Climate Change Vulnerability Assessment in Kurichhu Watershed: A case of Gangzur and Kengkhar, Bhutan

Center for Water, Climate and Environmental Policy
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Acronyms

ARDC	Agriculture Research and Development Centre
BHU	Basic Health Unit
CCAP	Climate Change Adaptation Program
CSO	Civil Society Organization
DoFPS	Department of Forests and Park Services
EU-GCCA	European Union Global Climate Change Alliance
FYP	Five Year Plan
GLOF	Glacial Lake Outburst Flood
GNHC	Gross National Happiness Commission
GPS	Global Positioning Systems
HWC	Human-wildlife Conflict
IPCC	Intergovernmental Panel on Climate Change
l/c/d	litre/capita/day
MoAF	Ministry of Agriculture and Forests
MoH	Ministry of Health
NEC	National Environment Commission
NSB	National Statistics Bureau
PHED	Public Health Engineering Division
PRA	Participatory Rural Appraisal
PRECIS	Providing Regional Climates for Impacts Studies
RGoB	Royal Government of Bhutan
RNR	Renewable Natural Resources
RWSS	Rural Water Supply and Sanitation
UNICEF	United Nations International Children's Emergency Fund
WCNP	Wangchuck Centennial National Park
WMD	Watershed Management Division
WHO	World Health Organization
WUA	Water User Association

Glossary of Bhutanese Terms

Bab	Mask
Chhu-sungpa	In-charge of drinking and irrigation water in a village
Chiwog	Sub-block or basic electoral precincts
Choesham	Altar
Chorten	Stupa
Drupchu	Holy spring
Dungkhag	Sub-district
Dzongkhag	District
Dzongkhag Tshogdu	District level planning meeting
Gangchu	Spring water
Gaydrung	*Gewog* Clerk
Gewog	Block
Gewog Tshogde	Block level planning meeting
Goempa	Monastery
Gung-dang-woola	Labour contributions from each household
Gup	Elected *Gewog* leader
Mochhu	Female river
Omchu	Small pond
Palang	Wooden container for storing local wine
Rongchu	Stream
Sachu Bumteer	Ritual to appease deities to keep the water source intact and prevent flood
Tsangchu	River
Tshogpa	Head of *Chiwog*

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Executive Summary

Bhutan is a net sink for greenhouse gases yet it is vulnerable to the effect of climate change due to the steep mountainous terrain and high dependence on climate-sensitive economic sectors such as agriculture and hydropower. Increasingly, communities are exposed to the risks of climate change effects and more communities become vulnerable and ultimately causing huge impacts on the livelihood and their sustenance. Although Bhutan has committed to maintain its carbon neutrality and devise means for a green economic development pathway, climate change impacts are real and evident being a vulnerable mountainous region. We really need to devise means of adapting to these impacts (although challenging) but it's crucial for the future well being of Bhutanese people, economy, and ecosystem. Thus, assessment of climate change vulnerability of communities, livelihood, and ecosystems is very important for devising concrete adaptation measures. This study in two communities within Kurichhu watershed is an initial step towards enhancing community resilience to the impacts of climate change.

Communities in Gangzur and Kengkhar are mainly dependent on agriculture and livestock rearing for their livelihood. Several studies have shown that livelihood based on subsistence farming and pastoralism may be affected the most by climate-induced changes such as new pests, diseases, and parasites and shifts in phenological and seasons. Thus, the communities dominant with subsistence farmers are highly vulnerable to the impacts of climate change.

Our study reveals that human-wildlife conflicts and water scarcity are the main socio-economic constraints in both the communities. Farmers increasingly face acute water shortage during the paddy transplantation due to the huge requirement of water for paddy cultivation and irrigation of other crops. We also found that there are increasing incidences of conflicts with wild animals in the last decade.

Another dimension in which the communities will experience climate change impacts is the changes in water availability. Water sources are increasingly reported to be drying from most of the rural and urban communities. These facts can also be supported from the current study findings. In Kengkhar, 12 drinking water sources had less than 50 l/c/d. The maximum number of drinking water in this study area falls in basic to intermediate access. The water scarcity in Kengkhar has been

attributed to its geographical topography and severity of water scarcity increases with elevation, as most of the settlements are located at uphill slopes. Given the nature of the landscape, few water sources are seasonal that forces the communities to collect water from distant sources (more than 3 hours in some cases) and some also rely on rainwater harvesting. The water-related problems in Kengkhar had improved compared to past years due to management interventions by various agencies such as Ministry of Health, United Nations International Children's Emergency Fund, Tarayana Foundation, Agriculture Research and Development Centre Wengkhar, and *Dzongkhag* Administration. However, a much-concerted collaborative effort among the institutions and pooling of resources will further aid to solve the issue of water scarcity.

In Gangzur, about 18% of the respondents reported of having insufficient water for their daily consumption. The main reason behind the water shortage could be the management issue at the individual households level as we observed over 50 water taps were non-functional though there was an adequate water discharge at the source. These issues can be addressed by creating awareness on proper water source management; existing rules, regulations, and policies related to water sources.

The results of climate change vulnerability assessment in these two communities may be used for future planning and specific adaptation interventions to increase the adaptive capacity of the studied communities and other vulnerable communities in Bhutan as well.

1. Introduction

1.1. Project Background

Climate change is a global phenomenon affecting the economy, society, and natural environment (Tshering et al, 2010). Poor people in the developing countries are more vulnerable to the impacts of climate change, as the capacity to cope up with the climate change is closely related to access to resources (Hoy et al., 2015).

The Global Climate Change Alliance (GCCA) was set up by the European Union (EU) in 2007 to support vulnerable countries to adapt to climate change and participate in global climate change mitigation efforts.

Though Bhutan is a net sink for greenhouse gases, Bhutan remains highly vulnerable to emerging climate change impacts due to its geographical location and high dependence of the country on climate-sensitive sectors such as agriculture, hydropower, and forestry (MoAF, 2016; NEC, 2016a). The objective of the European Union-Global Climate Change Alliance (EU-GCCA) supported Climate Change Adaptation Program (CCAP) is to enhance the resilience of Bhutan's rural household to the effects of climate change, and to ensure climate change readiness of the Renewable Natural Resources (RNR) sector in Bhutan by mainstreaming climate change programs into the RNR sector and ensuring that the steps are taken towards increasingly addressing climate change adaptation at multi-sectoral level.

The Department of Forests and Park Services (DoFPS) is one of the main implementing partners to implement the RNR-Sector support program activities under EU-GCCA project. The Ugyen Wangchuck Institute for Conservation and Environmental Research (UWICER) under DoFPS was to lead the assessment of community vulnerability and adaptation to climate change impacts and water scarcity in communities within Kurichhu watershed in Bhutan.

1.2 Climate Change in Bhutan

Bhutan is a small landlocked country situated at the southern slope of eastern Himalaya with an area of 38,394 km^2 with an estimated population of 757,042. From the total land area, 71% of the country is under forest cover (FRMD, 2016) absorbing more carbon than emitted. Bhutan is highly vulnerable to the adverse impacts of climate change as the economy of the country is largely driven by agriculture and hydropower sector coupled with low economic stability of the country (NEC, 2016a).

There is a lack of reliable historical records of rainfall and temperature in Bhutan and un-availability of these data at the local level is proving to be a great hindrance in generating evidence of climate change in Bhutan (Shahnawaz & Strobl, 2015). The analysis of metrological records within the four representatives "eco-floristic zones" of Bhutan from 2000-2009 shows increasing trends for both maximum and minimum temperature (NBC, 2011; NEC, 2011; Wangdi & Kusters, 2012). The future climate projections for Bhutan using Providing REgional Climates for Impacts Studies (PRECIS), as reported in Second National Communication (NEC, 2011) also indicates an increasing trend in the annual mean temperature from 1980 till 2069. An analysis of available surface air temperature records of Bhutan shows a warming trend of about 0.5°C from 1985 to 2002 during the non-monsoon season (Tshering et al., 2010). The analysis of the monthly annual profile of surface air temperature of Bhutan for the year 1996-2005 also indicates a wide range (mean=17.58°C, max=34.85°C, and min= -11.50°C) of seasonal and spatial variation in temperature (Tshering & Sithey, 2008).

Bhutan receives 70% of the precipitation during monsoon season (NEC, 2011, 2016a). However, it is difficult to identify general pattern and trend in precipitation due to regional specificity, and various factors affecting the rainfall pattern (NEC 2011; Wangdi & Kusters 2012; Shahnawaz & Strobl, 2015). There are also reports of increasingly more erratic rainfall patterns and less snowfall in the localities of Wangchuck Centennial National Park (WCNP) in Bumthang (Lhendup et al., 2011), and decreasing and erratic rainfall patterns and delayed onset of monsoon in Punakha and Wangduephodrang valleys in Bhutan (NEC, 2016a; Wangdi & Kusters, 2012). The future climate projections for Bhutan by National Environment Commission (NEC, 2011) also indicate a moderate increase in mean total annual rainfall for the period of 2040-2069 in Bhutan. A wet monsoon season getting wetter and the dry season becoming drier resulting in more incidences of water shortages during the dry winter season and increased rainfall during monsoon season in southern part of the country is likely to occur (NEC, 2016a).

1.3. Water Resources and Scarcity: Global Scenario

Water is a fundamental resource essential for all ecological, societal (Gleick, 2012), and economic activities (Postel, 2000). Most of the freshwater is not accessible for human use due to uneven distribution of water in time and space (Gleick, 2012; Jiang, 2009; Postel, 2000). Around 3% of the water on our planet is freshwater out of which only 0.3% is available as surface water (Gleick, 1996).

The large spatial and temporal variation of water demand and availability leads to water scarcity in several parts of the world at specific times of the year (Mekonnen & Hoekstra, 2016). There is an ongoing debate on the concept of water scarcity for some time as it can be determined as supply problem (physical) or a demand (social) or both (Mukheibir, 2010; Rijsberman, 2006).

According to the second interim report (European Commission, 2007, p.7)**,** water scarcity is defined as 'A situation where insufficient water resources are available to satisfy long-term average requirements. It refers to long-term water imbalance, combining low water availability with a level of water demand exceeding the natural recharge'.

Water scarcity is driven by increasing population (Mekonnen & Hoekstra, 2016), depletion of water resources due to over withdrawal of both ground and surface water (Jiang, 2009; Ostel, 2000) and reduced water quality due to pollution (Jiang, 2009).

Climatic parameters, such as rainfall, temperature, snowfall, and anthropogenic changes such as the increase in human and livestock population also influences water availability (Kundzewicz & Somlyody, 1997; Neupane et al., 2013). The increase in the climate variability alters the present hydrological resources adding pressure on the water availability in future (Mukheibir, 2010). The phenomenon of climate change also increases the frequency and severity of droughts and floods (World Economic Forum, 2015) as a result of the rapid retreating of glaciers in the Himalayas. The conditions of water scarcity due to climate variability generally results in increased cost of water supply (Mukheibir, 2010), which is beyond the economic adaptive capacity of those communities in the least developed countries.

Most of the scientific studies on global water scarcity concluded that up-to two-third of the global population will be affected by water scarcity over the next several decades (Rijsberman, 2006). This seemed to be a correct prediction with the current report of about four billion (two-third of the global population) declared to be living under severe water scarcity at least one month in a year (Mekonnen & Hoekstra, 2016). Severe water shortages are observed in areas with high population, intensely irrigated land, and low natural water availability (Mekonnen & Hoekstra, 2016) coupled with lesser economic resilience. The capacity of the economic potentiality of the country plays a greater role in addressing the water issues as no water scarcity was observed in the developed world

(Rijsberman, 2006). In Asia, nearly half of the population of India and China lives under severe water shortage (Mekonnen & Hoekstra, 2016).

Freshwater shortage affects food security (Postel, 2000; Seckler et al., 1999; Taylor, 2009), public health, environmental health (Seckler et al., 1999; Taylor, 2009) and may even instigate civil conflicts or political instabilities (Brown & Halweil, 1998; Gleick, 2012; Postel, 2000; Taylor, 2009).

1.4. Water Resources and Scarcity in Bhutan

Bhutan has rich perennial water resources owing to the permanent glacier fed headwater sources, vast forest coverage, and recurrent monsoon. Though major rivers can form the main water resources in Bhutan, communities mostly depend on smaller streams, spring and lakes for domestic and agricultural use (NEC, 2016a) due to easy accessibility. Bhutan has one of the highest per capita water availability in the world (109,000 m^3) with an estimated mean annual discharge of 73,000 million m^3/year (Chhopel et al., 2011; NEC, 2011, 2016a). However, localized availability of water remains an issue owing to accessibility and the topography in which settlements are located.

Though current water demand is below water availability in Bhutan, the growing population, increasing economic development and improving lifestyles has resulted in increasing demand for water (NEC, 2016b). Acute localized water scarcity is increasingly being observed in the country largely due to climate change such as drying up of water sources and change in precipitation and temperature patterns (NEC, 2011; Hoy et al., 2015), and further augmented by poor management and accessibility (Gyelmo, 2016). However, there is no water scarcity at national and *Dzongkhag* level looking at the water balance estimates calculated by NEC. According to a rural water supply inventory by Public Health and Engineering Division (PHED), Ministry of Health (MoH) in 2014, 13,732 rural households across the country are facing drinking water problem (Gyelmo, 2015).

Water scarcity has been an emergent issue in Bhutan and will be further aggravated especially towards the end of the dry season, when snowmelt from the northern high-altitude regions, largely accounts for the river base flows. The observed and projected temperature rise for the coming decades in Bhutan supports increasing discharges by higher glacier melts during the wet season and a declining water availability associated to increased evaporation during the dry season (Hoy et al., 2015). Thus

communities will remain vulnerable to the problem of scanty in terms of water resources and further aggravated by the impacts of climate change. Thus assessment of existing water sources in communities and understanding the water use patterns among households is very crucial in Bhutan to understand the issues and to recommend the plausible solution for managing the existing water resources effectively.

1.5. Objectives

The main objectives of the study were to:

- Assess the climate change vulnerability of the communities of Gangzur and Kengkhar within Kurichhu watershed.
- Assess and evaluate water resources availability and water use status in communities of Gangzur and Kengkhar.
- Assess the existing local level institutional mechanisms in place for water resources management.

2. Study Area

The study is part of larger project "Assessing Climate Change Vulnerability and Adaptation capacity of communities along the Kurichhu Watershed supported by the EU-GCCA and implemented by DoFPS.

The project area was scaled down to two *Gewogs*; Gangzur in Lhuntse and Kengkhar in Mongar *Dzongkhag*s (Figure 1). Gangzur *Gewog* had highest poverty rate of 46.76% (NSB, 2007) among eight *Gewog*s in Lhuntse, while Kengkhar *Gewog* was reported of facing acute water shortage in Mongar *Dzongkhag*.

2.1. Gangzur *Gewog*

Gangzur *Gewog* under Lhuntse *Dzongkhag* covers an area of approximately 536km^2. It has a total of 452 officially recorded households, with a total population of 5067 (*Dzongkhag* Administration, Lhuentse, 2011). For administrative purpose, Gangzur *Gewog* is divided into 5 *Chiwog*s. Agriculture and livestock farming are the main source of livelihood. Of the total 1415 acres of arable land, about 1044 acres (88.4%) are dry land and 371 acres (31.4%) are wetland (Gangzur *Gewog*, 2016).

The *Gewog* is topographically characterized by high ridges; steep slopes, deep gorges, and lowlands in some areas. The *Gewog* lies within the subtropical altitude range of 1,350-2,100 masl. Broad-leaved forest dominates the area though other forest types such as fir, chirpine, blue pine, and scrubs are also present (WMD, 2017). *Gewog* is accessible by

motorable road and has electricity and connected by rural water supply schemes.

2.2. Kengkhar *Gewog*

Kengkhar is one of the remotest *Gewogs* in Mongar *Dzongkhag* with an area of 100 km^2. It has 6 *Chiwogs* with a total of 437 households and a population of 3886 (Mongar *Dzongkhag* Administration, 2014). Chirpine forest is the dominant forest type with the blend of cool and warm broad-leaved forest. Agriculture crops particularly dryland farming and livestock rearing are the primary source of livelihood.

About 400 households have access to clean drinking water supply (GNHC, 2013a) and further asserts to achieve 100% by the end of 11th five year plan (GNHC, 2013b). However, few villages in the *Gewog* stills face shortage of clean drinking water. In the past, to meet the increasing demand for timber due to growing population in Kengkhar lead to over-harvesting of trees within water source catchment areas for residential constructions, shifting cultivation, woodcraft activities and excessive grazing (Gurung, 2012). Consequently, the natural spring ponds and water sources have dried, and gradually the communities experienced an acute water shortage (Gurung, 2012).

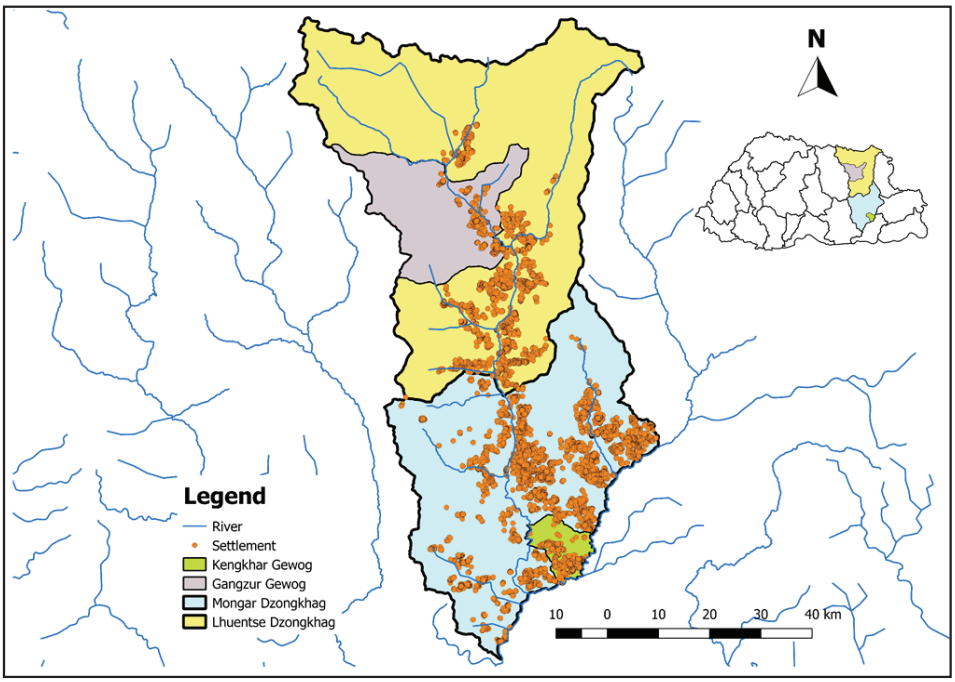

Figure 1. Map showing study area and settlement in Kurichhu watershed

3. Methods

The study used both primary and secondary data. Primary data on various aspects of vulnerability were obtained through Participatory Rural Appraisal (PRA) tools; household interviews and key informant interviews. Detailed field assessment of drinking water source was carried out to understand the issue of water availability and scarcity. Secondary data for the study area were gathered from available records within the relevant agencies and reports.

3.1. Household Interviews

Household interviews were conducted in both study areas by the representative sampling of households (Figure 3). Households from each *Chiwog*s under the *Gewogs* were listed and more than half of the households were randomly selected for the questionnaire survey. The respondents were not necessarily the household heads. We used semi-structured questionnaire (Annex I) for the household interviews. The questions were grouped into different parts to gather information on respondent's household, local awareness and perception on climate variability, and water availability. A total of 259 households in Gangzur, and 267 households in Kengkhar were interviewed (Table 1). Prior to household interviews, awareness on climate change and its impact on the water were carried out during the public consultation meetings (Figure 2).

Table 1. Respondent details for household surveys

Gewog	**No. of Households**	**Total Respondents**	**Age Range**	**Male**	**Female**
Gangzur	452	259	20-89	64	195
Kengkhar	437	267	19 -92	148	119

The perception of the respondents on climatic elements were corroborated with available temperature and rainfall data of nearest station; Sumpa-Khoma meteorology station (1990 -2016) for Gangzur *Gewog*, and Lingmethang meteorology station (1996- 2016) for Kengkhar *Gewog*, maintained by National Centre for Hydrology and Meteorology, Royal Government of Bhutan.

Key informants interviews were conducted to validate the information gathered through the household questionnaire survey. Key informants

including local leaders and *Gewog* officials were selected based on their experience and knowledge about community livelihood (Annex II).

Figure 2. Public consultation

Figure 3. Household interviews

3.2. Drinking Water Sources Assessment

The existing water sources used for drinking water supply were identified through consultation with *Gewog* officials and village *Chhu-sungpa*. The estimated number of population supported by each water sources were also collected from *Chhu-sungpa* and *Chiwog Tshogpas.* Drinking water sources were mapped using handheld GPS (eTrex, Global Positioning Systems, Garmin). Discharge from the respective water sources was estimated using a volumetric method and flow method (Figure 4). For the latter method, a correction factor of 0.8 was adapted from Michaud and Wierenga (2005). Depending on the type and size of water sources, the most suitable method was applied to estimate the discharge. Water discharge was determined as a product of the velocity of the moving water and cross-sectional area of the water in the channel (Annex III).

Figure 4. Researchers measuring water discharge from a stream in Gangzur

4. Results and Discussions

4.1. Socio-economic Scenario

4.1.1. Livelihood

Agriculture and livestock rearing were two of the main sources of livelihood in Gangzur and Kengkhar *Gewogs*. The main crops grown include maize, potatoes, beans, and cabbage in both *Gewogs*. People in Gangzur also grow fruit trees such as mandarin, banana, cardamom, guava, peach, pear, and plum. While in Kengkhar, mandarin and mango are grown for commercial purpose, and litchi, banana, plum, groundnut, and papayas are grown on a smaller scale. Water shortage and human-wildlife conflicts were the two main factors affecting agriculture in both the *Gewogs* (Table 3). In the year 2013, Lhuntse *Dzongkhag* lost about 238 metric tons of maize and 64 metric tons of paddy to wild animals (GCBS, 2015). More than half of the respondents (55% and 54%) from Gangzur and Kengkhar respectively reported the increase in the incidences of human-wildlife conflicts over the last decade.

Figure 5. Vegetable cultivation in Ngar village, Gangzur *Gewog*

On average, farmers in Gangzur own six cattle per household and earned an income of approximately Nu. 754/- per month through the sale of surplus milk and other dairy products. In Kengkhar, farmers own three cattle per household and earn an average of Nu. 330/-in a month.

Non-farm activities also substantiated the household income for farmers in both the *Gewogs* (Table 2). In Gangzur, 55% of the respondents reported that they also engaged in other non-farm activities (Table 2); 70% of people worked as labourers in road construction and contract works generating on average of more than Nu. 22,000/- per household annually. About 32% of the respondents also reported that they got additional income through remittances from their family members working away in other places. Annually, on an average they received cash or goods worth more than Nu. 12,000/-.

In Kengkhar, 33% of the respondents engage in woodcraft such as carpentry, painting and other handicrafts and earning an average annual income of Nu. 57,000/- approximately per household. Around 80% of the households in Kengkhar are dependent on woodcraft for their livelihood due to low productivity and limited modern techniques (Gurung, 2012). People of Dogtang_Moorong *Chiwog* had specialized in *Palang (Traditional storage bottles)* making, while Neykolog_Warongborang and Olokid_Tsalabi C*hiwogs* had specialized in carving *Babs (masks)* and *Chortens (stupas)*. People of Tongla_Zi-Tsibi *Chiwog* had specialized in making *Choesham (Altars)*. People also worked as contract labourers and earned an average annual income of approximately Nu. 33,000/-per household. 30% of the respondents reported receiving additional income from remittances in the form of money and/or goods worth more than Nu.10,000/- per household in a year.

About 36 households in Gangzur and 70 households in Kengkhar were left unoccupied (*gungtong*) (Table 4). The number of *gungtongs* in Kengkhar is one of the highest in Mongar *Dzongkhag* (Tshering, 2018) and there are reports of increasing number of *gungtong* in the *Gewog* (Yangden, 2017). The reason for the existence of gungtong in the area was not determined in the study. However, this may be attributed to increasing number of rural-urban migration, water scarcity issues, and poor road conditions.

Table 2. Most important non-farm activities (% of respondents)

Non-Farm Activities	Examples	Gangzur	Kengkhar
Blue collar	Contract labour	70.4	45.2
Trade	Small shop/trade in vegetables	4.2	7.3
Woodcrafts	Carpentry/painting/ weaving/Handicraft making	4.9	33.1
White collar	*Gup/Tshogpa/ Gaydrung*	2.1	2.4
NTFPs	Medicinal plants/ Wild fruits	15.5	4.8
Others	Rituals/pension	2.8	7.3

Figure 6. Carving masks and making *Palangs*

Table 3. Socio-economic constraints and adaptation measures

Gewog	**Socio-economic constraints**	**Measures taken by *Gewog***
Gangzur	1. Human-wildlife conflict	1. Solar fencing
	2. Water Shortage	2. Water source protection
	3. Outbreak of diseases for crops and domestic animals	3. Treatment and vaccination
	4. Steep and unproductive land	4. Sustainable land management practices
Kengkhar	1. Water Shortage	1. Spring source protection and renovation of irrigation channels.
	2. Human-wildlife conflict	2. Solar fencing

Table 4. Number of gungtong in the study area

	Total No. of HHs	Gungtong (Nos.)
Gangzur *Gewog*	**434**	**36**
Jang_Ngar	101	5
Nyimshong_Tongling	61	6
Nye	95	15
Shawa_Zhamling	63	3
Kyidloong_Somzhing	114	7
Kengkhar *Gewog*	**455**	**70**
Dogtang_Moorong	89	13
Neykolog_Warongborang	82	20
Olokid_Tsalabi	55	8
Phosothong_singchongri	111	20
Tongla_Zi-Tsibi	63	5
Kyidpari_Yuldari	55	4

Source: Data collected from individual *Tshogpas*, 2016.

4.1.2. Food Security

Food security is one of the most pressing concerns arising due to the impacts of climate change among a large majority of Bhutanese population due to their dependence on subsistence agricultural activities (Shahnawaz & Strobl, 2015). Despite multiple sources of income, some of the households in the study area experienced an occasional problem with food security. About 38% of the respondents from Gangzur, and 21% of the respondents from Kengkhar indicated they have experienced food shortage at least once in the past (Figure 7). This may be attributed to harsh climate, increase human-wildlife conflict incidences, crop diseases, and water scarcity and limited arable land.

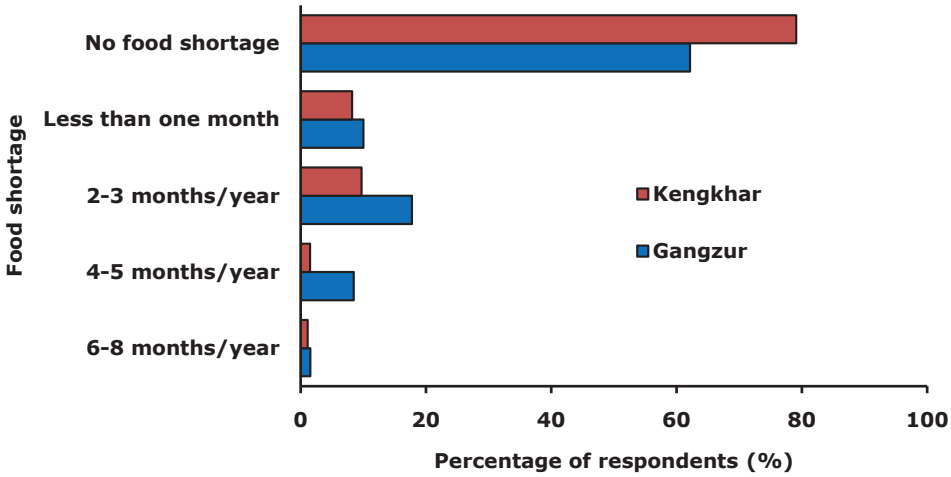

Figure 7. Perception on period of food shortage in a year

4.2. Climatic Trends

4.2.1.Temperature

Despite the increasing global temperature, more than half of the respondents from Gangzur (65%) and Kengkhar (53%) observed no change (decrease or increase) in local temperature for the past decade (Figure 8). However, analysis of temperature data for both study areas obtained from the nearest meteorological stations (Figure 9 & 10) showed slightly increasing trend. This differences may have resulted due to limited knowledge of climate change and people may not have experienced the small change in the temperature over a decade. The slight change in the temperature can be a useful indicator for monitoring future changes in the local communities and to be better prepared for adaptation in the future.

The Watershed Management Division (WMD), DoFPS has conducted similar studies, in Gangzur *Gewog* in 2017. The analysis of the met station data shows increasing trend which is similar to our result. However, the perception of the respondents contradicts our result. The respondent sample size, coverage of the study area and the degree to which survey respondents perceived the temperature change in their locality are some of the plausible reasons for the contradicting results.

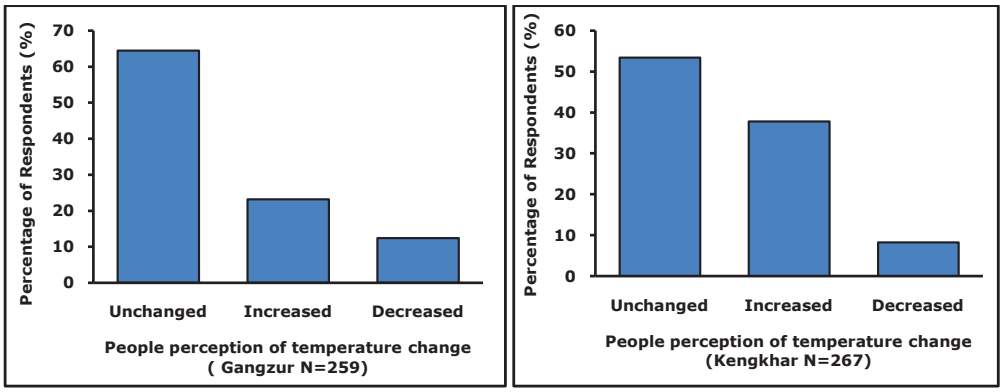

Figure 8. Perception on changes in temperature

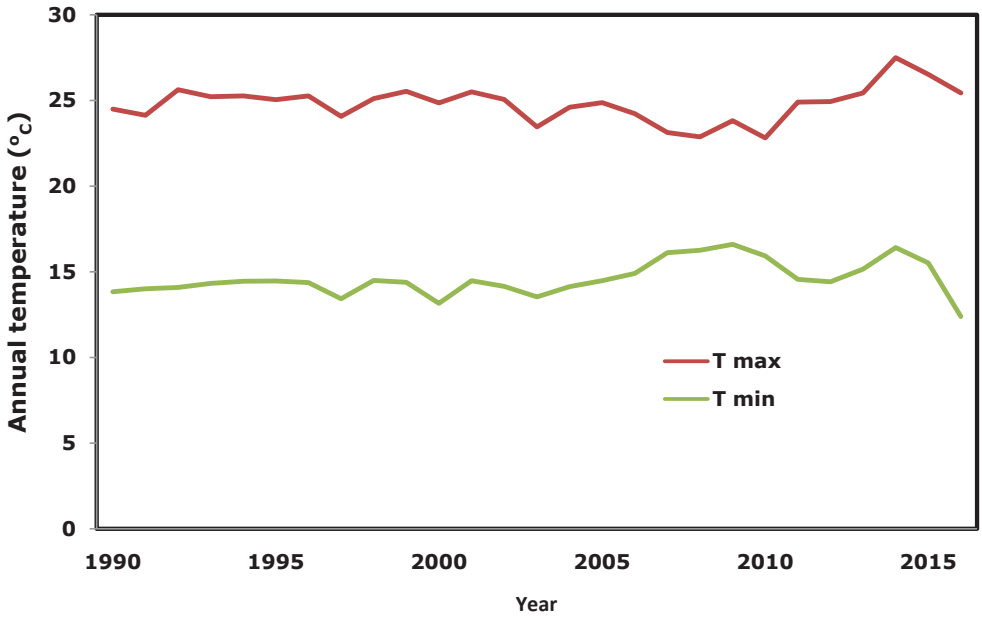

Figure 9. Maximum and minimum annual temperature for Sumpa-Khoma Met station (Gangzur)

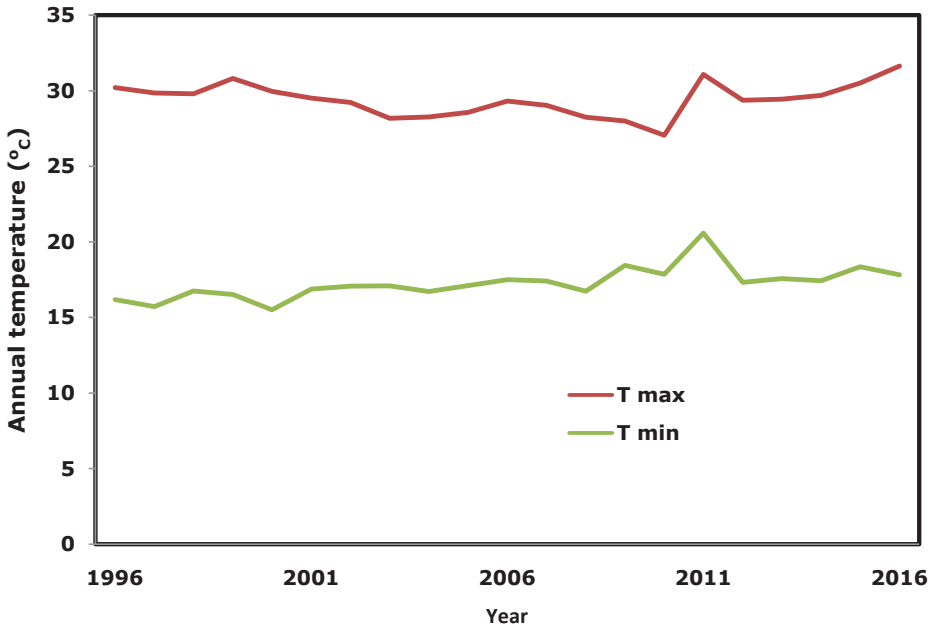

Figure 10. Maximum and minimum annual temperature for Lingmethang Met station (Kengkhar)

4.2.2. Rainfall

In Gangzur *Gewog*, about 66% respondents perceived consistent annual rainfall, and about 34% of respondents observed changes in annual rainfall pattern over the last decade (Figure 11). Unless in cases when excessive rainfall has caused a significant damage to agricultural crops or hugely impacted the people's livelihood, the slight changes in annual rainfall pattern over a decade may not have been noticed by the people. Studies revealed that in Bhutan random rainfall fluctuation with no systematic changes is largely detectable either on an annual or monthly scale (Tse-ring, 2003). However, the local perception seems to correspond with the rainfall data of Sumpa-Khoma meteorology station (Figure 12). The change in rainfall is a critical factor to understand the overall impact of climate change to the local communities. The scale of rainfall variation over the decade seems insignificant. However, this minimum rainfall change may have certain effects on agricultural productions, although the severity of impact on the local scale is difficult to ascertain.

About 39% of the respondents from Kengkhar expressed the change of annual rainfall pattern over the last 10 years. Their claim seems to

support the rainfall data obtained from Lingmethang meteorology station, which showed a slightly decreasing (23%) trend (Figure 13). Though there is less than 40% of the respondents indicating "change" in the annual rainfall in Kengkhar, the local communities must be prepared to adapt to the changes.

The people of Kengkhar *Gewog* have started to adapt to the changes in annual rainfall pattern by increasingly relying on non-farming activities. Apart from the existing adaptation mechanisms, the study reveals other potential measures such as adjusting their farming calendar, growing crops that require less water or drought-resistant crop. These kinds of coping mechanism have been hugely beneficial to farmers, as the people of Udzorong *Gewog* under Trashigang *Dzongkhag* practices the similar sort of adaptation measures (Lhakpa, 2015). Similarly, the people of Punakha *Dzongkhag* claimed to have changed the growing of water-intensive crops to crop that requires less water to cope up with decreasing rainfall (Wangdi & Kusters, 2012).

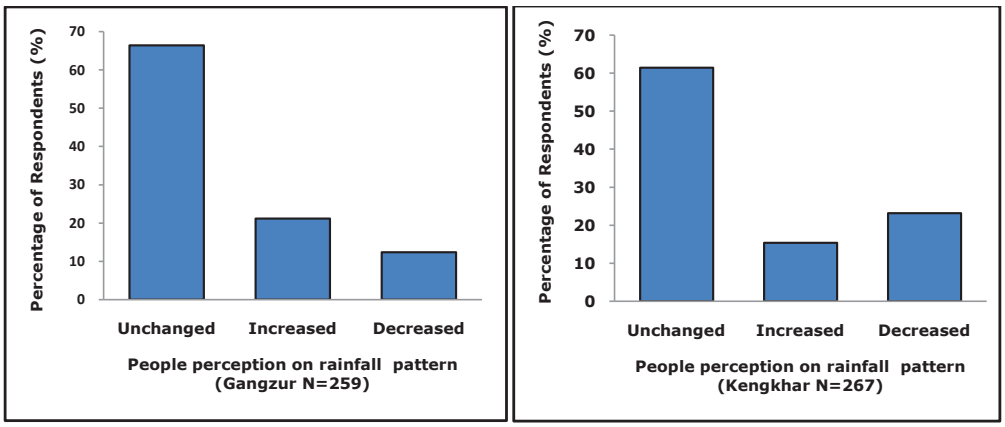

Figure 11. Perception on the changes of rainfall pattern

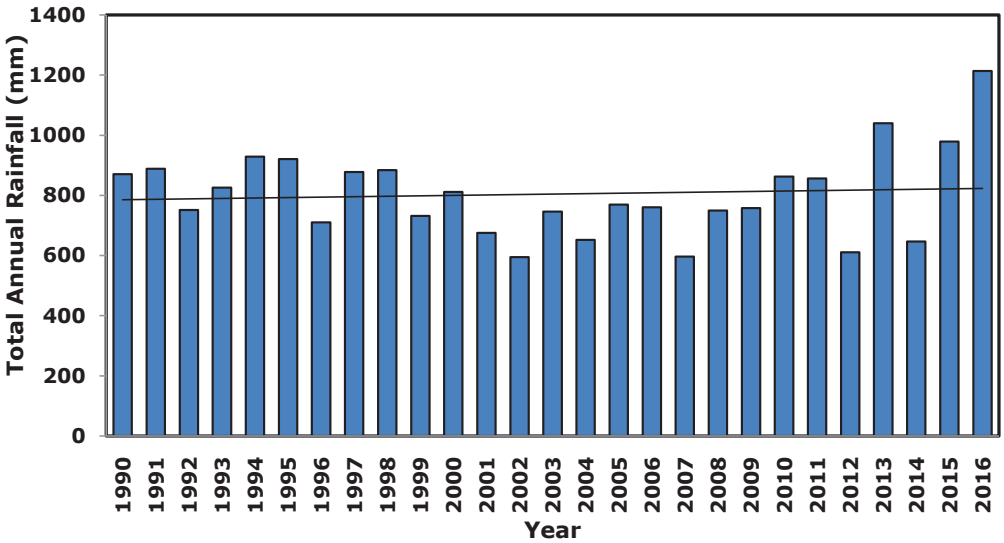

Figure 12. Trend of total annual rainfall in Lhuntse (Data: Sumpa-Khoma Met station, Lhuntse)

Missing data (2009-9 days, 2011-90 days, 2015-66 days)

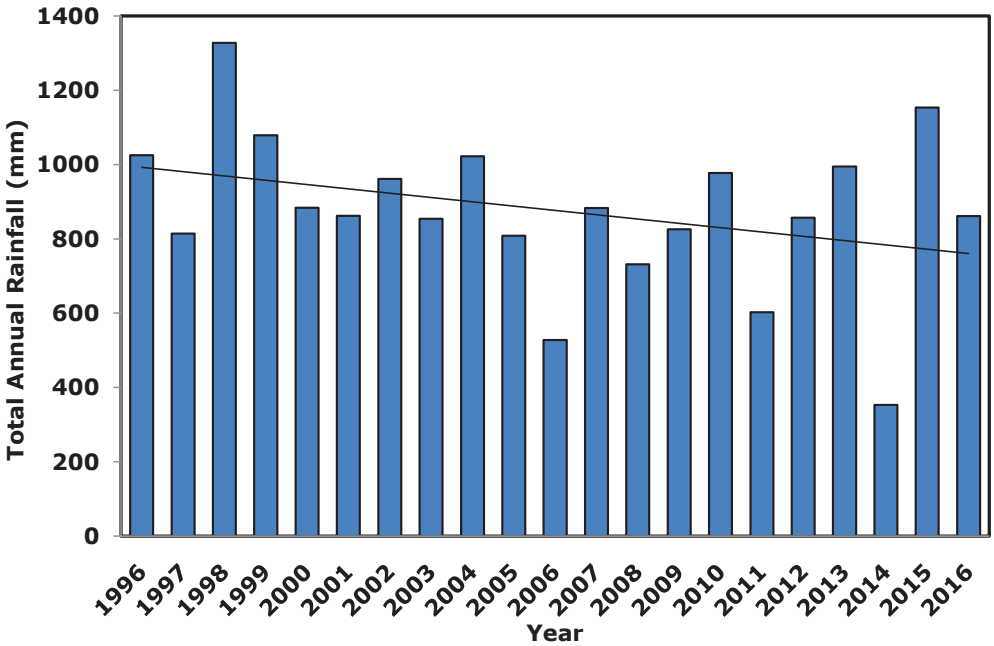

Figure 13. Total annual rainfall in Mongar (Data: Lingmethang Met station, Mongar)

Missing data (2009- 9 days, 2011-90 days, 2015-35 days, 2016-30 days)

4.2.3. Extreme Events/Natural Hazards

Almost all the respondents from both study areas stated that they did not experience any extreme events such as hailstorm and windstorm in the past 10 years. However, the *Gewog* office reported an incident of the heavy hailstorm on October 2015 in Tsholing village of Gangzur *Gewog*, which caused significant damage to paddy fields. The coping mechanism used by the farmers of Gangzur includes seeking alternative income source by taking up non-farming activities, temporary migration for labour works, and selling of livestock and other assets (Figure 14). Such regular asset liquidation due to similar frequent exposure to extreme climate can narrow down the coping range and also increase vulnerability (Zheng & Byg, 2014).

The occurrence of the extreme events is expected to increase despite uncertainties in how climate change will manifest in future (IPCC, 2007). The climatic related disaster is impossible to avoid but the intensity of the impact of hailstorm can be prevented with the use of anti-hail nets over the high-value crops, and also with the tree shelter belt (Bal et al., 2014). Some of the potential key strategies, such as encouraging natural disaster insurance schemes, providing micro-loan during crises, generating economic opportunities, introducing climate resistant crops along with dispersal of immediate disaster relief (Zheng & Byg, 2014) can be implemented for farmers of Gangzur in the face of climate change threat.

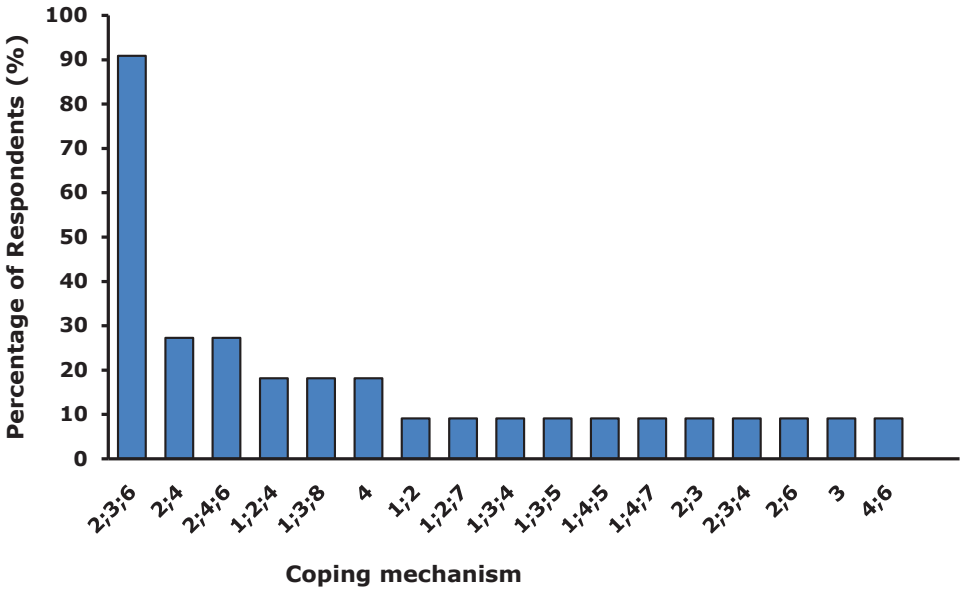

Figure 14. Coping mechanism used for occurrence of hailstorm (Gangzur)

1. Relied on less expensive food.
2. Borrowed money from bank/village fund.
3. Spent savings on food.
4. Consumed seed stock held for next season.
5. Reduced spending on education.
6.Taken new off-farm activities.
7. Migrated for work.
8. Introduced new crop types and varieties.

4.2.4. Frost

Majority of the respondents (86% and 93%) from Gangzur and Kengkhar did not observe any change in the occurrence of frost in the study areas over the last decade. Only 8% from Gangzur and 3% respondents from Kengkhar felt that there was decrease in the occurrence of frost while negligible number of respondents (1.5% and 1.5%) from Gangzur and Kengkhar respectively felt that the frost increased in the last decade. About 5% and 2% of the respondents had no idea on the trend of the occurrence of frost.

4.2.5. Occurrence of Crop Diseases

Changes in the occurrence of crop diseases were observed in the study area. More than half of the respondents in Gangzur (53%) and Kengkhar (54%) *Gewogs* observed the increase in the occurrence of crop diseases. Agriculture extension officer of Gangzur *Gewog* reported the occurrence of crop diseases such as chilli and potato blight, turcicum leaf blight and corn grey leaf spot in maize, rice blast, infestation by armyworm, cutworm, and white grubs in paddy and maize. The occurrence of citrus

greening is also reported from Kengkhar *Gewog.* In order to cope up with these crop diseases, people reported using ash to prevent further occurrence of crop diseases and taking help from *Gewog* agriculture extension office to examine the crops and provide solutions to mitigate crop diseases such as the use of pesticides and new improved seeds.

Rising temperature strongly relates to increasing incidences and outbreak of pest and diseases in agricultural crops. Thus rendering the communities' mainly dependent on subsistence agriculture more vulnerable to climate change. The existing plant protection measures such as the use of the diverse variety of crop species, adjustment in the sowing or planting dates, application of integrated plant management strategies, and use of disease-tolerant species (Juroszek & Tiedemann, 2011) can be some potential strategies to manage crop disease in the study area.

4.3. Water

4.3.1. Water Availability

Gangchu (spring water) is the main source of drinking water in the study areas besides other sources such as *Rongchu* (Stream), *Tsangchu* (River), *Omchu* (Small ponds), and *Drupchu* (Holy water). However, only 2% respondents in Kengkhar reported having to depend on rainwater for basic water needs.

About 98% of respondents in Gangzur have piped water, of which only about 4% have piped water inside their house. Most of the people need 15 minutes for collecting water. However, about 18% of the respondents reported that they have insufficient water. The management at the individual households level could be the main issue behind the water shortage as we observed over 50 water taps were non-functional (Table 6) though there was adequate water at the water source. In Kengkhar, 12% of the respondents directly fetch drinking water from the open water source (Figure 15) because the water source for the Rural water supply and sanitation (RWSS) scheme has dried (Figure 16) and also further impeded by poor maintenance of water taps and pipes (Table 6).

About 72% of the respondents in Gangzur irrigate their farm as a result, about 49% of the respondents reported occurrence of conflicts over water sharing (Figure 17). Increasing local conflicts for water were reported among farmers in the area that requires intensive irrigation (Wangdi & Kusters, 2012).

In Kengkhar, about 50% of the respondents reported not having adequate water supply for their daily consumption (Figure 18). Furthermore, almost half of the respondents observed decreasing water discharge at the source, which is a great concern for the people. Given the rugged landscape and rapid population growth, the per capita water availability may gradually decrease and cause an adverse impact on their living. The thriving of woodcraft industry may further decrease the water availability due to excessive over-harvesting of trees from nearby forest resulting in drying up and disappearance of natural spring ponds as reported in Gurung (2012) if appropriate measures are not taken up. The already susceptible communities of Kengkhar *Gewog* may be further aggravated by global climate change impacts, which may disrupt water regimes and availability in the future.

Various interventions by the government agencies and CSO's so far have helped the communities to reduce water scarcity problems up-to a certain extent although water shortage still remains to be one of the main challenges for the community. More interventions such as support for water source management, identification of water recharge area and awareness is required to improve their socio-economic livelihood and well being.

Table 5. Frequency of water supply in Gangzur and Kengkhar *Gewog*

Frequency of Water supply	**Gangzur (%)**	**Kengkhar(%)**
24 hrs a day	73.0	43.4
More than once a day	15.8	33.3
Once a day	3.5	10.5
Once in two days	5.0	7.9
Twice in a week	2.7	4.9

Table 6. Number of functional and non-functional water taps

Gewogs	***Chiwogs***	**Total Taps**	**Functional**	**Non-functional**
Gangzur	Ney	87	79	8
	Shawa_Zhamling	48	48	0
	Jang_Ngar	77	77	0
	Kyidloong_Somzhing	149	122	27
	Nyimshong_Tongling	36	20	16
Kengkhar	Olokid_Tsalabi	36	20	16
	Tongla_Zi-Tsibi	37	18	19
	Dogtang_Moorong	54	42	12
	Phosothong_singchongri	80	55	25
	Kyidpari_Yuldari	68	49	19
	Neykolog_Warongborang	n.a	n.a	n.a

*18 taps of Tongla *Chiwog* functions only during summer
*25 taps of Eudaree *Chiwog* functions in winter
* no information from Nanaree *Chiwog*
Source: Data collected from individual *Tshogpas*, 2016.

Figure 15. People fetching water directly from the source in Kengkhar

Figure 16. Dried water source in Kengkhar

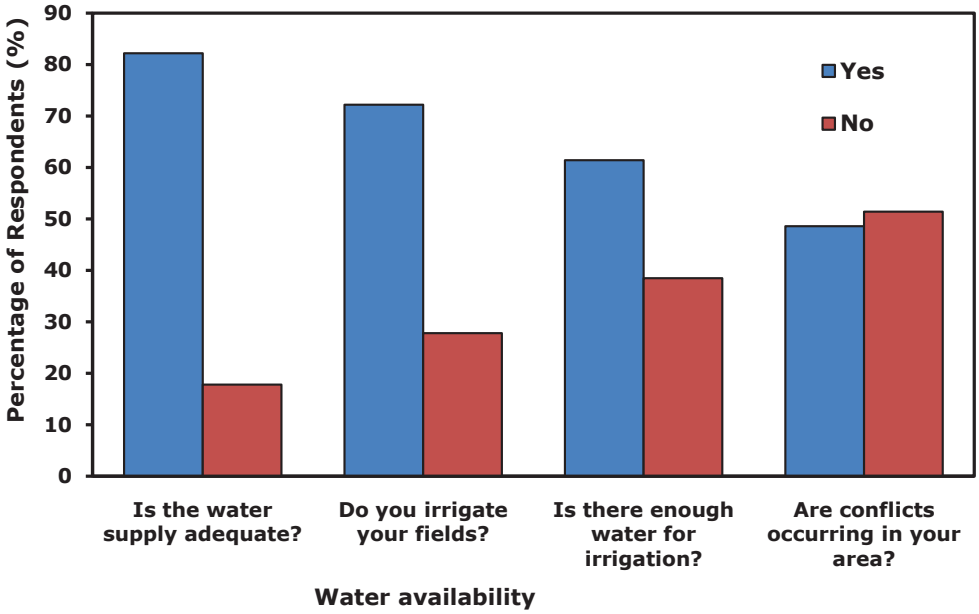

Figure 17. Perception of water availability in Gangzur

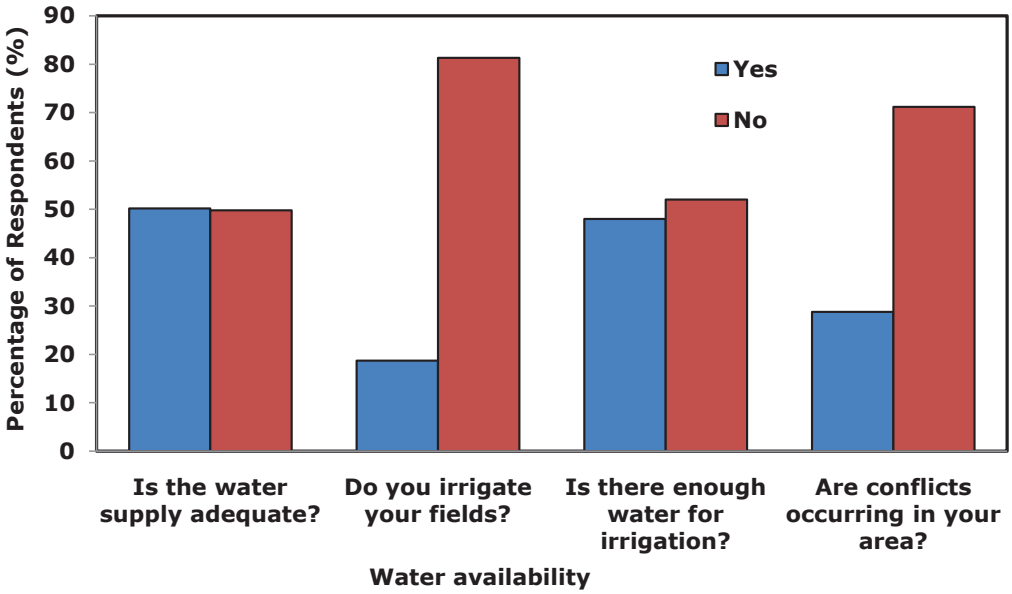

Figure 18. Perception on water availability in Kengkhar

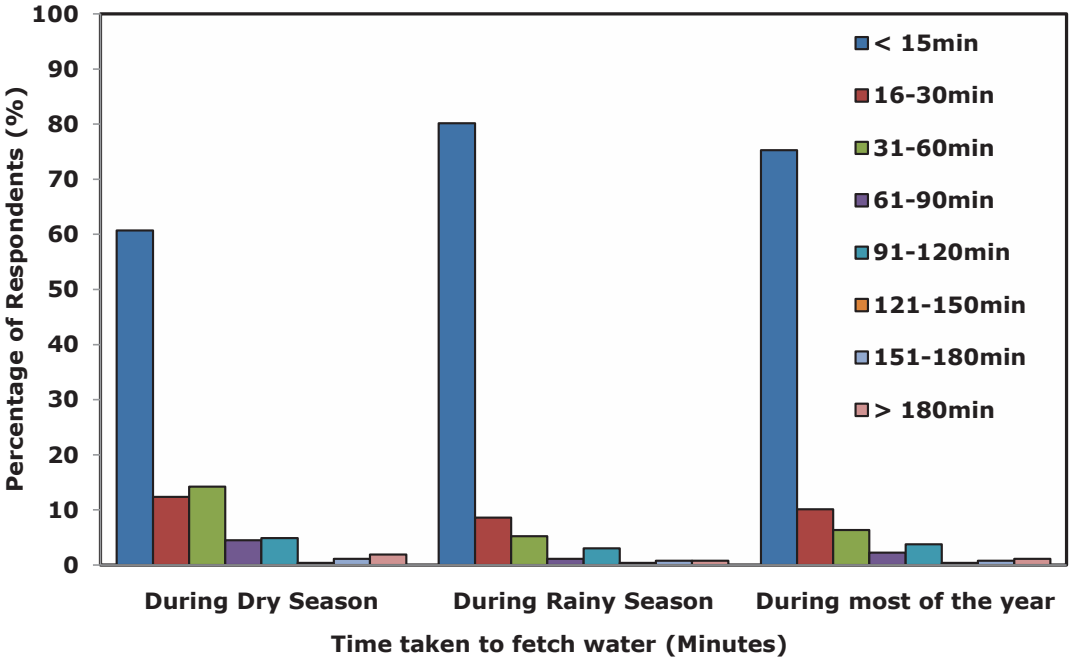

Figure 19. Time spent to collect drinking water in Kengkhar

4.3.2. Drinking Water Source

In this study, we assessed 17 drinking water sources in Gangzur (Fig.21) and 31 water sources in Kengkhar (Fig.23). The water sources in Gangzur supports around 5718 people in about 580 households while the water sources of Kengkhar supports about 2612 people in 483 households. In here, population and households include Schools, BHU, Gewog Extension Centers and Business Centers. The drinking water sources are located in different forest types and the cool broad-leaved forests are the typical water source for the communities in both *Gewogs* (Table 7 & 8).

The drinking water availability at *Chiwog* level in Gangzur revealed that Nyimshong_Tongling and Kyidloong_Somzhing had the lowest with 170.91 l/c/d (litres/capita/day) and 649 l/c/d respectively (Table 7). However, data used to calculate the l/c/d was from the total discharge and does not consider environmental flow, evaporation and other factors affecting the discharge. Without considering the other factors, Gangzur *Gewog* has an adequate drinking water though weak management practices and break down of water supply infrastructures seem to be the main issue.

Compared to Gangzur *Gewog,* Kengkhar *Gewog* has acute shortage of drinking water. Five water sources, namely Bartshang (Phosothong_singchongri), Drubchhu, Nuputsho, Kumshingree and Demnangree (Tongla_Zi-Tsibi) in Kengkhar had discharge immeasurable during the time of the survey (Table 8). We observed that these water sources are of seasonal and almost 26 households are affected during the lean season. However, communities manage their water needs by storing and harvesting rainwater. As per the local people, the water appears only during late spring to autumn in most of these dried streams and ponds.

The minimum water requirement projection by Gleick (1996) and WHO (2013) for drinking, cooking, personal washing, washing clothes and cleaning room may need 50 l/c/d. Considering this requirement, we found about twelve sources (Table 8) in Kengkhar had inadequate discharge to meet the demand. About 116 households are expected to face shortage of drinking water during the lean season. As per the WHO (2003) basic water service level to promote health has been categorized into four categories; i) no access (quantity less than 5 l/c/d), ii) basic access (quantity less than 20 l/c/d), iii) intermediate access (average quantity about 50 l/c/d) and iv) optimal access (average quantity 100 l/c/d and more). Data showed Gangzur Gewog has optimal access to the drinking water while Kengkhar Gewog falls in all categories from no access to

optimal access to drinking water with maximum between basic access to intermediate access (Table 7 & 8). In terms of access measure, Gangzur has tap points within 100m which may take five to 10 minutes collection time. Similarly, most of the households in Kengkhar has tap points within 100m. However, from an about 10 water sources, people have to collect water directly from the source that has a mean distance of 697m (distance from village to source) which may take half an hour to an hour collection time.

The only reliable source with highest discharge was at Sepnangree under Neykolog_Warongborang *Chiwog* which accounted for the higher per capita water availability (Table 8). However, this source is located downstream of the most populated settlement. From this stream, water has been pumped (about 4 hours in a day) for the upstream community of Shingchongri including the School, RNR offices, *Gup* office, Basic Health Unit (BHU), and business centers.

Figure 20. Water pumping station at Sepnangree to meet the water demand in Kengkhar *Gewog* Center

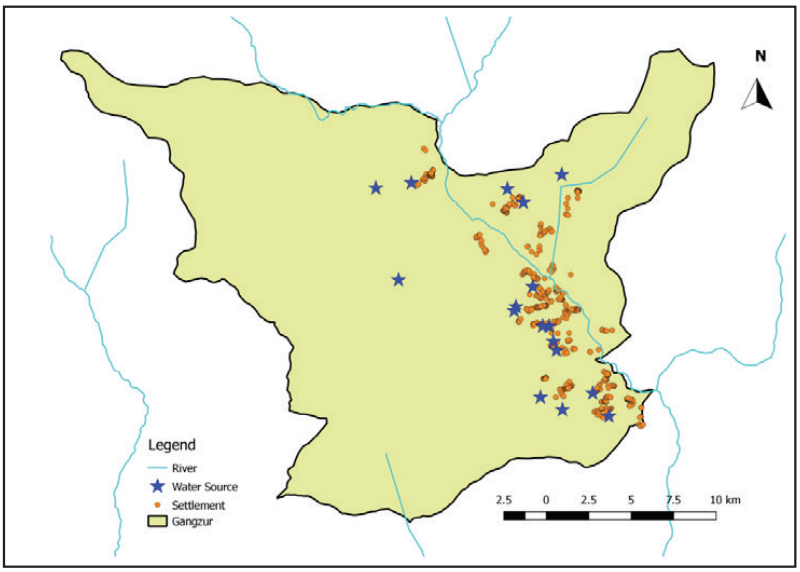

Figure 21. Drinking water sources and households of Gangzur

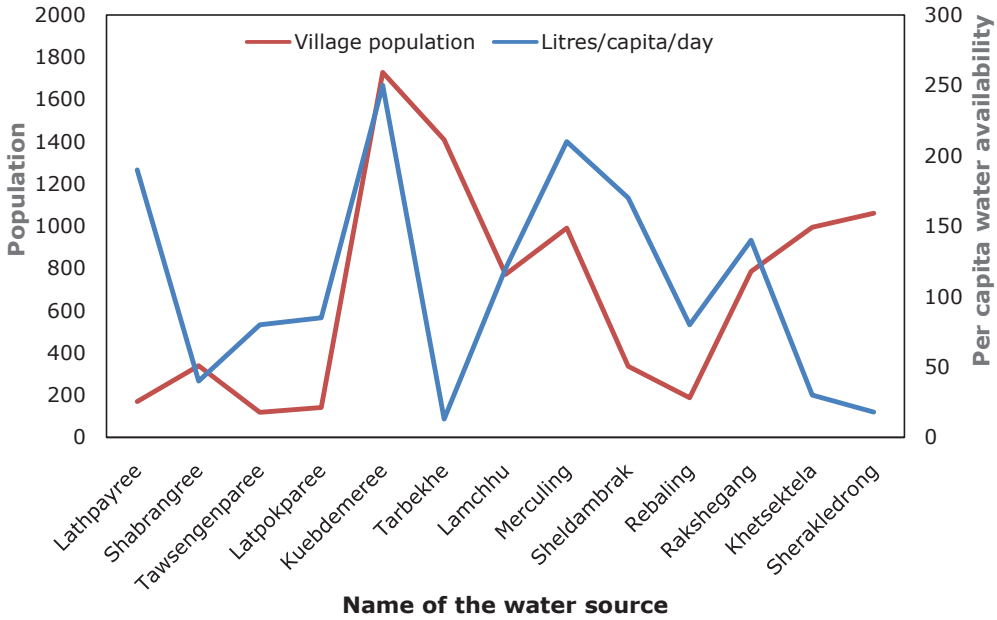

Figure 22. Per capital water availability and population supported by each water sources in Gangzur

Per capita water availability for Lekpagang (1813363 l/c/d), Reyngaytse (4634911 l/c/d), Khelume (728524 l/c/d), and Taktsekhe (56465 l/c/d) are excluded in the Figure 23, as the streams had exceptionally higher per capita water availability.

Table 7. Water extraction at the different *Chiwogs* under Gangzur *Gewog*

Stream Name	*Chiwog*	Nos. of Users	Nos. of Household	Distance (Village-Source (m)	Liter per Capita per Day (l/c/d)	Forest types	General Observation and interview with *Chhu-Sungpa*
Lathpayree	Nyimshong_Tongling	190	27	50	170.274	Chir Pine	
Shabrangree		40	8	500	339.600	Cool Broad-leaved	Water tapping tank constructed at the source. Downstream seems to yield higher discharge but tapping not possible as the settlements are at higher elevation
Tawsengenparee		80	20	500	119.100	Cool Broad-leaved	About 15 years ago, water was adequate and now dried. The discharge was three-fold in the past than the present discharge
Latpokparee		85	17	800	141.741	Cool Broad-leaved	Water source located in the Kuenphel Meday Community Forests
Kuebdemeree	Ney	250	55	1500	1728.000	Cool Broad-leaved	Water supply constructed in the year 2012 for the resettled communities from Lhuentse *Dzongkhag*
Khelume		200	50	800	728524.704	Cool Broad-leaved	Water source located downstream of Ney resettlement. Water is shared among school and BHU. Water is also used for irrigation.
Taktsekhe	Shawa_Zhamling	60	20	700	56465.280	Cool Broad-leaved	Water source located upstream of the village. At the distant upstream the area has meadow grassland
Tarbekhe		45	15	3000	406.987	Cool Broad-leaved	Source located at upper valley of Zhamling village. No reliable protection and management has been done.
Lamchhu		120	30	1500	771.800	Cool Broad-leaved	Source recently maintained through the climate smart village project. However, close to the source, trees are lopped and felled for fodder and fencing post.
Reyngaysey	Jang_Ngar	2000	150	1000	4634910.720	Cool Broad-leaved	Nearest village to the water source is Ngar village. The stream serves as a boundary for Gangzur, Denkaling and Renysa community forest (187.3 acre).The water source has been proposed to tap for the Lhuentse town including schools, hospitals and other institutions
Merculing		210	30	800	991.429	Cool Broad-leaved	Water source is within the Merculing Community Forest. It has an area of 175 acres
Sheldambrak		170	17	1500	337.271	Cool Broad-leaved	The source was intact with good vegetation. Serves as a source for irrigation especially during the paddy transplantation seasons.
Lekpagang		2000	150	1800	1813363.200	Cool Broad-leaved	The area has been proposed to establish community forest for Tazebar community. Proposed water supply from Ngar as the present source drains lots of sediments from Jang village during summer.
Rebaling	Kyidloong_Somzhing	80	14	500	187.800	Cool Broad-leaved	Water tapped right from the source
Rakshegang		140	20	500	786.000	Cool Broad-leaved	The stream is shared between two villages Magar and Changrey. The stream is also shared for irrigation of paddy. Thus, community face acute shortage of drinking water
Khetsektela		30	6	200	995.200	Cool Broad-leaved	Predominant forest at the source is oak.
Sherakledrong		18	6	2000	1061.333	Cool Broad-leaved	Source is located about 2 kilometers at the uphill of the village.
All streams were connected with pipes between source/tapping point and water tap							

Table 8. Water extraction at different *Chiwogs* under Kengkhar *Gewog*

Stream Name	*Chiwog*	Nos. of Users	Nos. of Household	Distance (village-source (m))	Liter per Capita per Day (l/c/d)	Forest types	General observation and interview with *Chhu-Sungpa*
Ngulthaphu	Phosothong_singchongri	19	4	50	773.305	Chir Pine	Farm road passes right above the water source (Figure 26). Likely to affect the water discharge in future
Groksabee		64	16	30	268.125	Warmbroad-leaved	The source is located in middle of the settlements. Downstream and upstream water users carry water on their back in times of shortage.
Wangkhocheree*		60	12	15	32.800	Chir Pine +Warmbroad-leaved	Source in middle of the settlements. Water reservoir was constructed by Wengkhar RNR-RC. A decade ago water discharge was observed 3 time the present discharge. In the month of Bhutanese calendar (BC) 3rd and 4th water dry up.
Dayephodrangree		50	11	500	88.800	Chir Pine	15 years from now, discharge was observed 4 times higher. Trail passes between Olaki and Tshalabi. Water collected from the pond (Dungkargonpa, Dungmanma, Khetengla, Dezung) when their water sources do not have adequate discharge. It takes 30 to 40 minutes round trip to fetch the water
Daephodrang		50	12	1000	76.656	Warm broad-leaved	Source protected and planted trees upon technical assistance from forest personnel
Kuleree		54	9	10	696.000	Warm broad-leaved	
Bartshangree*		30	9	100	0.000	Warm broad-leaved	Water source located in mid of farm. No water discharge during 9th month of BC, and discharge on 5thmonth of BC. During water shortage people collect water from Broksabee, and harvest rain water. Have plan to connect the water supply from Dochuree
Resingma*		45	12	10	5.973	Warm broad-leaved	This source dried up once in 2013. Planted trees at the source. This stream is said to migrate from other places. During winter and spring, water migrate to other place (not able to specify place exactly)
Dochuree*		500	17	6000	20.304	Cool Broad-leaved	In the past, this source had 6 times higher discharge. Discharge decreased drastically after road construction.
Kaisengmaree	Dogtang_Moorong	90	40	600	126.960	Warm broad-leaved	water source constructed in 2011 and plantation and fencing was carried out in 2015 with the financial support from Tarayana Foundation. Over 200 trees were planted at the source.
Tsangdaree		50	22	500	1015.680	Warm broad-leaved	The source has number of water extraction tank being constructed with the financial support from different organizations.
Soitshangree		8	45	10	1428.000	Warm broad-leaved	During summer the water discharge falls, 9th and 10th month of BC high discharge is observed. This stream migrates to Rongthung during (summer) for supporting paddy transplantation. No trapping tank at the source
Musuree*	Olokid_Tsalabi	40	15	100	34.560	Warm broad-leaved	Used as an alternative source when dischrage from upstream water supply dries up. Water discharge decreased. No tapping tank (Omchhu)
Phoidongborang		40	25	1500	1375.200	Warm broad-leaved	Source maintained by public, no concrete structure at the source. Farm road has affected the downstream water source and flood had formed gullies.
Gurtseree		90	17	500	2620.533	Chir Pine + Warmbroad-leaved	The source is very close to recently constructed farm road. Require special protection as the site is expected to exposed to flesh flood during the monsoon
Sepnangree	Neykolog_Warongborang	450	16	1000	2906723.797	Chir Pine + Warmbroad-leaved	The water is shared between Nekolog village, School and Dunkargonpa (Shingchongree). The water has been pumped uphill to the school (270 students) and Dunkargonpa (13 households) about 4 hours a day. Water pump was funded by UNICEF

Rangthungree	Neykolog_Warongborang	200	45	3000	540.000	Warmbroad-leaved	Had flood in 2004, 2014 and 2015. People can get water supply from 8th to 4th BC. Other time from Sepnangree (carry on back) and harvest rain water. Conducted *Sachu Bumteer* ceremony in January, 2016. Proposed construction of water storage tank to harvest rainwater. Upstream exposed to heavy landslide.
Moitangree	Kyidpari_Yuldari	130	16	500	188.862	Cool Broad-leaved	The water supply is shared among Yuldari school and village. The community from Pinphu also carry water uphill from this source. People in Pinphu has no water source nearby their village as their settlement is on hilltop. So, they fetch water from this stream and harvest rainwater.
Kitparee		40	8	500	82.800	Cool Broad-leaved	Water reservoir constructed (Dec, 2015) at the source measuring 3m* 4m*1m funded by Tarayana foundation. Plantation of different species at the source. 2nd month of BC source dries, 6th month of BC water appear. During off season community carry water from Dochuree.
Kognangree		72	19	100	190.333	Warmbroad-leaved	Source located close to Yuldari school and below road.
Mukiamaree		50	15	10	90.720	Cool Broad-leaved	Water storage tank (4m*2m*1m) funded by Tarayana. No fluctuation in discharge. Bamboo and native tree were planted. This source serves 5 villages
Liberee		25	4	500	1265.280	Cool Broad-leaved	Source is above the road before reaching to tri-junction of Khengkhar and Jurmey geog. Water tank constructed below the road. Source is not well protected.
Manshingree*		25	6	50	42.240	Cool Broad-leaved	Source not maintained well. Source located above Yuldari schoool
Perkheree*		20	5	200	9.000	Cool Broad-leaved	Water storage tank (2m*3m*1m) funded by Tarayana. Discharge remains same throughout the year.
Shingchongree	Tongla_Zi-Tsibi	120	15	4000	418.320	Cool Broad-leaved	The water supply located in Yuldari village which is connected to Tongla village (including school and BHU). Source is located above the road junction connecting between Kengkhar and Jurmey *Gewog*
Drubchuu*		40	8	800	0.000	Cool Broad-leaved	Lam Sherub Jungney created *Drubchuu* while meditating. Discharge is sufficient for water offering even during dry season. Source never dries up completely. Discharge was immeasurable during the survey. This source is considered as *Phochhu*.
Nukputsho*		5	1	1000	0.000	Cool Broad-leaved	The source was completely dried during our visit. Discharge on 4th month of 10th or 15th day of BC. Dry during 1st month of every BC. This is also *Drubchhu* (*Mochhu*) created in the form of lake by Lham Sherub Jungney.
Tonglagonparee*		200	50	50	23.640	Chir Pine + Cool Broad-leaved	Storage tank (3*4*1m) funded by Tarayana constructed at the source. Every 9th and 10th month discharge falls. People transport water from Shingchongree if it gets dried.
Kumshingree*		20	4	2000	0.000	Chir Pine + Cool Broad-leaved	Dry Oak forest. Water discharge has decreased compared to 15 years back. Water was so small to measure discharge.
Demnangree*		20	4	2000	0.000	Chir Pine + Cool Broad-Leaved	Discharge was negligible to measure. Beneficiaries of this water is also from Tonglagonpa. Community carry water on their back.
Nublaree		5	1	2700	729.600	Chir Pine	Water source managed and utilized by single household.

**Water is usually collected from the source on their back while other sources had trapping point at the mid of the stream or at the source connected with pipes. Text (l/c/d) with red color are water availability less than 50 l/c/d*

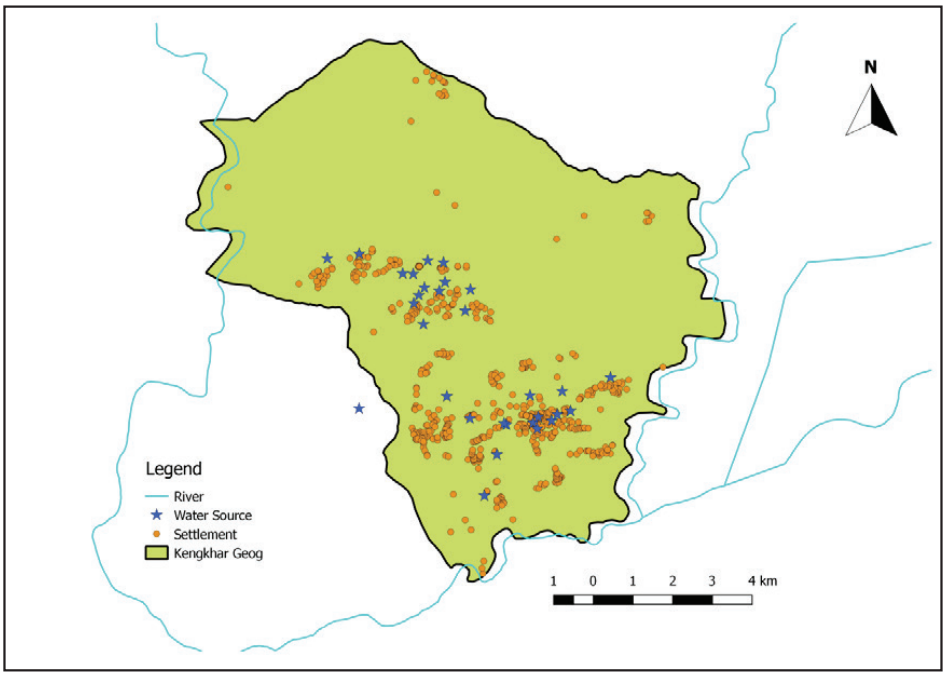

Figure 23. Drinking water sources and households of Kengkhar

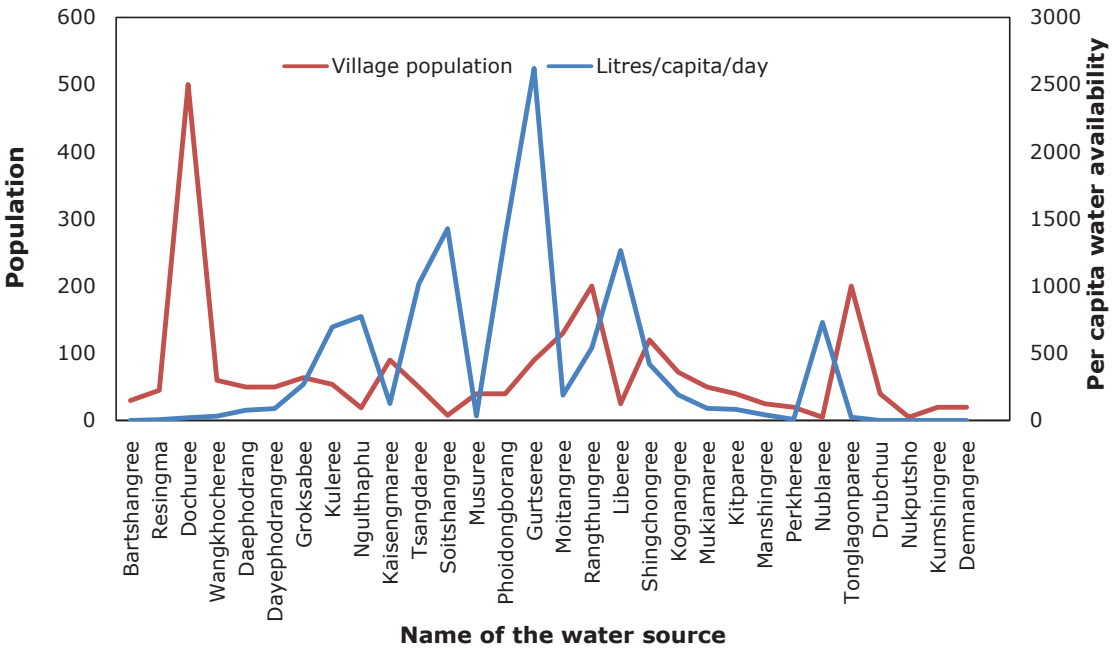

Figure 24. Per capita water availability and population supported by each water sources in Kengkhar

Figure 25. A degraded water source in Kengkhar

Figure 26. A water source located below the farm road in Kengkhar

4.3.3 Institutional Mechanisms of Water Resource Management. National Level

Water is one of the most important natural resources of the country and it is acknowledged as a state property. In Bhutan, there are many organizations working on specific water-related activities. NEC serves as the apex body at the national level for developing policies, coordinating plans, programs and monitoring water resources in the country. Ministry of Agriculture and Forests in Bhutan is responsible for irrigation development, watershed and wetland management. The *Dzongkhag Tshogdu* and the *Gewog Tshogde* supported by *Dzongkhag*, *Dungkhag*, and *Gewog* administration in collaboration with the MoH plan, implement and manage infrastructure for rural drinking water while Ministry of Works and Human Settlement, and the municipal office is responsible for planning, implementing and managing urban water sources. The MoH is also mandated to monitor the drinking water quality in both urban and rural areas. Ministry of Education is responsible for creating awareness by including water resource issues in schools and institutional curricula. On the other side, Ministry of Home and Cultural Affairs in collaboration with the relevant local Government is responsible for the protection of mineral and medicinal hot springs such as *Menchhu, Drupchhu, Tsachhu* and *Neychhu* (RGoB, 2011).

All the construction works related to water supply in *Dzongkhag*s are carried out by engineering cell in collaboration with relevant agencies. The *Dzongkhag* water management committee is also instituted to ensure proper and effective protection and management of water resources at *Dzongkhag* level. The common water facility users form a group known as water users association (WUAs) to maintain the water source and to manage water supply services according to the water regulations (RGoB, 2011).

Local level

The *Dzongkhag Tshogdu* and the *Gewog Tshogde* supported by *Dzongkhag*, *Dungkhag*, and *Gewog* administration play a vital role in water resource management. The *Dzongkhag* Tshogdu and *Gewog Tshogde* plans and allocate budget and implement planned activities to ensure clean drinking water. In the 11th Five Year Plan, Gangzur *Gewog* has allocated Nu. 2.62 million for RWSS construction, innovation, and improvement of water supply schemes and spring source protection and plantation in the *Gewog* (GNHC, 2013b). With the successful implementation of planned activities, the *Gewog* anticipates access to

clean drinking water supply to increase from 99% in 2012 to 100% in 2018. Kengkhar *Gewog* has also planned to renovate and construct RWSS, construct water storage tanks, and protect watersheds. Altogether, Nu. 2.25 million is budgeted in the 11th FYP to ensure clean drinking water supply for the communities of Kengkhar *Gewog* (GNHC, 2013a).

The *Gewog* health extension office monitors the quality of drinking water in their respective *Gewog* while *Gewog* forestry offices protect the water catchment area within the *Gewog*. The *Gewog* agriculture extension offices undertake irrigation development activities and deal with irrigation water shortage issues.

At the village level, *Chhu-sungpa* is responsible for regular monitoring and maintenance of water sources. *Chhu-sungpa* is exempted from Gung dang woola (contribution of labor from each household for their community), and in addition gets Nu. 100/- from each household annually. In Kengkhar village, people were unwilling to serve as *Chhu-sungpa* because of the low benefit in comparison to the responsibility and risk involved such as it requires walking to distant water sources frequently during monsoon seasons.

Apart from the *Gewog* administration, other government institutions and CSOs also assist and facilitate in addressing the water shortage. In Gangzur *Gewog*, government institutions such as WCNP, WMD and UWICER were undertaking water security projects to solve drinking and irrigation water issues. In Kengkhar *Gewog*, Tarayana Foundation, ARDC Wengkhar, Dzongkhang Forest Extension, MoH and UNICEF had assisted people to solve water shortage issues through construction of water tanks, supply of PVC water storage tanks (for rainwater harvesting), supply of water pumps, plantation, and protection of water source (Phuntsho Dorji (*Gaydrung)*, personal communication, August 29, 2016).

6. Recommendations

Climate change will certainly affect all the sectors, and an integrated adaptation approach that includes agriculture, livestock, water resources, soil conservation, forests management, disaster management and risk reduction, diversification of livelihood opportunities is inevitable. As climate change will also affect the developmental activities, all development sectors also need to consider climate change adaptation while implementing development projects.

We propose the following plausible adaptation strategies that would further enhance the community resilience to climate change impacts.

Community awareness programs on climate change and its impacts.

Although the communities studied were quite aware of the local climatic situation, they were not very much informed on the causes of climate change and their impending impacts on the rural communities.

Raising awareness level of rural communities is very crucial to build the resilience of such communities and in promoting doable simple practices like minimizing waste, pollution, forest protection, sustainable use of resources etc. Community awareness program will also enhance better adaptation planning and community cohesion and collaboration. People will also value existing traditional practices and knowledge and be better prepared for the future.

Diversification of agricultural crops

Since agriculture and livestock rearing is the main source of livelihood for these two communities, ways and means to further enhance and support these livelihood sources in these communities must be given priority.

Introduction of new cultivated species and crop varieties must be initiated and diversified to include more high yielding improved varieties adapted to low water requirements. The rural farmers need to be trained in organic farming practices, which will improve soil fertility and result in better yields**.**

More importantly, the use of poly houses for vegetable production should be encouraged, which requires less water through the use of drip sprinklers. This will enable farmers to grow fresh organic vegetables in large scale and has huge potential to generate additional income for them.

Enhance sustainable land management practices

In order to build the resilience of agricultural systems in these communities, plausible climate adaptive practices must be adopted. Farmers should be trained in low tillage and organic farming practices such as crop rotations, leaving crop residue. All these will ultimately help in soil conservation and also reduce the loss of topsoil and improve soil fertility and lead to better yields. Farmers should also be exposed to agroforestry options. Drip and sprinkler irrigation system must be promoted in order to reduce wastage of water and this will also prevent topsoil erosion and floods.

Enhance livestock rearing and poultry farming

In order to enhance the livelihood of the farmers, encourage and empower farmers to engage in productive livestock rearing programs and practices in addition to agriculture farming.

Thus improved breeds of livestock, poultry farming, and stall-feeding should be promoted. A community-based dairy farm could also be established to market their dairy products

Promote commercial horticulture and agroforestry practices

In order to substantiate the income of the rural households, growing economical fruit trees like persimmon and avocados near their houses or taking up as commercial orchards can be promoted. Fodder tree species and improved varieties of fodder grasses can also be promoted. The *Gewog* livestock and agriculture extension offices could also explore opportunities for training the farmers on the techniques of growing fruit trees and fodder species. This will also help reduce the impact on the nearby forest areas for grazing or fodder collection for the livestock population. People can also raise nurseries for economically important fruit species and the *Dzongkhag* agricultural sector can help them to sell the saplings.

Measures to reduce human-wildlife conflicts

The *Dzongkhag* Agriculture and *Gewog* agriculture extension officers, livestock and forestry sectors should all come together and implement appropriate measures and find resources to solve the increasing human-wildlife conflicts in these two *Gewogs*. Since agriculture and livestock rearing are the main sources of livelihood, increasing human-wildlife conflicts would have a direct impact on the food security and the overall

wellbeing of the already vulnerable farming community in these two areas.

Build capacity of the local leaders and community

To enhance the local community resilience, the community leaders must be well informed about the climate change and its impacts and various adaptation options. Thus community leaders and representative should be equipped with the knowledge of climate change adaptation measures such as livelihood diversification, crop and livestock insurance. Capacity building program targeted on these areas should be developed and implemented. Conduct of such programs and activities has a huge potential to enable healthy and safe local communities, reduce vulnerabilities and enhance community resilience to the impact of climate change. Local community leaders can influence better strategic planning and fully informed decisions for the climate-smart development.

Establish weather-monitoring stations in the communities

Hydro-metrological stations should be established within the communities for long-term monitoring of climate changes in the communities. For this study, we used the data from a nearest Hydromet station, which may not be fully representative of the local climate conditions. Establishment of a weather station within the locality is necessary to ensure appropriate climate change adaptation plans and programs in the future.

Strengthen local institutions for adaptation

The capacity of local institutions such as the RNR-extension centers (livestock, agriculture, forestry), basic health units, schools and the Non-formal education centers should be strengthened for facilitating effective adaptation measures in the community. Thus adequate resources and information should be provided to these institutions as they have the most potential for helping the communities and bringing change and enhance the livelihood of the communities.

Strengthen community water user association and water resource management

Strengthen and initiate the community-level water user associations and capacitate them on the water source management, water quality monitoring, equitable distribution and conflict resolution**.** The existing WUA needs to be trained for a new water source identification and assessment so as to prepare for the future needs.

Ensure local communities are properly trained on various water conservation techniques such as water storage and management so that they are more prepared to face the future climate change impacts on water availability. The promotion of water resource management measures such as small-scale water reservoirs and rainwater harvesting techniques by local communities or even individuals will assist in addressing the water shortage during the lean seasons for both farming and local uses.

Site Specific recommendations

Gangzur

- Conduct awareness programs on water resources management, existing rules, regulation, and policies related to water.
- Strict implementation of existing rules, regulation, policies with periodic monitoring.
- Identify and determine reliable water sources and provide adequate water delivery and storage facilities wherever deemed necessary.
- Promote community participation and instill a sense of ownership for common properties such as water supply scheme equipment.
- Human-wildlife conflicts have proven to be the main hindrance in cultivating various vegetables to generate livelihood income in the community. The *Gewog* administration in collaboration with agriculture and livestock sectors needs to mobilize additional resources towards the installation of electric fencing and other innovative strategies for reducing the HWCs in these communities.

Kengkhar

The water problem at Kengkhar cannot be solved at the *Gewog* level. Site-specific interventions are required, as households located uphill are facing acute water shortage while people downhill have enough water.

- A much concerted and collaborative effort is needed among the institutions and resource sharing to solve water issues.
- An adequate financial resource is required to construct a larger distribution/collection tank at the source; this will not only save construction and maintenance costs but also enhance water quality and quantity.
- Initiate plantation and water source fencing with proper knowledge on the ecology and societal impacts.

- Undertake a proper assessment of water source before tapping to serve the long-term purpose and reduce resources and ecological impacts.
- Build small and low-cost communal farm reservoirs in acute water scarce areas to collect rainwater for agriculture and livestock farming.
- Explore and implement improved technologies such as water pumps and rainwater harvesting structures to solve both drinking and farming needs.
- Establish a proper institutional mechanism for water resource management at *Chiwog* level to ensure effective water allocation and quality for the communities.

7. Conclusion

Bhutan is considered to be an exemplary country where adaptation and mitigation options for climate change have been successfully implemented. Despite several adaptation and mitigation efforts Bhutan still continues to be affected by the impacts of climate change and will be aggravated in the future. To this effect, the adaptation response for this impact will play a role in our society at large especially in rural communities, economy, and ecosystems of Bhutan.

The results from this climate change vulnerability assessment in two communities Gangzur and Kengkhar, within Kurichhu watershed, presents a case scenario of how future climate change will impact on these vulnerable communities. We also suggest few plausible adaptation measures geared towards enhancing adaptive capacity and resilience of rural communities. Some of the specific activities suggested for further follow up are:

- Create awareness of the cause of climate change, its impacts and the adaptation options to the rural communities
- Improve the capacity of local leaders and institutions on climate change impacts, adaptation options, adaptation planning and livelihood opportunities.
- Build capacity of the local communities on various adaptation measures such as crop diversification, horticultural crops, land management, water management, allocation and water conservation techniques.
- Mainstream climate change adaptation into local level planning process so that all developmental activities are targeted to enhance climate change resilience of the vulnerable communities.

Though this study was primarily focused in two communities within the Kurichhu watershed, all other rural communities are equally vulnerable to the climate change impacts as indicated by the national level future climate projections and vulnerability assessment for Bhutan.

The findings and recommendations of this study can potentially serve as baseline data for building enhanced resilience and adaptive capacity of rural communities of Bhutan to climate change.

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Annexure I

Section A: Respondent, household, livelihood and food security

1 Respondent and household information

1.1 Household composition, Education level and Occupation: [including the interviewee]

Sl. No	Sex (F/M)	Age (yrs)	Marital Status ***	Education level*	Occupation **	Relationship with HH-H	Place of Residence ****
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

* Education: N=None |L= Literacy classes | P=Primary | S=Secondary |T=Tertiary

* *Occupation :F= Farmer| S=Student | B=Businessman |G=Govt. Servant| M=Monk.. etc

*** M= married | U= Unmarried | D= Divorced | W= Widowed

****Indicate the place of residence and *Dzongkhag* if they are residing outside their Village

1.2 What is the primary source of income for your household?

1 =Agriculture | 2 =Livestock | 3 =Business | 4 =off-farm income (NWFPs, labour etc.) | 5 =Others, specify_____

2. Land and farm

2.1 Do your Household own a farming land? Yes | No

2.2 What is your total land holding ?. _____Acre

2.3 Specify units in(Acre|langdo|Decimal) (1 acre=100 decimal= Approx 4 Langdos) of land types

Type:	Cultivated	Fallow	sharecropped / rented in	sharecropped / rented out
Chhuzhing (wetland)				
Kamzhing (dryland)				
Tseri (shift.cult)				
Orchard				
Sokshing				
Tsamdrog (private)				
Others, Specify				

2.4Crop cultivation and production in last 12 months

Crops/Fruits (Name)	Production(kg)	Trend of crop/ Fruit production in last 10 years*	Reasons**

* I= Increase | D=Decrease | S= Same

** HWC, weather and Climate conditions, farm mechanization etc..

3. Livestock

3.1 Do you own livestock? Yes | No
3.2 If yes, Please specify in the table below,

Livestock	Numbers	Average Annual Income
Local breed Cows		
Improved breed Cows (Jersey, brown Swiss etc)		
Horses/ Mules		
Yaks		
Goats & Sheeps		
Poultry		
Pig		
Others,		

4. Other income generating activities

4.1. Do you or any of your household members derive income from any of the following non-farm activities?

Non-Farm Activities	Yes/ No	If yes, estimated income in last 12 months (Nu.)
Contact Labour		
NTFPs(mushroom, Herbs etc)		
Others, Specify_____		

5. Housing and other assets

5.1 Housing information (Can be self assessed)

Type (storied)	Wall Material	Roofing material	Pvt. Toilet?	Electrified ?	Water tap?
a. 1-storied _____ b. 2-Storied _____ c. 3-storied _____ d. Others,_____	a. Mud _____ b. Stone _____ c. Wood _____ d. Others_____	a. Shingles_____ b. CGI_____ c. Thatch_____ d. Others_____	Yes____ No ____	Yes ____ No ____	Yes____ No_____

Section B: Water and Climate

1. Climate

1.1What kinds of weather hazard did you experience in your village?

	Tick if yes	How severe the problems/shocks are? (tick the appropriate box)			Coping mechanism used (enter code of coping mechanism-enter applicable codes)			
		Low	Medium	High				01 = Relied on less preferred/ less expensive food
Drought								02= Borrowed money from bank/village fund
Flood								03=Spent savings on food
Changes in rainfall pattern								04=Consumed seed stocks held for next season
Frost								05=Sold farmland
Hailstorm								06=Reduced spending on education
Snow or blizzard								07=Taken on new off-farm activities (i.e. wage labour)
Landslide/ erosion								08=Migrated for work
Earthquake								09=Sold HH assets (incl. small animals, jewellery)
Strong wind								10=Took children out of school to work
Extreme heat								11=Introduced new types of livestock
Crop diseases/ pests Extreme cold								12=Introduced new crop types and varieties
								13= others, specify_____ _____ _____

1.2 Which of the following assisted the household to deal with the effects of the events that you have mentioned above (Tick *the appropriate box*)

Agency	Tick		Tick
Family members living outside		Insurance company	
Neighbours		Financial institution	
Local community organization		NGO	
Gewog/*Dzongkhag* Office		Monasteries	

1.3 What is your understanding on the occurrence of calamities in the past 10 Years?*] (tick the appropriate box)*			
Calamities	*Increasing*	*Decreasing*	*Same*
Drought			
Flood			
Rainfall			
Frost			
Hailstorm			
Snow or blizzard			
Landslide/erosion			
Earthquake			
Strong wind			
Extreme heat			
Extreme cold			
Crop diseases and pests			
Bad seeds			
Lack of fertilizer &/or too expensive			
Soil problems			
Irrigation problems			
Livestock disease			
Labour shortage			
Fire			
Low market prices for crops / livestock			
Family sickness			
Death of HH member			
Debt			
Poor market access			
Local conflict			
Unemployment			
Imprisonment			
Wildlife related shocks			
Kidu Office		Others, Specify	

2. Water Sensitivity 2.1 What is the main means of drinking water for your household?*(tick the appropriate box)*

Means	Tick	Means	*Tick*
Public standpipe/Tap (RWSS)		Rainwater collection	
Piped water inside the house		Pond (*Omchu*)	
Protected spring (*Gangchu*)		River/stream (/Tshangchu)	
Unprotected spring(*Gangchu*)		Well	

2.2 What is the main source of water supply to your drinking water? *(Tick the appropriate box)*

Source	Tick
Tshangchu(river)	
Gangchu (Spring)	
Omchu (Small ponds)	
Rongchu (Streams)	
Underground water	
Rain water	
Drupchu (Holy water)	
Don't know	

2.3 Questions on Water availability and pollution

	Tick the appropriate Box			
How much time does it take to fetch water for your Household (In *minutes*)	During Rainy Season			
	During Dry Season			
	During Most of the year			
What do you feel about the volume of water supply at the source.	Increasing			
	Decreasing			
	Same			
Who from your household fetches the water most often?	Adult man			
	Adult Female			
	Male Child			
	Female Child			
What is the frequency of water supply to your Household from main water supply facilities?	24 hrs a day			
	more than once a day			
	once a day			
	once in two days			
	Others,_____ _			
Is the frequency of water supply sufficient?	Yes		No	
1. Generally, how does the water smell?	No Smell		Foul Smell	
Generally, does the water have a taste?	Yes		No	
Generally, How does the water look like?	Clear		Dirty	
Do you irrigate your land?	Yes		No	
If yes, Do you get enough water for Irrigation	Yes		No	
Are there conflicts over the use of water in your community for agri, irrigation, etc?	Yes		No	

---THANK YOU FOR YOUR TIME---

Annex II

Question checklist on Water Scarcity and coping mechanism at community/ *Gewog* level

a) What are the socio-economic constraints in your *Gewog*?

b) What are the measures taken by the *Gewog* administration to overcome those problems?

c) Had there been any disasters related to climate change in the past? What was the coping mechanisms adapted by the people?

d) How many percent of the population in the catchment area have access to safe drinking water?

e) Is there any water shortage in your *Gewog*? If yes, how do people manage water requirement?

f) How safe is the water supply? How often do the health sector monitor and treat the water?

g) How is the water supply managed and distributed in the community?, especially distribution?

h) Do they appoint the caretaker? If yes, what are their roles, tenure, benefits offered to the caretaker?

i) What are the roles of *Dzongkhag* and *Gewog* health sector in ensuring the safe drinking water supply for the community?

j) Where does the wastewater from household go? Stream/ forest/ farmland

k) Where do communities dump solid waste? Stream/ Forest/ Farm land

l) Has the downstream drinking water source/ stream/ river impacted by the improper dumping of wastewater and solid waste disposal?

Annex III

Drinking Water Source Mapping

Community details (from field guide)

Name of the Village_____
Gewog _____
*Dzongkhag*_____

Community Population_____ No. of Households_____

Altitude._____ GPS Coordinates _____, _____

Water Discharge

Discharge = Velocity * Area

Velocity(flow method), Distance(Length)_____
Speed_____

Area, River width_____ Depth at 3 equi-points _____, _____,_____

Rapid assessment of watershed(as per guidelines of WMD)

_____
_____
_____
_____
_____
_____
_____

Picture ID of the Watershed/Stream_____

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