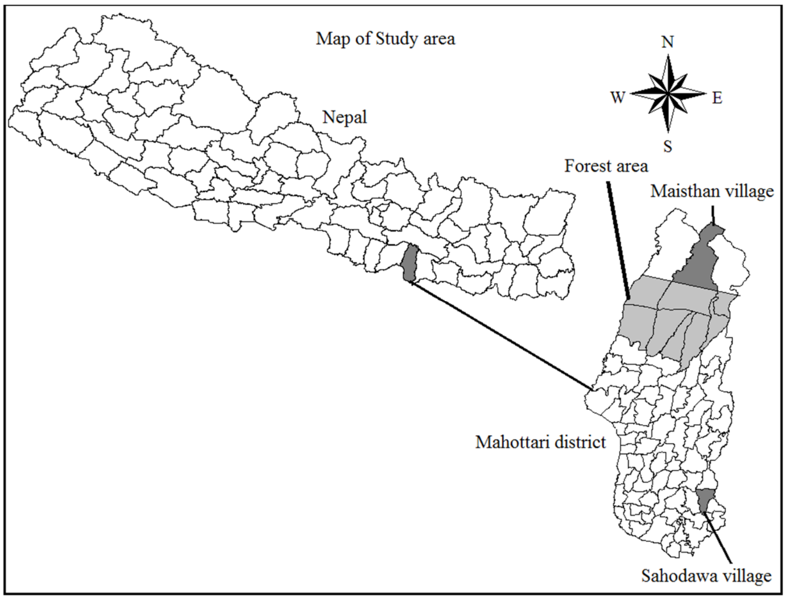

Figure 1 Map of the research site

2.2 Socio- economic data collection

Before describing about the stepwise socio-economic data collection, it is essential to explain about the habits and normal behavior of the communities in these villages. In the case of Sahodawa village people are used to living in joint family units, so numbers of family members was normally 6-8 in Tarai while it was 5-6 members in the Hill communities of, Maisthan village. People tend to work in the morning in Tarai in order to avoid the mid day heat while hill people like to start work in the fields around 10:00 AM. So, the Tarai community needs to cook breakfast in the morning, lunch at mid-day and dinner at night while the hill communities prefer to cook before 10:00 AM and in the evening. The cooking stoves are not much different in the two villages.

In the beginning, the record of total household were collected from the central bureau of statistics (CBS) and village profiles, there were 1130 households in Maisthan village and 1500 households in Sahodawa village. Next, households in villages were categorized into three groups explicitly rich, medium and poor applying the participatory well being ranking process. The criteria focused on types of house, employment, land holding, cattle keeping, education, income source (business) and food security (Chapagain and Banjade, 2009). If a household has an annual income of about US$ 1000- 2000, Khapada (roofing burnt clay tile), 1 employee, 1 ox and 1 cow and educational qualifications, class 10 pass are categorized as a medium family, while having more than that are grouped under rich and less than that are grouped as poor households (hh). The number of households in each category rich, medium and poor was 404, 424 and 303 respectively in Maisthan village while they were 420, 540 and 540 respectively in Sahodawa village. The number of households was considered as a sample unit and 5% sample intensity was taken. Lastly, 138 households were selected randomly from these villages for sampling. Out of that, 60 samples including 22 rich, 22 medium and 16 poor households were taken from Maisthan village while 78 samples (24 rich, 27 medium and 27 poor households) from Sahodawa village but only 56 and 76 samples were used for analysis since six samples appeared as outliers.

At the same time records of cattle keeping like number of oxen, cows, goats, buffalos, pigs and chicken were taken from selected household using the participatory rural appraisal (PRA) technique. Apart from that, a short meeting was organized to find the best management options of CH_4 emission targeting the simultaneous reduction of CO_2 sources.

2.3 Bio-physical data collection

Bio-physical data were focused on types and consumption of fuels and their samples. People of Maisthan generally use firewood, but in the case of Sahodawa village they use firewood, dung and dried leaves together, however it depends up on the type of household. Thus, types of fuels used by rural people were recorded applying PRA technique. The fuel consumption varied according to the season, generally, people use more fuel in winter than summer. So, a record of fuel was taken in April (summer) and January (winter) from selected families. Then, fuels used by each family were weighed in the morning and evening for 7 days in summer and 7 days in winter to determine the daily consumption. Then, as fuels were not completely dried, about 100 gram samples of different fuel types were weighed. These samples were dried in the laboratory at 105^0 C until their weight stabilized (Akagi et al., 2011).

2.4 Calculation of CO_2 and CH_4 emission:

Nepal proposed a 2 tier approach, so the factors suggested by IPCC (2006) are used to calculate CO_2 and CH_4 emissions. Practically, Nepal has 4 months of winter and 8 months of summer season. Hence, this variation was taken into account for calculation purposes of CO_2 emission from fuel burning (Bhattrai, 2005). According to IPCC (2006) carbon conversion factor was 0.46 for wood and bamboo, 0.39 for dung cake and stick and 0.32 was for straw and leaves.

$$\text{Lastly, } CO_2 \text{ emission} = \text{Carbon content} * 44/12 \qquad (1)$$

Similarly, the calculation of CH_4 emission was done by the estimation of enteric fermentation and manure management of the domestic cattle. The values of CH_4 emissions through enteric fermentation were 47, 55, 5, 1 and 0 kg head^{-1} yr^{-1} from cow/ox, buffalo, goat, pig and chicken respectively while these emissions through manure management were 1, 2, 0.22, 7 and 0.02 kg head^{-1} yr^{-1} from cow/ox, buffalo, goat, pig and chicken respectively (IPCC, 2006).

$$\text{Finally, } CH_4 \text{ emission} = (\text{enteric fermentation} + \text{manure management}) * \text{number of domestic cattle} \qquad (2)$$

2.5 Determination of CO_2 saving from biogas plant:

Technically, about a 4 m^3 biogas plant is considered sufficient in size to meet the cooking, heating and lighting needs of a family of 5 people (Biogas Support Programme (BSP), 2009).

Thus, Number of biogas plant (4 m^3 size) potential =No. of cows or buffalos/2
= No. of pigs/ 7
CO_2 equivalent yr^{-1}= 2.56 t of 1 biogas plant (4 m^3)
Value of CO_2= US$ 4.5 per t (3)

3. Results and discussion

3.1 CO_2 emission from fuel consumption in Maisthan and Sahodawa villages

The result showed that the daily fuel consumption and annual CO_2 emission varied according to family category, season and location. Average fuel consumption was the highest at 11.50 kg by the rich family of Sahodawa village and it was the lowest at 5.89 kg for the poor family of Maisthan village in summer. Similarly, in winter, the highest fuel 13.37 kg was consumed by a rich family of Sahodawa village and it was the lowest 6.81 kg by a poor family of Maisthan village. Consequently, the highest CO_2 emission was 7.321t $yr^{-1}hh^{-1}$ by a rich family of Sahodawa village. Total values of CO_2 emission were 4792.25 t and 9235.68 t in Maisthan and Sahodawa villages respectively (Table 1).

The values of CO_2 emission depends up on the use of fuel types and their heating and lighting capacity, season, number of members in a household, quantity of fuels burned, types of stove, times of cooking and moisture content in fuels. However, the strong influencing factors are time and duration of fuel used. Generally, Tarai community likes to cook thrice a day while Bhawar (foot hill) communities cook twice daily consequently more fuel is consumed in Tarai than in the hill villages. On the other hand, occasions of feasts and festivals and preparation of alcohol also require more fuel use and consequently there is more CO_2 emissions. In the hills villages, alcohol preparation is more common than in Tarai.

The study done by Panthi et al, (2009) showed that, the daily firewood consumption was nearly 5.59 kg which is matching the value of fuel used by a poor family of Maisthan village in summer while Metz (1991) stated that, it was about 12.87 kg which is close to the value of fuel used by rich householders of Sahodawa village in winter. Obviously, the estimated values of CO_2 emission of daily firewood consumption will be similar to the values of present research. Though, no specific study has been done so far on the estimation of CO_2 emission from different family categories, Hoeven (2012) reported that it was about 3.7 million tCO_2 emitted from fire wood consumption in 2010 in Nepal.

Table 1 CO_2 emission from fuel consumption

Village		Maisthan Village			Sahodawa village		
Family Types		Rich	Medium	Poor	Rich	Medium	Poor
Types of fuel used		generally Fire wood in all family types			Fire wood/ dung in both family types		Fire wood, dung, leaf , straw
Consumption of fuel (kg day^{-1})	Summer	6.58	6.14	5.89	11.50	9.60	6.90
	Winter	7.39	6.89	6.81	13.37	11.02	8.02
CO_2 emission (t yr^{-1} hh^{-1})		4.48	4.22	3.93	7.32	6.62	4.79
Total CO_2 emission (t yr^{-1})		1811.94	1788.01	1192.31	3074.82	3574.26	2586.60

3.2 Comparison of annual CO_2 emission among rich, medium and poor

The Analysis of variance using SPSS showed that, there were significant differences in CO_2 emission per household among rich, medium and poor families of both Maisthan and Sahodawa villages at 5% level of significance.

In addition, comparisons were also carried out to test whether there was a significant difference in CO_2 emission hh^{-1} among family categories. The Tukey Honestly Significant Difference (HSD) test showed that, there was a significant difference in CO_2 emission hh^{-1} between rich and poor families in Masithan at 5% level of significance but in the case of Sahodawa village, average values of CO_2 emission hh^{-1} differed among rich, medium and poor (Table 2).

Besides, the two-tail t-test showed there was a significant variation in average CO_2 emissions between Sahodawa and Maisthan villages at 5% level of significance because the value of t -stat (-13.65) > t Critical (1.98) and P value was 0.00.

Table 2 Tukey HSD Test of CO_2 emission (Household based analysis)

Location	Family Category (I)	Family Category (J)	Mean Difference (I-J)	Std. Error	P -value
Maisthan	Rich	Medium	0.27	0.12	0.07
		Poor	0.55(*)	0.13	0.00
	Medium	Rich	-0.27	0.12	0.07
		Poor	0.28	0.13	0.07
	Poor	Rich	-0.55(*)	0.13	0.00
		Medium	-0.28	0.13	0.07
Sahodawa	Rich	Medium	1.11(*)	0.17	0.00
		Poor	3.01(*)	0.17	0.00
	Medium	Rich	-1.11(*)	0.17	0.00
		Poor	1.90(*)	0.16	0.00
	Poor	Rich	-3.01(*)	0.17	0.00
		Medium	-1.90(*)	0.16	0.00

* The mean difference is significant at the 0.05 level.

3.3 CH_4 emission ($t\ yr^{-1}$) in Maisthan and Sahodawa villages

Estimated total annual CH_4 emission was 318.24 t from domestic animals in both villages which can emit 7319.52 t CO_2 equivalents in atmosphere. Out of the values of CH_4 emission from the livestock, there were 160.58 t and 157.66 t in Maisthan and in Sahodawa villages respectively. The estimated CH_4 emission was the highest 54.67 t from the buffaloes kept by medium families in Maisthan village while there were very low values produced by pig and chicken farming (Table 3).

Quantity of CH_4 emission varied according to the types and number of livestock. Generally rich families like to keep more cows, oxen and buffaloes so the values of enteric fermentation and manure management CH_4 emission were higher and ultimately the total CH_4 emission was higher in that case. However, most of the families keep cows and buffaloes in Maisthan village so it produced higher CH_4 emission than in Sahodawa village. In addition, other reasons are that pigs and chickens are farmed in Maisthan, whereas they are not allowed in Sahodawa village.

The profile of Mahottari district showed that rich families keep 1-2 buffaloes or 1 cow and 2 oxen while medium families keep 1 buffalo or 1 cow and 1-2 oxen but poor households keep only 2-4 goats in Tarai and 2-4 pigs and 3-5 chickens in Bhawar area (District Development Committee (DDC), 2011). The values of CH_4 emission through enteric fermentation and manure management of these cattle may be similar, however the research related to the estimation of CH_4 emission has not been carried out yet. There is an increasing number of livestock population and consequently additional rises in total CH_4 emission. The record of the department of livestock services showed that the number of cows is only 954,680 but the number of buffaloes, goats and pigs has increased to 4836,984, 8,844,172 and 1,064,858 respectively (Department of Livestock Services (DoLS), 2012) from 2010 to 2011. So, the estimated enteric fermentation, manure management and in total CH_4 emission will be 356,189.8, 20,028.37 and 376,218.2 t respectively from these animals only.

Table 3 CH_4 emission in Maisthan and Sahodawa villages

Animal types	Village	Maisthan village			Sahodawa village			Total
	Family types	Rich	Medium	Poor	Rich	Medium	Poor	CH_4
	CH_4 emission types	CH_4 emission t yr^{-1}			CH_4 emission t yr^{-1}			t yr^{-1}
Cow/ox	Enteric Fermentation	52.73	23.64	0	41.36	32.62	6.06	156.41
	Manure Management	1.12	0.50	0	0.88	0.69	0.13	3.32
Buffalo	Enteric Fermentation	23.76	52.75	0	22	23.82	20.35	142.68
	Manure Management	0.86	1.92	0	0.8	0.87	0.74	5.19
Goat	Enteric Fermentation	0.22	0.61	0	2	2.17	2.85	7.85
	Manure Management	0.01	0.03	0	0.09	0.1	0.13	0.36
Pig	Enteric Fermentation	0	0	0.60	0	0	0	0.6
	Manure Management	0	0	0.09	0	0	0	0.09
Chick	Enteric Fermentation	0	0	0	0	0	0	0
	Manure Management	0	0.66	1.08	0	0	0	1.74

3.4 Comparison of CH_4 emission in Maisthan and Sahodawa villages

ANOVA showed that there was significant variance CH_4 emission t yr^{-1} hh^{-1} among rich, medium and poor families at 5% level of significance in both Maisthan and Sahodawa villages.

At the same time, HSD Tuky test showed that there was significant differences in CH_4 emission (t yr^{-1} hh^{-1}) produced by the cattle of each of the family types in Maisthan village at 5% level of significance. In case of Sahodawa village, it was found that the CH_4 emission of cattle of poor families differed from that of rich and medium households (Table 4).

The two- tail t-test showed that there was a significant difference in CH_4 emissions by cattle keeping in Sahodawa and Maisthan village at 5% confidence interval because value of t -stat (-11.09) > t Critical (2.00) and P value was 0.00.

Table 4 Tuky HSD test of Household based CH_4 emission

Location	(I) Variable	(J) Variable	Mean Difference (I-J)	Std. Error	P- value
Maisthan village	Rich	Medium	0.05(*)	0.01	0.00
		Poor	0.12(*)	0.02	0.00
	Medium	Rich	-0.05(*)	0.01	0.00
		Poor	0.07(*)	0.02	0.00
	Poor	Rich	-0.12(*)	0.02	0.00
		Medium	-0.07(*)	0.02	0.00
Sahodawa village	Rich	Medium	0.01	0.01	0.66
		Poor	0.09(*)	0.01	0.00
	Medium	Rich	-0.01	0.01	.66
		Poor	0.08(*)	0.01	0.00
	Poor	Rich	-0.09(*)	0.01	0.00
		Medium	-0.08(*)	0.01	0.00

* The mean difference is significant at the .05 level.

3.5 Variation in sources of CH_4 and CO_2 emission

There are some similarity and differences in sources of CO_2 and Ch_4 emisions. Generally, the common source of CO_2 emision was fuel wood burning in both villages, while the burning of dung cake and stick, straw and leaves only occur in Sahodawa village. Similarly, cow, buffalo and goat keeping are common in both villages but pig and chicken keeping are not found in Sahodawa village (Table 5).

Sources of CO_2 emission differed according to location because families living in Sahodawa village have no, or very limited access to the national forest but households of Maisthan villave have no problem collecting and using firewood. Similarly, livestock of Maisthan village are openly grazed in the forest but that is not applicable for livestocks of Sahodawa village. That is why households of Sahodawa village use dung cake and stick, straw, leaf for cooking and heating. The use of dung and urine of livelstock for biogas are the best alternative options to reduce domestic emissions (Bhattrai, 2005; BSP, 2009).

About 99% families used firewood for cooking and heating in Maisthan but in the case of Sahodawa, more than 90% households used fire wood and dung cake, stick and other materials simultaneously. The study done by Bhattrai (2005) showed that about 89.2 % people used fire wood for domestic energy in Nepal. About 3,470,224 households have been using firewood and nearly 563,126 households have been using cow dung which is common in Tarai (CBS, 2012).

Table 5 Sources of domestic emission

GHGs	Sources of Domestic Emissions		Emission % by domestic sources in		Remark
			Maisthan village	Sahodawa village	
CO_2	Common sources	Fuel wood	99%	90%	1 % biogas in both village
	Differences	Dung cake & stick	Nobody use these materials	7%	
		straw, leaf		2%	
CH_4	Common sources (dung & urine of live stock)	Cow & ox	0.48%	81.74%	
		Buffalo	0.49%	68.58%	
		Goat	0.54%	7.34%	
	Differences	Pig	0.43%	Nobody keeps pig & chick	
		Chick	1.08%		

3.6 Economics, management and policy of CO_2 and CH_4 emission

The establishment of biogas as a regular has a dual role in reducing GHGs emissions. The first role, is the management of dung of cows, buffaloes and pigs to produce biogas as a fuel for cooking and heating and, the second role is to reduce the pressure on the forest by reducing firewood consumption. The establishment of biogas can save about 9,514.27 tCO_2, while the equivalent use of firewood can emit 14,027.93 tCO_2 from these two villages. However, poor communities in Sahodawa village have no capacity to establish a biogas plant, while only very limited poor communities can use biogas in Maisthan village because of their economic capacity to keep cows, buffaloes and pigs (Table 6). Nevertheless, installation cost is too high at nearly US$ 300 to 350 per biogas plant of 4 m^3 size (BSP, 2009).

Saving the CO_2 by use of biogas plant is indicated as a candidate for certified emission reduction (CER) under clean development mechanism (CDM) or reducing deforestation and forest degradation (REDD). Economic evaluation showed that establishing biogas plants in these two villages can offer about US$ 47,568.35 CER. Presently, only 11 households are using the biogas plants which are less than 1% of total households in these villages while records showed that, about 2.43 percent of the total households are using biogas in Nepal (CBS, 2012).

Nepal has put high emphasis on alternative energy programmes, specifically on alternative energy such as establishing biogas plants. Biogas establishment is the best option to manage the dung of these domestic animals and reduce the use of firewood as energy. In this context, the climate change policy of 2012 aims to reduce the GHGs emission using alternative energies to firewood. Similarly, the ministry of energy has prioritized using alternative energy in order to reduce the load shading (Ministry of Science, Technology and Environment (MoSTE), 2011) as a preferable option. In addition, the department of livestock development under the ministry of agriculture has started to promote the improved variety of livestock keeping, and to integrate it with rural energy transformation (Ministry of Agricultural Development (MoAD), 2012). This is why; the Biogas Support Programme (BSP) has been functioning to promote biogas in rural areas. BSP has installed 260,899 domestic biogas plants in over 2,800 villages by managing cattle manure as a raw material between 1992 to 2012 (BSP, 2012).

Table 6 Valuation of CO_2 saving from biogas

Location	Household category	Total (cow, ox, buffalo)	Total Pigs	No. of Biogas	tCO_2 equivalent	Value US $	Remarks
Maisthan	Rich	1553	0	621	2485.76	12428.78	Installation cost is not included
	Medium	1462	0	584	2339.20	11696.00	
	Poor	5	86	10	39.31	196.57	
Sahodawa	Rich	1280	0	512	2048	10240	
	Medium	1127	0	451	1804	9018	
	poor	499	0	199	798	3989	

4. Conclusion and recommendations

The CO_2 emission was found to be higher in Sahodawa village compared to Maisthan village but the value of CH_4 emission was higher in Maisthan village than in the next village. The higher CH_4 emission, the higher is the potential for biogas plant installation. It is recommended that further intensive studies on rural CO_2 and CH_4 emission are carried out in order to clearly analyze the potential and choose the best alternatives to reduce the use of fire wood, dung cake and dung stick. Moreover, biogas plant share considered as one appropriate way to manage the CH_4 emission from animal dung and reduce CO_2 emitted from fuel burning. Hence, it is recommended to assess the livestock population and their CH_4 emission factors based on the average weight of animals so that entric fromentation and manure management can be calculated more precisely.

5. Acknowledgement

We acknowledge Mr. Ram Bilash Yadav, Ram Rijhan and Molhu for their kind support during field work in Sahodawa village and Renuka Kafle, Manoj Adhikari, Saroj Thapa and Sohan Nepal for recording data during fieldwork in Maisthan village. Similarly, we thank Mrs Menuka Shrestha and Ramesh Pantha for their support in laboratory work.

6. Reference

Akagi, S.K., Yokelson, R.J., Wiedinmyer, C.M.J., Alvarado, J.S., Reid, T., Karl, J., Crounse, D., and Wennberg, P.O. 2011. Emission factors for open and domestic biomass burning or use in atmospheric models, **Atmosphere, Chemistry and Physics** 11: 4039–4072.

Bhattrai, T.N. 2005. **Renewable Energy Development Strategies and Solid Biomass Fuels in Nepal**. Institute of Engineering, Tribhuban University, Kathmandu. Food Agriculture Organization: Regional Wood Energy Development Project.

Biogas Support Programme (BSP). 2009. **Biogas as a renewable source of energy in Nepal: Theory and Development**. Kathmandu, Nepal.

Central Bureau of Statistics (CBS). 2011. **Environment Statistics of Nepal 2011.** Kathmandu Nepal: Government of Nepal, National Planning Commission Secretariat.

Central Bureau of Statistics (CBS). 2012. **National Population and Housing Census 2011 (National Report) Volume 01**. Nepal: Government of Nepal. National Planning Commission Secretariat. Central Bureau of Statistics Kathmandu.

Chapagain N. and Banjade M.R. 2009. Community Forestry and Local Development: Experiences from the Koshi Hills of Nepal. **Journal of Forest and Livelihood** 8(2): 78 -92.

District Development Committee (DDC). 2011. **District Profile, Mahottari.** Mahottari, Jaleshwar, Nepal.

Dherani, M., Pope, D., Mascarenhas, M., Smith, K. R., Weber, M., and Bruce, N. 2008. Indoor air pollution from unprocessed solid fuel use and pneumonia risk in children aged under five years: a systematic review and meta-analysis. **World Health Organization** 86(5): 390–398.

Department of Livestock Services (DoLS). 2012. Livestock Statistics of Nepal [Online]. Available: http://www.dls.gov.np/publications.php [Accessed on 8 January 2013]

Hoeven, M.V. 2012. CO_2 emissions from fuel combustion highlights [Online]. Available: www.iea.org [Accessed on 8 January 2013].

International Energy Agency (IEA). 2002. World Energy Outlook 2002, Energy and Poverty (Chapter 13) [Online]. Available: http://www.worldenergyoutlook.org/weo/pubs/weo2002/energypoverty.pdf [Accessed on 8 January 2013].

Intergovernmental Panel on Climate Change (IPCC). 2006. Guidelines for National Greenhouse Gas Inventories. In: Egglest H.S., Buendia, L., Miwa, K., Ngara, T., and Tanabe, K. (eds.): **National Greenhouse Gas Inventories Programme** (pp. 67-69). Japan: IGES.

Koopmans A. 2005. Biomass energy demand and supply for South and South-East Asia - assessing the resource base. **Biomass and Bio-energy** 28:133-150.

Metz, J.J. 1991. An Outline of the Patterns of Natural Vegetation Use in Upland Nepal. **Banko Janakari** 3(1): 21–34.

Ministry of Agricultural Development (MoAD). 2012. **Statistical Information on Nepalese Agriculture 2011/2012**. Singhadarbar, Kathmandu: Ministry of Agricultural Development.

Ministry of Finance (MoF). 2007. **Economic Survey: Fiscal Year 2006/07**. Singhadarbar, Kathmandu.

Ministry of Science, Technology and Environment (MoSTE). 2011. **Climate Change Policy 2011.** Singhadurbar, Kathmandu: Ministry of Science, Technology and Environment.

Panthi, J., Pradhananga, D., and Sapkota, R.P. 2009. **Renewable energy technology for reducing greenhouse gas emission**. Nepal: Central Department of Environmental Science, Tribhuvan University.

Pokharel, S. 1998**.** Energy in Nepal. In: **Nepal National Committee of the World Energy Council and circulated** (pp. 8-19). Proceeding of the 17th World Energy Congress, Houst, Water and Energy Commission Secretariat. Kathmandu, Nepal.

Skutsch, M. and Van, L.P. 2009. REDD as Multi-level governance in Making. **Energy and Environment** 19(6): 831-844.

Yevich, R. and Logan, J.A. 2003. An assessment of biofuel use and burning of gricultural waste in the developing world. **Global Bio-geochemistry** 17(4): 1095-1100.