

Research Article





Coping with climate change: water availability and adaptive strategies in irrigation waters in a transhimalayan basin

Abstract

Trends and changes in temperature, precipitation and water sources, their implication on water availability, how households are perceiving the impact of climate change and, how effectively irrigation water is managed is explored in two selected communities of Trans-Himalayan region of Nepal. The paradigm of mixed research is followed. Quantitative and qualitative approaches are used to explore trends and irrigation waters deficit. Social data visualization included observations, peoples' perception surveys, key informant interviews and focused group discussions. Numerous pertinent literatures in climate changes and farmers' managed irrigation practices and other relevant subjects are reviewed. The research findings showed that snow melts and its contribution in maintaining soil moistures and crop water requirements have been playing a major role in peoples' livelihoods. The effects of climate change on waters for irrigation have been adversely affecting and is compelling people in adopting strategies locally to sustain livelihoods threatened by climate changes.

Keywords: climate change, irrigation waters, water availability, adaptive strategy, trans-himalayan

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Background

Agriculture was developed from forest gardening¹ to the jungleclad river banks² and in the wetted foothills of monsoon regions.³ An analysis indicated that the irrigation water demand would increase by 38% of the existing climate and by 53% in climate change by 2070-2099.4 Climate change, particularly changes in temperature, precipitation and hydrological flows are some of the drivers of global change. Climate Change has been affecting higher altitude region⁵ and, has led to the variability in water resources in the mountain, which has a direct effect on water availability for agricultural economy.67 Nepal Himalaya is found to be more vulnerable to climate change.⁸ Climate change induced water scarcity is the pertinent challenge to the agriculture and irrigation. Mountain hydrology has been impacting the existing pattern of water sources, river flows, forest and vegetation grow, and grazing land and other resources on which mountain people are dependent for their livelihood.^{5,9} The rising trend of mean annual temperature in Nepal will be in 0.045°C per year whereas there will be no changes in annual precipitation.¹⁰ If the present prediction on average temperatures¹¹ trend continues, it would have a serious impact on human and natural life.

The impact of decreasing water availability due to the rise in temperature has been affecting the agricultural production, food security and hardship to subsistence farmers in Nepal.¹² Many rural areas of Nepal are in rapid transformation phase in social and economic change, urbanization, out migration¹³ increased off-farm employment opportunities, increased absentee landowners and share croppers.¹⁴ Model studies were showing that winter runoff could increase theoretically, by 50% in the scenario of a rise of 2 degrees Celsius rise with no change in precipitation.¹⁵ In reality, water scarcity is one of the challenges in irrigation management and livelihood sustainability in most part of the globe.⁶ Climate change has been influencing the agriculture and irrigation practices in Nepal.¹⁰ Indigenously managed

farmers' irrigation systems in Mustang are built and sustained on the foundations of power relation and social differentiation. Water rules and, rights are exclusively power-ridden in the regions.¹⁶ Traditionally, disputes on ownership of water sources are common in Mustang area.^{17,18} Barley, buckwheat, a kind of millet and pea, apricot and rose were crops available in Mustang, a trans-Himalayan region of Nepal since around 1000 BC.19 Since then, irrigation was practiced due to low precipitations in the area. Rice and bean were imported food in the area in later periods. The winter precipitation as snow has a great role in fulfilling the soil moisture deficit and crop production in Mustang. Increase in surface temperature also affects the existing water availability situation.²⁰⁻²² This research assessed the climate change and adaptation strategies in irrigation practices in Mustang. Research was focused to find out the strategies in irrigation water management and practices adapted by local communities in the changing context of climate and environment.

Research questions

All ecological regions of Nepal are most reflective to the changes²³ MoE 2014. Mustang where local residents depend on farming for their livelihood, water is a crucial resource especially for irrigation and livestock farming. Water shortages have been creating conflicts on water sources¹⁸ and stresses in the livelihoods.²⁴ Communities have been coping to the water shortage through various ways and means in order to sustain their farming system and livelihoods.²⁵ The pertinent issues are how local households in the mountain areas are coping with climate changes and what strategies, they are adapting. Research questions were also focused on the trends of change in the seasonal temperature and precipitation, climate change implications placed in water availability situation and irrigation practices and, on how the farm households have perceived the impact of climate change in managing irrigation water needs.

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Research methodology

The paradigm of the research is mixed method,²⁶ which is also categorized as pragmatic research^{27,28} and a method that move both forth and back between induction and deduction reasoning.²⁹ The research model is the process model (reduced size) by Johnson et al.³⁰ with slight modification as given in (Figure 1). People's perception, knowledge, experiences, practices in self-managed irrigation system and socio-cultural aspects of communities are collected by ethno methodological approach.³¹ Fieldwork was done in 2010 and from 2012 to 2015. Thirty-six households out of total 81 are selected for detail survey. Data on land uses, population, agriculture and livestock, irrigation practices, livelihoods and adapting strategies and institutions are also collected from secondary sources. Statistical tools are used to analyze trends in precipitation, temperature and stream flows. People's perception and understanding on climate change are validated by statistical analysis of observed quantitative natural science data on stream flows, precipitation and temperature. Stream flows were frequently measured during the research period from 2012 to 2015 at canal intake by using the methods prescribed by WMO³² with price type current meter. Long term flows series and temperature and precipitation were taken from published data of a hydrological station of the Department of Hydrology and Meteorology Nepal.³³



Figure I Research model.

Study area

The research area is the rain shadow Trans-Himalayan area of Mustang of Nepal. The area lies in the cold arid zone of Nepal Himalaya (Figure 2) (Figure 3). The region possesses beautiful landscape and is rich in nature and cultural tourism which is flowering support to agricultural livelihoods.^{34,35} Historically, the area was said to be dependent mainly on agropastorism. In the course of development, irrigation practices were followed with time. Farming included cultivation of crops as well as rearing of animals. Decreasing trend in livestocks' pastureland and horticulture is also an eminent concern of agricultural livelihoods of the area.36 Focused watershed and hydrological regime lie at above 3000 meter altitude (Figure 2). The specific research sites include two communities named Dhakarjong and Phalyak of Kagbeni in Mustang district. These two communities lie within the watershed of Lumbuk stream which is also the water source stream for communities. This is one of several small tributary streams of Kaligandaki River in Mustang.

Findings and discussions

Trends in temperature and precipitation

In Nepal, maximum temperature rise per year has been reported to

be 0.042°C (10). This study showed that the rising trend on average maximum temperature data (April to August) is 0.019°C per year and the rate of change on average minimum temperature data (January to March) is 0.004°C per year over the study basin. The maximum temperatures for May, July and August has increased at a rate of 0.03°C per year (Figure 3). The correlation coefficient for annual minimum temperature and maximum temperature in June is higher, whereas in April to August is minimum. Hence, the warming is evident over the study basin. There is no any change on average annual precipitation in observed data between 1971 and 2006.8 However, the spatial and temporal variations are noted. During site visit, it was observed that there is also a little variation in snow fall over Lumbuk watershed in the winter (January to March), the annual runoff of Kaligandaki river at a monitoring location is found to have increased at a rate of 2.3 mm/ year over the period 1975 to 2012. This result indirectly indicated that there has been an increase in annual precipitation of 1.8 mm/year in the region over the period 1975 to 2012. As there is not substantial increasing and decreasing trend observed in total annual precipitation (10), the increase of liquid precipitation is an indication of decrease in solid precipitation. The reason for the increased surface runoff in the main Kaligandaki River is the rise of surface temperatures. But water sources fed by springs are found decreasing due to drying up springs. The drying of spring is caused by decreasing inputs by infiltration caused by less snow accumulation, decrease in snow fall frequencies and accelerating snow melts.



Figure 2 Focused watershed, land use pattern, hydrological regime and communities.

#Note: Boundaries, land use pattern are delineated by the authors on base map downloaded from freely available Google Earth Pro (https://www.google. com.np/maps/place/Kagbeni; Imagery date 6/24/2014). This map is used under principles of "fair use" (https://www.google.com/permissions/ geoguidelines. html) and, is not intended to be used for any commercial purposes.



Figure 3 Average maximum and minimum temperature trend (1969 to 2012) over Upper Kaligandaki basin.

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Water availability

130

110

90

70

50

30

10

-10

Amount in mm

Long-term precipitation during monsoon, pre monsoon. Post monsoon and winter is determined as given in (Table 1). Evapotranspiration in May and June exceeds 112 mm³⁷ which is about 40% of the annual precipitation. Evapotranspiration requirement exceeds precipitation in every month (Figure 4). The study basin does not contain any permanent snow covered areas. Maximum snow contribution is calculated from basin area of 3200 sq. km of upper Kaligandaki river. Annual precipitation is equivalent to 705 million cubic meters over the region, whereas annual water volume discharging out of the same region amounts to 1,060 million cubic

Table I Mean monthly precipitation (mm) over Lumbuk basin

meters. The difference showed that the water reserve is empting by 355 million cubic meters annually. This is a clear indication of snow and glacier melt contribution to basin could reach up to 40%²⁵ which is a significant contribution. Annual volume of water in Lumbuk khola at the canal intake is 1,625543 cubic meters. Total water demand for all crops in the communities including barren land, is calculated to be 1,338271 cubic meters, which is equivalent of 82.33% of the total average annual water volume available in the stream. The analysis revealed that available water is enough during the summer (Figure 5) but it seemed insufficient for non-irrigated and for areas left barren that are potentially cultivable. About 25% areas that can be cultivated are left barren because of water scarcity.³⁸

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation	9.7	13.6	19.2	14.9	14	23.5	63	53	33.3	17.8	4.8	8.1	275
Percent (%)	3.5	5	7	5.4	5.1	8.5	22.9	19.3	12.1	6.5	1.8	2.9	100
[Source : DHM Base data (1975-2012)]								Monsoon		Pre	Post	Winter	
									173		48	11	31
									63%		17%	4%	11%

130

110

90

70

50

30

10

-10

Am ount in mm



Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Precipitation (mm) at Lumbuk watershed

∃Evapotranspiration (mm) at Muktinath area



Figure 5 Available water and crop water requirement in summer.

Agricultural livelihoods

The major crops in the communities are naked wheat, barley, buckwheat, and potato. Pulses and maize are also grown. The total area used for naked wheat and barley is 52 percent and 13 percent respectively. Apple trees have been occupied 29% of the total cultivated land and are in increasing trend. While in summer, 39 percent areas are cultivated for buckwheat, followed by 11 percent for potato. Out of the total labor, 27 percent labor goes to ploughing and land preparation, 33% labor force is required for harvesting

whereas weeding requires 22%. Other activities are managed by 18 percent of the total labor. Water is shared in hours among farmers within communities which are based in Dhongba unit that is being practiced traditionally as the measure of the ancestral property right of a household inherited as the share of water allocation and the share of responsibilities to bear for the society. One "Dhongba" is equivalent to 12 hours of water allocation. A household gets water for 3 to 18 hours depending on the amount of Dhongba that he or she has inherited. Farmers get their next turn after 34 days in Phalyak and 29 days in Dhakarjong. Due to a month gap, crops do not get irrigation as per in required duration.

Decreasing trend in the amount of water in Lumbuk stream has arosed water right conflict sharing communities. After a long dispute between communities, water of Lumbuk stream is allocated two days to Dhakarjong and three days to Phalyak. Except conflicting opinion in water right, communities have been showing cooperation in the construction, maintenance and upgrading of canals and storage ponds of irrigation systems. Flooding irrigation is becoming inefficient to irrigate large plots due to decreasing flows in the sources. Farmers are terracing big plots into smaller units to irrigate their lands as one of tools in mitigating to scarcing waters (Figure 6). People are storing water in ponds during nights as an additional scheme to increase canal flows. Ponds are also constructed in series (Figure 6) to tap water seeping from upstream areas. Still, every farmer in the study area had reported that they have been facing water scarcity for more than 25% of their cultivable lands which are left abandoned. Increase in temperature and shortage of labor due to short or a long-term migration forced cropping pattern shift. Apple plantation appeared also as one of the mitigation measures adopted by the communities to cope with decrease in water. Summer and winter cropping seasons are in the area. In both seasons, farmers with their capacities have been adopting traditional knowledge while struggling with climate changes for sustainable agribusiness. In average, cereal crop production supports only 83 percent of the food requirements. The food deficiency of 17 percent is managed by purchasing food from various sources such as income from labor migration, cash from selling agricultural local

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Figure 6 Terrace divided into sub-terraces (left); Water pond in series (right).

Adaptive strategies

Farmers of the area are not aware of the fact on how much water they need for all crops and for all cultivable land they hold or land they are cultivating. Farmers do not have access also to the basic scientific information on crop water requirements and frequencies of irrigation that they need for each crop they sow. In flooding irrigation, communities could realize that the downward seepage rate is equaling or surpassing the horizontal sheet flow irrigation in low water due to which a longer time is required to irrigate a plot or not possible to irrigate completely. Therefore strategically, large terraces are divided into several parts to irrigate from a small volume of water. Because of adverse impact of climate change in water sources, people are now considering land and water as two separate commercial units. People have been adopting practice of selling land without selling water right inherited with it. Like in other parts of the globe, changes in cropping pattern are potentially, a method of adaptation to the climate change in the area. Communities have been adopting with scarce waters by crop diversification as well as by land abandonment. Farmers strategically used apple farming instead of land leaving barren. Introduction of mechanized planting and harvesting cropping system is not yet introduced because of extreme topography and poor economy. Apple farming strategy is emerging as an option to cope with scarcing water as well as to manage for labor shortages.

Human behavior is found directly related to climate changes in the area. Decrease in crop production at the local level has been resulting in food habit changes and in increase of imported crops like rice and dry foods. Organic manure local varieties are getting high prices and so people are motivated to sell their local products to earn money to meet their livelihoods and other needs. Scarcing water for irrigation has been arising disputes on ownership of water sources in communities. Indigenously applied flow dividing techniques did not work and so people adopted water sharing strategy as "time turn" in "days turn" among communities and "hours turn" specified in "Dhongba" unit between farmers, no matter how much flow is available in the stream.

Conclusion

The agro pastoral life was easier in the past because of the smaller population density and the abundance of virgin natural resources including fresh water. People had have been accessing freely the highland pasturelands. With passes of time and environmental changes, highland pasture productivity and irrigation waters have been reducing in line with decreasing snowfall and changing rainfall patterns. Snowfall which had been contributing significantly in supplementing the soil moisture to crops and pastures is continuously reducing to impact traditional livelihoods. The thinning frequency of snowfall, the temporal and spatial variability in precipitation induced by climate changes is the main reason that yields on most of water sources went on decreasing and drying out. If significant rise in temperature continues, runoff in the snow fed streams would increase for some years but, water sources fed by spring would go drying out due to decreasing inputs as infiltration. The system of production in the study areas is influenced by climate change and globalization. The negative impact of globalization is giving labor shortages due to alternative job opportunities and youth migration. This has further increased the trend in barren lands even though the region possesses very limited cultivable areas that always needed to be exploited most to maximize crop yield for food security.

People are feeling the changes but, are found to be unaware of scientific reasoning of climate variability underpinned effects on water sources. Farmers lack knowledge on the porosity of soils and infiltration therein. The inherent cause of drying sources of water is also a root of water conflicts and disputes among communities. People are adopting irrigation practices at their own innovative knowledge but are not fully aware of the linkages of water sources with hydrological cycles and climate change. These gaps are critical in proper water management in the irrigation systems. It is thus, concluded that unless their resumes again a regular precipitation as snow in the winter and a longer period of snow accumulation in the area, drizzly type of rainfall in the monsoon, spring sources would not yield water constantly as in the past. The strategies adopted on only traditional knowledge would be ineffective in minimizing effects in local livelihoods induced by climate changes.

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Conflict of interest

The author declares no conflict of interest.

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