International Journal of Latest Engineering and Management Research (IJLEMR)
ISSN: 2455-4847
www.ijlemr.com || Volume 02 - Issue 09 || September 2017 || PP. 28-35

Use of Rocket Stove for Firewood Savings and Carbon Emission Reductions by the Households involved in Allo (*Girardinia diversifolia*) Fiber Processing at Khar VDC, Darchula District, Nepal

Bijay Raj Subedee[1], Ram Prasad Chaudhary[1], Krishna Raj Shrestha[1], Tashi Dorji[2]

[1](*Research Centre for Applied Science and Technology/Tribhuvan University, Nepal)*
[2](*International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal)*

Abstract: Firewood collection is main driver of deforestation and forest degradation in many South Asian countries. The study assessed the firewood consumption, emission of CO_2e, adoption process and sustained use of Traditional Three- Stone Cook Stoves (TCS) and Rocket Stoves (RS) by local communities living in Khar Village Development Committee, Darchula District, Kailash Sacred Landscape (KSL)-Nepal. Households involved in processing of fiber from Himalayan giant nettle (Girardinia diversifolia (Link) Friis) locally known as Allo were selected for study. Firewood consumed by TCS was 3.68 Tons per year per household and the firewood consumed after the use of Rocket Stove (RS) was 2.706 Tons per year per household. Firewood consumption was significantly reduced and savings was of 974 kg per household per year. The reduction in emission of CO_2e would be 1782.42 kg per household per year. About 96.6 per cent of the people in Khar VDC collect Quercus lanata and Persea odoratissima as major firewood species to meet their energy needs. The excessive use of these species for cooking was found as the main cause of resource depletion in forest. This study concluded that the use of RS could be one of the good choices to reduce firewood consumption and CO_2e emission reduction.

Keywords: Biomass, Fuel wood, Himalayan nettle, Kailash Sacred landscape, Rocket stove

1. Introduction

The rigorous use of firewood for cooking and space heating has highly contributed to increased carbon emissions and deforestation in developing countries [1, 2, 3]. At the same time, people of these countries are reliant on firewood for their energy needs [4]. It is also assumed that use of inefficient technology lead to face energy crisis [5]. Efficient use of energy helps in enhancement of socio-economic status of financially weak people [6].

Energy demand of people living in rural areas of Nepal is primarily dependent in biomass resources. About 64% of the total populations of Nepal utilize firewood as a primary source of energy for cooking [7]. Cooking and space heating are major firewood consuming sectors mostly in high hilly areas of Nepal [8]. People living in Kailash Sacred Landscape (KSL-Nepal) comprising: Baitadi, Darchula, Bajhang and Humla are dependent on biomass source to meet their energy requirement. In a rural community situated in Api-Nampa Conservation Area (ANCA) of Darchula District, livelihood of the local people is highly dependent in biomass energy. Especially women and children spend several hours per day to collect the firewood. Therefore, strategies on efficient use of energy are needed to reduce the firewood consumption which has potential for conservation of forests and improving livelihoods.

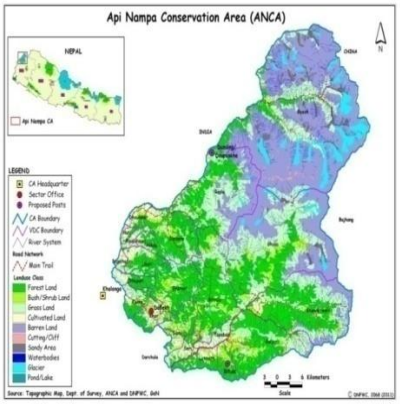
Uncontrolled use of firewood is a major reason of deforestation and degradation of forest [9, 10]. In rural areas of Nepal people are using traditional three stone cooking stoves (TCS). Various studies have shown that these stoves have created indoor air pollution and caused acute respiratory infection [11, 12]. Local people of KSL- Nepal cook food in TCS but no study has been conducted in this area on the effects of these stoves.
Governments, development organizations are giving attention on improved cooking stoves (ICS). Many models of cooking stoves have been introduced in rural households of Nepal. But very less study has been conducted to understand disseminated stoves adoption and sustain use by local people. The study was focused on the households involved in livelihood activities related to (*Girardinia diversifolia*) locally know as Allo using Rocket Stoves at Khar VDC, Darchula district.

Households of Khar VDC were selected on the basis of the people involved in the processing of natural fiber from Allo. Selected households dependent on Allo were selected to analyzed two consecutive year to observe the consumption pattern of firewood utilizing TCS and RS. Field survey, interviews, focus group

discussion has been conducted with users of TCS and RS. Correlation between firewood collection and firewood consumption in a year was investigated. Major plant species used as firewood were identified.

The overall objective of this study was to assess the effectiveness of RS on firewood use and potential carbon impact in KSL-Nepal. Specific research questions are:

- How much quantity of firewood is consumed by households in a year utilizing TCS and RS?
- What is the expected impact of the distributed RS on carbon emissions at households per year?
-What were the acceptance and sustained use practices of RS in study area?



1.1 Study area

The study was conducted in Khar village development committee (VDC), which lies under Api Nampa-conservation Area (ANCA), Far Western region of Nepal. ANCA was established in 2010 with the area of 1903 square kilometer. It has 21 VDCs located in Darchula district. Khar VDC has total of 698 households with total population of 4272 (2056 Male and 2216 Female) based on NPHC 2011 data. The major species found in the area are *Quercus semecarpifolia*, *Quercus lanata*, *Persea odoratissima*, *Rhododendron species*, *Alnus nepalensis*, *Pyrus pasiha*, *Prunus cerasoides*, *Toona serretas* etc. Forests are managed under community and national forest. Firewood, fodder, leaf litter, medicinal plants, and timber are collected by the people from community as well as national forest. Being firewood as only one source of energy, some interventions and dissemination of improved cookstoves are being implemented in this area. Kailash Sacred Landscape Conservation and Development Initiative (KSLCDI) has disseminated rocket stoves to selected households who were involved in collection and processing of Allo.

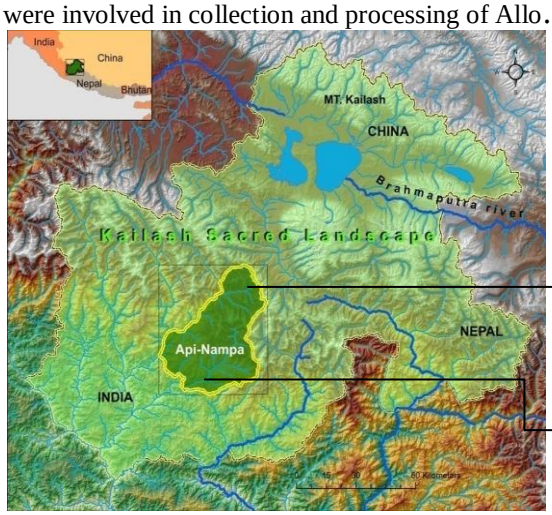


Fig 1: Area of Kailash Sacred Landscape Conservation and Development Initiative and ANCA. (source: ICIMOD)

Since 2013, a joint initiative KSLCDI is being implemented across the borders of China, India and Nepal. In Nepal the programme is jointly initiated by Ministry of Forests and Soil Conservation, Government of Nepal, Research Centre for Applied Science and Technology (RECAST), Tribhuvan University, International Centre for Integrated Mountain Development (ICIMOD). The initiative aims to achieve long-term conservation of ecosystem, habitats, biodiversity and encourage sustainable development of local people.

1.2 Traditional Three Stone Stove (TCS) and Rocket Stove (RS)

Traditional three stone stoves consist of three stones around a fire and a pot is balanced for cooking. Fig. 2 shows its arrangement. These types of stoves are highly used in developing countries because they utilize locally available materials, cheap and easy to build [13].

The Rocket stove (RS) was developed by Dr. Larry Winiarski, Aprovecho Research Centre, Pregon, U.S.A. It has L shaped combustion chamber and a pot skirt. The combustion chamber consists of a horizontal firewood insertion area and vertical internal chimney which is insulated from inside. Fig 2 shows its arrangement. Rocket stoves are capable of complete combustion of firewood at high temperatures [14].

Various parameters are involved in different model of stove in combustion process, such as the type of fuel, design of the stove and operating conditions [13].

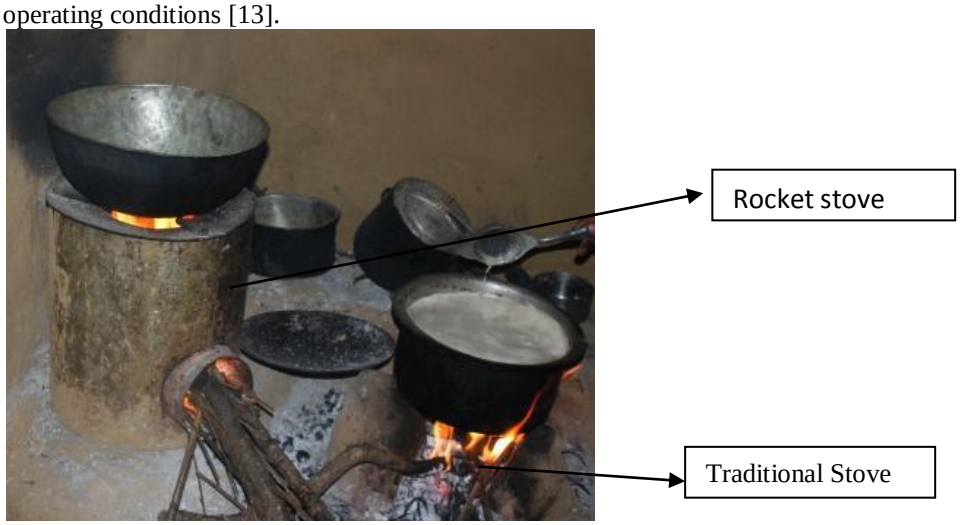


Fig 2: Rocket stove disseminated at Khar VDC and the cooking practice along with the Traditional stove.

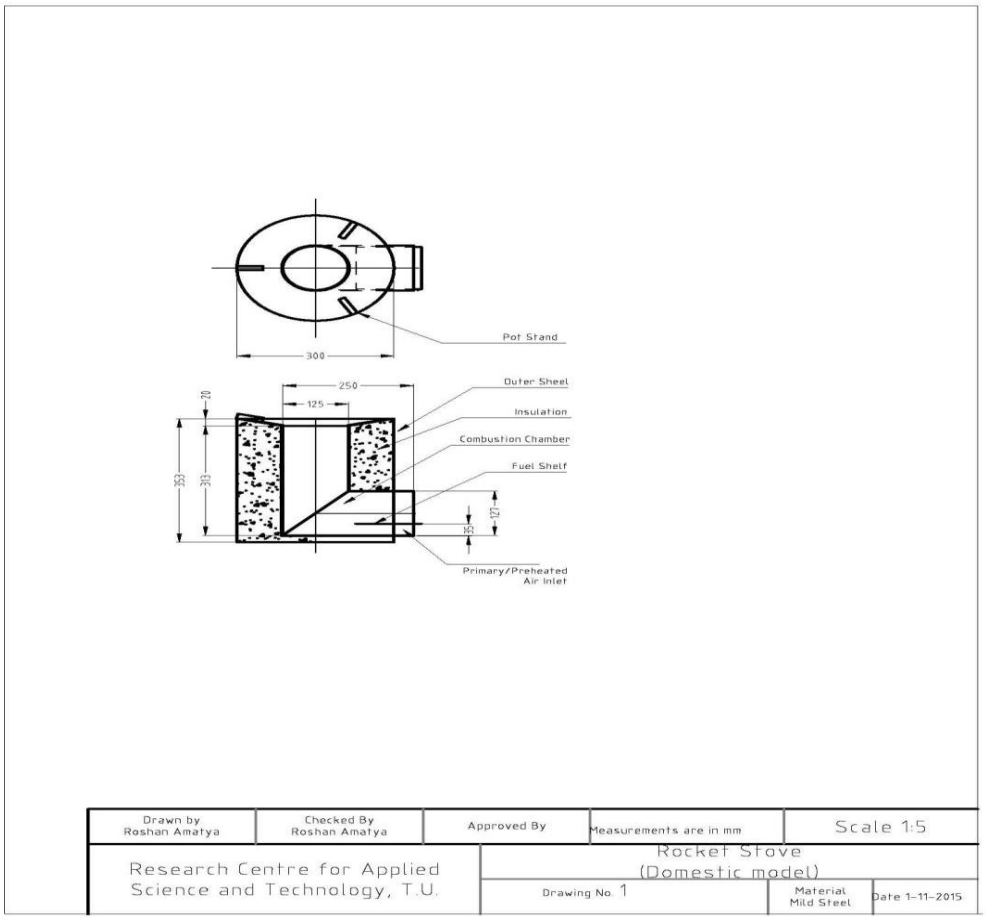


Fig. 3: Diagrammatic Sketch of Rocket Stove (Longitudinal Section)

2. Material and Methods

The study was conducted during 2015 - 2016 at Khar VDC. The study included communities of Godhyani and Sundamunda village, Darchula district utilizing RS and TCS. The two processing groups of Allo from Darchula district were selected; Bhumiraj group of Godhyani village had seventy five members and Kedarnath group at Sundamunda village had thirty six members. Among them 20 households who received rocket stoves were selected for study. The information was collected on the basis of regular cooking practice followed by the people using TCS and RS. Information were obtained through direct interviews, focus group discussion and semi-structured questionnaires. Respondents were both RS users and TCS users. Only households that had been using RS and TCS together for at least two year and lived in Khar VDC were considered. Rocket stove was fabricated at Research Centre for Applied Science and Technology (RECAST) of Tribhuvan University (TU) workshop using the principle approved by Aprovecho Research Center [14]. Distribution of tree species used as firewood and its present resource situation was recorded.

3. Results and Discussions

3.1 Quantity of firewood consumed by households in a year utilizing Traditional Stove alone and Rocket Stove with Traditional stove.

Results shows that mean value of firewood collected in a year was 4060 Kg (4.06 Tons) minimum value of firewood collected was 2000 Kg (2 Tons) where as maximum value of firewood collected was 6400Kg (6.4 Ton) per year per household (Table 1). The expected value of firewood consumed by traditional stove was found as 3680.00 (3.68 Tons) but the average value of wood consumption by the use of RS with TCS was 2706Kg (2.706 Tons) which was significantly decreased by 974 kg (0.974) per year per household. It indicates that the consumption of firewood by TCS is greater than RS.

Similar study was conducted in Tamil Nadu by Aprovecho Research Center showed that Single pot rocket stove (without pot skirt) consumed 18% less fuel than traditional stove [15]. Rocket stove is portable and use small chunks of wood. Rocket stove have an average efficiency of 25-30%. Rocket stove showed various advantages over traditional stove like low emission, shorter cooking time, low maintenance and affordable (AEPC). Traditional three-stone fires are fairly inefficient and for basic cooking about 2 ton of biomass are needed each year per family [16].

Table 1: Descriptive Statistics of Firewood Collection and Consumption by Respondents

Descriptive Statistics	N	Minimum	Maximum	Mean	Std. Deviation
Firewood collected in year (kg)	20	2000	6400	4060	1293.058
Firewood consumed using traditional stove in (kg)	20	2000	6000	3680.00	1228.435
Firewood consumed using rocket stove and traditional stove together (kg)	20	1200	5200	2706.00	1075.764

3.2GHG Emission Reduction Due to Rocket Stove

Study showed that with the use of RS along with TCS, 974 kg of firewood was annually saved. The emission factors for various fuel combustion given by EPA (2014) were used for GHGs emission and reduction from respective fuels as given in table 3.The global warming potential of GHGs is given in Table 2. With the savings of 974 kg of fuel wood per year, the reduction in emission of CO2e would be 183.46 kg CO2e per year

Table 2: Global Warming Potential (GWP) Factors [17].

S.N	GHG	100 year GWP factor
1	CH4	25
2	N2O	298

Table 3: Emission Factors of Combustion of Various Fuels [18].

S.N.	Fuel source	Emission factor (CO_2e)
1	Fuel wood	1.830 kg/kg
2	Kerosene	2.689 kg/lit
3	LPG	2.953 kg/kg

(Source: EPA, 2014)

According to emission factors one kg of firewood on combustion emits 1.830 kg/kg CO_2e thus saved amount of firewood using rocket stove was 974 kg, which is equivalent to 1782.42 kg (1.782t) CO_2e per household. A study conducted by Dhakal and Raut estimated that one ICS would reduce emissions by 1.09 t CO_2e per year compared to a traditional cooking stove[19].

Table 4: Paired Samples t Test for firewood consumption using Traditional stove alone and with Traditional stove and Rocket Stove.

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Firewood consumed in a year by using TCS(in kg) Firewood consumed in a year by using RS and TS (in kg)	974.000	456.490	102.074	760.356	1187.644	9.542	19	.000

Paired Samples Correlations				
		N	Correlation	Sig.
Pair 1	Firewood consumed in a year by using TCS(in kg) & Firewood consumed in a year by using RS and TCS (in kg)	20	.930	.000

Table 4. Showes the paired sample t test for firewood consumption using TCS alone and both TCS and RS together. P value was less than 0.05 i.e level of significance, there was significant difference in firewood consumption by TCS alone and using both RS and TCS at a kitchen.

3.3 Adoption and sustained use: stoves and cooking practices

Adoption of new cooking stove in a kitchen is a dynamic and complex process in which culture, cooking tradition and resource availability plays an important role [13, 22]. Many studies conducted on users of new technology plotted against time have suggested an S-shaped distribution curve [22]. New technology (stoves) proceeds slowly at first, accelerates througout the adopters and then slow down after the population becomes saturated [20]. The three principles suggested by Slaski and Thurber 2009 especially for the cooking stoves (motivation, affordability and users engagement) are the major factors for the success of new technology in rural area[21]. Adoption process is also controlled by different extents by cooking tradition, resource availability. These suggestions are also applicable in the study area. As, people at Khar VDC accepted the Rocket stove in their kitchen.

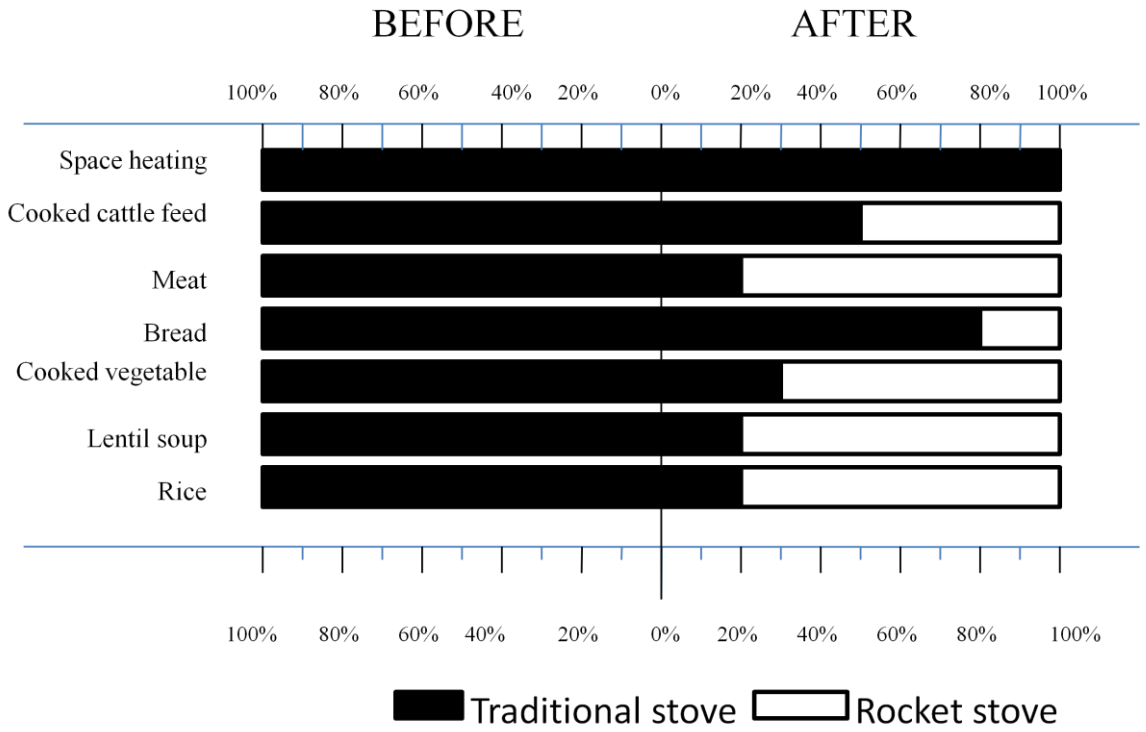


Fig.4 Adoption of RS and distribution of main cooking practices by using TCS and RS. Before (left) and after (right) the introduction of RS in Khar VDC in Darchula district.

Rocket stove has been accepted by the local people with the TCS. The study showed that households used RS to cook daily food like rice, lentil soup, meat and cattle feed. But for space heating and bread baking TCS were preferred. The current preference of the local people living in ANCA is on cheap, portable, small, affordable and low cost maintenance stove. Rocket stove has most of the applications suggested by the rural community. Rocket stove distributed in Khar VDC utilized available local material like clay, cow dung, rice husk etc, but the combustion chamber was made up of iron. According to the users, iron cast needs yearly interval maintenance for the sustainability of the stove.

Table 5: Problems faced in traditional cooking stove and use of Rocket stove to mitigate problems

Problems		N=20		Percent
*Problem faced in TCS	More consumption of wood	13		65
	More emission of smoke	4		20
	More time taken for cooking	6		30
	Eyes Irritation	3		15
* Benefits of RS	Less consumption of firewood	14		70
	Less emission of smoke	7		35
	No irritation on eyes	2		10
	Less time consumption for cooking	9		45
* multiple response				

Table 5 shows the description of multiple responses about problem faced and problem raised by respondents utilizing TCS and Rocket stove. About 65% users responded that high quantity of firewood consumption by TCS was a major problem. About 20% responded high emission of smoke,30% responded more time taken for cooking food 15% of the respondents suffered from eye irritation using traditional cooking stove. Majority of the respondents were benefited from less consumption of firewood by using rocket stove. About 70 % of the respondents responded that rocket stove consumed less firewood. About 10% of the respondents experienced no eye irritation while using rocket stove which was quite frequent in using traditional stove.

Table 6: Distribution of tree species used as firewood

Tree species		Percent of Cases	
		Number	Percent
	Quercus lanata	18	90
	Rhododendron Sp	9	45
	Persea odoratissima	17	85
	Quercus semecarpifolia	13	65
	Aesculus indica	5	25
	Rhododendron barbatum	3	15
	Pinus roxburghii	3	15
	Juglans regia	3	15
	Alnus nepalensis	8	40
	Aesculus indica	2	10

*multiple response

Table 7 shows that distribution of tree species in different community forest used as firewood in a study area. *Quercus lanata* and *Persea odoratissima* has been reported as highly consumed species among the tree species for firewood purpose. About 90% respondents utilized *Quercus lanata* and about 85% *Persea odoratissima* as a major species for firewood. Tham,Chandan, Gokarna were the community forests of study site in which about 50% of the respondents have collected firewood from Gokarna community forest.

Results from this study suggested that RS has firewood saving capacity, than TCS. The current preference of the local people living in ANCA is on cheap, portable, small, affordable and low cost maintenance stove. Thus rocket stove has most of the applications suggested by the rural community. Though, different models used for cooking have their own advantages and limitations. Rocket stove disseminated in Khar VDC utilizes available local material like clay, animal dung, rice husk etc, but the combustion chamber is made up of iron. According to the users, iron cast needs yearly interval maintenance for the sustainability of the stove.

4. Conclusion

Study concluded that the saving of firewood by the use of Rocket stove was 974kg per household per year. The reduction in CO_2e emission was 1782.42 kg per household per year than the traditional cooking stoves in study area. Rocket stove helped to reduce firewood consumption for the people working on *Girardinia diversifolia* and provided longer time to work on livelihood activities more efficiently and eco-friendly way. In rural communities, where biomass is only the source of energy to sustain livelihood, in these places Rocket stove could be useful and helps to encourage home based workers. Thus, to reduce deforestation and conservation of forest Rocket stove is one of the good choices.

Acknowledgements

This study was supported by Kailash Sacred Landscape Conservation and Development Initiative (KSLCDI). KSLCDI is a joint effort to promote transboundary cooperation on landscape conservation among China, India and Nepal through the respective governments and partners which is supported by the Ministry for Economic Cooperation and Development (BMZ), Germany and the DFID/UKAid. The views and interpretations expressed in this publication, however, are those of the authors. We would like to thank Mr. Nabaraj Poudel Kathmandu model hospital school of nursing, Purbaanchal University, Nepal for his contribution on analysis of users data of both the stoves.

Funding source

This research was funded by Kailash Sacred Landscape Conservation and Development Initiative (KSLCDI).

Competing interests

The authors declare that they have no competing interests.

References

[1]. N. Hosonuma, .M. Herold, V. de Sy, R.S. de Fries, M. Brockhaus, L. Verchot, A. Angelsen, E. Romijn, An assessment of deforestation and forest degradation drivers in developing countries. *Environmental Research Letter,7*, 2012, 12, doi:10.1088/1748-9326/7/4/044009

[2]. T. R. H. Pearson, S. Brown, L. Murry, and G. Sidman, Greenhouse gas emissions from tropical forest degradation: an underestimated source. *Carbon Balance and Management. 12(3)*, 2017. doi: 10.1186/s13021-017-0072-2

[3]. S. Stevens, Tourism and deforestation in the Mr. Everest region of Nepal. *The Geographical Journal* , 169, 2003, 255-277 doi:10.1111/1475-4959.00089

[4]. A. K. Shukla, K. Sudhakar, and P. Baredar, Renewable energy resources in South Asian countries: Challenges, policy and recommendations. *Resource-Efficient Technologies*, 2017. doi: 10.1016/j.reffit.2016.12.003

[5]. I. Jan, H. Khan, and S. Hayat, (2012). Determinants of rural household energy choices An example from Pakistan. *Journal of Environmental Studies 21 (3)* 2012, 635-641.

[6]. T. Ekholm, V. Krey, S. Pachauri, and K. Riahi, Determinants of household energy consumption in India. *Energy policy 38(10)*, 2010, 5696-5707. doi:10.1016/j.enpol.2010.05.017

[7]. CRT. National Energy Situation Survey Report Nepal-Focus on Renewable Energy and Poverty Reduction, Nepal 2005.

[8]. B. P. Bhatt, S.S. Rathore, M. Lemtur , B. Sarkar, Fuelwood energy pattern and biomass resources in Eastern Himalaya . *Renewable Energy*. 94, 2016, 410–417. doi: 10.1016/j.renene.2016.03.042

[9]. M. J. Specht, S. R. R. Pinto, P. U. Albuquerque, M. Tabarelli, and F.P.L Melo, Burning biodiversity: Fuelwood harvesting causes forest degradation in human-dominated tropical landscapes. *Global Ecology and Conservation. 3*, 2015, 200-209. doi: 10.1016/j.gecco.2014.12.002

[10]. B. P. Bhatt, and M. S. Sachan, Firewood consumption pattern of different tribal communities in Northeast India. *Enegry Policy. 32(1)*, 2004, 1-6. doi: 10.1016/S0301-4215(02)00237-9

[11]. K. R. Smith, J. M Samet, I. Romieu, and N. Bruce, Indoor air pollution in developing countries and acute lower respiratory infections in children. *Thorax 55(6)*, 2000, 518-532. doi: 10.1136/thorax.55.6.518

[12]. J. J. Jetter, P. Kariher, Solid-fuel household cook stoves: characterization of performance and emissions. *Biomass and Bioenergy, 33*, 2009, 294–305

[13]. O. R. Masera, B. D. Saatkamp and D. M. Kammen, From linear fuel switching to multiple cooking strategies: A critique and alternative to the energy ladder model. 2000, 28(12) 2083-2103 doi:10.1016/S0305-750x(00)00076-0

[14]. K. M. Bryden, D. Still, P. Scott, G. Hoffa, D. Ogle, R. Bailis, and K.Goyer. *Design Principles for Wood Burning Cookstoves.* Aprovecho Research Center Shell Foundation Partnership for Clean Indoor Air. 2005.

[15]. N. Mac Carty , D. Still, D. Ogle and T. Drouin . *Assessing Cook Stove Performance: Field and Lab Studies of Three Rocket Stoves Comparing the Open Fire and Traditional Stoves in Tamil Nadu, India on Measures of Time to Cook, Fuel Use, Total Emissions, and Indoor Air Pollution*. Aprovecho Research Center, 2008

[16]. D. M. Kammen, R Bailis and A.V. Herzog. 2002. Clean Energy for Development and Economic Growth: Biomass and Other Renewable Energy Options To Meet Energy and Development Needs in Poor Nations. New York: United Nations Development Programme and Government of Morocco.https://rael.berkeley.edu/wpcontent/uploads/2015/04/RAEL_UNDP_Biomass_CDM.pdf

[17]. IPCC 2000, Revised Guidelines for National Greenhouse Gas Inventory,2000

[18]. EPA , 2014. Emission Factor for Green House Gas Inventories, Last Modified 4th April, 2014. Climate Registry Default Emission Factor, Environmental Protection Agency.

[19]. S. Dhakal and A. K Raut, Potential and bottlenecks of the carbon market: The case of a developing country Nepal, *Energy policy*, 38, 2010, 3781-3789 doi:10.1016/j.enpol.2010.02.057

[20]. M.O. Makame "Adoption of improved stoves and deforestation in Zanzibar", Management of Environmental Quality: An International Journal, 18 (3) (2007), 353-365, doi: 10.1108/14777830710731798

[21]. X. Slaski and M. C. Thurber. 2009. Cookstoves and obstacles to technology adoption by the poor. Freeman Spogli Institute for International Studies, Stanford University, Working paper #89.

[22]. I. R. Mercado, O. Masera, H. Zamora and K. R. Smith 2011. Adoption and sustained use of improved cookstoves. *Energy policy*, 39, 7557- 7566 doi:10.1016/j.enpol.2011.03.028