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Case Study

Climate Change and Fuel Wood Energy Use in Cold Desert of Drass in the Himalaya, India

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Abstract: This paper has identified the impacts of climate change on fuel wood energy use in Drass, District Kargil, Ladakh in the Himalayan region and drawn the policy implication to improve the livelihoods of the people in the context of climate change using a case study approach. The study reveals that the major source of energy used and consumed in Drass is fuel wood. Almost all energy requirements for cooking and heating are met by burning fuel wood which produces smoke, cause air pollution, emits carbon dioxide and thereby contributes to climate change. Less than half of the farmers grow fuel wood in gardens or homesteads. Most farmers purchased fuel wood from the market. Awareness of environmental effects of using fuel wood is significant. Despite this, the exposure of women to indoor air pollution from biomass fuel combustion was significantly high. The use of cleaner energy was significantly low due to economic reasons as well as inadequate accessibility and availability. Forest resources are meager in Drass. Therefore, efforts should be made to increase forest cover with the stronger participation of local communities. The government sponsored schemes targeting efficient energy usage and energy insecurity should be implemented in letter and spirit through greater people's participation.

Keywords: climate change, cleaner fuels, energy use, health, Himalayan region

JEL Codes: I12, Q01, Q40, Q54

1. Introduction

High mountain regions have a low-temperature climate regime (Budhathoki et al., 2021; Khanal et al., 2021; Vinnå et al., 2021) and often feature cryosphere components, such as glaciers, snow cover and permafrost, which significantly impact the physical and social-ecological processes (O'Neill et al., 2017). The mountain cryosphere plays a major role in large parts of the world (Mukherji et al., 2019; Wunderling et al., 2020). Climate change is a significant environmental challenge faced across the world (Pritchard, 2021). Climate change refers to any change in climate due to natural variability or human activity over time (Chiang et al., 2021; Forster et al., 2020). It implies variation in the mean state of the climate persisting over an extended period, which has the potential to inundate, degrade, and alter the chemistry and composition of our planet. Climate change has wider implications for the natural ecosystem, food

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production, water availability and health (Weiskopf et al., 2020), which affects the physical, biological and human systems. Developing countries are expected to suffer the most from adverse impacts of climate change due to their high dependence on agriculture (Huong et al., 2108). Climate change also impacts human settlement, transportation, industry and energy use (Ilhan et al., 2019).

Climate change significantly affects socio-economic activities (Bhardwaj et al., 2018) and energy use (Forster et al., 2020). It affects energy consumption and production and damages the infrastructure (Ifeanyi & Oloyede, 2011). Changes in precipitation patterns (Mukherjee et al., 2018) affect the energy generation from hydropower and bio-fuels production (Krishnan et al., 2019). Climate change affects the demand and supply of energy (Negi et al., 2018). Energy is also a major contributor to global greenhouse gas emissions (Deb et al., 2020). Fossil fuel use is the single largest contributor to climate change in mountain regions (Akpan & Akpan, 2012).

The Himalayan region is one of the youngest and most complex mountain systems on the earth (Kumar et al., 2017). Due to its fragile ecosystem and seismic sensitivity (Sharma et al., 2013), the Himalayan region is extremely vulnerable to climate change (Dasgupta & Badola, 2020). Climate change vulnerability of the Himalaya is also rising due to surging effects of varying composition and distribution of natural resources forests, water and agro-biodiversity. The Himalayan warming is reported to be higher than the global average. This has resulted in the continuous retreat of glaciers affecting millions of people living in mountains and downstream (Shresth, 2019). In recent years, the Indian Himalayan region is also facing increased occurrences and duration of extreme weather events, which caused huge loss of life, property and natural resources (Kumar et al., 2017). Forests in the Himalayan region are already degrading due to anthropogenic pressure (Awasthi et al., 2003; Negi, 2009). Climate change impacts on forests have wider implications for the people who depend on forest resources for their livelihoods. The implications are even more severe for people in the Himalayan region who depend directly or indirectly on forest resources for their daily energy requirements.

The usage of biomass is widely prevalent in the Himalayan region. Other sources of energy are limited due to geographic isolation (Mislimshoeva et al., 2014). Commercial and clean energy is generally out of reach of people in the Himalayan region due to their poor socio-economic conditions, lack of communication facilities, high prices and limited supply of reliable energy. Therefore, mountain people remain highly dependent on forests to fulfill their energy demands. Degradation and depletion of forest resources can have severe consequences for mountain people, who depend on forests for meeting fuel wood energy needs. This paper, therefore, focuses on the usage of fuel wood energy by mountain people. Against this backdrop, the main objectives of this study have been to identify the impacts of climate change on energy use in Drass in the Himalayan region and to draw the policy implications to improve the livelihoods of the mountain people in the context of climate change.

2. Review of literature

The Himalayan region is facing natural hazards such as floods, droughts, and landslides (Barnett et al., 2005), which impact both the current and future climate change (Kitoh, 2017; Jin & Wang, 2017). In the Himalayan region, climate change is expected to affect food and water security (Gautam et al., 2007) and also cause death, devastation, and poverty (Grey & Sadoff, 2007). Mountain areas are already prone to landslides and floods (Ray et al., 2019), and glacial lake outburst floods (Kattelmann, 2003; Singh et al., 2011). Floods and flash floods are common during the monsoon (Ali et al., 2019) and lead to the death of thousands of people every year making communities vulnerable to the adverse impacts of climate change (ICIMOD, 2010a; Negi et al., 2012) specifically on their livelihoods, health, and energy security (Sharma et al., 2009).

The people in the Himalayan region are generally poor and depend on natural resources for their livelihoods, which are vulnerable to climate change (ICIMOD, 2010a). The major source of livelihood for Himalayan people is agriculture (Tiwari & Joshi, 2014). However, climate change and related changes in precipitation patterns (Sabeerali & Ajayamohan, 2018; Krishnan et al., 2019) and the frequency of extreme events (Sharma et al., 2018; Singh et al., 2019; Karmakar et al., 2017) are projected to directly affect crop yields and livestock and thus have an urgent consequence for the livelihoods of mountain people (ICIMOD, 2010a). The agriculture in Himalayan regions is generally rain-fed and thus vulnerable to changes in timing and frequency of rainfall (Gautam et al., 2013).

Climate change impacts the food and water security in the Himalayan region due to changes in rainfall timing and frequency. The crop yield depends on biophysical processes (Challinor et al., 2009), which is influenced by climate uncertainties (Sheehy et al., 2006; Singh & Rao, 2018). Increased temperature and water stress reduce the fertilizing effect and increase the pest infestations (Gornall et al., 2010) on crop yields. However, studies on climate change impacts on agriculture are scant in the Himalayan region, except focusing on the decline in apple yields, rice production and maize yield (Nayava & Gurung, 2010).

Due to limited livelihood opportunities and climate stress, mountain people also resort to migration as a vital livelihood strategy in the mountainous region to deal with climate stress (ICIMOD, 2012). However, the decision to migrate may be influenced by climate change and variability directly through rapid-onset of events like floods or more gradual phenomena like soil degradation, drought, and dry spells, or indirectly by influencing economic drivers (McLeman & Smit, 2006; Perch-Nielsen et al., 2008). There is growing consensus that labour migration reduces mountain communities' vulnerability to different sources of stress, as it helps them diversify their livelihoods (Fahad & Wang, 2018; Huong et al., 2018b; Kollmair & Hoermann, 2011). However, migration can put excessive burdens on those left behind, especially women, children, and the elderly (Hoermann et al., 2010). Due to high migration rates, gender roles in the region have significantly changed as already overburdened women are forced to take up added roles for both farm and household activities (Schild, 2007).

Few studies analyzed the impact of climate change on human health in the Himalayan region (Ebi et al., 2007; Majra & Gur, 2009; Dhiman et al., 2010; Bush et al., 2011). Some studies focused on the impact of rainfall variability on water- and vector-borne diseases (Pemola & Jauhari, 2006). Extreme climate causes significant mortality and morbidity in the Himalayan region (Shrestha, 2008). Climate change is expected to have wide ranging effects on human health leading to high mortality and morbidity and likely to expand the geographical distribution of some vector-borne diseases such as malaria and dengue to higher altitudes and higher latitudes. Recently, the existence of malaria mosquitoes has been reported at high altitudes in the Himalayan region (Eriksson et al., 2008). The mountain people have limited access to primary health-care and sanitation facilities and face significant food deficiencies, which led to above average maternal and infant mortality rates in mountain areas (FAO, 2008) and their well being is further challenged by crop failure due to water shortages and more frequent natural disasters, and the spread of crop and livestock pests and diseases due to rising temperatures in higher altitudes (ICIMOD, 2010b).

Climate-induced events such as glacial retreat (Evans & Clague, 1994) and rock avalanches (Kattelemann, 2003) have caused severe socio-economic impacts such as destruction to infrastructure, property and human lives (Vuichard & Zimmermann, 1987; Richardson & Reynolds, 2000). Studies on the the economic impact of climate change focus on poverty, human values and equity but lack in the Himalayan region except studies focusing on agriculture, hydropower, and tourism (Kumar & Parikh, 2001; Wang et al., 2009).

The Himalayan region is the hotspot for energy poverty-related development challenges. The clean, safe and sustainable and accessible energy strategy is crucial for the sustenance of the Himalayan ecosystem and the survival of its inhabitants. However, most studies on the impact of climate change on energy use have focused on hydropower via rainfall variability (Rupa Kumar et al., 2006) and an increase in glacier melting (Rathore et al., 2009). Both the cutting of trees for biomass production and burning of fuel wood for energy have a negative impact on the water balance of the Himalayan region (Dhakal et al., 2019).

Fuel wood is the major source of energy used and consumed by people in the Himalayan region (Singh et al., 2021). The usage of biomass is also widely prevalent in the Himalayan region. Other sources of energy are limited due to geographic isolation (Mislimshoeva et al., 2014). In the Himalayan region, fuel wood is the primary form of biomass energy. It is used for lightening, heating and cooking activities (Dhanai et al., 2014; Shaheen et al., 2016; Singh et al., 2021). Consumption of fuel wood is responsible for severe environmental problems including deforestation, the land degradation and contributes to climate change. Burning of fuel wood also impacts human health due to the indoor air pollution (Shaheen et al., 2016; Bailis et al., 2015).

Climate change is increasing energy insecurity in the Indian Himalayan Region. The energy sufficiency, quality, and security on the supply side and accessibility and affordability on the demand side are important targets for sustainable energy transitions (Dhakal et al., 2019). Despite the significance of energy for economic development in the Himalayan region, an analysis of the impact of climate change on energy has been conspicuously missing. Therefore, the present analysis of the impact of climate change on energy in the Himalayan region is highly valuable and will provide significant policy implications.

3. Methodology: Source of data and approaches

This study used a case study approach to achieve its objectives. The case study approach has been applied to acquire detailed knowledge of the climate change impacts on mountain communities specifically focusing on fuel wood energy use in Drass. A case study refers to an in-depth study of a phenomenon in its natural setting. It is, therefore, also called naturalistic research in contrast to experimental research. The case study approach is primarily a scientific inquiry of the unique phenomenon under investigation. The case studies are applied to clarify, illustrate or investigate the phenomena in a natural context. It aims to explore the causal relations to draw policy implications. The case study approach has been used to collect data and information on how, what and why questions of climate change and its impact on fuel wood energy use. This case study has selected the case of climate change impact on fuel wood energy use in Drass and collected the data through a pre-tested questionnaire, and analyzed and interpreted data to derive significant policy implications.

The primary data and information have been collected using well structured questionnaire. The field survey was conducted in September-October 2014. This case study was a part of the project on "The Himalayan Cryosphere: Science and Society" funded by the Department of Science and Technology, Ministry of Science and Technology, Government of India. Under the project we have to collect the data and information from all the 20 villages of the Drass administrative block. According to the Census 2011, the total population of the block Drass was 21988 consisting of 2149 households. The sample size was restricted to approximately 20% of the total households. Therefore, the sample size has been restricted to 440 households consisting 52.27% males and 47.73% females belonging to randomly selected 22 households each from all the villages. The sample households were personally visited by the survey team to collect the data and information using a pre-tested questionnaire. In addition, a number of focus group discussions comprising 8 to 10 members per group with the active participation of both male and female members were also undertaken to get the relevant information on the phenomenon under study. The data collected has been carefully scrutinized and misunderstanding, if any, has been corrected thereof. Besides descriptive statistics, the content analysis technique has been used to analyze the data and information qualitatively. The content analysis technique was supplemented by the use of code and label field notes, sorting, shifting, constructing and reconstructing these materials.

4. Profile of the study area

The Indian Himalayan region spans over 5 lakh Km^2 (16.2% of the total geographical area of the country) and covers 11 Indian states and 2 Union territories (UTs) - Jammu & Kashmir and Ladakh (UTs), and states of Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, and Meghalaya and hill districts of West Bengal and Assam. (Kumar et al., 2017) is home to 46,790,642 persons living in 61,592 inhabited villages and 540 urban centers (Pant & Chand, 2021) at diverse altitudes and in tough environmental conditions.

Drass is situated in district Kargil of Union Territory (UT) of Ladakh in North-West Himalayan region of India. Drass, a small town is approximately 60 km away from Kargil on the road to Srinagar in UT of Jammu and Kashmir (Figure 1). It is located at the longitude of 75.75 and latitude of 34.43 with an altitude of 10,990 feet above sea level and is widely recognized as the second coldest inhabited place in the world, after Siberia. Drass has dazzling meadows and magnificent mountain peaks which surround the whole valley formed by the river Dras originating from the Machoi glacier near the Zojila Pass. The water volume of this river rises significantly in summer when the snow in the uplands melts. Drass valley attracts tourists from all parts of the world.

Drass starts from the base of the Zojila Pass which is often dubbed the "Himalayan gateway to Ladakh" and comprises 14 panchayats (village level administrative units), 20 villages and 81 habitations. Drass experiences an altitude influenced by the sub-arctic climate. Winters are cold and recurring. Snowfall during winters lowers the temperature to as low as 40 degree Celsius below the freezing point. Winters in Drass last from October to May with an average low temperature of around minus 22 degree Celsius. However, summers are short which start in June and go on up till September. Annual precipitation is concentrated from December to May when Drass gets around 550 millimeters to water equivalent of snowfall. During winters, the valley remains snowbound with a thick layer of snow all around and a chill breeze blowing. Zojila pass, which connects Drass with Srinagar closes down during the winters and region's communication with the external world remains cut off for six months.

Figure 1. Location of drass

Barley is the main crop grown in Drass. There is a short growing season in Drass which hampers agricultural production. Crops are usually sown belatedly; however, harvesting is done early before the beginning of snowfall. Due to the poor and unproductive soil and lack of irrigation facilities, agricultural production is poor. Consequently, agricultural yields become insufficient to meet the needs of the inhabitants of Drass. The inhabitants of Drass are known as Brolpas, who have believed to be migrated to this place from Gilgit several centuries ago. Even in hostile natural conditions, people in Drass are full of life and hardworking. The low temperature does not only restrict people to their homes, it also hinders those seeking help in medical emergencies due to blockages of roads and inaccessible passes.

5. Socio-economic profile of respondents

Socio-economic profile of respondents is depicted in Table 1. This study included both males and females as respondents. However, the majority of our respondents were males. More than one-third of households had more than 8 members due to the prevalence of a joint family system. One-fifth of them were illiterate. Among those who were literate, a comparatively high proportion of them was having middle school education. A high proportion of respondents was employed in the government sector to eke out their livelihoods. While about 38.86% of total respondents reported income above INR7500 per month (1 USD = INR 60.8 at the time of the survey), very few reported INR1000-2000 as monthly income. Livestock rearing was found to be most prevalent in Drass for milk, meat, and wool requirements as majority of respondents owned livestock.

Table 1. Socio-Economic profile of respondents

Parameters	Frequency	Percentage
Sex		
Male	230	52.27
Female	210	47.73
Age		
30-40	87	19.77
40-50	123	27.95
50-60	174	39.55
> 60	56	12.73
Household head		
Male	425	96.59
Female	15	3.41
Household size		
< 4	15	3.41
4-6	144	32.73
6-8	128	29.09
> 8	153	34.77
Educational status of Respondents		
Illiterate	86	19.55
Primary	102	23.18
Middle	149	33.86
High	51	11.59
Higher sec	39	8.86
College & above	12	2.73
Technical	1	0.23
Major Source of Livelihood		
Agriculture/livestock	121	27.5
Skilled/unskilled labour	43	9.77
Government	168	38.18
Private	38	8.64
Self-employment	70	15.91
Family Income		
Rs. 1000-2000	20	4.55
Rs.2000-Rs.3000	75	17.05
Rs.3000-5000	66	15.00
Rs. 5000-7500	108	24.55
>Rs.7500	171	38.86
Ownership of Livestock	405	92.05
Type of Livestock Owned		
Cows	405	100
OX	33	8.15
Goats	149	36.79
Sheep	172	42.47
Horse	175	43.21
Others	111	27.41
Tree plantation on own land	195	44.32

Source: Field survey

The households keep cows, goats, sheep, and yaks to meet their nutritional and wool needs and donkeys and horses for transportation purposes. Horses and donkeys were used as porters in the army to supplement the households' income. Less than half of respondents reported plantation of trees on their own land to meet daily fuel wood energy needs. The use of water harvesting methods to conserve scanty water is virtually absent and participation in the conservation of community lands was marginal.

6. Results and discussion

Energy is a basic necessity for human existence and development. The Sustainable Development Goal (SDG) 7 states that access to affordable, reliable and sustainable energy is critical not only for securing future energy security but for also meeting other SDGs. The Himalayan region is the hotspot for energy poverty-related development challenges. The clean, safe, sustainable and accessible energy strategy is crucial for the sustenance of the Himalayan ecosystem and the survival of its inhabitants. In the Himalayas, the forests have diminished and degraded due to population growth, land use change, unsustainable development activities and climate-induced factors. Climate-induced forest degradation and depletion can have severe consequences for the forests dependent population to meet their fuel wood energy needs. In the following paragraphs, the results of the study have been discussed which covered awareness of climate change, climate change and use of fuel wood energy, energy consumption and expenditure, energy scarcity, its costs and reliability, effects of traditional energy use, use of improved cooking appliances and cleaner fuels, and energy use and health.

6.1 *Awareness of climate change*

Awareness is the capacity to identify, experience, and be cognizant of outcomes, thinking, and sentiments. Situation awareness refers to understanding the acuity of a situation over the period and place space and likely outlook of the condition (Endsley, 1995). An increase in local awareness followed by suitable action can help react to climate change (Wilbanks & Kates, 1999). Better awareness of climate fears, likely threats, and climate change impacts can help initiate adaptation action (Lebel et al., 2015). Climate change awareness refers to knowledge of the occurrence of the events and their impacts and suitable adaptation behavior and involves knowledge formation to understand facts and change in opinion to realize an enhanced environmental value. Increasing awareness can be possible via knowledge sharing and mobilization of local skills and resources. Climate change awareness and perception can influence future actions to combat climate impacts. Local communities' perceptions, attitudes, and expectations can play a vital part in tackling climate change impacts (Doss & Morris, 2001). However, there is a lack of climate awareness, capacity, and know how to develop climate-compatible behavior among local communities (Kollmuss & Agyeman, 2002). Greater climate change awareness in mountain communities can aid in better climate adaptation.

In most ethnic communities, climate change awareness can be significant. However, awareness of climate change impacts and the exigency to tackle climate change is small, which hampers the effort to initiate climate-compatible actions. Local communities have inadequate knowledge about existing programs to maneuvers favourable climate actions. Increased climate awareness movement can boost knowledge about the impacts of climate change, their opinion, adaptive capability and policy, which in turn can lower climate vulnerability. Climate awareness and information are vital to intensify political pressure on public agencies for developing climate-compatible policies to maneuvers climate actions. Climate change awareness can inspire local communities to pursue climate adaptation and develop their coping capacity to address climate change (Marshall et al., 2011).

Greater climate change awareness helps novel climate adaptation practices (Patt & Schroter, 2008). Most studies on climate change centered on biological and physical aspects of agriculture impacts (Husnain et al., 2017). Some recent studies evaluated farmers' perceptions on climate change (Nazir et al., 2018), negative outcomes of agriculture (Husnain et al., 2017), specifically crop production (Ali & Erenstein, 2017). However, studies on climate change perceptions are scant. Better perceptions and knowledge about climate change can foster better coping mechanisms and boost climate adaptation. Climatic uncertainties lower resilience in mountain communities (Lal et al., 2011). Better adaptive capacity can improve climate adaptation, which can moderate climate change impacts on agriculture and increase farm returns. Therefore, improved awareness and perceptions on climate change can stimulate adaptation. However, the issues linked to tackle inadequate climate awareness are less explored (Lorenzoni & Pidgeon, 2006) and studies in climate awareness, perceptions and adaptation options among local mountain communities linked to the use of fuel wood energy are virtually absent.

Respondents' concern about climate change has been shown in Figure 2, which shows that more than half of them perceived and was concerned about changing climatic conditions and a significantly high proportion of them were aware of the impact of climate change and perceived adverse climate change impact in recent years due to human actions. Self perceptions and experience played a vital role in climate change awareness among mountain communities, besides knowledge sharing and dissemination of climate change information from electronics and print media also created significant climate change awareness among the communities and improves their perceptions about climate change and its impacts on their livelihoods. For instance, about half of them experienced rising temperatures and changing rainfall patterns, which impacted their lives and livelihoods and about two-third of them has experienced a reduction in the amount of snowfall, which lowered irrigation water availability and also reduced soil moisture needed for agricultural and plantation activities. About four in ten households have experienced an adverse impact on their level of income due to climate change impacts.

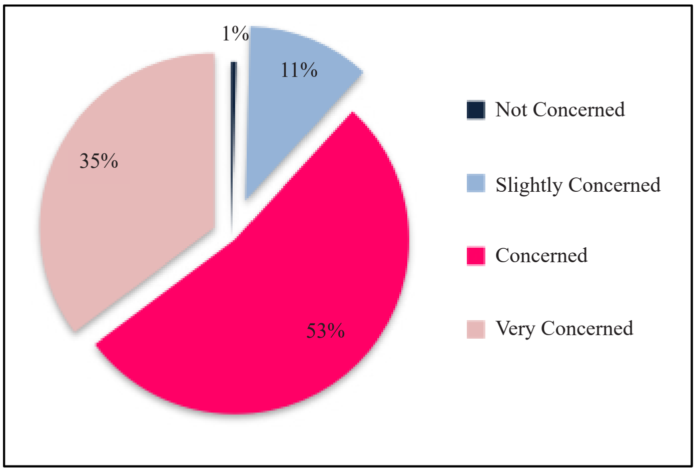

Figure 2. Concern about climate change

The majority of households experienced negative impacts of climate change on day-to-day activities, which compelled some members of communities to migrate to cope with a severe cold in winter. The fast melting of glaciers has also been perceived as an important impact of climate change, which threatened the current and future livelihoods of people residing in Drass. A high proportion of the households' members perceived adverse impacts of climate change on both humans as well as livestock health conditions. Overall, the level of awareness about climate change has been reportedly high, which translates into better local coping mechanisms and adaptation capacity among the mountain communities.

6.2 *Climate change and fuel wood energy use*

In the Himalayan region, fuel wood is the primary form of biomass energy, which is used for lightening, heating and cooking activities (Dhanai et al., 2014; Shaheen et al., 2016; Singh et al., 2021). Consumption of fuel wood is responsible for severe environmental problems including deforestation, land degradation and contributes to climate change. Both the cutting of trees for biomass production and the burning of fuel wood for energy have a negative impact on the water balance of the Himalayan region (Dhakal et al., 2019). The burning of fuel wood also impacts human health due to indoor air pollution (Shaheen et al., 2016; Bailis et al., 2015).

Despite the significance of energy for economic development in the Himalayan region, an analysis of the impact of climate change on fuel wood energy has been conspicuously missing in extant literature. Therefore, the following analysis of the impact of climate change on fuel wood energy in the Himalayan region is highly valuable and will provide significant policy implications.

The major source of energy used and consumed in Drass is fuel wood. Almost all energy requirements for cooking and heating purposes in Drass are met by the burning of fuel wood. This aligns with studies conducted by Dhanai et al., 2014; Shaheen et al., 2016; Singh et al., 2021 in their respective studies found that fuelwood was the primary form of biomass energy used for lightening, heating and cooking activities in the Himalayan region. However, the burning of fuelwood produces smoke, causes air pollution, emits carbon dioxide and thereby contributes to climate change (Ozturk & Al-Mulali, 2019). The burning of fuel wood also impacts human health due to indoor air pollution (Shaheen et al., 2016; Bailis et al., 2015). Mountain people have contributed very little to climate change, but they are the first to face its dire consequences. This study explored the types of energy used and consumed by the people of Drass and how far mountain communities contributed to climate change and coping mechanisms adapted to mitigate the ill effects of climate change. Figure 3 revealed that less than half of households grow fuel wood in the homestead and the majority of households met their fuel wood energy demand from local markets, which have been mostly transported from the valley of Kashmir and the surroundings hills of Srinagar city for selling purposes. Those who grow and purchase fuel wood were not all mutually exclusive since there were some who both grow and purchase as fuel wood grown by them were insufficient to meet their household energy demand. Besides growing and purchasing fuel wood, people also go to the surrounding forests to collect fuel wood and also depended on biomass and crop residue and animal dung. More than a quarter of households collected fuel wood from surrounding forests. Almost all the adult members of households were engaged in collecting fuel wood, which took a heavy toll on other households' tasks and economic activities. In addition to fuel wood, crop residue and animal dung, most households have also used Liquefied Petroleum Gas (LPG) for cooking purposes.

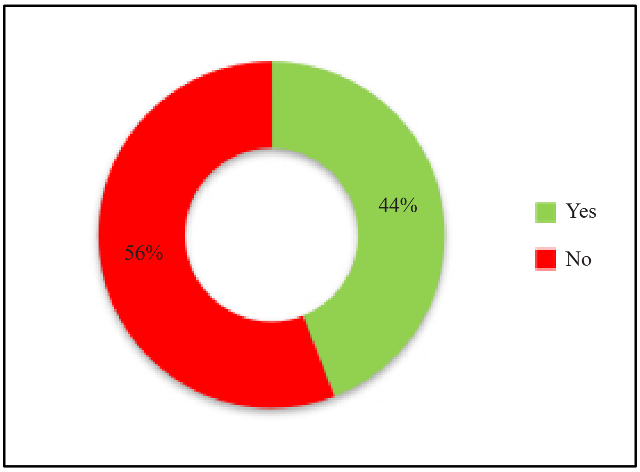

Figure 3. Fuel wood grown in garden or homestead

The above results and discussion make it evident that the mountain communities are highly reliant on biomass energy to meet fuel wood energy needs derived from crop residues, nearby forests and wasteland, which potentially contributes to energy security (Negi & Mukherjee, 2020). However, climate change impacts increase energy demand and supply gap. The poor households in mountain communities lack access to modern energy such as electricity. Therefore, biomass has been used as the main energy by most poor households for cooking and heating. Climate change impacts make biomass supply highly uncertain and unreliable, which increases energy poverty among mountain households. Rising energy prices also forced them to depend on biomass sources including crop residues and animal dung for cooking, which in turn lower soil fertility and agricultural productivity. Not only this, biomass used for cooking generates severe indoor pollution and negatively impacts the health of the people. Therefore, increased access to clean energy such as electricity and LPG can lower the reliance on biomass energy and carbon intensity and mitigate the impacts of climate change.

6.3 *Energy consumption and expenditure*

In addition to usage levels of various fuels for cooking purposes, information on energy consumption for heating and lighting purposes was also ascertained. About two-third and more than three-fourth of households relied on fuel wood energy for heating and lighting purposes respectively. Significantly, none of the households was fully dependent on fuel wood for lighting purposes. In the recent past, the government had implemented a subsidized solar energy system in the area and propagated wider use of solar lanterns for households and street lighting and the villagers have benefited immensely. The majority of respondents spend more than INR500 per month on meeting their energy needs (Table 2). However, expenditure on various kinds of fuels for cooking purposes was significant. In most households, a quarter of household's budget was used for meeting the cooking energy, mostly LPG. One-fifth of households had incurred no expenditure on fuel wood, as these households grow enough fuel wood on their own lands or collect the fuel wood from the surrounding forests and waste land. The use of kerosene oil for cooking was reportedly low due to the high cost of its use. More than one-third of households do not use kerosene oil, because the wood that they use for cooking also helped them in heating their houses. Besides, the price of kerosene oil had surged rapidly in recent years, which forced poor households to use less kerosene oil. It has also been reported that the use of kerosene oil for cooking changed the taste of food, so the villagers were afraid of using kerosene oil for cooking.

Table 2. Household expenditure on fuels for cooking purposes (Rs./per month)

Expenditure	Frequency	Percentage
< 200	48	10.91
200-300	6	1.36
300-400	9	2.05
400-500	10	2.27
> 500	354	80.45
None	13	2.95

Source: Field survey

6.4 *Energy scarcity and its cost and reliability*

In Drass, there is a scarcity of locally grown fuel wood. As discussed earlier, some households buy fuel wood imported from Kashmir valley for cooking and heating. A very high proportion of households perceived a significant shortage of fuel wood in near future due to the impact of climate change. The declining forest cover was a major concern for sustaining their livelihoods including more scarcity of fuel wood in the future. All respondents from both the landholders' groups expressed that more trees should be planted to reverse deforestation and the consequent impact of climate change. Besides fuel wood scarcity, information on the cost and reliability of household electricity was also ascertained. The majority of them opined that electricity supply was not reliable and nearly two-third of households was willing to pay more for electricity if its supply becomes more reliable. About one-fifth of them perceived that electricity was more expensive than kerosene for lighting. Therefore, there is a need to improve the electric supply to the households of Drass.

6.5 *Effects of traditional cooking energy use*

There has been reportedly greater use of traditional energy such as animal dung for cooking due to its intense heating capacity than other local sources of fuels. Animal dung was available free from the livestock maintained by households and nearby grazing grounds and forests. Very few households also reported that cattle owners do not permit them to collect the animal dung from their fields, as it lowered soil fertility and adversely impacts crop productivity. Thus, the scarcity of animal dung was an issue among mountain households. Consumption of fuel wood is responsible for severe environmental problems including deforestation, land degradation and contributes to climate change. Although fuel wood was extensively used as cooking energy, the respondents were well aware of possible environmental effects of using it, such as reductions in tree cover and deforestation and deterioration of the local environmental. The respondents also expressed that fuel wood shortages is likely to limit the carrying capacity of land and extensive use of fuel wood are expected to lead to climate change. Other perceived environmental impacts of use of fuel wood for cooking energy include desertification, soil depletion and erosion and a decrease in agricultural yields (Figure 4). In addition to environmental effects, socio-economic consequences of using extensive fuel wood for cooking purposes include a decline in wood and plant stuff needed for construction and making of household wares by more than half of the households and other household needs and income-earning activities by about four in ten households.

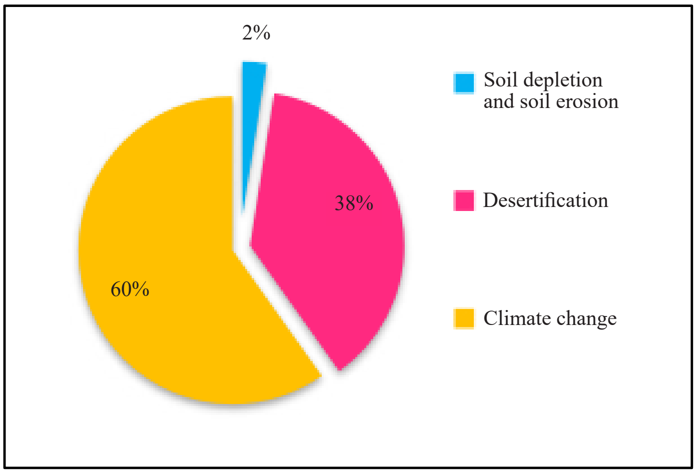

Figure 4. Different effects of deforestation

Besides burning traditional fuel wood such as animal dung and crop residue, smoking was reported as a major source of indoor air pollution in sample households. Less than one-half of respondents reported smoking by one or more family members at home, which led to harmful health consequences too. More than one-half of them reported the size of their burning room was between 3-5 m^2. More than three-fourth of households have two windows in a burning room. The majority of households used wood stoves along with LPG. More than half of the households used solid fuel burning for more than five hours a day. About four in ten households used more than 200 kg of wood per month for cooking and heating purposes. Similarly, usage levels of animal dung were less than 100 kg of animal dung per month. Overall, the use of cleaner sources of energy was significantly low due to economic reasons as well as accessibility and availability. Therefore, there is a need to improve the accessibility and availability of the LPG by strengthening the government-led schemes. Since fuel wood is the primary source of cooking energy, exposure of women to indoor air pollution from biomass fuel combustion was also ascertained. A significantly high proportion of women members of the households were engaged in cooking with wood for 3-5 hours a day, which exposed them to indoor air pollution and at the same time (Figure 5), they were also aware of technical options to reduce indoor air pollution and using the chimney for directing smoke out from the kitchen. Thus, the quality of indoor air remained satisfactory.

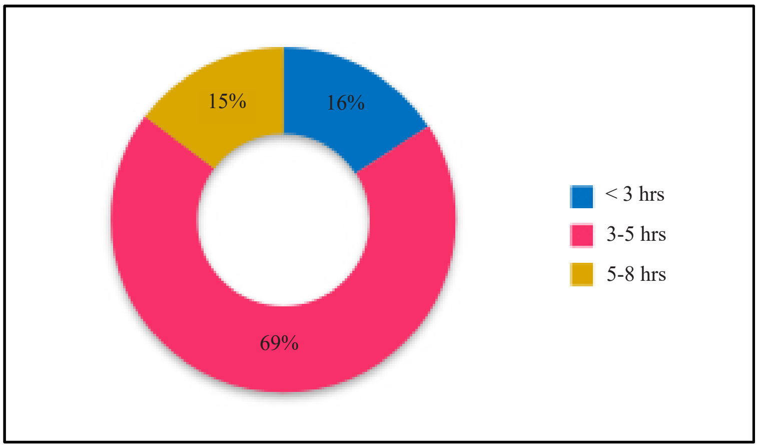

Figure 5. Women's exposure to indoor air pollution

6.6 *Use of improved cooking appliances and cleaner fuels*

All respondents used improved stoves. The most important feature of the improved stove is a chimney to remove smoke from kitchens. The use of metal casing provided strength and durability and the careful design of the pot holder to maximize heat transfer from the fire to pot in improved stoves led to greater energy efficiency. A significant proportion of respondents revealed the benefits of improved cooking fuels, which include less time for preparing food (54%) including energy efficiency (45%). Significantly, all respondents were known of fuel efficient cooking techniques and used these techniques in varied proportions, such as the use of pre-soak beans, lentils or other legumes followed by use of tight fitting lids and thorough milling of whole grains before cooking to shorten the cooking time (Figure 6). LPG was used by more than 83% of households. None of the households reported use of the briquettes, biogas, charcoal, coal, and electricity for cooking energy.

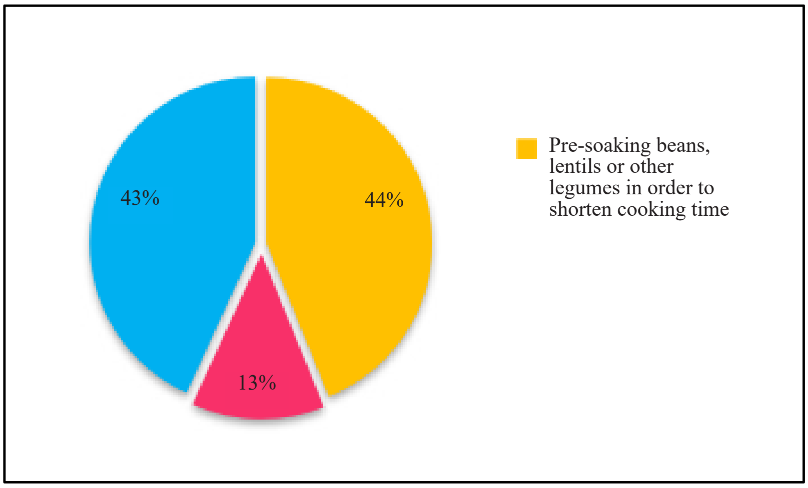

Figure 6. Fuel efficient cooking techniques adopted

6.7 *Fuel wood energy use and health impact*

Climate change is expected to have wide ranging effects on human health leading to high mortality and morbidity and likely to expand the geographical distribution of some vector-borne diseases such as malaria and dengue to higher altitudes and higher latitudes. The existence of malaria mosquitoes has been reported at high altitudes in the Himalayan region (Eriksson et al., 2008). There was no incidence of climate change related diseases such as malaria, cholera, and diarrhea reported. However, cough, cold, and running noses among children were widely reported due to excessive cold in the area. Children and women members of the households suffered from respiratory infections in a small proportion. Tuberculosis and anemia were also prevalent.

Since climate change and households' fuel wood energy use are expected to impact the health of people, respondents were asked about their awareness and perceptions about the impact of fuel wood energy use on health status. Households were well aware of different harmful effects of inhaling biomass smoke during cooking, which include chronic inflammation of lungs (41.36%), chronic bronchitis, (25.7%), acute respiratory diseases (21.82%), asthma (8.64%), eye infections (1.36%) and tuberculosis (1.14%). However, none of respondents' households suffered from heart disease, cataracts, low birth weight, infant mortality and retarded fetal development due to inhaling biomass smoke. None of the households' members suffered from ischemic heart disease, chronic obstructive pulmonary diseases, diabetes mellitus, cancer of the cervix and malignant neoplasm (liver). The respondents were asked about possible biomass combustion related respiratory illnesses symptoms during last 1 month prior to the survey. More than half of them reported possible biomass combustion related illness such as dry and wet cough, sneezing, watering, itching and redness of eyes including burn injuries.

The study found that Drass is experiencing climate change impact on fuel wood energy use at the household level. Fahad et al. (2020) reported different levels of awareness and understanding of climate change impacts on energy use. This study found that a significant proportion of households were aware of climate change and its impact and have experienced considerable climate change due to an increase in temperature and a decrease in snowfall and uncertain precipitation over the years. The majority of them perceived these changes as bad for their livelihoods and wellbeing and reported the melting of glaciers more than usual over the years due to the adverse impact of climate change. There were mixed responses on the impact of climate change on fuel wood energy use. No occurrence of climate change impacted diseases such as malaria or dengue or the emergence of any new disease in the study area.

The types of energy used and consumed for cooking and heating purposes were predominantly fuel wood. Mountain communities completely or partly relied on surrounding forests and waste lands to meet fuel wood energy requirements (Negi et al., 2017). The use of LPG in the winter season was limited due to its less availability. Clean and improved energy such as LPG, biogas, solar energy, and electricity have substantial potential to lower the reliance on biomass and forests to meet fuel wood demand in mountain regions (Katuwal & Bohara, 2009). Demand for energy has increased due to increase in population. The Ladakh region of Jammu and Kashmir consists of two districts: Leh and Kargil. As per the latest assessment carried out by the Forest Survey of India (MoEFCC, 2019), the total forest covered in the Ladakh region is estimated at 169,421 sq. km of which 155,219 sq. km and 14,202 respectively belongs to Leh district and Kargil district. The dense forest is virtually nil in Kargil compared to 77.62 sq. km in Leh, while moderately dense forest covers 657.73 sq. km in Leh compared to only 2.16 sq. km in Kargil and open forest constitutes 1,694.27 sq. km in Leh compared to 57.52 sq. km in Kargil. Forest resources are meager in Drass, which has been estimated at 89.21 hectares only by the Forest, Environment and Ecology Department, Government of Jammu and Kashmir vide Order No. 274-FST of 2017.

The negative impact of climate change on local forest resources is likely to adversely affect the energy security in the region. Recent forest rejuvenation activities have led to an increase in forests cover compared to the past. This has been attributed to the extensive participatory forest management and governance along with people's participation in managing community forests and surge in planting trees on private lands for meeting the growing households' energy needs as well as to supplement income by selling fuel wood in the local markets.

Livestock rearing was heavily opted to supplement households' food security and nutritional level. Livestock rearing depended on grasslands. However, the productivity of grasslands has declined due to the rise in temperature and reduction in snowfall and precipitation, which led to a scarcity of fodder and fuel wood energy. Low productivity of grasslands forced the grazers to move their livestock to higher mountains for grazing, which added to their hardships. Scarcity of fodder for livestock has resulted in malnutrition and degradation of livestock quality, which reduced commercial dairying for nutritious food like butter, cheese, meat and wool along with scarcity of animal dung to meet the cooking energy needs of the households.

Mountain communities contribute to fuel wood energy insecurity through extensive burning of fuel wood and animal dung for cooking, which led to a significant increase in the emission of carbon dioxide. At the same time, local people were well aware of the impact of inhaling smoke during indoor cooking, which caused chronic inflammation of lungs. Awareness about environmental effects of using fuel wood was also widespread. However, deforestation induced climate change was a direct consequence of greater reliance on fuel wood energy. The electricity supply was unreliable. However, the willingness to pay for reliable electric supply was significantly high. For mitigating energy insecurity and reducing excessive dependence on fuel wood, expanded liquid-bio fuels, rural electrifications, biogas and solar cooker and ovens were widely recognized and thus needs to be propagated. Respondents were asked about specific interventions required for mitigating fuel wood energy scarcity and they suggested supply-side measures such as increased liquid bio fuel supply, followed by agro-forestry practices and improved forest management. Other measures like the use of biogas, climbing the energy ladders, improved stoves, solar cookers and ovens, and bio fuels were also suggested to mitigate fuel wood energy scarcity.

7. Policy implications

Greater awareness and perceptions about climate change and its adverse impacts on fuel wood energy use are necessary conditions to build resilience among local communities to mitigate and adapt to adverse impacts of climate change. Fortunately local people were found to be well aware of the changes in climatic conditions. However, they could not perceive the adverse impacts of climate change clearly. Thus, there is a need to bring greater awareness among local people about potential impacts of climate change on their local ecosystem and environment. If informed, local people can play an important role in determining adaptation practices based on their local indigenous knowledge (Huong et al., 2017). Therefore, there is a need to create greater climate awareness to build adaptive capacity and promote adaptation measures for stronger climate resilience among mountain communities. Local communities must be encouraged to diversify their livelihood strategies. Livelihood diversification can offer them immense opportunities to avoid climate shocks and increase income from alternative options.

Local communities should be involved in forest management and conservation initiatives (Bisht et al., 2014). This can also improve fuel wood supply to meet households' energy requirements on a sustainable basis (Dhyani & Maikhuri, 2012), which has been hampered by non-availability of clean energy sources (Sandhu & Sandhu, 2015). There is a need to integrate forest institutions and mountain communities for participatory forest management, which can potentially improve climate adaptation and mitigation and sustain fuel wood supplies to local communities and therefore promote climate resilience (Seidl et al., 2016). Access to clean energy can lower the use of biomass sources to meet households' energy needs and reduce indoor air pollution and also lower respiratory illness and diseases (Dhimal et al., 2021). In the mountain region, there is an urgent need to promote unconventional energy resources to reduce greenhouse gases and adverse impacts on human health (Eriksson et al., 2009).

There is a need to adopt climate resilient and energy efficient policies and regulations. Renewable energy resources have a bright future to ensure fuel wood energy security in the region. There is huge potential of solar energy in the region, which needs to be tapped appropriately. For sustainable energy, renewable energy resources such as wind energy should be considered as part of the future energy transition, which also required dynamic pricing, distributed generation, storage technologies, and smart grids. In the future, a more reliable and efficient energy system will surely reduce the indoor air pollution significantly and also improve the health status of mountain communities including women and children, which will also benefit the users in terms of reduced energy expenditure.

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Conflict of interest

The authors declare no conflicts of interest.

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