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Economics of climate adaptive water management practices in Nepal

Rajesh Kumar Rai [a,b,*], Kaustuv Raj Neupane [b], Roshan Man Bajracharya [b], Ngamindra Dahal [b], Suchita Shrestha [b], Kamal Devkota [b]

[a] South Asian Network for Development and Environmental Economics (SANDEE-ICIMOD), Lalitpur, Nepal
[b] Southasia Institute of Advanced Studies, Kathmandu, Nepal

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ABSTRACT

This study analyses costs and benefits of the selected climate adaptive and equitable water management practices and strategies (CAEWMPS) in Dhulikhel Municipality and Dharan Sub-metropolitan city of Nepal. The CAEWMPS adopted the construction of water recharge pit at household level in Dharan and recharge ponds at community level in Dhulikhel. The results of household survey reveal that households have employed different coping strategies including minimizing consumption, purchasing from market, harvesting rain water and installing equipment for storing and pumping in both cities. In Dhulikhel, a significant number of households (18.56%) minimize consumption during the dry season but this is not the case in Dharan. Rather, around one-fifth (19.27%) of the households harvest rainwater in Dharan. In addition, households are forced to give-up their regular activities in order to implement coping strategies such as household chores, leisure time, meeting and gardening. The average estimated annual coping cost in Dharan (USD 87.5) is eight times higher than in Dhulikhel (USD 11.05); however, per unit coping cost is nearly equal in both the cities. In terms of benefit-cost ration, the community level recharge ponds in Dhulikhel (5.15) were found to be cost effective compared to the household level recharge pits of Dharan (1.72). These results provide policy makers with a comparative basis for adopting appropriate strategies to tackle problems related to water shortage under city-specific contexts.

1. Introduction

Water is essential for life as it is used for domestic purposes, agricultural use, industries, and energy production [1, 2, 3]. It contributes substantially to the local as well as national economy. On the other hand, rapid population growth along with improved living standard, urbanization and industrial growth have led to increased, which ultimately encourage competition and conflicts among water use sectors [4]. At the same time physical destruction of surface water bodies, higher cost of infrastructure, and climate change have further reduced the accessibility to freshwater and put ever-increasing pressure on water resources that are available for various uses [5, 6].

As a result of inadequate distribution as per the demand of consumers, most of the urban areas are reeling under acute shortages of water [7]. The changing climatic phenomenon, particularly rising temperature and disproportionate distribution of rainfall, have triggered the disruption of the smooth supply of water [8]. Urban areas, in particular, are increasingly subject to the scarcity of drinking water due in large part to the heavy influx of migrant populations, lack of technical and management capacity, inadequate water distribution system, and the ever-intensifying impacts of climatic change [9]. Such situation could be more severe in the Himalayan Mountains because this area is experiencing higher temperature increased than the world average, which may have negative impact on water resources, and urbanization is rapid [10, 11].

Urban households in water scarce areas usually have three options: (i) adjust with available water, (ii) find alternatives to increase the supply of water, and (iii) migrate to water rich areas. Since, the first and the third options are not highly preferred, a majority of households adopt several coping strategies to make water available such as drilling wells, storing water, buying from the market, and collecting water from alternative sources [12]. This means households have to incur significant costs while applying coping strategies. Urban households mainly carry out five types of coping behaviors: collecting water from public taps and water bodies; installation of tube-wells; treating (either filtering or boiling) before drinking or cooking; keeping storage tanks; and purchasing from vendors and neighbors [13]. The cost could be in terms of cash to purchase storage tank, pump or buy from market, or in terms of time to collect water from other sources, which is usually farther from the regular

* Corresponding author.
E-mail address: rjerung@gmail.com (R.K. Rai).

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source. An estimation carried out in Kenya indicates that coping costs are higher than the average water bills and could be greater than 10% of the household income [14]. Assuming that water scarcity continues in the future, the best approach could be to identify the most appropriate coping strategy enabling households to attain safe and sufficient water at the lowest cost [15].

However, considering the changing environment and climatic variables, it would be better to identify coping strategies that could go beyond the household level. This is because sensitivity and adaptive capacity of individuals may vary within the society [16]. Focusing on household level activities alone may create conflict in the future. In addition, it is also well established that collective action is more effective in developing economies like Nepal, where most of the households are depend on subsistence activities [17, 18]. Moreover, collective action can contribute to address market failures in developing economies and provide opportunities for smallholders to enhance their benefits [19]. Therefore, a concept of “climate adaptive and equitable water management practices and strategies” (CAEWMPS) has been developed which contributes to address the issue of disproportionately distributed water resources, increasing water scarcity, and uncertainty in water supply [20].

The proposed CAEWMPS focused on enhancing water availability and the distribution system at community level rather than only identifying effective coping strategy at the household level. These strategies may have an array of alternatives from water source protection to institutional capacity enhancement. They include, among others, recharging ground water, conservation of small springs, incentivizing watershed communities to protect water sources and strengthen institution to monitor water quality and quantity. But, selecting the best strategy requires understanding of the costs and benefits of selected strategies.

In this case, benefit generated by the selected CAEWMPS is the aggregated reduced cost for a household to cope with water scarcity [21]. Therefore, it is important to have information on the costs that households incur when adopting coping strategies to fulfill their water demand. In addition, this study estimates the cost required to implement the selected CAEWMPS activities. Further, the study also determined willingness-to-pay (WTP) of households to improve water supply condition in their cities. However, coping cost is the indirect estimates of WTP for improved and more reliable water services [22]; determining WTP may help to assess households' behavior in actual and hypothetical scenarios.

The main objective of this study was to assess the costs and benefits of CAEWMPS. The specific objectives were to identify the strategies of households to cope with water scarcity and compare between two different CAEWMPS modalities in two hill towns of Nepal. Unlike the existing literature on estimating coping cost, this study estimates the costs of both coping strategies and foregone activities using market and non-market valuation approaches.

2. Materials and methods

2.1. Analytical framework

As cities are facing water shortage, there are various efforts to cope with water shortage which could be either at household level or at community level. The benefits and costs of CAEWMPS were estimated separately for different types of activities and the analytical framework is presented in Fig. 1. The net benefits of CAEWMPS are the benefit generated from minus the cost of implementing each CAEWMPS activity.

Adopting coping strategies means households have to pay the cost of these activities, which are additional to the usual activities. These costs are observed in two forms in the study area: (i) forgone activities to implement coping activities, and (ii) payment to implement coping activities. Implementing CAEWMPS activities may reduce the total coping cost of households, which is the benefit of CAEWMPS. The first cost can be estimated asking people their willingness-to-pay (WTP) and the

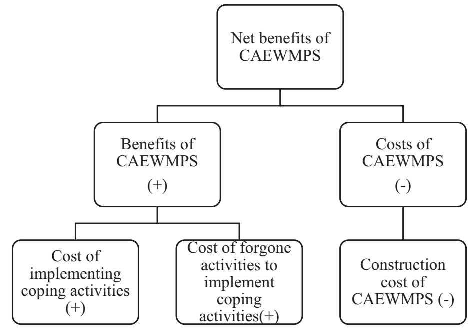

Fig. 1. Analytical framework for costs and benefits of CAEWMPS.

second cost is can be estimated using market approach. Here, coping behavior of households and costs are primarily focus on water quantity.

Implementing CAEWMPS require several activities including coordination with concerned authorities and community; and construction of infrastructure to retain water. This study includes only the cost of infrastructure as CAEWMPS cost, this is because local municipal authorities may incorporate such activities into regular mainstream activities. The present value was estimated using 10% discount rate, which is the rate of returns on debenture provided by the banks in Nepal at the time of the study.

2.2. Study sites

Many mountain areas across the Himalaya are experiencing water shortage due to decline of precipitation and the drying up of springs [23]. Therefore, this study was carried out in mountain towns of Nepal (Fig. 2). Dharan sub-metropolitan city (26.7944° N, 87.2817° E) is in the foothills of Siwaliks, where municipal residents use both surface water and ground water. Dhulikhel Municipality (27.6253° N, 85.5561° E) is in the mid-hills uses only surface water. Both municipalities are located in the Koshi River Basin, indicating the similarity in civilization and traditional livelihood activities. Dhulikhel has well-functioning payment for ecosystem services (PES) scheme for drinking water, whereas Dharan has not implemented any PES activities for water source management [18, 24].

Dharan sub-metropolitan city is a historical city in the eastern part of Nepal, is constantly under pressure of acute water shortages in the recent years [18]. Dharan accommodates 27,750 households with estimated population of 116,181 inhabitants [25]. The town is regarded as the gateway to Eastern hills of Nepal and dominated by the indigenous communities including Rai, Limbu, Gurung, and Newar. Sardu khola and Khardu khola are the major surface sources in the north and ground water extraction from the nature forest of the Charkoshe Jhadi to the south.[1] Existing supply system of the city depends on both of these sources for distribution of drinking water in Dharan.[2] It is located in the Bhavar region, which has gently sloping alluvial deposit comprised of course sediments at the foothills of the Siwaliks, thus, has high surface infiltration rates that contribute to recharge groundwater during rainfalls.

Public demand of water is about 20 million liters per day but the water supply is estimated to be thirteen million liters during the dry

[1] Initial Environmental Examination (IEE) of Rehabilitation, Extension and Development of Water Supply Works at Dharan Municipality submitted by IUDP, PIU and Dharan Municipality.

[2] Initial Environmental Examination (IEE) of Rehabilitation, Extension and Development of Water Supply Works at Dharan Municipality submitted by IUDP, PIU and Dharan Municipality.

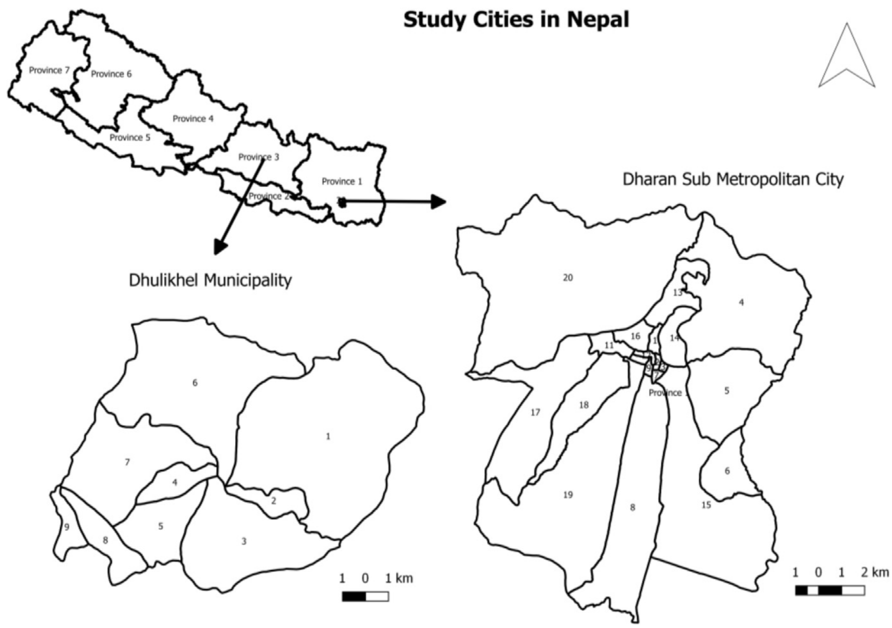

Fig. 2. Locations of the two study cities in Nepal.

season and 17 million liters in the rainy season.[3] Nepal Water Supply Corporation is serving 81% of the population of the town. This means a household receive 144 liter less water per day in the dry season [26]. The corporation distributes water 1–2 hour/day in wet season and average 1–2 hours/day in every alternative day in dry season2. This indicates the acute water scarcity particularly in dry season. In addition to the scarcity in drinking water availability, existing water sources and reservoirs have found to be highly contaminated and polluted. Therefore, municipal water users are more likely to be exposed with serious water borne diseases [27].

Likewise, Dhulikhel municipality in the mid-hills has 4,321 households with an estimated population of 21,190 inhabitants [25]. The indigenous Newar community resides at the core of the town with hospitality services and business as major sources of income [28]. Dhulikhel municipal area is dominated by rural and agricultural land-use (74%), which is followed by forest (22%) and urban settlements (4%). The water supply system is managed by a water user committee (WUC). Almost 80 % of households in the Dhulikhel municipality have access to the drinking water on a regular basis, and those who do not have access to this system are connected with 27 public taps distributed via pipe network system from water sources other than the main water source. There are huge losses in the distribution system in Dhulikhel municipality [29]. In addition, a recent study reported a declining trend of annual rainfall and stream flow of Rosi River, which is the source of drinking water supply to Dhulikhel residents [30]. The WUC pays certain amount to the community living in the source area as a part of Payment for Ecosystem Services (PES) for the use of water.

In both municipalities, construction of the recharge ponds/pits are considered as one of the most appropriate CAEWMPS. Rainwater harvesting is an age old practice [31, 32] and there are several excellent examples of converting mountains into rainwater harvesting park such as Kilimanjaro Mountain of East Africa, which is also known as Kilimanjaro concept [33, 34]. The proposed CAEWMPS here focused on rainwater harvesting plus social mobilization and policy engagement [20]. In Dharan, ground water is one of the major source of drinking water [26]. Here small recharge pit construction was carried out at household level to facilitate the ground water recharge. In the case of Dhulikhel, recharge ponds were constructed in a public area, particularly in the Thuloban Community forest to revive local water bodies.

2.3. Data collection

The total coping cost (cost of implementing coping activities and cost of foregone activities to implement coping activities) was estimated through household survey. The cost of implementing CAEWMPS, particularly infrastructure construction, was the actual cost computed during the project implementation.

2.3.1. Household survey

Household survey is related to the costs that households are incurring to cope with drinking water shortage and was carried out in both cities. The number of sample households (n) was selected using Slovin's formula:

$$n = \frac{N}{(1 + Ne^2)} \quad \text{(i)}$$

where, N is the total population and e is margin of error. In this estimation, we took 92 % (e = 0.08) and 93 % confidence level (e = 0.07) for Dhulikhel and Dharan respectively. Based on this, the sample size in Dhulikhel is 150 and Dharan is 205. In this study, 194 household in Dhulikhel and 275 in Dharan were interviewed using a questionnaire. The questionnaires were prepared based on the consultation with local stakeholders and a pilot survey. A pilot survey was carried out in Dhulikhel with 30 respondents.

In each town, the first step was to select wards[4] randomly. In Dhulikhel five wards, and eight wards in Dharan, were selected randomly. Then, sample size was determined proportionately based on the ward population (Table 1). We have adopted systematic random sampling to select the households for interview. This means in each selected ward, the first house was selected randomly and then next house in the selected interval. The interval is the ratio between total populations of the selected wards and sample size. This was 13 in Dhulikhel and 40 in Dharan. It means in Dhulikhel, the second house

[3] The Himalayan Times, Sunday 3 June 2012, http://www.eco-business.com/news/dharan-reeling-under-water-shortage.

[4] Ward is the lowest administrative unit of local government.

Table 1
Descriptive statistics of sample.

Variables	Dhulikhel (n = 194)	Dharan (n = 275)
Age (Years)	37.42 (6.67)	38.32 (8.75)
Female (Number)	24 (12.37%)	233 (84.73%)
Family size (Number)	5.60 (2.06)	5.62 (1.75)
Water demand (liter/day)	234.27 (90.60)	277.45 (72.50)
Education		
Primary education (Number)	98 (50.52%)	62 (22.55%)
Secondary education (Number)	48 (24.74%)	141 (51.27%)
Higher secondary (Number)	39 (20.10%)	51 (18.55%)
Bachelor and above (Number)	9 (4.64%)	21 (7.64%)
Annual Income (NPR)		
≤5 lakh	154 (79.38%)	32 (11.63%)
5–6 lakh	25 (12.89%)	105 (38.18%)
≥6 lakh	15 (7.73%)	138 (50.18%)

* mean and SD in parentheses where value is not followed by % in parentheses.

will be the 14th house. The household head, of either gender, of the approached household was interviewed.

2.3.2. Infrastructure construction cost

In Dharan, private recharge pits were constructed at household level. This is expected to contribute ground water recharge, which is the primary source of drinking water. The size of individual recharge pit was 1.5 m^3 (1 m × 1 m × 1.5m). The materials for recharge pit construction include the costs of 2 sacks of each sand, gravel and stone; 1 sack of cement; and PVC pipe of 4–5 inch. The cost of construction materials and wage labor was NPR[5] 8,000 for a pit. In addition, annual maintenance cost was estimated assuming that one person-day requires for cleaning and maintenance. The market wage rate was NPR 700 per day. The estimated life span of the construction is 30 years based on the estimated life of the roof materials. Hence, all costs and benefits were carried out for a 30 year time period.

In Dhulikhel, 24 climate adaptive recharge ponds (CARPs) of 259.07 m^3 capacity were constructed across a sub-watershed. The size of ponds varied from 3.44 m^3 to 34.69 m^3. The cost items include labor cost, gabion wire and stone. The total cost of construction was NPR 138,800 (USD 1,239.29). In addition, the CARPs require regular maintenance, estimated at 18 labor-days required per year. The market wage rate is NPR 800 per day.

2.4. Data analysis

2.4.1. Coping cost

The coping cost is the cost that household are paying or spending on alternatives to fulfill their water demand. This is the additional cost of water that a household spends for the alternative source.

The coping cost can be expressed as:

$$C = \beta_0 + \beta_1 X_i + T + \varepsilon \tag{ii}$$

Where, c is coping cost to water scarcity, i is household, β1 is coefficient of X is household characteristics, T is city dummy, and ε is the error term.

In our study area, it was noted that households have mainly two types of coping strategies: (i) buying tanker water from market, and (ii) harvesting rain water. These have increased electricity cost also. Electricity price for water use was estimated from the percentage of electricity use for water pumping, monthly electricity bill and number of months having water scarcity. Rain water harvesting cost was annualized by the life of zinc sheet and 4.5 % discount rate. This is the inflation rate for Nepal in 2017.

2.4.2. Cost of forgone activities to implement coping activities

Households have to compromise with their activities in order to cope with water scarcity. This may be because either they have to spend more time to manage water or have to use additional resources. A contingent valuation method (CVM) was used to elicit WTP of households if they can retain their activities if water availability resumed as per their requirement. In this survey, households were asked how much they have WTP annually for improving water supply situation that may recover their foregone activities to manage coping strategies for the next 10 years. In addition, we analyzed the factors affecting WTP for the given water availability scenario using following equation:

$$WTP_i = \beta_0 + \beta_1(H_i) + \beta_2(S_i) + \varepsilon \tag{iii}$$

where, H_i is a household profile or characteristics that include average monthly income, family size and level of education, and S_i is a service characteristic that includes total time taken to fetch water.

2.4.3. Water availability due to CAEWMPS

The costs of CAEWMPS were estimated as the cost per unit water availability due to CAEWMPS. The water availability was estimated using infiltration rate. The infiltration rate of soil was assessed using the double ring infiltration test [35] and soil texture was analyzed using the soil hydrometer and sieving for particle size distribution [36]. The infiltration apparatus consists of two concentric rings of 15 cm and 30 cm diameters. The larger diameter ring was used to control the lateral flow of water below the surface. The ring was hammered into the soil until the lower edge of the ring is 5 cm below the ground surface. A jute cloth was placed inside the ring above the soil to prevent soil dispersion and sealing while pouring the water. The water was filled in both the inner and outer rings and the water level in the inner ring is measured using the measuring rod or tape. The record was kept according to increasing time intervals. The recording process was continued for two to three hours until a steady-state infiltration rate is maintained.

The equilibrium infiltration rates of soils from 16 land systems ranged from 9 to 400 mm per hour. This study uses the mean infiltration rate for all land systems calculated to be 124 mm/hour, which corresponds to 124 l/m^2 in the estimations.

3. Results

3.1. Descriptive statistics

Table 1 reports the description of samples taken. Both cities have similarities in average family size and average age of the household heads. Dhulikhel had less female participation, whereas Dharan had a high number of female participants. There could be two reasons for this. First, Dharan is known as a city of people who work abroad, hence fewer men are available in the household. Second, Dhulikhel is mostly dominated by a rural setting, therefore, male domination is the norm. The location of these two towns: Dharan mainly as urban setting, and Dhulikhel as semi-urban setting was also reflected in the sample characteristics as water demand and education level was higher in Dharan compared to Dhulikhel.

It was observed that Dharan residents have higher water demand compared to the residents of Dhulikhel municipality. This could be due to the urban setting of Dharan as well as the warmer climate. Usually, urban water use increases with living standards of urban residents [37]. Since, income is associated with living standard, residents of Dharan had consistently higher income than Dhulikhel residents, hence, corresponding living standards. Dharan is known as a city of ex-Gurkhas, who served in the United Kingdom, Brunei, Hong Kong and Singapore in British army regiments.

[5] NPR is Nepalese Currency. 1 USD ~ NPR 112.

3.2. Water supply

In Dharan, all households have piped water into the house. In Dhulikhel, a majority of households have pipe water (79%), and rest use public water sources/taps (21%). In Dharan, all households pay water tariff, but in Dhulikhel only 84% households pay water tariff. The average monthly water tariff is NPR 164.74 and NPR 515 in Dhulikhel and Dharan, respectively. Both municipalities face water shortages for more than four months of the year. In Dhulikhel, the average water shortage months is 4.05, whereas it is 5.51 months in Dharan. However, intensity is different across these two cities. For instance, in Dhulikhel municipality, during the dry season, only 14% water is less available compared to other months, while it is 49% less in Dharan. As a result, municipal residents of Dharan have adopted several types of coping strategies reported in Table 2.

Mainly, households have adopted four types of coping strategies. Among them, buying water from the market is the most popular option in both cities. Installing new equipment such as water pump is also common in both cities. In Dhulikhel, a substantial number of households (18.56%) reduce their water consumption, but in the case of Dharan, rainwater harvesting is one of the popular options adopted by 19.27% households.

In Dharan, a household supplements their water supply by an additional 18,324 liters through their coping activities including purchasing and rainwater harvest. This estimation is based on the water demand; water availability; length of dry period and percentage of households purchasing water and harvesting rainwater. Similarly, on average, a household augments water supply by an additional 2,670 liters through coping activities in Dhulikhel, which is considerably lower than in Dharan.

3.3. Coping cost

Managing coping strategies means households have to put in additional effort or spend extra time beyond their regular activities. Households gave up various activities in order to manage coping activities as shown in Table 3. In both cities, the majority of households gave up their leisure time. In addition, they minimized the time allocation for household chores and meetings in both cities. In Dharan, a substantial number of households (13.45%) gave up their gardening to cope with water scarcity.

Since, about 69% of households in Dhulikhel did not have to forego productive activities in order to manage coping strategies (indicated by responding that they gave up leisure time or nothing), only 36.6% (71 households) have shown WTP for improving water condition. However, in the case of Dharan 85% (234) households have shown WTP for improved water availability, which would help to resume their foregone activities. The estimated average annual WTP for improved water access that allowed for maintaining their daily activities is NPR 217.26 (USD 1.93) in Dhulikhel and NPR 473.63 (USD 4.22) in Dharan. The estimated WTP varies with the severity of problem and socio-economic condition of the respondents. For instance, WTP for improved water supply was USD 1.47 in Bolivia, while it was between USD 7.46 to USD 10.6 in Kazakhstan [38, 39].

Table 4 reports, key reasons why respondents did not show WTP for water improvement. Among the households, those that indicated zero WTP for water improvement, i.e., the majority in Dhulikhel, stated that either they did not believe such activities would improve the water supply, or felt that they were already paying considerable water tariffs. On the other hand, in Dharan, most household did not wish to pay because are not interested in the water improvement issue.

Table 2
Coping strategies (Number of respondents and % in parentheses).

Coping strategies	Dhulikhel	Dharan
Installed new equipment	28 (14.43%)	52 (18.91%)
Minimize consumption	36 (18.56%)	0
Buy from market	130 (67.01%)	170 (61.82%)
Rainwater harvest	0	53 (19.27%)

Table 3
Forgone activities to manage coping activities (Number of respondents and % in parentheses).

Forgone activities	Dhulikhel	Dharan
Household chores	49 (25.26%)	25 (9.09%)
Leisure time	101 (52.06%)	203 (73.82%)
Meetings	10 (5.15%)	10 (3.64)
Gardening	0	37 (13.45%)
Nothing	34 (17.52%)	0

Table 4
Reasons for not having WTP (Number of respondents and % in parentheses).

Reasons for not having WTP	Dhulikhel	Dharan
Already paying more	52 (41.60%)	0
Do not believe it can improve water supply	55 (44%)	7 (17.07%)
Do not have enough income	5 (4%)	0
Not interested in water improvement	8 (6.4%)	34 (82.93%)
Other reason	5 (4%)	0

Besides allocating time for managing coping activities, households often have to spend money to implement coping strategies. They have to purchase water from the market, buy machines and materials for rainwater harvesting, and may have to pay additional electricity charge to pump water. These costs are reported in Table 5. In this analysis, costs associated with underground tank, rooftop tank, water pump, and the regular electricity bill for water pumping were not included. In Nepal, these structures are a regular component of the building, and an improved water supply system also may not be able to directly lift water to the roof-top tank without pumping.

The estimated average annual cost of the coping strategy in Dharan (NPR 9,327 or USD 83.27) was eight times higher than in Dhulikhel (NPR 1,021 or USD 9.11). This is as expected since Dhulikhel has a lower water demand and a shorter water shortage period than Dharan. In addition, Dhulikhel receives only 14 % less water available in the dry season compared to the rainy season against 49% in Dharan. Similarly, around 19 percent of households in Dhulikhel do not spend extra money on coping strategy as they simply adjust with less water. In addition, the average monthly water tariff paid by Dharan residents is more than three times higher than that of Dhulikhel.

The total coping cost is the sum of the cost of foregone activities and the cost of implementing coping activities. The cost of foregone activities is equivalent to the WTP for the foregone activities. Therefore, average annual cost of coping activities was calculated to be NPR 1,238.17 (USD 11.05) and NPR 9,800.69 (USD 87.50) in Dhulikhel and Dharan, respectively. Based on this result, the total annual costs of coping activities for all households in Dhulikhel and Dharan was determined to be NPR 5.35 million (USD 47,768) and 271.97 million, (USD 2.42 million) respectively.

In Dharan, the estimated present value of the coping cost for a 30-year period is NPR 101,622 per household. The estimated present value of water, as per their coping activities, is NPR 0.18 per liter. In Dhulikhel, the estimated present value of coping cost is NPR 12,839 per household.

Table 5
Average annual costs of implementing coping strategies in NPR (standard deviation in parentheses).

Activities	Dhulikhel	Dharan
Additional electricity cost	95.24 (105.73)	512.41 (382.36)
Buy water from market	925.67 (545.54)	5,866.51 (2,586.29)
Rain water harvest cost	0	2,948.14 (1,153.85)
Total	1,020.91	9,327.06

Based on this, the estimated present value of water is NPR 0.16 per liter for Dharan.

3.4. Construction cost and water increment

In Dharan, the present value of a recharge pit cost is NPR 14,559. This value was calculated based on the number of rainy days and rainfall intensity in a year in Dharan (10–24.99mm = 54 days, 25–49mm = 28 days and >50mm = 12 days) and assuming that 25%, 50% and 75% of rainfall contribution to recharge, respectively, for the three different rainfall intensities. This means, a recharge pit filled up 36.5 (13.5 + 14 + 9) days per year, allowing a recharge pit to infiltrate 4,526 liters of water per year into the ground. This is a rather conservative estimate, as there is no accurate information on how much infiltrated water reaches the ground water aquifer. If the estimated infiltrated water contributes to the ground water and becomes available through the central distribution system, then one liter of water would cost NPR 0.11.

In Dhulikhel, the present value of CARPs cost is NPR 273,722. The estimated water increment from the CARPs is 303,496 liter water per year. The estimate is based on the mean annual rainfall of Dhulikhel area between 1971-2014 (Department of Hydrology and Meteorology), which is 1,558.5 mm. The number of rainy days with ≥25 mm is 18.90 days. If all of the infiltrated water becomes available for the residents, then the estimated water cost of the CAEWMPS in Dhulikhel would be NPR 0.03 per liter.

4. Discussion

The results indicate that Dhulikhel currently has a better drinking water supply system compared to Dharan sub-metropolitan city in terms of water scarcity months and percentage of availability of water in dry season compared to the rainy season. This could be due to the lower demand for water in Dhulikhel as the population is significantly higher in Dharan sub-metropolitan city. In addition, Dhulikhel drinking water supply is more systematic compared to Dharan since the former has a well-established payment for ecosystem service (PES) scheme [24]. In the case of Dharan, a PES scheme has yet to be implemented and a new project for drinking water supply is ongoing [26]. This indicates the important role of PES scheme to ensure water supply for urban households.

Households have shown collecting, pumping and purchasing strategies in order to cope with the water scarcity during the dry season. Purchasing water from the market is the dominant coping strategy that is employed by households in both cities. Such behavior has also been observed widely in other cities of developing countries [13, 40]. Minimizing water consumption was observed as one of the primary coping strategies in Dhulikhel. This could be the reason that a substantial number of households did not have to give up their regular activities. In Dharan, almost one-fifth of the households have collected rainwater as a coping strategy. This is mainly due to the fact that Dharan Municipal authority encourages the public to utilize rainwater providing 30% subsidy on building permit revenue for households that install a rainwater harvesting system during construction of the house.

A noteworthy fact is that in both cities, the majority of households were willing to give up their leisure time to manage coping strategies. This suggests that a member of households who have leisure time become involved in managing the coping strategy. Similarly, compromising time for household chores in order to manage water is the second dominant strategy in both cities. This may indicate that women have to put additional effort to manage water as they are the ones who are engaged in household chores; taking responsibility of the home after out-migration of male family members. Although, in theory, women are supposed to generally have leisure time during the day, this appears to not be true in practice [41].

The results of this study also indicate that households incur a substantial amount of money to cope with water scarcity. The estimated cost of coping strategy can be up to 2.16 % of the urban households' average expenditure in Nepal. It was NPR 431,337 per year in 2016 [42]. In other word, it is around two percent of the average household income of the study area. This estimate is based on the per capita income of Nepal in 2017, which is currently USD 853 (~NPR 87,006) [43]. This is higher than the estimated coping cost in Kathmandu, Nepal, which was one percent of the household income [13]. But, the estimate seems reasonable since the prices of all consumptive goods have skyrocketed over the recent decade in Nepal.

Though, the average cost of coping activities is substantially higher (almost 8 times) in water scarce area (Dharan) compared to Dhulikhel, the estimated present value of per unit coping cost (NPR/Liter) is similar. It was calculated to be just 12% higher in Dharan compared to Dhulikhel. The estimated net benefits of CAEWMPS in Dhulikhel (NPR 0.13/liter) is 1.67 times higher than that of Dharan (NPR 0.08/liter). Similarly, the benefit-cost ratio is far higher in Dhulikhel (5.15) compared to 1.72 of Dharan. This finding is in line with existing literature that community-based approach is more cost-effective than individual household approach [44]. The estimation also indicates that the cost of CAEWMPS can be equalized to the coping cost when only 59% and 19% of the infiltrated water becomes available to the municipal drinking water supply in Dharan and Dhulikhel, respectively. Such, artificial ground water recharge technologies have been found to be economically viable and socially acceptable in other parts of the region as well [45].

5. Conclusions

The study suggests that CAEWMPS can contribute to improve the welfare of water scarce communities. Despite the huge discrepancy in average coping cost between households in two cities, the present value of per unit coping cost is nearly the same. This could be due to the fact that households in both cities are almost similar in terms of implementing coping strategies and giving-up their regular activities to manage coping strategies; and coping cost is positively associated with the quantity of water and whether households purchase water from the market or not. This is also reflected by the WTP of households for improved water condition. However, CVM is often criticized for overestimating the consumer's WTP; the estimated WTP for foregone activities are far less than the actual expenses for coping activities. The estimates of the infiltration rate, water recharge, and expenses of households to cope with water scarcity require long-term observations to improve robustness. The estimations used in this study are very conservative, which do not overstate the results.

In general, one would assume that appropriate climate adaptive water management practices would generate more benefits in terms of per unit cost in Dharan compared to Dhulikhel, but this has not happened because the former city had an individual adaptive measure while the latter had a community-based approach. It is expected that per unit cost is high while constructing small pits compared to larger ponds. In addition, households may not be motivated to construct large pits as it increases total cost, even if the space is available, to increase public goods. This indicates the cost-effectiveness of community based system compared to individual level effort.

In fact, the individual household strategy was chosen considering the rainfall pattern in Dharan as it has high potential of harvesting rainwater [20]. The harvesting of rainwater is encouraged by the subsidy policy of Dharan Sub-Metropolitan city to rebate building construction permission revenue. This suggests further efforts to explore how to encourage households who have old buildings with no rainwater harvesting system. The results of this study provide comparative examples for municipal policy decision-making with regard to water management. It is noted that city-specific contexts are important for adoption of policy measures and practices for water supply enhancement. However, further investigation is needed on how much infiltrated water contributes to ground water recharge and source augmentation. The benefits of water harvesting practices could be maximized if its contribution to erosion and flood control through runoff regulation is assessed along with groundwater recharge and provision of drinking water."

Declarations

Author contribution statement

Rajesh Rai, Roshan Man Bajracharya: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Kaustuv Raj Neupane: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Ngamindra Dahal: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Suchita Shresth: Contributed reagents, materials, analysis tools or data; Wrote the paper.

Kamal Devkota: Performed the experiments; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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