Assessment of role of water harvesting technology in vegetable-based income diversification in Palpa district, Nepal

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Abstract: With increasing incidence of drought and scant rainfall it has now become mandatory for farmers to opt to techniques like water harvesting to fulfil the demand of water for farming. The study was focused on the role of water harvesting on vegetable based income diversification of farmers in Tansen Municipality of Palpa. Altogether 120 water harvesting technology adopters were chosen using purposive and simple random technique to collect household level data from personal scheduled interview. In addition, focus group discussions (FGD) with farmer groups and key informant interviews (KII) with enablers were also conducted. Comparison between commercial and non-commercial farmers was carried out on different parameters using chi square test, t test and descriptive statistics. Findings revealed with the adoption of almost all farmers had changed their cereal based cropping pattern to vegetable based cropping pattern after they adopted water harvesting technology due to which vegetable share in total income was higher (47.6%) than cereal (2.03%). Average income from vegetable per household was NRs. 185,654 which was significantly higher in commercial farmers. Accessibility to road was also a major determinant of type of water harvesting structure adopted by farmers, its type and capacity. Income from vegetable, cereals and total income were significantly higher among farmers having direct access to road than farmers who did not. The benefit cost ratio, net present value and internal

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PUBLIC INTEREST STATEMENT

Water harvesting is the process in which precipitation that falls on a site is diverted, captured and stored for use on site as opposed to allowing it to runoff, evaporate or infiltrate in soil. It is done by collecting rainwater and diverting it to the reservoir that would help in coping up with erratic rainfall pattern and drought. Water can be harvested in the storage unit from other different sources such as streams, hand pumps and tank. This technique is generally regarded as fairly simple technique and has been in practice in much of the world from ancient times with very powerful results in area of water scarcity.
rate of return of plastic pond was 7.78, NRs. 422,185 and 135%, respectively implying that adoption of water harvesting was highly beneficial at farm level.

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1. Introduction
Nepal is considered one of the top ten countries to be impacted by the changing climate (WFP, 2009). In Nepal less than 52% of the total cultivable land is irrigated with the remaining land depending solely on rainfall (MoAD, 2016). And climate change has altered the rainfall pattern thus changing the whole cropping calendar of the farmers. Rainfall is decreasing at the rate of 3.7 millimetre per month per decade in Nepal (Wang & Yoon, 2013). In addition, winter precipitation has almost declined to zero and ground water is hardly replenished (Wang & Yoon, 2013). According to IPCC (2007), water and its availability and quality will be the main pressures on, and issues for, societies and the environment under climate change. To cope up with this changing scenario farmers have to come up with non-conventional irrigation systems such as drip irrigation, sprinkler irrigation and other adaptive measures such as water harvesting.

The crop yield is strongly associated with the amount of water it receives. The increase in temperature and availability of irrigation water are negatively related. Research finding shows that, if the temperature is increased by 1°C the effectiveness of the irrigation is decreased by 10% (Pradhan, 2007). The pattern of precipitation has been noticed fluctuated for the past 30 years in Nepal. According to the precipitation trend analysis, the annual average precipitation over Nepal is decreasing at the rate of 9.8 mm/decade. Due to over and under precipitation, crop production is highly uncertain. The actual monsoon month and the main rice-planting month, July, is becoming drier. Furthermore, climate change would dramatically decrease water yield from other sources of irrigation such as river since glaciers would have mostly melted-out by 2035 (Poudel & Gautam, 2011). Nepal was self-sufficient in food grain production until 1990. Due to drought condition in 2005/06, production fell short by 21,553 metric tonnes and by 179,910 metric tonnes in 2006/07 due to drought and natural calamities.

In mid-hills changes in precipitation pattern will result in early maturation of crops, crop failures and reduce agricultural productivity. In addition, it will likely decrease run-off water to feed natural streams (used for irrigation) and re-charge natural ponds, reservoirs and lakes. In the Terai region similar issues will be noted, particularly reduced recharge rate of groundwater that has resulted in a reduction of discharge of water in shallow and even deep tube-wells, failure of canals, drying of rivers, rivulets, streams, lake, ponds, reservoirs and wells for irrigation of crops (MoAD, 2014). Furthermore, the spatial and temporal distributions of freshwater are highly sensitive to changing scenario of climate (GoN, 2011).

Such changes are not limited to Nepal. Around the world climate change has brought water shortage as one of the major crisis (IUFRO, 2011). The comprehensive assessment of water management in agriculture revealed that one in three people are already facing water shortages (IPCC, 2007). By 2025, an estimated 1.8 billion people will live in area plagued by water scarcity, with two third of the world's population living in water stressed regions (UNwater, 2014). The complex interdependency between water and agriculture production have been referred to in recent studies as evolving global food crisis (Hightower & Pierce, 2008). So, proper availability of water is instrumental in raising productivity of the field and solving the pressing problem of food crisis.
1.1. Water harvesting and crop diversification

Crop diversification is an essential tool for maintaining food security of a country (Shibil et al., 2016). Initiatives to make water available for irrigation can help in enabling farmers to farm year-round and diversify crops which can increase food security and profitability by enabling them to grow great range and variety of commodities and benefit from seasonal price variation in market. With the advent of modern agricultural technology, especially during the period of the Green Revolution in the late 1960s and early 1970s, there is a continuous surge for diversified agriculture in terms of crops, primarily on economic considerations (Hazara, 2003). Crop diversification takes places not only for production reasons but also, often more importantly, for use and consumption demands. It is an important strategy for overall agriculture development in the country. It is a very useful technique to augment income and reduce poverty in rural areas. It provides the farmers with viable choices of commodities to grow on their land. Nepal has different agro-ecological zones with a variety of climates ranging from tropical in the Terai to alpine in the high mountains. Besides the climatic factors, the farmers need options on high value exportable commodities. Crop diversification can meet this type of need of the farmers (Sharma, 1999).

Irrigation scheme such as rain water harvesting can play a key role by allowing farmers to diversify their product from cereals to high value crops as vegetables. The rate of adoption of rainwater harvesting technology, however, is highly dependent on the income level of farmers with adoption rate higher in the farmers with higher income (Pasakhala et al., 2013). Adhikari et al. (2018) found that other determinants such as years of schooling, total physical assets and organizational membership of household members were also crucial in determining the adoption of the technology (Thapa et al., 2017) estimated a positive correlation between household access to irrigation and the adoption of high-value crops in Nepal. Resource-related factors covering irrigation, rainfall and soil fertility, technology-related factors covering not only seed, fertilizer and water technologies but also those related to marketing, storage and processing, household-related factors covering food and fodder self-sufficiency requirement as well as investment capacity, price related factors covering output and input prices as well as trade policies and other economic policies that affect these prices either directly or indirectly institutional and infrastructure related factors covering farm size and tenancy arrangements, research, extension and marketing systems and government regulatory policies are the major factors determining the extent of crop diversification (Hazara, 2003).

Tiwari et al. (2008) compared outcomes among cereal producing and vegetable producing farmers and found that net income of vegetable producing farmers was 50% higher than the farmers producing cereals. In vegetable producing communities employment opportunity also increases as more labours were required for year round cultivation of the vegetable (Shively & Sununtnasunk, 2015). In addition vegetable based crop diversification also aids in maintaining food and nutrition security (Gunansena, 2001). It helps in minimizing price and yield risk created by climate vulnerability and price volatility of agriculture product. Generally, 60–90% of annual rainfall occurs between June and September in Nepal (Nayava, 2010). In higher elevation the intensity of rainfall is generally lower than the intensity of rainfall in lower elevation (Nayava, 2010). This is exacerbated by the drying of natural reserves that are the major source of irrigation for the farmers in higher altitude. Furthermore, the analysis of the precipitation records of the past revealed a decreasing trend in the number of rainy days. Conversely, the days with more intense precipitation were increasing, that is more precipitation occurred in fewer days (GoN, 2011). In such scenario, rainwater harvesting during peak period of rainfall can enable farmers to grow vegetables during lean period. This can enable to gain premium by growing vegetable during dry season (Wachira, 2013).

1.2. Statement of the problem

Vegetable farming can help farmers to generate cash even from a small area of land in a short period of time and helps farmers to improve their livelihood (Gurung, 2016). However, most of the farmers have higher propensity to grow cereals rather than the high value vegetables. Problems
such as high price inputs, severe disease and insect attack, lack of technical knowledge and losses of vegetable from natural calamity were linked to the farmer’s hesitance to move towards vegetable production (Azad et al., 2014). Highly perishable nature of vegetable is another important factor that has made vegetable farming less attractive (Alamerie et al., 2014). Lack of strong financial institution to help farmers make initial investment also reduces farmer’s capacity to diversify their field crops. (Debisree & Uttam, 2014). Lack of sufficient studies on commercial vegetable production has narrowed the development of vegetable sector although, different initiative have been conducted in national level (Rai & Nepal, 2019). Deficit of important resources such as water is also a major limiting factor for growing vegetables that have higher water requirement than cereals (Rai & Nepal, 2019). In Palpa, major source of water for irrigation are rain water and water from natural reserves. However, in recent years precipitation pattern has become erratic and water reserve has become prone to drying. This has become major hurdle for the farmers to grow vegetables in Palpa.

1.3. Rationale of the study
Rainwater harvesting is very effective method for irrigation in places like Palpa where farming is done in upland and water availability remains a major constrain. By providing easier access to water, rain water harvesting can open the prospect of commercial and diversified farming even in the difficult terrains of the district. Information on the problems of adoption of rain water harvesting can help in making necessary intervention to make the scheme effective so that farmers can cultivate higher value crops profitably. Quantitative data on the role of water harvesting on crop diversification can help in formulating policies to initiate such technology in the district where proper water supply would help farmers to diversify their field output. Statistical evidence on whether rainwater harvesting would profitably aid in diversifying the crops would help in encouraging farmers to adopt the technology.

1.4. Objectives
The major objective of this research was to assess the role of water harvesting in vegetable based income diversification in Palpa

Specific objectives were as followed:

- To assess different techniques of water harvesting in Palpa
- To investigate the role of water harvesting in crop diversification and commercialization of vegetables
- To analyse the benefit cost analysis of water harvesting technology
- To identify major problems in different water harvesting techniques adopted in the district

2. Methodology

2.1. Study area
This study was conducted in Palpa district of Province number five. Palpa district was selected purposively as it suffers from acute water shortage and many farmers have embraced water harvesting technology. As most of the progressive farmers of the district are located in Tansen municipality and farmers in most of the wards of municipality carry out water harvesting this local body was also purposively selected for study. Farmers in lower areas of municipality had sufficient water as they could tap into ground water for irrigation. So, mostly the farmers from upper hills adopted water harvesting technology. In line with this fact, ward number 1, 5, 6, 7, 8, 9, 10 and 12 were selected purposively.

2.2. Description of study area
Palpa district is one of hilly district with an average annual temperature ranges from 8°C to 28°C. The district is situated at 250 meters to 2500 meters from the mean sea level. The district consists of two
Municipalities—Rampur Municipality and Tansen Municipality. Tansen Municipality is the administrative centre of Palpa district in the hills of western Nepal. It is located on the highway between Butwal and Pokhara, on the crest of the Mahabharat range or Lesser Himalaya overlooking the valley of the Kali Gandaki river to the north. The municipality enjoys a moderate climate with temperatures rarely exceeding 30 Celsius (86 F) or going below freezing. The municipality consists of 13 wards.

2.3. Sample size and sampling procedure

2.3.1. Selection of farmers adopting water harvesting and categorization of farmers
The study population was mainly water harvesting adopters of Tansen municipality. The samples were taken from ward number 1, 5, 6, 7, 8, 9, 10, 12 and 13 of municipality. As the areas were more or less homogeneous in nature, samples were selected randomly from these areas. Before conducting field survey, sampling frame was prepared by collecting the name list from PMAMP-vegetable zone, Palpa and visiting the study site. A sample size of 120 adopters was selected from these areas using simple random sampling and visiting the study site. The sampling units were water harvesting adopters of Tansen municipality. After preparing the sampling frame the farmers were selected randomly. The farmers were majorly categorized into commercial and non-commercial groups on the basis of area of vegetable cultivation. Farmers were also categorized into two groups on the basis of accessibility of road.

2.4. Nature and source of data
The study involves both primary and secondary data for collection of necessary information.

2.5. Primary data
The primary data pertaining to the income and water harvesting characteristics were collected with the help of a specially designed pre-tested schedule by direct personal interview. The data collected from the respondents included some general information about the farmers, type of water harvesting adopted, source of water, purpose of water harvesting, problems in different water harvesting structures, etc. The relevant information on other aspects such as land use, crops grown and maintenance cost and returns of the water harvesting were also collected.

2.6. Secondary data
Secondary data were collected from district profile, journals, research articles, thesis, Ministry of Agriculture and Livestock Development (MoAD), Central Bureau of Statistic (CBS) and Prime Minister Agriculture Modernization Project (PMAMP).

2.7. Data analysis techniques
All the collected data was carefully scrutinized and refined before analysis. After collection of necessary information it was coded and entered in to the computer for analysis. Data entry and analysis were done by using Statistical Package for Social Sciences (SPSS) and Microsoft Excel software package. The data was analysed by using tools like descriptive statistics, mean comparison, frequency distribution, chi square, independent sample t-tests, etc. The findings was represented and demonstrated by using tables, figures, bar-diagrams, pie-charts, etc.

2.8. Socio demographic and economic variables
Variables like age of household head, education status, family size, dependency percentage and educational status, ethnicity and size of holding were compared between small and large farmer using independent sample t-test and chi-square.

2.9. Cost of construction and maintenance
For analysing the cost of water harvesting, the construction cost and maintenance cost items were considered. The construction cost included cost of material, labour and other cost such as transportation cost. The maintenance cost was calculated adding material, labour and other cost for maintenance.
2.10. Benefit analysis
The benefit analysis of water harvesting was done by creating the assumption scenario. It was assumed that farmers in absence of water harvesting would have farmed cereal crops such as wheat and maize instead of vegetable crops as they require higher amount of water compared to cereals. The net benefit of acquired from different cereal crops from the area where farmers have cultivated vegetable at present was calculated using the average benefit acquired by the actual cereal growers in the region. After that the benefit from cereal was deducted from vegetable to get actual benefit due to water harvesting.

Benefit due to water harvesting = Net benefit from vegetable – Net benefit from cereals

2.11. Financial feasibility analysis
The following techniques were used for analysing the financial feasibility of rubber plantation:

- Net Present Value/Worth (NPV)
- Benefit-Cost Ratio (B: C Ratio)
- Internal Rate of Return (IRR) and
- Pay Back Period (PBP)

2.12. Net present value
It is simply the present worth of net benefit of the project discounted at the opportunity cost of capital. The criterion assesses the present worth of accrued benefits over costs. The criterion also ranks the investments for selecting the alternatives. Generally, higher the Net Present Value better would be the projects performance. In order for the project/investment to be viable, the NPV should be positive. In calculating the Net Present Worth, the difference between the present value of the cost stream and present value of benefit stream were considered at a discount rate of 12 per cent.

2.13. Benefit cost ratio
It was taken as the ratio of present worth of incremental benefit stream (cash inflow) to present worth of incremental cost stream (cash outflow) due to water harvesting.

The Benefit Cost Ratio (BCR) was worked out by using following formula

\[ BC \text{ Ratio} = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+i)^t}} \]

Adoption of water harvesting by farmers will be financially feasible if the present worth of incremental benefits is greater than the present worth of the incremental cost due to water harvesting or in other words B-C ratio exceeds one.

2.14. Internal Rate of Return (IRR)
It is the rate of return which equates the discounted benefits with the discounted costs. In other words, it is the discount rate which equates the present worth of benefits to present worth of costs. The rate at which the net present value of project is equal to zero is Internal Rate of Return (IRR) to the project. It represents the average earning capacity of an investment from the project. The net cash inflows were discounted to determine the present worth following the interpolation technique.

2.15. Pay Back Period (PBP)
Payback period represents the length of time required for the stream of cash proceeds produced by the investment to be equal to the original cash outlay, That is, the time required for the project to pay for itself. In the present study, payback period was calculated by successively deducting the initial investment from the net returns until the initial investment was fully recovered.
2.16. Indexing

Farmer’s perception on the importance given to the different water harvesting problems was analysed by using five point scale of problems comprising very high importance, high importance, normal importance, less importance and the least importance by using 1, 2, 3, 4, 5 respectively. The index of importance was computed by using the following formula:

$$I_{imp} = \sum (s_i f_i / N)$$

Where,

- $I_{imp}$ = Index value of importance
- $\Sigma$ = Summation
- $s_i$ = Scale value of ith intensity
- $f_i$ = Frequency of importance
- $N$ = Total numbers of respondents

3. Results and discussion

3.1. Socio demographic characteristics

In the study area, the average age of the household head was 48.19 years. Similarly, the average number of family members of households surveyed was 5.48. With an average family size of 5.98, commercial farmers had significantly higher number of family members than non-commercial farmers (4.98). The number of economically active members in commercial and non-commercial farmers was significantly different with commercial farmers having 3.86 numbers of family members within economically active age and non-commercial farmers having 3.07 numbers of family members within that limit. Due to the lower number of economically active population in non-commercial farmers the dependency percentage was, on average, found to be higher in their family. Regarding the education level of farmers, number of years of schooling in commercial-farmer was 7.43 years and that of non-commercial was 4.98 years, the difference being significant at 1% level of significance. This implies that education also played a pivotal role in motivating farmers towards commercialization. Only 19 out of 120 households had female as their household heads and 101 households had male as their household heads. This was in line with the patriarchal scenario of the country where major decision making power is granted to males as household heads.

The social backgrounds of the households were different with almost half of the households belonging to Brahmin or Chhetri and the other half belonging to Dalit or Janjati. Comparatively, the number of Brahmin and Chhetri was higher among the commercial farmers and that of Janjati and Dalit were higher among the non-commercial farmers. Among commercial farmers 56.6% of total were Brahmins or Chhetri, 22.6% were Janjati and 20.8% were Dalit while in non-commercial 31.3%, 52.2% and 20.8% were Brahmin or Chhetri, Jamjati and Dalit respectively. The commercial and non-commercial farmers were from significantly different social background (refer Table 1).

3.2. Land and livestock holding

The average cultivated upland in commercial farmers (11.47) was significantly (<1%) higher than non-commercial (6.52) farmers as shown in Table 2. The average area of cultivated lowland in commercial farmers was 6.08 ropani while in non-commercial farmers it was 2.09 ropani, the difference was significant at less than 1% level of significance. The amount of leased area was found significantly higher in commercial farmers (3.27) than in non-commercial farmers (0.43) at less than 1% level of significance. Irrigated upland as a percentage of total cultivated upland was
Table 1. Socio-demographic characteristics of respondents by commercialization

| Variables                                      | Overall (n = 120) | Commercial (n = 53) | Non commercial (n = 67) | Mean difference | T-value or Chi-square value | P value |
|------------------------------------------------|-------------------|---------------------|-------------------------|-----------------|-----------------------------|---------|
| Age (in year)                                  | 48.19             | 48.90               | 47.62                   | 1.27            | 0.590                       | 0.556   |
| Number of family members                       | 5.48              | 5.98                | 4.98                    | 1.00            | 2.79***                     | 0.006   |
| Education (in year)                            | 6.06              | 7.43                | 4.98                    | 2.45            | 2.61***                     | 0.010   |
| Economic active HH members (age group 15–59)   | 3.42              | 3.86                | 3.07                    | 0.79            | 3.769***                    | 0.000   |
| Dependency percentage of HH members            | 61.38             | 56.87               | 64.95                   | −8.07           | −1.38                       | 0.168   |
| Gender#                                        |                   |                     |                         |                 |                             |         |
| Male                                           | 101 (84.10)       | 50 (83.30)          | 51 (85)                 |                 |                             |         |
| Female                                         | 19 (15.83)        | 10 (16.70)          | 9 (15)                  |                 |                             |         |
| Ethnicity composition#                         |                   |                     |                         |                 |                             |         |
| Brahmin/Chhetri                                | 51 (42.50)        | 30 (56.6)           | 21 (31.3)               |                 | 12.79***                    | 0.005   |
| Janjati                                        | 47 (39.20)        | 12 (22.6)           | 35 (52.2)               |                 |                             |         |
| Dalit                                          | 22 (18.30)        | 11 (20.8)           | 11 (16.4)               |                 |                             |         |

Figures in parentheses indicate percentage. *** indicate significant at 1% level, and # represents categorical data.
found to be 64 in commercial farmers and 57 in non-commercial farmers, the difference being statistically significant at 5% level of significance. The value of livestock standard unit was 4.35 in non-commercial farmers and 3.42 in commercial farmers.

3.3. Involvement in training and organization

With 56.7% of them involved in saving and credit group the non-commercial farmers had significantly higher involvement in the group than commercial farmers who had only 33.9% involvement in it as shown in Table 3.

Among the household surveyed, 61.6% of the farmers had at least one of the members involved in cooperative. Both saving and credit group and cooperative were major source of credit for the farmers and also conducted various trainings occasionally.

Community forest user groups were also formed in many parts of the study area for the conservation and sustainable use of forest resources. On average 63.3% of the farmers were involved in community forest users group. Majority of the subsidies in the study area was distributed by government bodies through the farmers group. Due to which almost 91.6% of the total households had at least one of their members involved in the group.

Majority of the farmers (almost 66.6%) were involved in training related to vegetable cultivation. The trainings were organized by different governmental bodies such as AKC, Zone etc. and various non-governmental bodies. Among the commercial farmers 77.3% of the farmers had taken part in vegetable production related trainings such as IPM, nursery management, machinery, plastic house, etc., in case of non-commercial 58.2% participated in such trainings. The number of farmers

**Table 2. Land and livestock holding**

| Parameters                | Overall (n = 120) | Commercial (n = 53) | Non commercial (n = 67) | Mean difference | T value | P value |
|---------------------------|-------------------|---------------------|-------------------------|-----------------|---------|---------|
| Cultivated upland         | 9.14              | 11.77               | 6.52                    | 5.24            | 6.610***| 0.000   |
| Cultivated lowland        | 4.08              | 6.08                | 2.09                    | 3.98            | 4.657***| 0.000   |
| Irrigated upland          | 5.56              | 7.33                | 3.80                    | 3.52            | 6.866***| 0.000   |
| Leased land               | 1.85              | 3.27                | 0.43                    | 2.84            | 3.241***| 0.000   |
| Percentage of irrigated upland (cultivated) | 60.5 | 64 | 57 | 7 | 2.230** | 0.028 |

LSU\(^1\) = 3.88 3.42 4.35 -0.93 -1.646 0.102

Figures in parentheses indicate percentage. ***, and ** resemble significant at 1% and 5% levels, respectively. Value of area is mentioned in ropani\(^2\)

**Table 3. Involvement in training and organization**

| Involvement in organization | Overall (n = 120) | Commercial (n = 53) | Non Commercial (n = 67) | Chi square value | P Value |
|-----------------------------|-------------------|---------------------|-------------------------|-----------------|---------|
| Saving and credit group (Yes) | 56(46.6) | 18(33.9) | 38(56.7) | 6.15** | 0.013 |
| Cooperative (Yes) | 74(61.6) | 37(69.8) | 37(55.2) | 2.66 | 0.103 |
| CFUG\(^3\) (Yes) | 76(63.3) | 30(56.6) | 46(68.6) | 0.851 | 0.174 |
| Farmers Group (Yes) | 110(91.6) | 49(92.4) | 61(91) | 0.077 | 0.782 |
| Training (Yes) | 80(66.6) | 41(77.3) | 39(58.2) | 4.883** | 0.027 |

Figures in parentheses indicate percentage. ** resembles significant at 5% level
participating in training was significantly higher in commercial farmers than non-commercial at 5% level of significance (Dube & Gueveya, 2016) also suggested that training of small holder farmers was major determinant to encourage them towards commercialization.

3.4. Water harvesting characteristics
Farmers in Tansen municipality majorly adopted three ways of water harvesting techniques—plastic ponds, cement ponds and ferrocement tanks (jar). The average capacity of plastic ponds used for harvesting water was 67,474 litres and that of cement ponds was 52,235 litres. Ferrocement tanks (jar) used for harvesting water had relatively lower capacity of only 2302 litres. The average capacity of all water harvesting structure adopted by commercial farmers per household was 89,701 litres and that of non-commercial farmers was 60,553 litres, the difference being significant at 1% level of significance (Table 4). In total there were 112 plastic ponds, 22 cement ponds and 46 Ferro-cement tanks in the households surveyed. The number of water harvesting structure was significantly different between commercial and non-commercial farmers. Non-commercial farmers had higher number of jars per household than commercial farmers while the number of cement pond per household was significantly higher in commercial farmers than in non-commercial farmers. As the initial cost of building cement pond was higher than other water harvesting structure only the commercial farmers had higher propensity to build such pond. The number plastic pond per household was almost similar among the commercial and non-commercial farmers.

Among the plastic pond adopters, most of the commercial farmers had perennial source of water such as permanent streams, hand pumps and drinking water while the non-commercial farmers had temporary source of water such as rain water. Due to this the time of water retention in the water harvesting structure was higher in the commercial farmers than the non-commercial ones. For instance, while comparing the time of water retention in plastic ponds of commercial and non-commercial farmers, the time of retention was found to be about 10.65 months in commercial

### Table 4. Water harvesting characteristics

| Variable                                      | Overall (n = 120) | Commercial (n = 53) | Non Commercial (n = 67) | Mean Difference | T or chi square value | P Value |
|-----------------------------------------------|-------------------|---------------------|-------------------------|-----------------|-----------------------|---------|
| Total capacity of Water harvesting (in litre) | 73,427            | 89,701              | 60,553                  | 29,148.15       | 3.557***              | 0.001   |
| Number of jars                                | 0.38              | 0.16                | 0.55                    | −0.382          | 3.571***              | 0.001   |
| Number of cement ponds                        | 0.18              | 0.32                | 0.07                    | 0.246           | 2.488**               | 0.014   |
| Number of plastic ponds                       | 0.93              | 1.01                | 0.86                    | 0.153           | 1.454                 | 0.149   |
| Water retained in plastic pond (Months)       | 9.77              | 10.65               | 8.9                     | 2.92            | 3.082***              | 0.003   |
| Source of water for plastic ponds             |                   |                     |                         |                 |                       |         |
| Only from rain water                          | 23(23.70)         | 5(10.90)            | 18(35.30)               |                 | 10.461**              | 0.033   |
| Only from stream                              | 45(46.30)         | 24(52.20)           | 21(41.20)               |                 |                       |         |
| Both rainwater and stream                     | 7(7.20)           | 3(7.80)             | 4(6.50)                 |                 |                       |         |
| Drinking water supply                         | 12(12.37)         | 9(19.60)            | 3(5.90)                 |                 |                       |         |
| Hand pump                                     | 10(10.30)         | 5(10.91)            | 5(9.81)                 |                 |                       |         |

Figures in parentheses indicate percentage. *** and ** resemble significant at 1% and 5% levels, respectively.
farmers and 8.9 months in non-commercial farmers. The difference was significant at 1% level of significance.

3.5. Purpose and place of water harvesting

The purpose of water harvesting depended upon the technique of water harvesting adopted. Plastic ponds and cement ponds were majorly used for the vegetable production whereas water harvested in ferro cement tank was majorly used for drinking purpose for livestock. Few plastic ponds and cement ponds were also used for irrigation of rice (Figure 1).

Majority (88.7%) of the plastic pond adopters had the water harvesting structure near the homestead whereas the remaining households had it in the same ward but far from the homestead. All of the households having jar as the water harvesting structure had it near their homestead. In case of cement ponds 88.2% of the ponds were located near homestead and remaining were situated far from the household in the same ward.

Though all of the cement ponds and plastic ponds were in active stage, only 62.2% of jars were in active stage.

3.6. Source of knowledge of water harvesting

The major source of knowledge of climate change for the farmers was from other farmers and their own family members (Figure 2). However, as some of the harvesting structure were built by development organization themselves 18% of the total respondents also heard about water harvesting from them. Extension and training had also aided in providing farmers with the information about water harvesting.

3.7. Annual household income from different sub-sector and expenditure

The annual household income from vegetable was significantly higher in commercial farmers (NRs. 247,547) than in non-commercial farmers (NRs. 123,671) at 1 % level of significance. In addition, vegetable share in total income was also significantly higher in commercial farmers (54.4%) than non-commercial (40.87) farmers at 1% level of significance (Table 5). This was majorly due to higher amount of area devoted to cultivation of vegetable in commercial farmers and easier access to irrigation through water harvesting structures of higher capacity that captured water from relatively permanent sources. Off farm income of non-commercial farmer is significantly

Figure 1. Purpose of water harvesting.
higher than commercial farmers at 10% level of significance. The reason behind this can be the lesser amount of time devoted by commercial farmers in off farm activities compared to the non-commercial farmers.

Average income from cereals was only NRs. 7675 per household. Though the income from cereals was not significantly different between commercial and non-commercial farmers, cereal share in total income was significantly higher in non-commercial (2.80) than commercial farmers (1.26) at 5% level of significance. The average income from livestock was NRs. 32,591. The average total annual income of all the respondents was NRs. 465,721.

The total income of commercial farmer was also significantly (<1%) higher in commercial farmers (NRs. 523,742) than in non-commercial farmers (NRs. 407,700). Monthly expenditure of commercial farmers was also significantly higher than non-commercial farmers at 5% level of significance. The average monthly expenditure of commercial farmers was NRs. 20,660 and that of non-commercial farmers was NRs. 16,455.

### Table 5. Annual household income from different sub-sector and expenditure by commercialization

| Variable                        | Overall (n = 120) | Commercial (n = 53) | Non-commercial (n = 67) | Mean difference | T value | P value |
|---------------------------------|-------------------|---------------------|-------------------------|-----------------|---------|---------|
| Vegetable income                | 185,654           | 247,547             | 123,761                 |                 | 12.166*** | 0.000   |
| Off farm income                 | 44,329            | 26,764              | 58,223                  | −31,459         | −1.898*  | 0.060   |
| Cereals income                  | 7675              | 6981                | 8223                    | −1242           | −0.565  | 0.573   |
| Employment                      | 195,922           | 207,185             | 187,013                 | 20,171          | 0.487   | 0.627   |
| Livestock                       | 32,591            | 35,264              | 30,477                  | 4756            | 0.410   | 0.682   |
| Monthly expenditure             | 18,312            | 20,660              | 16,455                  | 4205            | 2.274** | 0.025   |
| Total income                    | 465,721           | 523,742             | 407,700                 | 116,041         | 2.893*** | 0.005   |
| Cereals share percentage        | 2.03              | 1.26                | 2.80                    | −1.54           | −2.102** | 0.038   |
| Vegetable share percentage      | 47.65             | 54.44               | 40.87                   | 13.50           | 3.095*** | 0.002   |

***, ** and * resemble significant at 1%, 5% and 10% levels, respectively
3.8. Annual household income from different sub-sector and expenditure (Road accessibility)

Income of the farmers on the basis of access to road was also compared. Vegetable income (NRs. 209,866) of the farmers who had easier access to road was significantly higher (<1%) than the farmers who had no direct access to road (NRs. 147,000) as presented in Table 6. Marketing of vegetable product for the farmers having direct access to road was easier. Consequently they were highly inclined towards commercialization than the farmers who did not have direct access. However, income from livestock was not significantly different among farmers differentiated by access to road as demand of most of the livestock product such as of milk and meat was high within the villages and had no need to be taken to external market. In case of cereal the income of farmers having higher access to road was significantly greater than farmers having no access to road.

Off farm income was, however, higher in farmer having no access to road (NRs. 60,331) than the farmers having greater access (NRs. 28,525), the difference being significant at 10% level of significance. Total income, cereal share and vegetable share were all significantly higher in farmers having higher access to road than farmers having no direct access to road at 5%, 10% and 5% level of significance respectively.

3.9. Water harvesting characteristics by access to road

The major water harvesting characteristics were also compared between farmers having access to road and famers having none. Table 7 showed that there was prominent difference between the two groups of farmers. It was found that farmers having access to road had higher capacity of water (93,486 litres) harvesting structures than famers not having access to road (53,368 litres), the difference being significant at 1% level of significance. This was majorly due to the availability of perennial source of water for farmers having access to road and ease of construction of water harvesting structures. As famers having access to road had more permanent source of water, time of water retention in water harvesting structure was also significantly higher (<1%) in them.

Table 6. Annual household income from different sub-sector and expenditure

| Variable          | Overall (n = 120) | Farmers access to road (n = 60) | Farmers not access to road (n = 60) | Mean difference | T-Value | P Value |
|-------------------|-------------------|-------------------------------|-----------------------------------|-----------------|---------|---------|
| Vegetable income  | 185,654           | 209,866                       | 147,000                           | 82,866          | 4.482***| 0.000   |
| Livestock income  | 32,591            | 33,150                        | 32,033                            | 1116            | 0.096   | 0.923   |
| Cereal income     | 7675              | 10,100                        | 5250                              | 4850            | 2.266** | 0.025   |
| Employment income | 195,922           | 222,514                       | 169,331                           | 53,183          | 1.300   | 0.196   |
| Off farm income   | 44,329            | 28,525                        | 60,133                            | −31,608         | −1.921* | 0.057   |
| Monthly expenditure| 18,112            | 19,658                        | 16,966                            | 2691            | 1.447   | 0.150   |
| Total income      | 465,721           | 504,156                       | 413,748                           | 90,408          | 2.239** | 0.027   |
| Vegetable share (%)| 47.65             | 50.64                         | 43.08                             | 7.55            | 1.688*  | 0.094   |
| Cereal share (%)  | 2.03              | 2.94                          | 1.30                              | 1.64            | 2.253** | 0.026   |

***, ** and * resemble significant at 1%, 5% and 10% levels, respectively
3.10. Climate change knowledge of respondents

Awareness about climate change among the respondents was found relatively lower. Only 42.5% of the respondents were aware about climate change (Figure 3). Among them majority had only a little bit (51%) knowledge about it. More than half of the farmers said they were only aware about climate change due to personal experiences such as rise in temperature, increase in insect pest, erratic rainfall and drought while only some farmers had learnt about climate change from organizations and media.

![Figure 3. Status, degree and source of climate change.](https://cogentfoodandagriculture.org/10.1080/23311932.2020.1758374)

Knowingly or unknowingly farmers had adopted various adaptations techniques to adapt with changing climate such as rain water harvesting, construction of plastic house, use of mulching, use of different insect pest management tactics and use of improved seeds.

| Variable                        | Overall (n = 120) | Access to road (n = 60) | Non access to road (n = 60) | Mean Difference | T or chi square value | P Value |
|---------------------------------|-------------------|-------------------------|-----------------------------|------------------|-----------------------|---------|
| Total capacity of water harvesting (in litre) | 73,427.5          | 93,486                  | 53,368                      | 40,118           | 5.193***              | 0.000   |
| Number of jars                  | 0.38              | 0.71                    | 0.05                        | –0.382           | –3.571***             | 0.000   |
| Number of cement ponds          | 0.18              | 0.21                    | 0.15                        | 0.246            | 0.663                 | 0.509   |
| Number of plastic ponds         | 0.93              | 1.13                    | 0.73                        | 0.400            | 4.04***               | 0.000   |
| Water retained in plastic pond (Months) | 9.77              | 11.29                   | 7.69                        | 3.59             | 7.62***               | 0.000   |

Source of water for plastic ponds

| Only from rain water | 23(23.70) | 2(3.5) | 21(52.5) | 35.07*** | 0.000 |
| Only from stream     | 45(46.30) | 33(57.8) | 12(30) |         |       |
| Both rainwater and stream | 7(7.20) | 4(7) | 3(7.50) |         |       |
| Drinking water supply | 12(12.37) | 8(14) | 4(10) |         |       |
| Hand pump             | 10(10.30) | 10(17.5) | 0(0) |         |       |

*** resemble significant at 1% level
3.11. Benefit due to water harvesting

Average annual benefit due to water harvesting was calculated by deducting assumed cereals income from total vegetables income. This was justifiable as farmers switched from cereal crops to vegetable crops mainly due to easy access of irrigation through water harvesting. Almost all of the respondents said that their cropping pattern had changed with the advent of water harvesting technology in their area. The farmers, who previously cultivated cereals such as wheat and maize had now abandoned the cereal cropping system and had started cultivating high value vegetable crop even in the season when the water availability is lean. The average income from wheat per ropani among the farmers in study area was about NRs. 5400 and that from maize was NRs. 3600. Average income from cereals was calculated using this value as reference and benefit was thus calculated. On average annual benefit due to water harvesting in commercial farmers was NRs. 127,781 while it was NRs. 75,873 in non-commercial farmers (Table 8). Commercial farmers gained significantly (<1%) higher benefits than non-commercial farmers because commercial farmers adopted water harvesting structures of higher capacity and collected water from more permanent source of water. This made the shift from cereals crop to high value vegetable crop easier and in wider scale. Though benefit due to water harvesting was higher in commercial farmers, the benefit as the percentage of present total income was almost same in both. This is due to higher income of commercial farmers from other sources than non-commercial farmers.

3.12. Benefit cost ratio of plastic pond

For the benefit cost analysis the cost of plastic pond of 60,000 litres was taken into account as it was most popular among the farmers. The average cost for construction of the pond was NRs. 61,331 and the life of a pond was 10 years. The maintenance cost per year was about NRs. 1573. Interest rate of 12% was used for discounting.

There was increase in farm income from second year onward and net benefit due to water harvesting was calculated to be NRs. 108,127. The calculated B: C ratio was 7.78 implying that adoption of water harvesting was highly beneficial while the value of payback period was 2 years means the time until when the initial investment is returned back is lower. NPV was calculated about NRs. 422,185 and the value of IRR was very high (135%) as shown in Table 9.

| Table 8. Benefit due to water harvesting |
|-----------------------------------------|
| Parameters | Overall (n = 120) | Commercial (n = 53) | Non-commercial (n = 67) | Mean difference | T value | P value |
|-----------------------------------------|
| Additional benefit due to adoption (NRs)** | 101,827 | 127,781 | 75,873 | 52,848 | 7.39*** | 0.000 |
| Benefit as percentage total income (%) | 26.79 | 28.58 | 25.00 | 3.58 | 1.834 | 0.189 |

**Represents significance at 1% level

| Table 9. Benefit cost analysis of water harvesting |
|---------------------------------------------|
| Parameters | Value |
|---------------------------------------------|
| Net Present Value (NPV) | 422,185 |
| Internal Rate of Return (IRR) | 135% |
| B:C ratio | 7.78 |
| Payback period | 2 years |
3.13. Problems in water harvesting
Adopters of plastic ponds, cement ponds and jar were asked to rank predesigned 5 main problems in each techniques of water harvesting. Based on the rank they gave to each problem final weightage of each problem was calculated and finally index of each problem was obtained. Based on the index the problems were ranked.

3.14. Problems in plastic pond
The most important problem in plastic pond was seepage of plastic. Adhikari et al. (2018) also identified these problems in water harvesting technology. The major reasons behind this were damage due to animals, weed emergence, alternate heating and cooling of plastic during day and night and fish farming in plastic ponds. After seepage the next major problem was weeds in the ponds. Emergence of weed and subsequent seepage was not an important problem in ponds where water remained in pond almost all year round. However, it was seen as a major problem in ponds where pond remained empty for some months due to scarcity of water. Watershed management and drainage management were ranked as third and fourth most important problem in plastic pond whereas distribution management was ranked as least important problem (Table 10).

3.15. Problems in jar
In jar most commonly farmers collected rainwater through pipe attached in roofs known as gutters. Leakage and blockage of such gutters was one of the most important problems for water harvesting in jar. As most jar adopters used buckets for water distribution it was ranked second most important problem by farmers as shown in Table 11. Similarly seepage of jar, storage tank management and drainage management were ranked as 3rd, 4th and 5th most important problem by farmers.

Table 10. Problems in plastic pond

| Problems in plastic pond | Frequency | Index | Rank |
|--------------------------|-----------|-------|------|
|                          | 1         | 0.8   | 0.6  | 0.4  | 0.2  |       |
| Watershed management     | 9         | 20    | 28   | 20   | 19   | 0.56  | III  |
| Distribution management  | 2         | 9     | 16   | 37   | 32   | 0.42  | V    |
| Drainage management      | 4         | 8     | 25   | 24   | 35   | 0.44  | IV   |
| Weed                     | 15        | 38    | 23   | 12   | 8    | 0.68  | II   |
| Seepage of plastic       | 66        | 22    | 3    | 2    | 3    | 0.90  | I    |

1 = Very high, 0.8 = High, 0.6 = Medium, 0.4 = Low and 0.2 = Very low

Table 11. Problems in jar

| Problems in jar              | Frequency | Index | Rank |
|------------------------------|-----------|-------|------|
| Roof top pipe management     | 19        | 11    | 5    | 2    | 1    | 0.84  | I    |
| Distribution Management      | 16        | 8     | 8    | 3    | 3    | 0.76  | II   |
| Drainage management          | 1         | 5     | 1    | 10   | 21   | 0.36  | V    |
| Storage tank management      | 0         | 4     | 8    | 17   | 9    | 0.44  | IV   |
| Seepage of jar               | 2         | 10    | 16   | 6    | 4    | 0.6   | III  |

1 = Very high, 0.8 = High, 0.6 = Medium, 0.4 = Low and 0.2 = Very low
3.16. Problems in cement pond

In cement ponds the most important problem was watershed management. Though for most of the plastic ponds adopters got net as subsidy, cement pond users didn’t get. Due to lack of net and frequent invasion of pond by external pest and debris, management of watershed was problematic. Due to lack of proper drainage channel in many households drainage management was also seen as one of the important problems in cement pond. Distribution management was ranked as third most important problem by farmers due to lack of distribution materials such as pipe and motors. Weed and seepage were least important problem in cement ponds though few farmers complained about seepage of cement ponds after earthquake (Table 12).

4. Conclusion

As water availability was a major limiting factor for vegetable production in Tansen earlier, most of the farmers had diversified from cereal crops to vegetable crops only after the adoption of water harvesting technology. The type, capacity and source of water harvesting were major determinants of level of commercialization of farmers. Higher capacity of water harvesting structures and more permanent source of water were directly linked to higher degree of diversification to vegetable crops from cereals. The level of commercialization directly affected the income status of farmers from different subsectors and total income. Access to road was also major determinant of type of water harvesting adopted by farmers. Due to lack of transportation facility subsequently leading to higher expense in labour for construction, famers having no direct access to road adopted water harvesting structure of lower capacity than the farmers with direct access. This directly affected the amount of income from vegetables and its share in total income. Though water harvesting had proven highly beneficial in Tansen some farmers had abandoned the technology due to various problems associated with them. Problems such high seepage, weed, watershed management and roof top pipe management had decreased the efficacy of water harvesting structures. However, if these problems are addressed by providing regular training on water harvesting technology and its maintenance, provision of materials like nets for proper management of water harvesting structures and adequate availability of subsidy from government for water harvesting, the benefits of it can be effectively realized.

| Problems in cement pond | Frequency | Index | Rank |
|-------------------------|-----------|-------|------|
| Watershed management    | 8         | 0.8   | 0.6  | 0.4  | 0.2  | 0.9 | I |
| Distribution management | 3         | 3     | 8    | 0    | 0    | 0.73 | III |
| Drainage management     | 3         | 6     | 5    | 0    | 0    | 0.77 | II |
| Weed                    | 0         | 0     | 0    | 3    | 11   | 0.24 | V |
| Seepage of pond         | 0         | 0     | 0    | 11   | 3    | 0.36 | IV |

1 = Very high, 0.8 = High, 0.6 = Medium, 0.4 = Low and 0.2 = Very low
Notes
1. Livestock Standard Unit.
2. 1 ropani = 0.05 hectare (19.67 ropani = 1 hectare).
3. Community Forest Users Group (CFUG).
4. Benefit:cost.

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