Chapter 11
Rainwater Harvesting and Rural Livelihoods in Nepal

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Key Messages

- Rainwater harvesting helps mountain farmers to overcome water scarcity during dry season and in diversification from traditional cereals crops to high-value vegetable farming.
- The investment on the technology could be recovered in two years time but adoption of the technology is low due to the high start-up cost in the absence of subsidy.
- Providing trainings and subsidy to the farmers would help increasing the adoption rates of the technology as a part of climate change adaptation.

11.1 Introduction[1]

Rainfed agriculture is one of the sectors most sensitive to climate change (Cline, 2007), and in many countries in South Asia, a decline in crop yield is observed due to rising temperature, rainfall variability and extreme weather events (Balasubramanian, & Saravanakumar, 2022, Chap. 10 of this volume; Cruz et al., 2007; IPCC, 2007a; IFAD, 2008). Water scarcity is expected to increase while heat stress is expected to

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[1] A significant portion of the materials is drawn with permission from author's working paper: Kattel (2015). Rainwater Harvesting and Rural Livelihoods in Nepal, SANDEE Working Paper No 102-15.

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contribute to reduction of area available for high-yielding wheat production in the Indo-Gangetic Plains (IPCC, 2014). If no adaptation strategies for climate change are implemented, agricultural productivity could decline by as much as 10–25% in South Asia by 2080. For some countries, the decline in crop yield in rainfed agriculture could be as much as 50% (IPCC, 2018). The adverse impact of climate change on agriculture will be especially detrimental to Nepal, where over 60% of the population is dependent on subsistence and mostly rainfed agriculture for its livelihood. With natural springs drying up in the hills and the mountains (Bharti et al., 2020; Rai & Nepal, 2022, Chap. 23 of this volume), it is important to explore how monsoonal rain water can be conserved better and used effectively for hill agriculture as ground water is difficult to obtain and expensive. In this paper, we look at rainwater harvesting, which is being increasingly used in mountain agriculture in Nepal.

Rainfed agriculture accounts for 65% of the total cultivable land area in Nepal. Since only 24% of the arable land is irrigated (mainly in the lowland Terai), crop productivity is significantly low in comparison to the rest of South Asia and the country relies heavily on food imports (Bartlett et al., 2010). Agriculture consumes around 96% of all water withdrawn in the country (CIA, 2010) and contributes slightly over 25% to the GDP (World Bank, 2019).

In Nepal, more than 80% of precipitation occurs during a short monsoon season (June to September) resulting in flooding, landslides and loss of topsoil (Malla, 2008) and leading to crop failure and increased food and livelihood insecurity (Gentle & Maraseni, 2012; Gurung & Bhandari, 2009; Kohler et al., 2010).[2] Mountain people in Nepal are subject to even more livelihood risks as water sources are drying up and rivers are located a considerable distance away, usually below the farmland making irrigation impossible without access to appropriate technology.

This makes rainwater harvesting increasingly important as an adaptation strategy, which is a traditional technology used in highland pastures for generations in Nepal for collecting rainwater for animals, which has been re-designed and re-introduced in the farming system in recent years. Cascade tanks are popular for rainwater harvesting in other South Asian countries (Vidanage et al., 2022, Chap. 15 of this volume). There are two types of rainwater harvesting (RWH) practices: surface rainwater harvesting and rooftop rainwater harvesting. The rooftop system is mainly used for collecting rainwater for either household use or recharging ground water, while the surface rainwater collecting system is used for supporting agriculture. The focus of this study is the individually managed plastic or cemented RWH ponds, which have been promoted in the hills of Nepal for collecting surface rainwater.[3]

Since 2003, the government has been promoting plastic and cemented RWH ponds (MoI, 2014). However, till date, only about 5% farmers were found to have adopted RWH for crop production in the area surveyed for this study. If RWH technologies

[2] Though livestock of buffalo, dairy cattle, goat and sheep are feasible enterprises in the hilly areas of Nepal, the lack of a reliable water supply can restrict the extensive use of grazing lands and create pressure on scarce water resources (Zomer et al., 2014).

[3] Harvesting rainwater for animals is an old-age tradition in the hills of Nepal but rainwater harvesting for agriculture is relatively a new phenomenon.

are to be scaled up as a climate adaptation strategy, it is important to understand the impetus behind farmer's adoption decisions and their profitability. In this study, we ask two interrelated questions: (1) who adopts the RWH technology? and (2) what is the impact of RWH technology on farm income?

To answer these questions, we use farm, household and community-level information from four districts of Nepal. We find that the training received by farmers regarding agriculture and livestock production as a part of extension services is a strong determinant of RWH technology adoption, which significantly increases annual household income from agriculture and livestock. Benefit–cost analysis suggests that the RWH technology is viable in rainfed agricultural systems because adopters can diversify from cereal crops into high-value off-season vegetable crops for enhancing household income and farm profits. However, farm households face a large start-up cost (almost 30% of their annual income) for adopting the technology and also lack knowledge, which can be overcome by providing related trainings and subsidizing the RWH technology as a part of climate change adaptation strategy.

11.2 Technology Adoption in Agriculture

Technology adoption models are generally based on the theory that farmers make decisions in order to maximize their expected profits or utility (Feder et al., 1985). Subsistence farmers may maximize utility but not necessarily maximize profits at the same time (Sadoulet & de Janvry, 1995).[4] For this study, we use a utility maximization framework since the farmers in our study area are mostly subsistence farmers who have small parcels of land for producing agricultural crops for their own consumption, with little or no surplus for selling.

Risk is generally viewed as a major factor that influences the rate of adoption of any kind of innovation (Jensen, 1982; Just & Zilberman, 1983).[5] There are two types of associated uncertainties: the perceived risk associated with farm yield after adoption and production; and uncertainty related to the costs of farm inputs and outputs. Koundouri et al. (2006) propose that farmers adopt new technology in order to hedge against production risk and that human capital plays a significant role in the decision to adopt more efficient irrigation technology. In this context, Adesina and Zinnah (1993) and Getnet and MacAlister (2012) emphasize the importance of farmer's perception of the innovation-related characteristics of the technology in making an adoption decision. Our study provides evidence on the impact of RWH technology on farm income and how the adoption rate could be improved for mountain agriculture in Nepal.

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[4] Despite its failure to identify the psychological processes that determine preferences, the framework is considered to be less restrictive than profit maximization approach (Lynne et al., 1988).

[5] Optimizing utility may also include considerations such as health benefits, environmental concerns, food security and risk (Napier et al., 2000; Ribaudo, 1998).

11.3 Study Area and Sampling

We conducted the study in 15 villages from four mid-hill districts of Nepal, namely Makwanpur, Palpa, Gulmi and Syangja. We chose these four districts deliberately for two main reasons: firstly, they have recorded the highest rates[6] of individually managed RWH technology adoption, and secondly, they allow us to capture variation in rainfall and elevation across the hilly districts of Nepal. Rainfed agriculture is predominantly practised in these areas and is associated with the cultivation of major staple crops such as maize, wheat, rice, millet and vegetables. For this study, we selected six Village Development Committees (VDCs)[7] from Makwanpur, four VDCs from Palpa, three VDCs from Gulmi and two VDCs from the Syangja district.

We used a multistage sampling technique to select four districts from two regions. We then selected VDCs from each district based on the RWH technology adoption rates. Secondly, we stratified farmers in each VDC into two groups, namely adopters and non-adopters. We identified adopters in each sampled village with the help of the District Agriculture Development Office (DADO) that keeps records of the adopters. In each sampled village, there were fewer numbers of RWH technology adopters than non-adopters.[8] We oversampled the RWH technology adopters such that the proportion of adopters and non-adopters is the same in our sample, and we applied the probability proportion to size technique to ensure that farmers in the large village clusters had the same probability of getting into the sample as those in the smaller village clusters. We sampled at least 10–15 households[9] from each VDC among the population of individually managed RWH adopters and non-adopters. The farm household survey was conducted between August and November 2012 through a structured survey interview of 282 farm households comprising 141 RWH adopters and 141 non-adopters (Fig. 11.1).[10]

We also conducted three community-level Focus Group Discussions (FGDs) of around 5–10 RWH adopters/non-adopters from different castes, genders and economic backgrounds in each district for obtaining qualitative information for understanding farmers' perspective on adopting/not adapting the RWH technology.

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[6] We used the National Population and Housing Census Report (2011), District Profile (2011) and the District Agriculture Development Office Report (2011) to gather secondary information, including information on the RWH adopters' list, household population size and the occupational diversity of the households living in the selected villages in order to develop the sampling frame. We obtained the list of villages and adopters from the 2011 Census of Nepal.

[7] A Village Development Committee (VDC) was the lowest-level administrative unit in Nepal (till 2015) comprising small villages (wards).

[8] We found 20–120 RWH adopters and 100–410 non-adopters in each sample village.

[9] We selected 10–20 households randomly from each VDC where 5–10 were RWH adopting HHs (Treatment HHs) and 5–7 were RWH non-adopters/participants (Control HHs).

[10] We define a farm household as one where a group of individuals related by blood or marriage live on the same premises, share a kitchen and practice agriculture farming system.

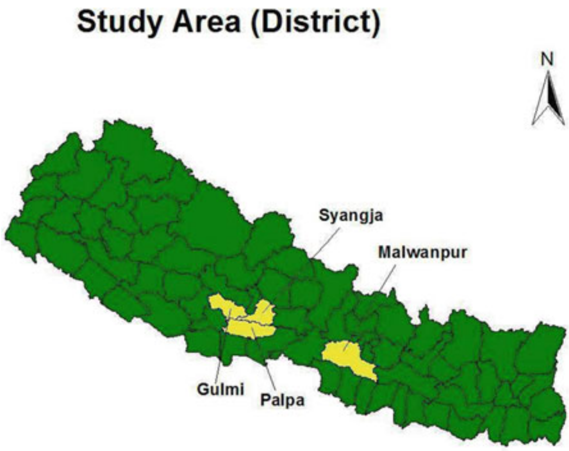

Fig. 11.1 Location of the four districts. *Source* Authors

11.4 Methods and Variables

Household income and adoption of RWH technology may affect each other, wherein households with higher income may adopt RWH technology and adoption of RWH technology may also increase farm income due to the availability of irrigation water for off-season agriculture. The problem can be resolved technically using either a treatment-effects model as in Maddala (1983) or an instrumental variable (IV) approach as in Angrist (2000). We estimate farmers' adoption decisions and farm income simultaneously using a treatment-effects model to control for self-selection (Heckman, 1978, 1979; Heckman & Navarro-Lozano, 2003). We also use an IV approach for checking robustness of the estimates obtained from treatment-effect models.

11.5 Results and Discussion

11.5.1 Rainwater Harvesting Technology

In this section, we discuss the key findings from analysing the survey data. Among the 141 RWH adopters, approximately 82% had constructed a plastic pond (cheaper option) and the rest (18%) had cement ponds (more expensive). The size of each pond ranged from 1000 to 75,000 L. Nearly half of the RWH adopters in the study area had received a subsidy from the government (i.e. District Agricultural Development Office) and/or non-governmental organizations (NGOs) (mainly materials like plastic, pipe or cement) amounting to between 30 and 50% of the total construction costs, while other farmers adopted the technology of their own cost.

Approximately, 94% of the RWH ponds are located near the homestead of the farmers. While 45% of the adopters used only rainwater, about 31% of them used both rainwater and stream water in their RWH ponds. Almost all (97%) adopters stated that they installed a RWH pond for producing vegetable and high-value crops. We found most of the RWH ponds to be actively used (93%) and a majority (85%) of RWH adopters reported that their cropping pattern had changed after RWH pond construction. A quarter of the respondents reported problems with RWH pond management and water-holding capacity of the pond due to seepage and weeds and 7% ponds were inactive because of this. About three-fourth of the adopters used RWH pond water in the field for irrigation purposes through a pipeline connection. The age of the RWH ponds varied from 1 to 14 years. Kattel (2015) provides further information about the technology used in the study area.

11.5.2 Socio-demographic and Economic Characteristics

In the sample, the average age of the household head was approximately 50 years. Though RWH adopters are on average younger than non-adopters, the difference (between the two means) is not statistically significant. Approximately three-fourths of the household heads are male with very little education (two years of schooling on average). The level of education is higher for adopters than for the non-adopters. Among other variables, the total number of spades in the house (an indicator of agricultural tools), the training received with regard to agriculture and livestock production and the social network (membership of the household head in any group, organization or cooperative) were found to be greater among RWH adopters than among non-adopters. There was a greater proportion of higher caste households and those with knowledge of climate change among the RWH adopters than among the non-adopters. The percentage of people below the poverty line is lower for adopters (34%) sub-sample than for non-adopters (45%). This indicates that there is a negative association between RWH technology adoption and household poverty. The difference between the sample means in the adopter and non-adopter sub-groups is not statistically significant for the following variables: the livestock standard unit, the availability of extension services at the farm, access to credit, size of landholding, total cultivated land and per cent of upland in total cultivated land. The latter indicates that the two groups of farmers are mostly comparable. Table 11.1 presents the socio-demographic and economic characteristics of the sampled farmers.

The proportion of farmers who had diversified their cropping pattern was higher among RWH adopters with more adopters growing cauliflower and cabbage (39% compared to 22% in non-adopters 22%), tomatoes (55% compared to 27% in non-adopters) as well as beans, pea, broadleaf mustard, and gourds. Cereal crop production was more common among the non-adopters than among the adopters. Most RWH adopters were growing a high-value crop (i.e. vegetable) due to the availability of water during the dry season. Figure 11.2 shows the distribution of different types of vegetables and cereals produced by the RWH adopters and non-adopters.

Table 11.1 Socio-demographic characteristics of RWH adopters and non-adopters

Particular	Full sample ($N = 282$)	RWH adopters ($n = 141$)	Non-adopters ($n = 141$)	Mean difference (*t*-test)
Age of household head (in years)	50.21	48.91	51.50	− 2.59
Gender of the household head (if male = 1)	0.74	0.81	0.67	0.13***
Years of schooling	4.51	5.31	3.69	1.62***
Caste (if higher caste = 1)[11]	0.48	0.53	0.43	0.099*
Family size	6.48	6.58	6.39	0.19
Economically active household members (15–60 years old)	4.08	4.22	3.93	0.29
Upland cultivated (in *ropani*)	6.47	7.03	5.91	1.12
Lowland cultivated (in *ropani*)	1.94	1.89	1.99	0.10
Total cultivated land (in *ropani*)	8.41	8.93	7.91	1.29
Per cent shared by upland in total land	79.5	80.2	78.7	0.41
Livestock standard unit (LSU)[12]	3.13	3.34	2.93	0.41
Number of spades (type of physical asset)	4.7	5.2	4.3	2.88***
Extension service (if yes = 1)	0.43	0.46	0.40	0.06
Agriculture and livestock production-related training received (if yes = 1)	0.46	0.67	0.24	0.43***
Access to credit (if yes = 1)	0.77	0.81	0.74	0.08
Social network (membership in any group, cooperative and/or organization [if yes = 1)]	0.63	0.72	0.55	0.16***

(continued)

[11] Brahmin, Chettri and Takuri are the higher castes in Nepal.

[12] LSU is livestock standard unit (based on cattle equivalent: 1 cow/cattle = 10 goats/lambs = 4 pigs and = 143 chicken/ducks).

Table 11.1 (continued)

Particular	Full sample ($N = 282$)	RWH adopters ($n = 141$)	Non-adopters ($n = 141$)	Mean difference (t-test)
Knowledge of Climate Change (if yes = 1)	0.49	0.54	0.43	0.11*
Poor (if yes = 1)	0.39	0.34	0.45	0.11*

Note Figures in parentheses are standard deviation. ***Significant at 1% level, *Significant at 10% level
Source Field survey

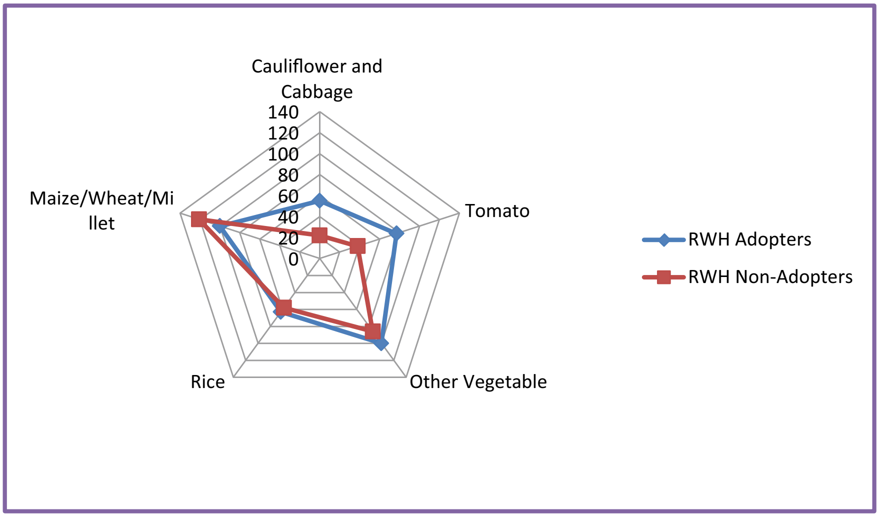

Fig. 11.2 Number of vegetable and cereal crop producers among RWH adopters and non-adopters. *Source* Field survey data

Table 11.2 presents the major crops produced and the revenue from the marketed crops in both the lowland and the upland during different cropping seasons. The production of cereal crops (mainly, rice, maize, and wheat) in upland and lowland areas is not statistically significant. With regard to farm revenue from different crops, revenue from tomato and other vegetables is significantly higher among the RWH adopters.

We found income from vegetables and fruits and from agriculture and livestock sectors as well as total annual household income to be significantly higher among RWH adopters than non-adopters. However, income from off-farm activities was significantly higher for non-adopters. The annual income from the agriculture and livestock sectors for RWH adopters (NRs. 104,969 (US$1049))[13] was almost double

[13] US$1 = NRs. 100.

Table 11.2 Crops production and revenue of RWH adopters and non-adopters

Particular	Full sample ($N = 282$)	RWH adopters ($n = 141$)	Non-adopters ($n = 141$)	Mean difference (t-test)
Crop production (quintal = 40 kg)				
Cauliflower/cabbage	20.08 (5.08)	22.05 (6.41)	14.69 (7.43)	7.35
Tomato	50.39 (26.82)	69.82 (39.95)	11.04 (2.21)	58.77
Other vegetable	8.33 (0.89)	9.76 (1.32)	6.66 (1.17)	3.09*
Rice	19.93 (6.75)	9.78 (1.94)	22.61 (13.95)	– 12.82
Wheat/maize	17.36 (9.04)	28.11 (19.93)	8.47 (1.22)	19.63
Crops-based HH revenue (in NRs.) from				
Cauliflower/cabbage	36,284 (7682)	42,559 (9932)	19,252 (8562)	23,306
Tomato	49,179 (5629)	59,175 (7557)	28,945 (6423)	30,220***
Other vegetable	19,711 (1877)	22,647 (2833)	16,297 (2337)	6350*
Rice	23,712 (2669)	26,379 (4546)	20,723 (2457)	5656
Maize/wheat	18,373 (2109)	19,151 (2533)	17,729 (3242)	1421

Note Figures in parentheses are standard deviation. ***Significant at 1% level, *Significant at 10% level
Source Field survey

as compared to the non-adopters (NRs. 53,876 (US$538)). The RWH technology adopters thus appeared to benefit from an increased supply of irrigation water during the dry season which allowed them to diversify their cropping system from cereal crops to high-value vegetable crops (see Table 11.3).

11.5.3 Results and Discussion

Results from econometric analysis indicate that RWH technology adoption significantly increases household income from agriculture and livestock. RWH technology adopters have earned around 270% more annual household income from agriculture and livestock sectors due to availability of irrigation water than the non-adopters farmers in the study area.

Table 11.3 Annual household income from different sectors among RWH adopters and non-adopters (NRs)

Particular	Full sample (N = 282)	RWH adopters (n = 141)	Non-adopters (n = 141)	Mean difference (t-test)
Cereal crops	23,671 (2050)	23,796 (2697)	23,546 (3111)	250
Vegetable and fruit	44,148 (4663)	67,446 (8414)	20,850 (2960)	46,595***
Livestock	11,603 (1322)	13,726 (2247)	9480 (1379)	4246*
Employment/services	40,604 (6532)	38,082 (9313)	43,127 (9191)	– 5045
Off-farm	34,881 (4311)	26,134 (5201)	43,627 (6815)	– 17,492**
Foreign employment	40,730 (6899)	47,368 (12,313)	34,092 (6232)	13,276
Agriculture and livestock (cereal + vegetable + livestock)	79,423 (5739)	104,969 (9988)	53,876 (4812)	51,092***
Total annual household income	195,640 (11,201)	216,555 (17,713)	174,724 (13,551)	41,831*

Note Figures in parentheses are standard deviation. ***Significant at 1% level, **Significant at 5% level, *Significant at 10% level
Source Field survey

Our results suggest that the most important factor affecting farmers' adoption decision is extension service such as trainings related to farming and livestock rearing. The age of the household head, annual household income from off-farm activities and poverty status have significant but negative impacts on RWH technology adoption, whereas the training received by the farmer and the gender of the household head (i.e. being a male) have significantly positive impacts on the RWH adoption decision. However, other variables like the economically active members in the household, the share of upland cultivated land, and education of the household head had no impact on the adoption decision.

If a farmer receives agriculture and livestock production-related training, the probability of RWH technology adoption decision increases by 28.5%. The training provides knowledge and skill to farmers to adopt innovative technology at the farm. Figure 11.3 illustrates household farm income by training received and RWH technology adoption. The probability of adopting RWH technology is 18.7% lower if the farmer is poor compared to a relatively better off farmer.

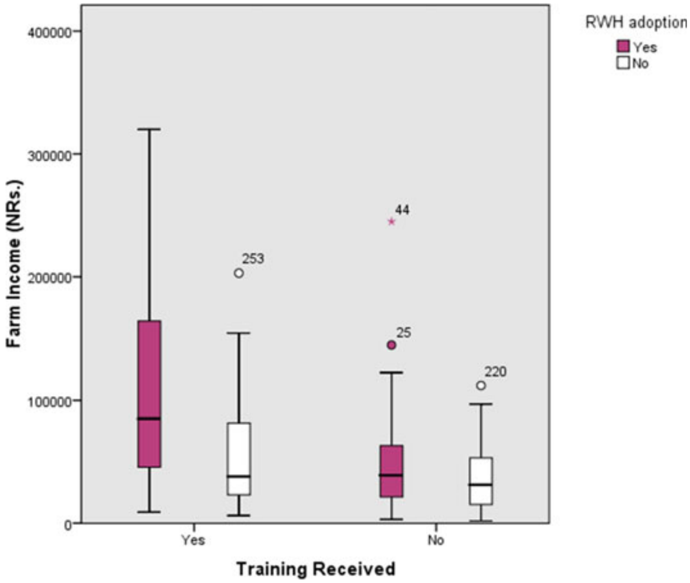

Fig. 11.3 Box plot of farm income by training received and RWH technology adoption. *Source* Authors

11.5.4 Cost–Benefit Analysis of RWH Pond Adoption

For cost–benefit analysis, we have chosen plastic ponds as they are cheaper and more popular than cement ponds. We calculate the annual benefit and cash flow for a ten-year period as a plastic pond functions well up to ten years. We estimate the benefit–cost (*B*/*C*) ratio, net present value (NPV), internal rate of return (IRR) and payback period (PBP) using the standard discount rate of 12% that is used in financial analysis in Nepal.[14] We perform sensitivity analysis to check the robustness of the results with alternative discount rates.

Cost calculations are based on the total investment cost including labour, plastic, other equipment and the opportunity cost of the land on which the pond is constructed. The initial average investment cost to construct a RWH plastic pond on 3 *ropani* of upland area (with a water-holding capacity of approximately 45,000 L) is NRs. 55,372 (US$543). In addition, there is a maintenance cost of NRs. 913 per year per household based on survey information.

We estimate the incremental income from RWH pond construction and crop diversification from the second year onwards using the benefits estimates. An average farmer using RWH technology obtains an annual incremental benefit of NRs. 69,456

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[14] ADB (2013) proposes a higher discount rate (about 12%) for cost–benefit analysis in developing countries considering higher production and market risks and uncertainty to introduce new technologies at farm.

(US$700). This number reflects the benefits a farmer receives from using this technology relative to farmers who do not.

Our calculations suggest that the NPV of investing in a RWH pond with a capacity of 45,000 L is NRs. 276,649 (US$2766) to a farmer, assuming a 12% discount rate. The benefit to cost ratio is 6.1 and internal rate of return is 34%. The payback period is approximately two years, which indicates that the time required for the repayment of the initial investment is rather short. Sensitivity analysis indicates that the investment is viable even if the investment costs increase by 20% or benefits decrease by 20%.

Although RWH technology is very profitable, findings from stakeholder meetings and field survey show that a majority of the farmers are not adopting this technology. This is because of lack of technical knowledge, large start-up cost (NRs. 55,000, which is 28% of total annual household income), limited subsidies (only 45% of the households received it in the sample) and lack of labour in the communities to construct ponds due to massive out-migration of adult population for better job opportunity (Karki Nepal, 2016). Additionally, in these communities, farming is not commercialized and most of the farmers seem to be risk averse and do not want to shift from cereal-based farming systems to high-value crops due to production and market risks.

Our analysis indicates that the training received by farmers on farm management, agriculture and livestock production helps to increase RWH adoption. The cost of a three-day community-wide training package is about NRs. 3000 (US$30) per farmer (including 30% organizational overhead costs). With training, the probability of RWH technology adoption increases by approximately 30%. Thus, in any district in our study area, if approximately 10% of households from the communities (i.e. some 7000 households), are trained, then we can expect 2030 trainees to adopt RWH (see Kattel, 2015 for more detail on Table 7). The net annual benefits from training on adoption of RWH technology are NRs. 66,457 per farmer. Thus, per district annual benefits from providing training to 10% of farm households from the communities is expected to be approximately NRs. 131 million (1.3 million US$). These benefits, however, would require substantial initial investment in building the RWH ponds and providing extension services to the farmers.

11.6 Conclusion

Mountain springs are drying up and disappearing rapidly, putting mountain agriculture at stake. Adapting rainwater harvesting technology helps mountain communities to address irrigation water scarcity to some extent allowing them to diversify their cropping system from subsistence cereal crops to high-value commercial vegetables that helps increase their resilience in the face of climate change.

Although RWH technology is highly profitable in rainfed mountain agriculture systems, a majority of farmers seem reluctant to adopt this technology. Our study suggests that at least some of the constraints for adoption of RWH technology can be reduced by providing appropriate training to the farmers. Thus, policy makers and extension service providers need to play a more proactive role in promoting RWH technology in the rainfed hilly region of Nepal by providing credits or subsidies and appropriate training to the potential adopters that helps building community resilience in the face of climate extremes such as droughts.

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