The costs of adaptation: changes in water availability and farmers' responses in Punakha district, Bhutan

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Abstract: There is growing evidence that monsoon patterns are changing in the Himalayan region, which could potentially result in loss and damage for local farmers. To understand how farmers adapt to changes in water availability, we conducted a study in Punakha district, Bhutan, using qualitative and quantitative research tools. According to 91% of 273 respondents, water availability for rice irrigation has been decreasing over the last 20 years due to changing rainfall. Most of them have taken measures in response. They may, for example, invest in the maintenance of irrigation channels, develop or modify water-sharing mechanisms, or shift to crops that need less water than rice. Of these farmers, however, 88% indicate that their adaptation measures are insufficient. Moreover, they come with extra costs. We argue that these costs should not only be conceived in monetary terms, but also in terms of time investment, social-cohesion and livelihood security.

Keywords: climate change; slow-onset changes; adaptation; loss and damage; irrigation; water availability; paddy cultivation; monsoon rains; Himalaya region; Punakha district; Bhutan; Asia.

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1 Introduction

1.1 Background

Empirical data on rainfall trends in the Himalayas is scarce, but some recent studies have been pointing at changing rainfall patterns in the region (e.g., Ashfaq et al., 2009; Bhutiyani et al., 2010; Macchi et al., 2011, see also NBC, 2011; The Economist, 2012). For a country like Bhutan, where most of the people are subsistence-oriented farmers depending on the South Asian monsoon rains for the cultivation of rice, changing rainfall patterns have significant implications (NEC, 2011; MoAF, 2011a, 2011b). The Royal Government of Bhutan recently identified water availability as one of the principal pressures on human development in the country (GNHC, 2011).

Although monsoon patterns seem to be changing, there is uncertainty about the direction of these changes and their local manifestations (NRC, 2012). It is difficult to identify general patterns and trends in the region, as precipitation is highly location-specific, depending on the local topography and microclimate factors (NBC, 2011). Hence, analyses and predictions vary. While some sources suggest an increasing trend in overall rainfall (NEC, 2011; Shrestha et al., 2012; Immerzeel et al., 2013), according to others overall rainfall is decreasing. Based on an analysis of available rainfall data between 1866 and 2006, Bhutiyani et al. (2010), for example, found a statistically significant decreasing trend in monsoon precipitation and overall annual precipitation. A climate model developed by Ashfaq et al. (2009) predicts that climate change will alter the dynamics of the South Asian summer monsoon by decreasing summer precipitation, delaying the start of the monsoon season and leading to longer breaks between rainy periods. What most analyses and predictions have in common is the increasingly erratic nature of rainfall (see also Macchi et al., 2011; Lhendup et al., 2011 for anecdotal accounts of changing rainfall patterns in Bhutan).

1.2 The research

It is widely known that farmers pro-actively look for ways to deal with changes in their environment due to climate change (Van der Geest and Dietz, 2004), but it is increasingly acknowledged that there are limitations to adaptation as well (IPCC, 2007). People's responses to change may not always be sufficient, or may even worsen the situation. This has become known as 'loss and damage' – a relatively new concept in climate change research. According to Warner et al. (2012) the concept refers to the negative effects of climate variability and climate change that people have not been able to cope with or adapt to. This definition includes the inability to respond to climate stresses and the costs associated with existing coping and adaptive strategies. A better understanding of people's adaptation strategies and their limitations is required to help policymakers to develop strategic interventions to minimize loss and damage.

As part of a wider study on loss and damage in vulnerable countries, coordinated by the UN University, we set out to study adaptation measures and associated loss and damage among farmers in Punakha district, Bhutan. We explored the following questions:

1 What evidence is there for changing water availability?

2 How do farmers adapt to (perceived) changes in water availability?

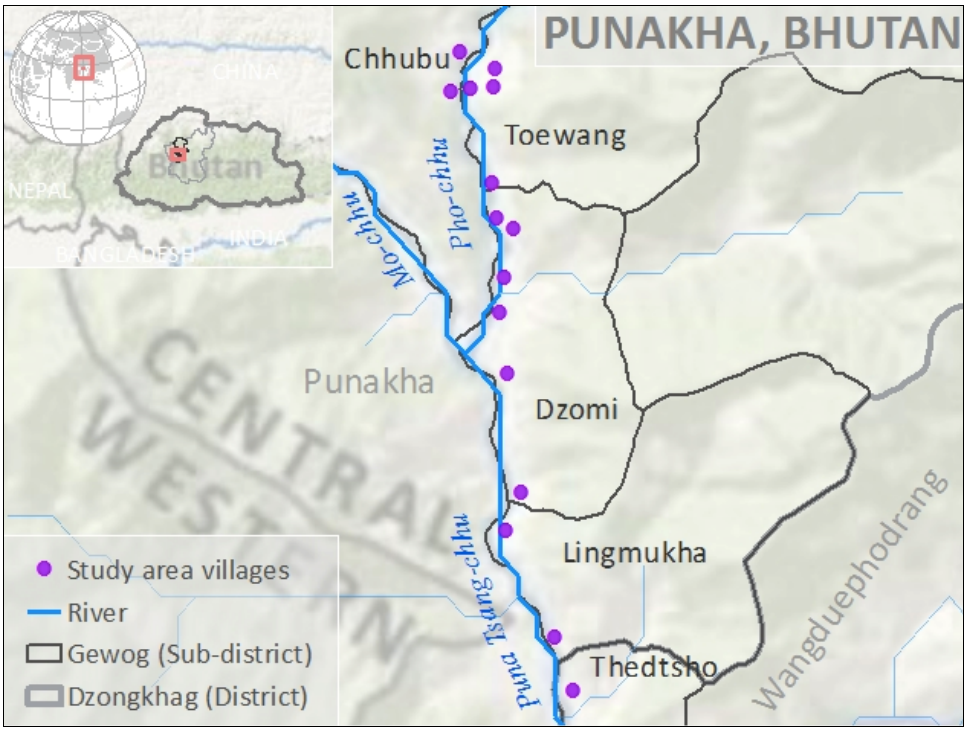
3 What are the limitations and costs of these measures?

We focussed exclusively on the availability of water for irrigation at the household level. Other consequences of changing rainfall patterns, e.g., on the generation of hydropower and the emergence of floods and landslides, were outside the scope of our research.

1.3 Methods and research area

In July 2011 we conducted a survey among 273 heads of households in Punakha district (Figure 1). In addition, we conducted 31 in-depth interviews with key informants, including village representatives, extension workers and government officials, and we organised four focus group discussions with a total of 20 men and women of different ages (some of whom were also respondents in the household survey).

Figure 1 Research area (see online version for colours)



Note: The dots indicate the administrative villages as recorded in the 2005 Population and Housing Census of Bhutan.

Source: Map by Dara Mendeloff, The Earth Institute, Columbia University

Punakha district has one of Bhutan's largest contiguous rice cultivation areas (NSB, 2010) and is referred to as Bhutan's rice bowl. Small-scale farmers grow rice along the river valleys of the Pho-chhu, Mo-chhu and Punatsang-chhu rivers. The cultivation of rice only takes place in the summer monsoon months, from early June to late September. About 75% of the annual rain falls in this period (Dorji et al., 1990). Only during these months there is sufficient water available in the streams and irrigation channels that come down from the high mountains into the Punakha-Wangduephodrang valley. Rice is the most important crop in terms of area, production and employment. It is also the most important crop for food, cash and barter (Dorji et al., 1990; NSB, 2010). According to FAO data, rice production in Punakha district gradually increased between 2002 and 2010 (FAO Country-STAT Bhutan), which seems mostly the result of the introduction of better seed varieties, fertilizers and pesticides. However, as we will discuss below, the increasing production trend does not apply to all farmers.

2 Results

2.1 Livelihood characteristics

More than 90% of the people in the research area are small-scale, largely subsistence-oriented farmers, producing rice in the summer and non-irrigated crops in the winter, such as wheat, mustard, buckwheat, chillies, radish, cabbages and tomatoes. In addition, they often own a small number of livestock and fruit trees. The average size cultivated per household is 2.1 acres and only about 4% owns more than six acres. The largest recorded landholding is 14 acres. Ninety-four percent of the farming households own the land they cultivate. Fifteen percent of the surveyed households have been living in the area for less than 10 years. The mean annual cash income per household is US$1,556 and the mean annual cash income per capita is US$330. About 60% of the households are involved in non-farm activities, often in the winter season. The non-farm sector is the main source of cash income in the area (Table 1). The relative importance of remittances is explained by the fact that many young people, especially those who have enjoyed some education, leave the area in search of non-farm jobs in the urban centres, mostly in the country's capital, Thimphu. Two basic features that influence people's food security in the area are the land size per capita, determining how much food one can produce, and the cash income per capita, determining how much food (and other consumer products) one can buy and the productive investments one can make (e.g., purchasing fertilizers).

All farmers were asked about changes in their crop production over the last ten years. According to about one-third of them, their crop production had been increasing, because of access to improved technologies like chemical fertilizer and pesticides, and improved seeds. Some also explicitly mentioned the assistance of extension officers and improved traction (ox or tractor). Another one-third indicated a decreasing crop production. Of the respondents who reported a decreasing production, 92% said that the decrease was primarily caused by changes in (timely) rainfall. Forty-two percent of the farmers in the tercile with the lowest cash incomes indicated a decreasing production, versus only 26% of the farmers in the tercile with the highest cash incomes.

Table 1 Income-earning activities (N = 273)

Activity	*Percentage of Households*	*Mean annual household cash income (US$)**
Crops	91%	301
Livestock	80%	55
Trees	66%	39
Non-farm	60%	820
Remittances	41%	204
Farm labour**	12%	12
Other***	7%	124

Notes: *income data were recorded in Bhutanese currency (*Bhutanese Ngultrum*, BTN), which we converted to US dollars using the exchange rate of July 2011 (BTN1.00 = US$0.0181591)
**households that earn cash income with farm labour
***this category includes renting out houses and machinery (e.g., tractor, mill, chainsaw, pump).

2.2 Changing rainfall patterns

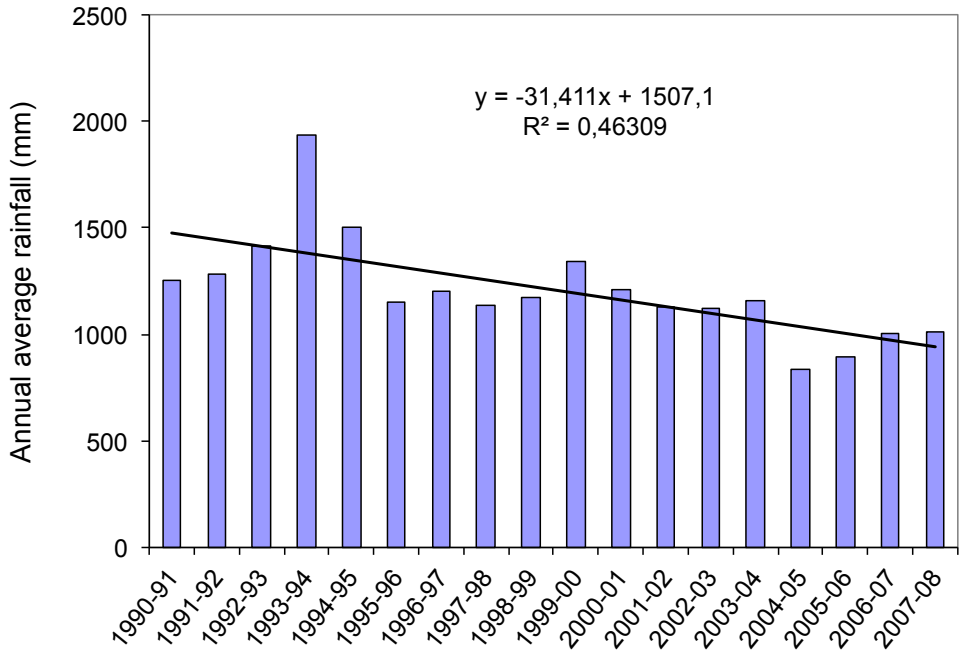
According to 91% of all respondents in the research area the availability of water in the streams and irrigation channels has been changing over the last two decades. As prime reason they point at the monsoon rains, which, they say, are decreasing in quantity and reliability. In an attempt to crosscheck these perceptions we collected data from the six weather stations located in the Punakha-Wangduephodrang valley; two in Punakha district and four in the neighbouring Wangduephodrang district. Analysis of rainfall data collected at these stations between 1990 up to 2008 seems to confirm farmers perceptions, showing a decreasing trend (Figure 2), which is significant (sig = 0.00187).

According to 89% of the respondents who reported a change in water availability, this negatively affected their household economy. Most of them (97%) mentioned a negative effect on the production of crops, particularly rice (Table 2). Some also expressed worries concerning the availability of water for fruit trees (23%) and livestock (12%). According to 8% of the respondents low yields cause the local market prices of agricultural products to increase in years with insufficient irrigation water.

Table 2 Impact of changing water availability (percentage of impacted households, N = 215)

	Percentage of households
Negative effect on production of crops	97%
Negative effect on tree crops	24%
Negative effect on livestock	12%
Negative effect on food prices	8%

Figure 2 Annual average rainfall in Punakha and Wangduephodrang districts (see online version for colours)



Source: Hydromet Services Department, Ministry of Economic Affairs, Thimphu, Bhutan

2.3 Adaptation measures

Of all the respondents who indicated their household has been affected by the changes in water availability, 88% said they have been taking measures to deal with these changes (these households are referred to as the 'adapting households' hereafter). With an open question we asked them to explicate their actions. The most mentioned measures were:

1 performing religious rituals to request for rain

2 developing new, or modifying existing water-sharing arrangements between households and villages

3 improving irrigation channels, to compensate for decreased availability of water

4 shifting from irrigated to rain-fed crops

5 buying irrigation water from upstream villages

6 purchasing or hiring a gasoline or electric water pump (Table 3).

Twelve percent of the adapting households indicated that their measures are sufficient to neutralise the effects of changing water availability. This group said that they no longer experience negative effects from the changes in water availability. Eighty-eight percent of all the adapting households, however, said that their measures are not sufficient. Of the farmers in the lowest income tercile, 91% indicated that they still experience negative

effects, despite their adaptation measures, against 82% of the farmers in the highest-income tercile.

Table 3 Most popular measures among adapting households (N = 192)

	Percentage of households
Perform rituals	71%
Develop or modify water-sharing arrangements	48%
Maintain irrigation channels	37%
Change crop mix	31%
Buy water	7%
Use water pump	5%

2.4 Performing rituals

While the performance of religious rituals would generally not be considered an adaptation measure in the realm of climate change science, the people in Punakha themselves saw it as the most important measure to deal with the perceived changes. Asked about the actions taken in response to changing water availability, most farmers first mentioned the performance of Buddhist rituals to request for rain. Rituals take place at the level of the household, the community, and the district. At the household level, rituals can be organised for different purposes, including the request for rain. During the ritual (locally known as *Soelkha*), individual household members make offerings to the deities, either in their house or a village monastery. According to local informants a household may spend US$100 or more on such a household-level ritual, although this amount will vary greatly between households. In addition to the *Soelkha* ritual, respondents also mentioned the annual *Lo-chhoe* ritual that they perform as a thanksgiving and to bring good fortune in the coming year.

Communities sometimes organise collective rituals (*Yu-lha*), for example when the monsoon rains are delayed, and people are worried about the timing of the planting season. In such a case, local monks are asked to perform the prayers and all members of the community are required to participate. Each household member is expected to make a contribution in kind and in cash – usually this is about 1.5 kg of rice and between US$3 and US$6 per household member – and community members failing to attend the ceremony are expected to pay a fine. In water-scarce years, rituals may even take place at the level of the district. Such an event involves a large group of monks and civil servants, often more than a hundred. Together they walk along the main river, covering a maximum number of communities, carrying volumes of Buddhist scriptures on their backs. According to government officials from Punakha district, they have been performing this ritual for the last six consecutive years.

2.5 Sharing water

In the research area arrangements are in place within and between villages in order to manage the use of irrigation water, i.e., who is entitled to use how much of the water and when. Such water-sharing arrangements are based on existing water entitlements – the right to use a share of the irrigation water – that are usually distributed at the time an

irrigation channel is constructed. Newly established households do not automatically receive such an entitlement and households with traditional rights will therefore share the water with their offspring, as soon as they establish their own households. Newcomers will only receive an entitlement under certain conditions, for example when they contribute labour during the construction of a new channel.

At the start of each paddy-planting season, the number of hours that each (entitled) household can use the irrigation water is determined during a village meeting, depending on the size of the land holding and the contributions made for ceremonies and the maintenance of irrigation canals. During the cultivation season, changes can still be made upon negotiations between the individual households, under supervision of the *Yu-poen,* who is the designated village irrigation manager. The *Yu-poen* also plays an important role in developing or modifying arrangements with other villages, which is necessary when two or more villages depend on one source of water. They may for example agree that each village is allowed to use the water for 24 hours alternately. When water is scarce, village representatives can open up negotiations in order to alter an existing arrangement, e.g., changing the number of consecutive irrigation hours from 24 to 48 hours per village, as, in times of water scarcity, it takes more time for the terraces to fill up with water.

According to 48% of the adapting households, the development of new, or modification of existing water sharing arrangements is an important measure in response to changing water availability. Sixty percent of these households, however, indicated that the arrangements are associated with an increase in the number and intensity of conflicts. This is because some farmers break agreements by secretively diverting an irrigation stream to their own fields during the night, even though it is not their turn yet to use the water. Essentially, such behaviour is a form of adaptation as well, be it an illegal one. Several respondents mentioned that this situation typically leads to tensions within extended families, as related households share one entitlement. Such conflicts are usually resolved among the households themselves. When a conflict occurs between two communities, both villages will send their representatives to solve the problem. If that does not work, and the conflict is about to get out of hand, the village representatives will approach the sub-district head and request for conflict resolution. The sub-district officials we interviewed all noted an increase in conflicts and tensions in recent years. Several respondents reported instances of physical violence and intentional damage inflicted on properties because of water-related disputes.

2.6 Maintaining irrigation channels

Thirty-seven percent of the adapting households mentioned the intensification of irrigation channel maintenance as a measure to prevent the unnecessary loss of water. Maintenance activities of the main irrigation channels are managed by the *Yu-poen.* Each year, he or she decides upon the number of days each household will need to contribute to the work, which depends on the size of their paddy fields. Those who cannot contribute physical labour may need to pay around US$3.50 per assigned working day (for comparison: the common daily wage for agricultural work in Punakha district is around US$5.00).

We asked several farmers and *Yu-poen* to estimate the number of days needed for the maintenance of the shared irrigation channels. According to them, this varies per year, depending on the availability of water. A household with one acre of rice fields would

typically spend one or two days on channel maintenance in a year with sufficient rainfall, while the same household may have to spend up to 15 days in a water-scarce year. These are significant time investments, especially considering the fact that labour is scarce during the paddy cultivation season.

2.7 Changing crops

When the water is not enough to irrigate paddy rice on all of the terraces, a farmer may decide to plant crops that need less water on part of the fields, like maize, millet, wheat, cabbage, potatoes, beans or radish. Thirty-one percent of the adapting households mentioned making such shifts in their crop mix, in response to the changes in water availability. Although the cultivation of irrigated rice is more labour-intensive compared to the cultivation of non-irrigated crops, changing from irrigated to non-irrigated crops is seldom the preferred option for farmers. This is not just related to the fact that rice is the staple food in the area; respondents also stressed that the yields of non-irrigated crops as less secure. Moreover, although a shift from rice to other crops usually implies decreasing costs in terms of labour and agricultural inputs, the income per acre from rain-fed crops is usually much lower compared to rice. FAO data on prices and production of maize and paddy rice between 2000 and 2010 in Bhutan suggest that the gross income per acre of paddy is on average about 2.5 times higher than that of maize (Faostat). Analysis of production and price data from the Ministry of Agriculture and Forests showed that incomes from rice in Punakha can be up to eight times higher than incomes from maize (MoAF, 2010).

2.8 Purchasing water

When farmers lack the entitlements to secure them of a share of the irrigation water, they depend on local rainfall for the irrigation of their paddy. Whenever it rains, the small irrigation channels fill up, and the farmers irrigate their terraces one by one. To access additional water they may request upstream farmers to share their water, for which they would provide financial compensation. If agreed, the upstream farmers will open the irrigation system for an agreed number of hours, allowing the water to flow into a channel going to the downstream households. Seven percent of the respondents mentioned this as a measure they resort to, in response to water scarcity. The amount of money that a household pays per season to access irrigation water from upstream villages differs, but estimations hover around US$70 per acre in an average year. This option is unreliable, as the upstream villagers will not share their water when they are faced with water scarcity themselves. Hence, in dry years the need to access irrigation water increases, while the willingness of the upstream communities to sell their water decreases, threatening the rice production of households without water entitlements.

2.9 Using a water pump

The main river that flows through the Punakha-Wangduephodrang valley contains plenty of water throughout the year, but the geography of the valley, with sharply inclined slopes, complicates its use for irrigation purposes. We discovered that some households have recently started pioneering with the use of water pumps to draw water from the

main river to the fields using long plastic hoses. The use of a water pump reduces farmers' dependency on local rainfall. We observed farmers pumping water to fields located as far as 200 meters from the river, and up to an estimated 15 meters above the water level. An average water pump cannot carry the water further up the slope.

Five percent of all respondents reported the use of a gasoline pump, of which four households had been able to actually purchase one. A strong-enough pump costs somewhere between US$1,000 and US$1,500, which is close to an average annual income. We found that the pump owners had been able to save the required amount of money with non-farm activities, usually in urban areas. For them, the purchase of a pump was a profitable investment, as it secured the access to water, while opening up opportunities to rent the pump to neighbours. Neighbouring households could hire a pump against an average rate of US$5.50 per hour. For a farmer with one acre of paddy fields this amounted to approximately US$163 per season.

3 Discussion and conclusions

3.1 Variability and vulnerability

Access to water is influenced by a range of factors, such as population growth, agricultural practices, changes in vegetation cover, and infrastructure development. Also, people's access to irrigation water is influenced by existing (traditional) access rules, water-sharing arrangements and household-level characteristics, such as origin, size of the landholding and wealth. Next to that, the weather conditions throughout the paddy season obviously are of crucial importance. Farmers' perceptions and meteorological data suggest that the volume of rainfall in Punakha district has been decreasing over the last two decades. According to the large majority of the interviewed farmers this has negatively affected their access to water for the irrigation of paddy fields. Still, however, overall rice production figures of Punakha district (as published in FAO Country-STAT Bhutan) have been increasing in recent years. The negative effects of decreasing water availability on rice production are outbalanced by general improvements in agricultural practices, at least at an aggregate level. There are two simultaneous trends in the research area, both influencing agricultural production, but in opposing ways. Firstly, due to increased access to fertilizers, pesticides and improved seeds – made available since the 1990s through extension services by the government – people have been able to improve their production. Secondly, farmers are dealing with unreliable water availability in the irrigation channels, hampering the quality and quantity of local rice production.

General improvements in agricultural practices thus play a crucial role, but our research suggests that not all households benefit equally from these developments. About a third of the respondents in our sample reported decreasing crop production due to changes in rainfall. This group includes the poorest households. Their access to water is compromised when they cannot contribute labour or money to the construction and maintenance of irrigation canals. Migrant households in this respect are particularly vulnerable, as they lack any *a priori* water entitlements, and – unlike newly established households from local origin – they usually cannot rely on the entitlements of relatives. These households thus have insecure access to water, which constrains their agricultural production, which on its turn results in limited means to invest in productive

improvements (e.g., access to external inputs and mechanised traction) to help them offset the negative effects.

3.2 The costs of adaptation

Farmers adopt adaptation measures to deal with changes in water availability, but according to 88% of the adapting households these are insufficient to neutralize the negative effects. Moreover, they are associated with extra costs (Table 4). Most concretely, there are the financial expenses needed to acquire access to irrigation water from an upstream community or a water pump. Also, farmers who shift from irrigated to non-irrigated crops will see their income per acre decrease. There are other kinds of costs as well. Firstly, the shift from rice – the local staple food – to the cultivation of vegetables or maize may compromise farmers' food security. Secondly, work on the maintenance of irrigation channels requires significant amounts of extra time, which is a great cost in times of labour scarcity. Lastly, we found that water-sharing arrangements are associated with costs in terms of socio-cultural cohesion within and between communities. We conclude that the costs of adaptation measures should not only be expressed in terms of money, but also in terms of food security, time, and social cohesion. These various kinds of costs associated with adaptation measures can be conceptualised as loss and damage incurred at the local level.

Although we argue that adaptation measures often imply extra costs, the difference between 'costs' and 'investments' is not always clear-cut. The purchase of a water pump, for example, may turn out to be a profitable investment, allowing the owner to rent it out to other villagers. Making such an investment, however, requires financial savings, which most households do not have.

Table 4 The costs of adaptation

Adaptation measure	*Costs*
Changing from irrigated rice cultivation to the cultivation of rain-fed crops.	Rice is preferred as food crop. Moreover, the harvest of rain-fed crops is less reliable, and the income per acre is lower compared to paddy rice.
Using a gasoline or electric pump to extract water from the main river.	For a household with one acre of paddy fields, hiring a water pump may costs around US$160 per cultivation season. Purchasing a pump costs around US$1,000.
Buying the right to access part of the irrigation water from an upstream village.	For a household with one acre of paddy fields, this may cost around US$70 per cultivation season.
Water-sharing arrangements between households and villages.	Violation of arrangements leads to (violent) conflicts, negatively affecting social cohesion within and between villages.
Intensifying maintenance of irrigation channels.	In water scarce years, the amount of time a farmer has to spend on the maintenance of irrigation channels can be much higher compared to wet years.

3.3 Policy options

Over the last decades, the Royal Government of Bhutan has been actively developing policies and implementing programs to deal with climate-related changes, particularly

related to the melting of glaciers and the risk of destabilizing ice-cored dams, which can lead to Glacial Lake Outburst Floods (GLOFs). The impact of gradual changes in water availability, however, is much less visible and less dramatic compared to the impact of such floods. Indeed, while ensuring access to irrigation water is a daily concern for farmers during the paddy cultivation season, for policymakers the impact of such gradual changes is an easily overlooked area for interventions.

Based on our research we identify several possible areas for intervention. Firstly, long-term and more reliable access to irrigation water may be achieved through the development of water reservoirs (so water available for irrigation can be spread more evenly over the paddy season), and the increased usage of water pumps (enabling people to use the water from the main river to irrigate their fields). As an average pump has limited capacity to elevate the water, a series of reservoirs could link up water pumps, and thus allow for greater elevation of water. Such efforts to improve farmers' access to water requires further development of credit facilities, and could involve both private investors as well as farmers' associations and cooperatives. Secondly, Farmers' vulnerability to gradual changes in water availability may be reduced through further agricultural diversification, i.e., by planting fruit trees (e.g., apple, orange and pear) and crops that need less water (e.g., maize, wheat, barley, buckwheat and millet, but also vegetables such as potato, chili, onion, cabbage, cauliflower, asparagus, tomato, carrot, radish and lentil). In Punakha district, the trend towards the cultivation of non-irrigated crops to complement paddy rice is likely to continue, due to a combination of unreliable access to water, a growing demand for cash crops in urban areas, and decreasing labour availability in rural areas. This demands specific attention from agricultural extension services to identify and promote economically feasible diversification options. Lastly, our research shows that it is particularly important to ensure equal access to agricultural extension services that promote improved agricultural practices, and to pay specific attention to the more vulnerable households, particularly those without water entitlements.

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