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Climate Change and Water Sources: A Case of Phobjikha and Gangtey Gewog, Wangdue Phodrang Dzongkhag, Bhutan

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ABSTRACT

Water is a fundamental resource and for millions of people living in the Himalayas, springs are their only source of water for household and farming. To meet the water requirements, the communities depend on rain-fed springs which are highly sensitive to climate change. Rural communities in developing countries would be the most affected among other communities around the world as they have limited resources at their disposal. The objective of this study is to document the local people's awareness of climate change and their knowledge of water source dynamics constrained by climate change impacts in Phobjikha and Gangtey Gewogs, one of the Ramsar sites in Bhutan. A total of 248 households were interviewed using structured questionnaires employing simple random sampling techniques. Chi-Square test of independence was conducted. Results indicate that education is associated with awareness and water source dynamics. However, the majority of the residents do not have a clear understanding of how climate change affects water sources and how those sources should be protected. We recommend the relevant agency provide education and awareness on climate change impacts and training on water sources protection and management to local people. This would not only help local people enhance their resilience against climate change impacts but also protect their local resources for sustainable livelihoods. Also, Phobjikha and Gangtey are important locations to study climate change impacts in high altitude areas concerning both local peoples' adaptation strategies and dynamics of water as vital natural resources.

INTRODUCTION

Water resources are in different forms such as glaciers, snow, rivers, lakes, streams, and springs. Springs are natural discharges of groundwater that flows out of rock holes, crack, fractures, and depression developing stream, pond, and marsh (Glazier, 2014). According to Tambe et al. (2012) springs are the primary source of water for millions of people in the Himalayas. Himalayan people depend on the springs for their daily activities such as drinking, livestock, and agriculture practices (Shrestha et al., 2018). Furthermore, springs play an important role in religious and cultural significance for those mountainous people. Rural communities regard springs as a sustainable and reliable source of obtaining water.

The springs largely depend on rainwater and recharge through rainwater infiltration. However, due to climate change such as a change in precipitation and temperature trends, there is a change in natural groundwater recharge (Tambe et al., 2012). Due to the adverse impact of climate change, the water resource in the Himalayan region is impacted. The rural communities are the most vulnerable groups exposed to the impact of climate change. However, despite being the most vulnerable groups exposed to the adverse impact of climate change, studies (Shields, 1988; Pidgeon, 2012) conducted in the developing countries reported that these people are not aware of the cause, knowledge, and preventive measures of climate change.

A recent study by Lee et al. (2015), corresponds with other studies that the awareness

level of climate change is high in developed countries compared to developing countries. Developing countries in Africa, the Middle East, and Asia revealed that the level of awareness of climate change is low and some of them have not heard anything about climate change.

According to Shrestha et al. (2018), due to the drying up of springs, people in the Himalayan regions are impacted. The drying up of springs has contributed to unsustainable practices such as drilling deep boreholes to overcome water problems (Aayog, 2018). According to Negi & Joshi (2004), due to the drying up of spring women are facing problems during the lean season. Since most of the nearby springs become seasonal and women have to travel long distances to collect water. In addition to the problem of drying up of springs, there is also the problem of water quality deterioration which is of great concern (Aayog, 2018). The problem of drying up of spring is increasing as it has not received much attention since the spring water occurs naturally on the surface. According to Dorji (2016), the major problem faced by people in some of the villages is the shortage of water for drinking and irrigation. Drying up water sources is found to be a major issue and threat to the people in the country. To meet the water requirements, the communities depend on those rain-fed springs which are highly sensitive to climate change and the drivers behind the drying up of water sources (Jeelani, 2008; Chapagain et al., 2019; Sharma et al., 2009; Kumar & Sen, 2018).

Households that are aware of climate change will be in a better position to adapt and cope with the effects. Assessing the awareness of local people of climate change impacts would be useful for implementers and donor agencies to focus on specific projects to be implemented concerning the management of water scarcity and the issue of food security.

This study was carried out to analyze local peoples' perception of climate change impacts on water sources and their knowledge of dynamics of water sources in Phobjikha and Gangtey *Gewogs* of Wangdue Phodrang district in Bhutan.

MATERIALS AND METHODS

Study Area

The study was conducted in Phobjikha and Gangtey *Gewogs* both located under Wangdue

Phodrang Dzongkhag. Phobjikha *Gewog* is one of the smallest *Gewog* and comprises five *chiwogs* with a total of 375 households (RGOB, 2020). It has an estimated area of 138.20 sq km, which is mostly covered by forest and has a wetland of 975 hectares. The altitude ranges from 2800 to 4000 meters above sea level. Phobjikha *Gewog* has a cold temperate climate with cold windy winters and warm rainy summers. Gangtey *Gewog* is located between 2900 to 3200 meters above sea level and is rich in coniferous forest. It has a cold temperate climate with snowfall in the winter months. Farmers in the valleys rely heavily on potato farming for nearly all of their income.

Phobjikha and Gangtey *Gewog* were selected for the study area because the *gewogs* are well known for the winter habitat of endangered bird species, Black-necked Cranes (*Grus nigricollis*) as the *Gewogs* have wetland and are one of the Ramsar Sites in Bhutan. However, over the years, the wetland area has been decreasing including the availability of groundwater (RSPN, 2014). Furthermore, the traditional system of farming is observed to have changed to mechanized farming practices including access to markets due to improved access to roads. As both *Gewogs* are well known as tourist destinations, and with improved access to markets and road access, there has been a significant increase in developmental activities such as the construction of hotels, homestays, and resorts. As the population and infrastructure increased, the water demand also increased significantly. It is therefore hypothesized that land-use change patterns constrained by climate change impacts have most probably affected water discharge in the valley (RSPN, 2014). Other studies also argue that spring water in the Dzongkhag including others in Bhutan is drying up as a result of climate and anthropogenic impacts which warrants further research.

Sample Size

To evaluate the sample size for a small population, a normal approximation to the hypergeometric distribution (Shrestha et al., 2018) was applied. A sample determination table is the simplest way to determine the sample size needed in the field. Therefore, for this study, a total household of 248 as the sample is considered with a confidence level of 95% and a 5% margin of error.

Data Collection

The data was collected employing a random sampling technique. To record the perception of people on springs and their level of awareness of climate change a structured questionnaire is used. Secondary data associated with the research site was collected from the relevant agencies' reports. Face-to-face interviews using semi-structured questionnaires with primarily open-ended questions were used to collect household data. The questionnaire was divided into two parts. The first part was to assess people's knowledge on the level of awareness of climate change and its impact on water resources, while the second part was to assess the people's perception of drying up of water sources and their knowledge of groundwater recharge. The questionnaire was pre-tested before using it to collect the final data. The data collected were analyzed using Microsoft Excel 2010, R software, and SPSS program version 20. The data were analyzed using descriptive statistics such as frequency and percentage and the chi-square test was performed using R software.

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RESULTS AND DISCUSSION

Profile of Respondents

A total of 128 households in Phobjikha and 120 households in Gangtey were interviewed (Table 1). The respondents comprised more females (62.5%) than males (37.5%). It could be because most men in rural areas work in non-agricultural jobs like construction, while women work on farms and mostly do household work in Bhutan. The majority (69.4%) of the respondents are illiterately indicating a relatively higher illiteracy rate in the Gewogs. Most (90.7%) of the respondents are farmers and depend on agriculture for their livelihoods.

Demographic parameters		Gangtey Frequency (%)	Phobjikha Frequency (%)
Gender	Male	46 (38.3)	47 (36.7)
	Female	74 (61.7)	81(63.3)
Level of education	Graduate	5 (4.2)	2 (1.6)
	Higher school	17 (14.2)	17 (13.3)
	Primary school	19 (15.8)	16 (12.5)
	Non-literate	79 (65.8)	93 (72.7)
Occupation	Farmer	105 (87.5)	120 (93.8)
	Civil servant	1 (0.8)	2 (1.6)
	Students	4 (3.3)	3 (2.3)
	Others	10 (8.3)	3 (2.3)

Socio-Economy

Agriculture and livestock are the two main sources of income in Phobjikha and Gangtey Gewogs (Figure 1). Farmers cultivate potato as the principal crop for cash income, and in addition, they also sell cheese, butter, milk, and non-wood forest products. Thus, potato cultivation is the main activity for farmers in these Gewogs. According to the Royal Government of Bhutan (RGOB) (2018) potato farming contributes to almost 90% of the farmer's cash income generated which in turn is

used for buying all the other necessities, enough to last for a year in these two Gewogs. Farmers also cultivate radish and turnip mainly as animal feed and other vegetables such as cabbage, cauliflower, spinach, carrots, and beans on a small-scale mainly for self-consumption. They also cultivate buckwheat as one of the food crops for self-consumption. All the respondents earn their income by selling potatoes and do not grow other vegetables or crops for sale according to the respondents.



Figure 1. The main source of income of Phobjikha and Gangtey Gewogs

Local Peoples' Knowledge of Climate Change

The majority (61.3%) of the respondents are aware that climate change is happening whereas about 38.7% of the respondents do not seem to be aware that climate change is happening and it is in anyways affecting them (Figure 2). A significant association between the educational background and the respondent's perception of the awareness

that climate change is happening ($\chi^2(1, 248) = 19.012, p = 0.000$) was observed. This result is consistent with the findings of (Ndambiri et al. 2012; and Deressa et al., 2008) that education level has a significant effect on the respondent's awareness of climate change.

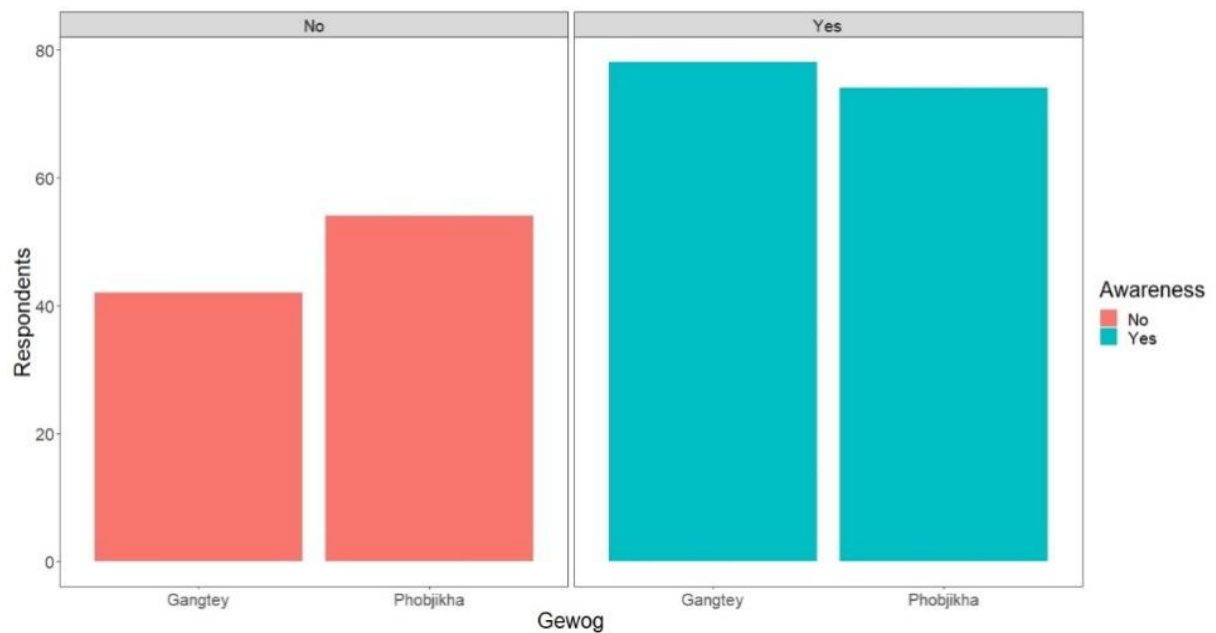


Figure 2. Local peoples' awareness of climate change

Local Peoples' Perception of the Causes of Climate Change

Half (57.7%) of the respondents seem to be not aware of the cause of climate change while less than half of the respondents stated that the climate is changing (Table 2). A Chi-square test of independence showed a strong correlation between respondents' perceptions of awareness of the cause of climate change with education ($\chi^2 (1, 248) = 12.777, p = 0.000$). Of the illiterate respondents, 78.3% were unaware of the cause of climate change. The level of association is medium (.227) and the strength of the relationship is significant ($p < .05$). Other studies on the awareness of the cause of climate change show that the level of education is an important factor whereby people who are educated are more aware of the cause and consequences of climate change (Akerlof et al., 2013).

Table 2. Local peoples' awareness of the cause of climate change

Variable	Responses	Frequency (%)
Cause of climate change	Yes	105 (42.3)
	No	143 (57.7)

Table 3. Awareness level of the cause of climate change

Cause of climate change	Responses	Frequency (%)
Deforestation	Yes	179(72.2)
	No	69(27.8)
Bush burning	Yes	181 (73.0)
	No	67 (27.0)
Burning of fossil fuels	Yes	165 (66.5)
	No	83 (33.5)
Emission of gas from the industries	Yes	164 (66.1)
	No	84 (33.9)
Uncontrollable use of aerosol	Yes	132 (53.2)
	No	116 (46.8)

Local People's Perception of the Consequences of Climate Change

Most (73.8%) of the respondents believed that climate change will lead to unpredictable weather or change in rainfall patterns (Table 4). The respondents also mention that increasing temperatures would lead to loss of crop yield and result in food insecurity although a relatively lesser number of people are aware of the consequences of

The respondents observed various reasons as the cause of climate change (Table 3) and among many reasons, deforestation and bush burning are stated by many of the respondents. Chi-square test of independence showed a strong correlation between the respondents perceptions on awareness of the cause of climate change on bush burning ($\chi^2 (1, 248) = 10.673, p = 0.001$), deforestation ($\chi^2 (1, 248) = 4.823, p = 0.028$), burning of fossil fuels ($\chi^2 (1, 248) = 4.711, p = 0.030$), uncontrollable use of aerosol ($\chi^2 (1, 248) = 6.948, p = 0.008$) with education. The study results contradict the earlier findings (Dal et al., 2015) where teachers were unaware of climate change. However, the study by (Dorji et al., 2021) revealed that teachers showed a medium level of awareness.

Elderly people are more aware of the causes and effects of climate change because they have been observing the climate system for a long time. Significant correlation between bush burning and age group ($\chi^2 (2, 248) = 8.534, p = 0.014$), deforestation ($\chi^2 (1, 248) = 11.310, p = 0.003$), burning of fossil fuels ($\chi^2 (1, 248) = 8.099, p = 0.0176$) and uncontrollable use of aerosol ($\chi^2 (1, 248) = 9.464, p = 0.009$) was observed.

climate change. Furthermore, respondents also mentioned that flooding, rise in sea level, and water security would happen with increasing impacts of climate change. A Chi-square test of independence showed a strong correlation between respondents' perception of awareness of the consequences of climate change on water security ($\chi^2 (1, 248) = 3.960, p = 0.047$) and rise in sea level ($\chi^2 (1, 248) =$

13.067, $p = 0.000$) with education, whereas half of the respondents 50.9% who were educated are aware of climate change impact on sea-level rise. The implementation of new strategies for mitigating

the impact of climate change in the area is affected by the lack of awareness and knowledge of the consequences of climate change regarding water resources.

Table 4. Awareness of the consequences of climate change

Consequences of climate change		Responses	Frequency (%)
1	Change in rainfall pattern / unpredictable weather	Yes	183 (73.8)
		No	65 (26.2)
2	High temperature	Yes	162 (65.3)
		No	86 (34.7)
3	Flooding	Yes	105 (42.3)
		No	143 (57.7)
4	The rise in sea level	Yes	53 (21.4)
		No	195 (78.6)
5	Water security	Yes	104 (41.9)
		No	144 (58.1)
6	Food security	Yes	93 (62.5)
		No	155 (37.5)

Local People's Perception of Mitigating Climate Change Impacts

On mitigating the impacts of climate change, the majority of the respondents perceive that tree plantation and recycling of wastes would help mitigate the negative impacts of climate change (Table 5). This shows that local people have been attending the awareness campaign by the Royal Society for the Protection of Nature (RSPN) and the local school. It is however surprising that residents perceive burning of Liquid Petroleum Gas (LPG) would mitigate the climate change impacts than the

use of charcoals and fuelwood. Significant correlation between proper recycling of waste and education (χ^2 (2, 248) = 9.728, $p = 0.002$) and encourage use of LPG instead of charcoals and firewood (χ^2 (1, 248) = 12.334, $p = 0.000$) was observed. The study results confirm the finding of Adebayo et al. (2013) where the level of education was influencing the level of awareness of the knowledge and methods of preventing climate change.

Table 5. Local perception of climate change impacts mitigation

Activities		Responses	Frequency (%)
1	Tree planting	Yes	199 (80.2)
		No	49 (19.8)
2	Recycling of wastes	Yes	199 (80.2)
		No	49 (19.8)
3	Encouraging the use of LPG	Yes	152 (61.3)
		No	96 (38.7)

Local People's Perception of Rainfall Patterns

Globally, there have been changes in rainfall patterns. In the study area, a majority (51.2%) of the respondents observed an increase in rainfall over the last decade, while the others perceive that there has been no change or decrease in rainfall (Figure 3). scholars argue that annual precipitation is expected to increase by 18% by the middle of the

century, and by 13%–34% by the end (Sharma et al., 2009). In Bhutan, random rainfall variability with no regular alterations is mostly apparent on an annual or monthly basis (Tshering, 2003). This is consistent with the climatic data obtained from NASA (Figure 4) that precipitation pattern is in an increasing trend for Gangtey and Phobjikha Gewogs.

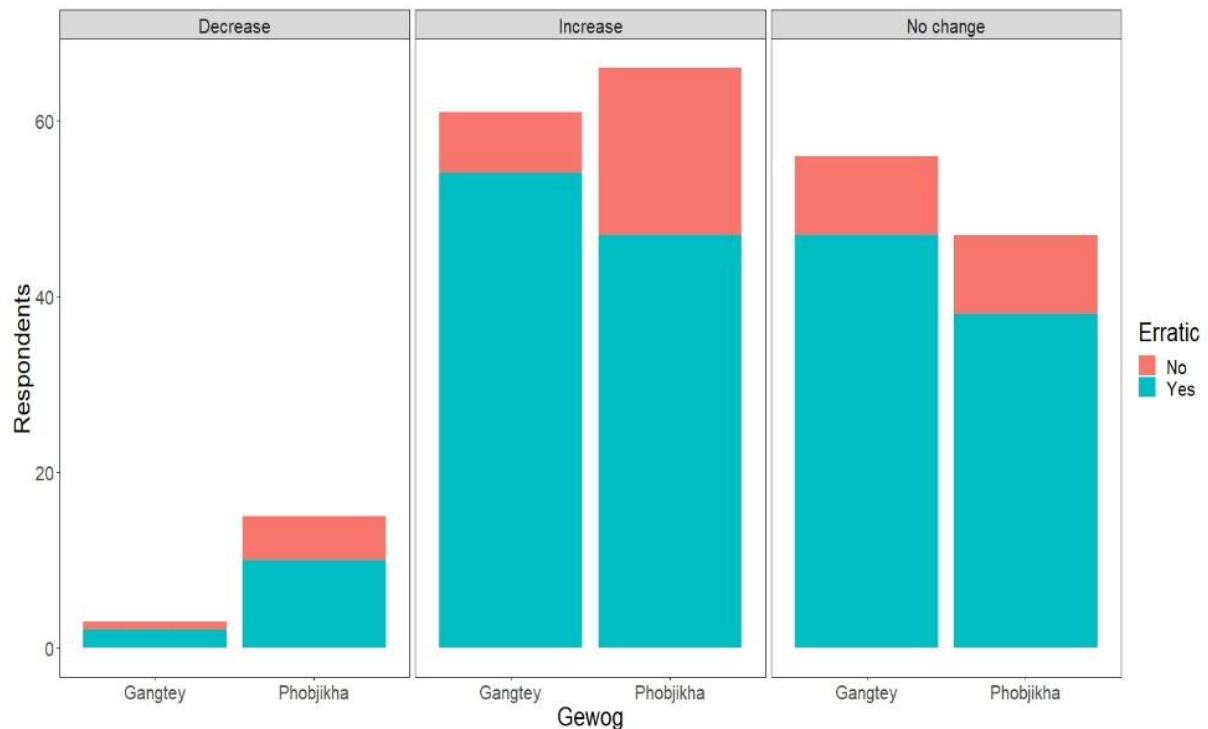


Figure 3. People's perception of rainfall pattern

A Chi-Square test revealed a significant association between the age groups (Young adults 17-30, Middle-aged Adults 31-45, and Old-aged Adults Above 45) and the knowledge of rainfall becoming more erratic ($\chi^2(2, 248) = 6.444, p = 0.04$) with the respondents in the old-aged adults 41.9% being more aware of erratic rainfall as compared to the young adults 25.3% and the middle-aged adults 32.8%. The findings show that the rainfall pattern is closely monitored as frequent and heavy rainfall has negative implications for potato production. Local people have experienced in the past that due to heavy rainfall farmers were either not able to harvest the potatoes on time or lost their crop completely. Also, there is evidence that a flash flood in the Khyimdro-Nemphel *chiwogs* under Phobjikha *gewogs* resulted in the loss of ready-to-harvest potatoes (Dorji, 2021). Similarly, Lhamo (2020) reported that a hailstorm affected thousands of acres of potato crops in five *chiwogs* of these two *Gewogs*. This may also mean that knowing snowfall intensity, duration, timing, and

also the probability to occur hailstorm is crucial to local people who are dependent on the crops that are closely associated with these events. However, the differences regarding the observed changes in erratic rainfall were not significant between gender ($\chi^2(1, 248) = 0.542, p = 0.462$), and it could mean that both men and women are involved equally in potato cultivation and may have similar observations.

Local Peoples' Awareness of Temperature Change

A majority (73.0%) of the respondents believe that temperature has been increasing at least over the past 10 years. Half of the respondents who believe that temperature is increasing also believe that cold spell during cold seasons has increased (Figure 4). This is consistent with reports of several scholars who indicated that in the last 30 years the temperature change has shown an increasing trend (Das, 2021; Ajuang et al., 2016; Adebayo et al., 2013).

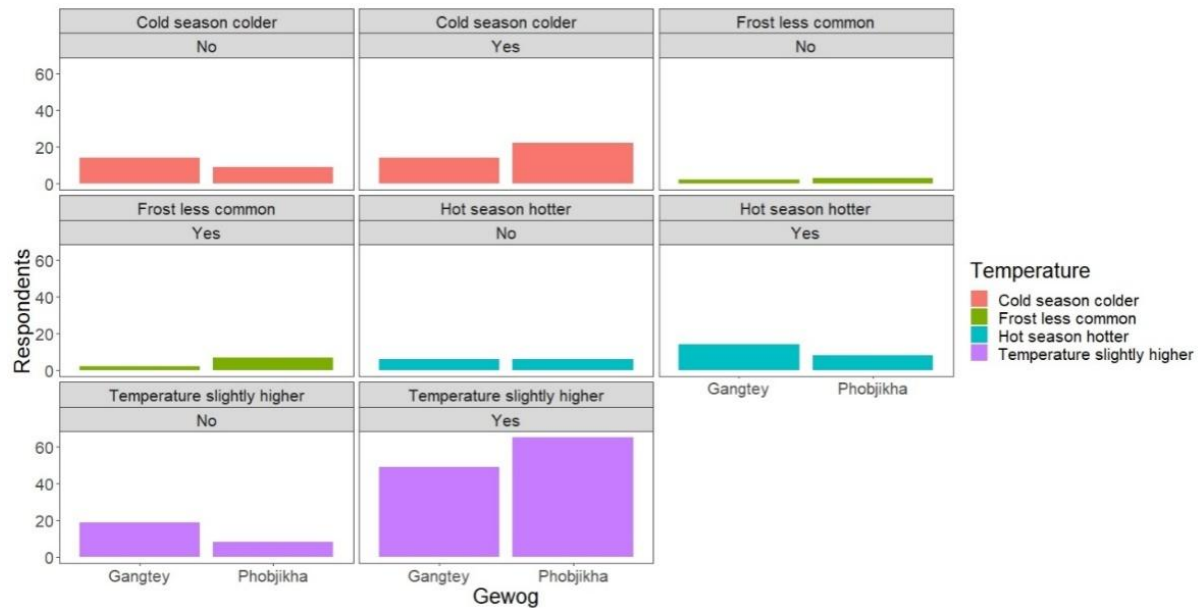


Figure 4. People's perception of temperature change

Local People's Perception of Snowfall

The majority of the respondents (93.5%) observed decreased snowfall in the study area over the last decade (Figure 5). Having snowfall and consistent snowfall regularly in winter is desired in the high altitude areas as this would indicate a

bountiful harvest in the following year, for the farmers doing crop farming. It also means that fodder for Yak would be available. Technically, snowfall would mean the presence of soil moisture and recharge of the aquifer.

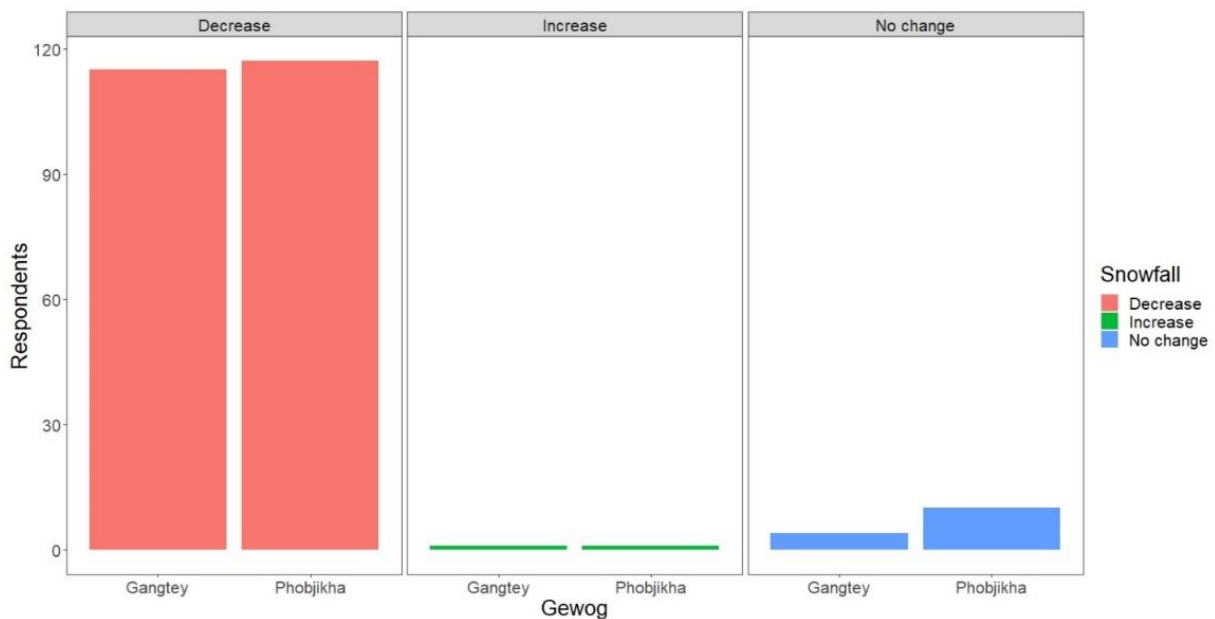


Figure 5. Local peoples' awareness of snowfall change

The Observed Change in Water Sources Over The Past Years

Half of the respondents (50.8%) stated a decrease in water sources over the last decade while 40.3% believe that there has been no change. The changes observed were evidenced by the drying up

of the spring water in their locality where 29.4% observed already dried up sources while 16.1% have been observing that the sources are gradually drying up (Figure 6). A significant association between gender and awareness of changes in water sources in the locality ($\chi^2 (2, 248) = 5.85, p = 0.05$)

was observed. However, the differences regarding awareness on changes in water sources in the locality with age group ($\chi^2 (4, 248) = 3.98, p = 0.40$) and education ($\chi^2 (2, 248) = 1.75, p = 0.41$) were not significant. It is reported that the springs are drying up in the Himalayan mid-hills. Drying up of the spring water affects local people significantly in the rural mountainous regions as they rely significantly on agriculture, and household use

including drinking and push the household into food insecurity situations. Usually, women and children are affected relatively more than others (Jeelani, 2008; Agarwal et al., 2012; Tambe et al. 2012; Kumar and Sen, 2018; Shrestha et al., 2018; Chapagain et al., 2019). Our results show consistent with earlier findings that drying up water sources would create vulnerability for rural farmers concerning water and food security.

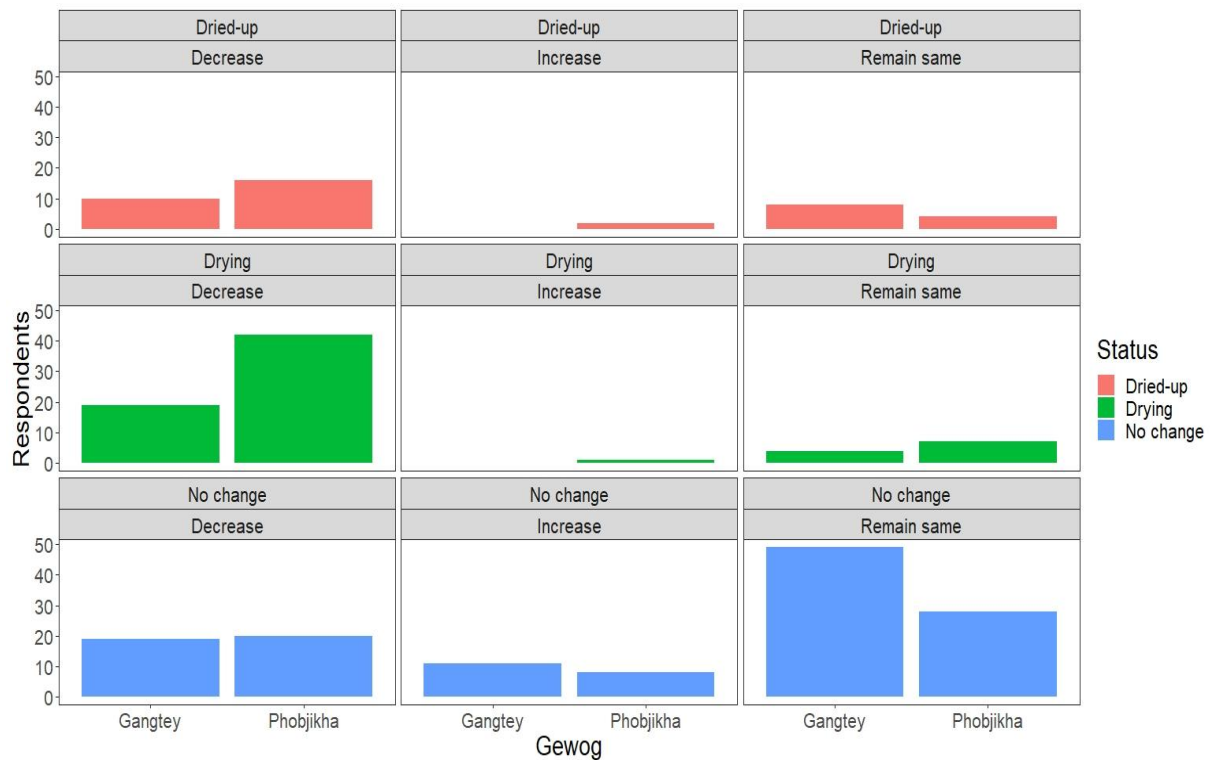


Figure 6. Status of water sources

Perceived Impact of Climate Change on Water Resources

Results revealed that 38.3% of the respondents perceive that climate change impact would be a very serious threat to water resources (Figure 7). While some others (21%) are not even aware that climate change would affect water sources. The Himalayan region, like many other parts of the world, is expected to have a significant impact on local ecosystems, biodiversity, agriculture, and human well-being as temperature and precipitation

change in the Himalayan region is predicted to warm relatively faster than in other regions (Chaudhary & Bawa, 2011; IPCC, 2021). Several studies (Sharma et al., 2009; Chaudhary and Bawa 2011; Chaudhary et al., 2011; Tambe et al. 2012) have concluded that rainfall has become unpredictable and erratic, with less and less snowfall on the mountains. The glaciers are retreating, and water sources are drying up due to climate change impacts.

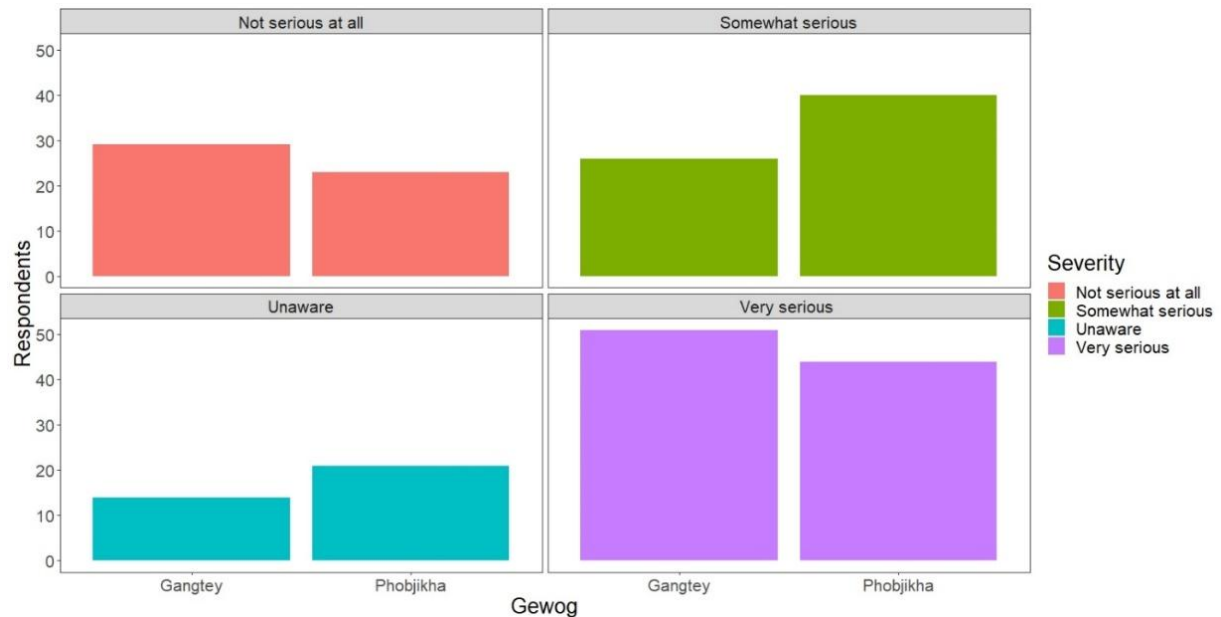


Figure 7. Climate change threat to water resource

Local People's Knowledge of Groundwater Recharge

The majority of the respondents (68.5%) are not aware of the recharge of groundwater. Knowledge of groundwater recharge is important so that while implementing plans and programs associated with catchment areas, local people would be able to understand the benefits that the projects will bring in the future. Respondents also stated that they have not implemented any techniques that would help recharge the water source. This could be because of their farming practices as they do not cultivate crops using water. Water is mainly used for household use and hotels, homestays, and restaurants. In the recent past, the number of hotels, and homestays including the incoming of new people to settle in the *Gewogs* has significantly increased which is now putting pressure on the existing water source. On the other hand, the water sources have been drying up which is why the local people are increasingly realizing that water sources have been drying up and would impact them significantly.

There is evidence that local people living in the rural areas usually have little knowledge of the hydrology of springs including the recharging processes of groundwater (Aayog, 2018). In rural areas, it is for this reason that educating local people on the dynamics of water resources would be important. A community-based participatory conservation approach must be employed. Such

engagement would help build the local capacity to address water scarcity, and food insecurity and enhance resilience to climate change impacts.

The engaging community would help them to educate themselves on how hydrogeology is important for water recharge and how to understand that water recharge has been changing (Mahamuni & Kulkarni, 2012).

CONCLUSION

This study documents information on the local people's awareness of climate change and their perception of the drying up of water sources in Phobjikha and Gangtey *Gewogs* of Wangduephodrang *Dzongkhag* in Bhutan. The objective of this study was to analyze how local peoples' knowledge concerning age, education, and gender were associated with climate change impacts and water sources. Results show that majority of local people believe that climate change is happening and that education is significantly associated with the knowledge and awareness of both causes and consequences of climate change.

Precipitation and temperature patterns were also found to be changing in Phobjikha and Gangtey *Gewogs*. Similarly, there is a significant association between education and the severity of climate change impacts and its threat to water resources. This is not surprising although local traditional knowledge appears to be missed out. The current study suggests adaptation strategies that help build

local peoples' resilience in the future concerning both protection of water sources and enhancing local resilience against the changing global environmental change. Furthermore, the Phobjikha valley is one of the most important wetland areas at the Ramsar site in Bhutan. Therefore, protecting water sources and conserving wetland areas as a habitat for black-necked cranes is crucial. Protecting water resources not only secures the livelihoods of local people but also protects the dwindling wetland ecosystem in Bhutan.

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