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Adoption of a multiple use water system (MUWS) to ensure water security for Nepalese hill farmers

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Abstract

Multiple use water system (MUWS) is an approach to water services planning and design of new and rehabilitated systems. It is informed by input on people's multiple water uses, reuses, and needs at their preferred sites within communities. Although MUWS has been implemented in different parts of Nepal to address water security, the motivating factors in adoption of MUWS have not been previously clear. To better understand farmers' interests, the socio-economic context, and severity of water scarcity problems, we analyzed determinant factors in adoption of MUWS related to the extent of area under vegetable production in Annapurna rural municipality of Kaski district. We surveyed 150 households and conducted eight key informant interviews. A binary logistic regression model showed that five variables, namely: households sharing a tap, water tariff, water volume used, availability of a water storage system, and water sufficiency during the dry season have significant positive influences on the adoption of MUWS. In contrast, two variables, namely: caste and access to water have significant negative influences on the adoption behavior of farmers. Likewise, the linear regression model showed agricultural crops grown, total landholdings, and water quality influenced the extent of vegetable production. Thus the socio-economic condition, access to resources and the institution affect the adoption behavior of farmers. Agriculture policy intervention at provincial/national level should highlight the importance of adoption of MUWS and its benefit in terms of securing water, economy and food in a changing climate.

Keywords: Binary logistic regression; Linear regression; Multiple use water system

Highlights

- MUWS has been successful in reducing water scarcity and enhancing economy of farmers in Himalayan country.

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- Various socio-economic, biophysical and institutional factors influence farmer's decisions about whether to adopt MUWS.
- Policy intervention at provincial-national level needs to highlight the importance of MUWS, and multidisciplinary research addressing motivating factors, constraints and challenges must be across different agro-ecological conditions.

1. Introduction

Water scarcity, an emerging problem, affects over half of the global population for at least one month of the year (Garrick *et al.*, 2020). It has been predicted that two-thirds of the world's population could face water stress by 2025 (Arms, 2008). Rapid urbanization and changing life styles puts pressure on water resources leading to water insecurity (Raut *et al.*, 2019). Extreme weather conditions and changing climate exacerbates the water scarcity situation. Large segments of the vulnerable population in South Asian nations, including Nepal (Bashyal, 2017), are likely to increasingly suffer resulting in hampered social and economic development. The poorest and most vulnerable communities are the ones which are most affected by water and food scarcity. Thus, the gradual reduction of water sources has increased the importance of effective and efficient utilization of existing limited water resources and water management practices (Van Koppen *et al.*, 2006; Sharma *et al.*, 2016).

Water use planning for communities in Nepal has often been based on a single use (Single Use Water System, SUWS). For example, a system might be designed, financed, and managed specifically for drinking or, alternatively, for irrigation or sanitation (Clement *et al.*, 2015). Quantity and quality of water for irrigation would often be different than for drinking. However, in most cases water from any kind of water project would be used by people for multiple purposes. Particularly in peri-urban and rural areas of developing countries, many people are dependent for their livelihood on agriculture, which in many areas is highly dependent on availability of water (Renwick, 2007). Drinking water supply systems, originally designed to meet domestic water needs, may not be adequate to fulfill the multiple water needs beyond domestic use (Van Koppen *et al.*, 2006; Mikhail & Yoder, 2008). Likewise, water supplied from irrigation schemes is also used for all water needs such as drinking, washing, cleaning, managing livestock and income-generating activities. This creates a situation in which water planned for one purpose often gets diverted for multiple purposes, and this can cause conflicts among users, result in water shortages, cause health problems due to inappropriate use of irrigation water for drinking, and in some cases result in premature system failure (Van Koppen *et al.*, 2006). As a response to this situation, the concept of a multiple use water system (MUWS) approach has emerged as a promising way to improve the productivity of water systems over those designed for a single use, e.g. for irrigation or drinking water supply, by incorporating multiple uses into the design of the single use systems (Clement *et al.*, 2015). However, there is no water quality treatment facility in both the systems.

MUWS is defined as 'water services planning and design of new systems or rehabilitations that start with people's multiple water uses and reuses and needs at their preferred sites within communities' (Van Koppen *et al.*, 2008). MUWS has been successful in reducing water scarcity issues (Sharma *et al.*, 2016). This is accomplished by incorporating multiple uses into the original design of systems or by modifying single water systems where possible (Clement *et al.*, 2015). MUWS has been applied mostly in rural South Asia and Sub-Saharan Africa, where there are high concentrations of rural poor with inadequate access to water for domestic and other purposes (Smits *et al*., 2010). Nepal is one of the pioneering countries for MUWS planning and implementation with the first implemented MUWS in Palpa district in 2003 by iDE Nepal (NGO). Objectives included capacity building for high-value crop production, through micro-irrigation technologies and connection to markets for sale of the products, rather than simply developing water sources for farmers (Khawas & Mikhail, 2008; Mikhail & Yoder, 2008; Clement *et al*., 2015). Today, Nepal has a number of MUWS particularly in the mid-hills of the western, mid-western and far-western development regions of Nepal and a number of publications have indicated benefits from these systems in the mid-hills of Nepal (Pant *et al*., 2006; Khawas & Mikhail, 2008; Mikhail & Yoder, 2008). The implementation of MUWS, including irrigation water, near homesteads has improved ease of access and resulted in time saved to fetch water especially beneficial for women and children (Mikhail & Yoder, 2008; Fontein *et al*., 2010; G.C., 2010). This has resulted in increased capacity to generate additional household income through improved vegetable production and marketing but also includes household-based enterprise like handicrafts (Sharma *et al*., 2010; Clement *et al.,* 2015).

Although MUWS has been implemented in different parts of the country with documented benefits, the problems encountered, constraints, and complexities in the adoption of MUWS are not thoroughly understood. Helpful in expanding the use of MUWS would be evaluation of farmers' interests, socio-economic context and severity of water scarcity problems. Although numerous studies have examined water scarcity in Nepal and possible options to secure water (Gurung *et al*., 2019), few have examined the driving factors that influence MUWS implementation. Therefore, pragmatic analysis of the performance of MUWS in its existing condition with different socio-economic settings and water quality for various purposes is necessary to confirm the effectiveness of MUWS. This paper firstly examines socio-economic, biophysical and institutional factors; and determinant factors that affect the adoption of MUWS. Secondly, since there are differences in the coverage of vegetable production due to water supplied for irrigation from MUWS system, this paper discusses the linkage of domestic and productive water uses due to MUWS and varied levels of vegetable production.

2. Research methods

2.1. Study area

The study area comprises Lumle and Dhikurpokhari villages in the Annapurna rural municipality, Kaski district of central Nepal (Figure 1). Dhikurpokhari lies at 28.2800° N, 83.8500° E and Lumle lies at 28.18° N, 83.48° E. The mean annual temperature of the study area is 17 °C. The mean annual rainfall is 3,551 mm and 5,600 mm in Dhikurpokhari and Lumle respectively (VDC, 2010; Timilsina, 2015). The climate in Nepal varies from tropical in the southern plains to temperate in the central region. As the monsoon comes, the intensity of rainfall varies in space and time and is expected to become more unpredictable with climate change. Many non-monsoon months can see no precipitation at all, and even within a monsoon month there can be weeks without precipitation (Gyawali *et al*., 2019).

2.2. Collection of data

The primary data were collected by means of household surveys and key informant interviews. The study was conducted in five MUWS and two SUWS drinking water schemes. A user group manages

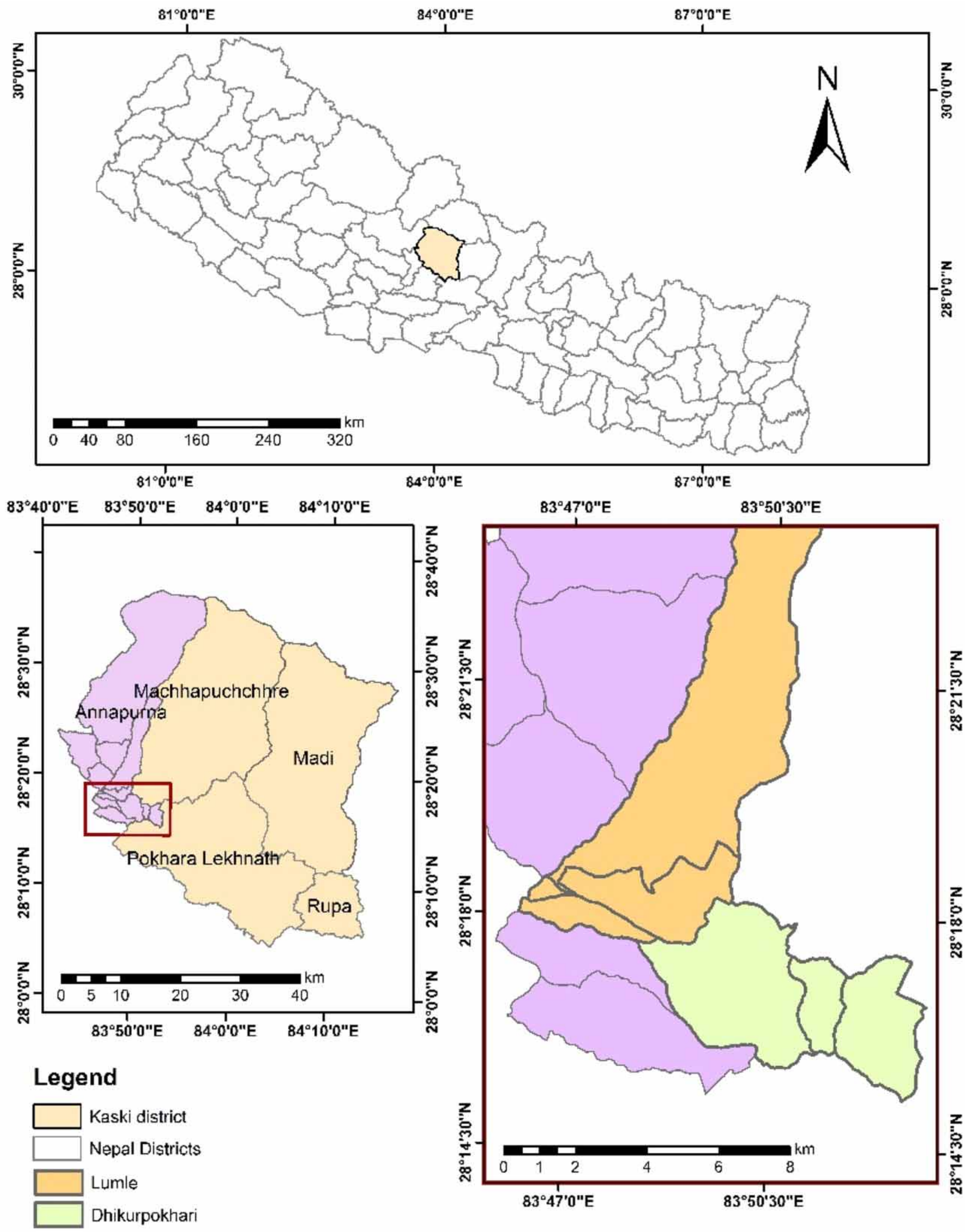

Fig. 1. Location of the study area.

each MUWS and SUWS. The total number of households in each useŕs group ranged from 20 to 72 (Table 1). Households for study were randomly selected from each useŕs groups. From 39% to 77% of the households in each useŕs group were selected. A sample of 92 and 58 households was chosen from the total of 194 and 82 households in MUWS and SUWS user groups respectively (Table 1). A structured questionnaire, including both closed and open-ended questions, was prepared. The questionnaire was pre-tested with five respondents from a village with the similar biophysical and socio-economic conditions as Dhikurpokhari to ensure validity. The survey was conducted in May 2018 by a Master's student who interviewed heads of the sampled households using the questionnaire. Information collected involved respondent's socio-economic conditions, landholdings, vegetable farming methods, types of water source, water availability, water supply facility, access to water, economic and health benefits, incidences of water borne diseases, and food security (Tables 1 and 2).

Furthermore, interviews were held with eight key informants to understand the basic layout of communities, institutional functioning of the water supply system, to identify the beneficiaries of water supply system, natural water sources and to assess the status of water supply tanks of MUWS. The key informants for the study were the program coordinator of *Dhikurpokhari Bikash Sangha*, and one member of each water user group. The additional information was used in the analysis to complement the information gathered from the questionnaire.

2.3. Determination of dependent variables

The degree of adoption of MUWS and the extent of area under vegetable production varies from one household to another and from one MUWS type to another. However, despite owning only small

Table 1. Sample size distribution of MUWS and SUWS water user group.

S.No.		Study location	Total number of households using the scheme	Sampled households
Name of water user group of MUWS				
1	*Subhakamana* MUWS *Samiti*	Lumle	20	14 (70%)
2	*Kalika Bahu Udeshya Khanepani Upabhokta Samiti Majhkhola*	Lumle	36	17 (47%)
3	*Batiko Dhara* MUWS *Samiti*	Lumle	20	10 (50%)
4	*Dalit Basti Sichaai Tatha Khanepani Upabhokta Samiti*	Dhikurpokhari	72	28 (39%)
5	*Majuwa Adhikari Dada Bahu Udeshya Khanepani Yojana*	Dhikurpokahri	46	23 (50%)
Total number of households			194	92 (47%)
Name of water user group of SUWS				
6	*Namuna Khanepani Tatha Sarsafaai Upabhokta Samuha*	Dhikurpokhari	56	43 (77%)
7	*Lakuribot Khanepani Tatha Sarsafaai Upabhokta Samuha*	Dhikurpokhari	26	15 (58%)
Total number of households			82	58 (71%)

landholdings, most farmers in the study area are strongly oriented towards vegetable production for their own purposes as well as for commercial purposes. For the adoption model, the dependent variable indicates whether or not a farmer has adopted MUWS replacing a SUWS system. In this study, a farmer who has been issued the membership of a water user group of MUWS was defined as an adopter. A value of 1 was assigned to respondents who adopted MUWS (the 'adopters') and 0 to respondents who were issued the membership of a water user group of SUWS (the 'non-adopters').

Determinants of the extent of area under vegetable production by individual farmers were analyzed by using a stepwise linear regression model, which used 'area under the vegetable production' as the dependent variable. Those farmers who were members of a water user group of a SUWS system were not included in the analysis of extent of area under vegetable production, as these farmers grew vegetables only in small kitchen gardens for household purposes.

2.4. Selection of explanatory variables

Initially, 18 independent variables were considered for inclusion in the logistic regression model. A multivariate-correlation analysis was done to determine the co-linearity effect of the independent variables (Paudel & Thapa, 2004; Tiwari *et al.*, 2008). Any independent variables with a high degree of correlation ($r > 0.5$) with another variable and a low degree of correlation with the dependent variable was excluded from the model. Therefore, a total of sixteen independent variables were included in the logistic regression model (see Table 2 for further details). For the linear regression model, nineteen independent variables with no co-linearity were included since of the twenty variables, land area under vegetable production had been chosen as the dependent variable.

'Education' is a variable that measures the level of formal education of the respondent. It is predicted that the more educated the respondents are, the higher their tendency to adopt MUWS (Nkamleu & Adesina, 2000).

'Caste' is a dummy variable divided into three broad castes, as is common in the Nepalese context, based on the profession (Tiwari *et al.*, 2008; Raut *et al.*, 2011). A score of three was allocated to the upper castes (Brahmin/Chhetri) that are more engaged in agriculture, two was assigned to the middle caste (Janajati), and one was allocated to the lower caste (Dalit etc.).

'Gender' is a dummy variable (female = 1; 0 = male) describing the sex of the respondents. Although male- headed households are typically expected to be more likely to adopt a new technology (Li *et al.*, 2008; Tiwari *et al.*, 2008), in this case, it is hypothesized that a female-headed households would adopt MUWS as women are the key actors in water management (Sülün, 2018).

'Occupation' is another dummy variable (agriculture = 1; 0 otherwise; business = 1; 0 otherwise; service = 1; 0 otherwise; remittance = 1; 0 otherwise; wage labour = 1; 0 otherwise). Farmers with agriculture as their main occupation are predicted to be early adopters of MUWS systems.

'Agricultural crops' is a dummy variable (crops grown = 1; crops not grown = 0) in this study as it is important to know whether farmers grow crops by themselves or not. It is because, in the hills of Nepal, lands are either kept fallow or used to grow private forest, due to shortage of labour as there is a high trend of migration for jobs (Jaquet *et al.*, 2019).

'Households sharing tap', 'Water insufficiency', 'Water storage system', 'Water tariff' are all dummy variables (Yes = 1, otherwise = 0). 'Households sharing tap' refers to the common tap that is shared by two households. There are no water tariff charges for two SUWS systems, while water tariff charges exist for all MUWS systems. Water scarcity and cost pose a negative effect in adopting water saving technologies (Zhang *et al.*, 2019).

'Economic benefit' is a dummy variable (Yes = 1; otherwise = 0). In this case, it is hypothesized that farmers are likely to adopt commercial vegetable production due to the economic benefit it provides (Bowman & Zilberman, 2013).

'Water quality' and 'Water purification' are dummy variables. Water quality refers to the water supplied by the MUWS scheme to the households and is a dummy variable (Good quality = 1, Bad quality = 0). It is predicted that declining water quality due to scarcity of water impacts on agricultural production (Bowman, 2003).

'Access to water', Water conflict' and 'Food sufficiency' are also dummy variables (Yes = 1, otherwise = 0).

'Household size', a continuous variable, is the total members in each household. The larger the family size, the greater are the possibilities of adoption of MUWS as the water demand increases (Arbues *et al.*, 2010).

'Total landholding', farmers with more land have a opportunity to increase their area in vegetable farming (Rai *et al.*, 2019), and these farmers with more land may be able or willing to invest in new water saving technologies and thus achieve better returns from their farm.

'Water volume' refers to the daily water use in liters. Higher amount of daily water use often enhances the supply process to fulfill the demand.

'Time spent' measures the time required to get water from the water source to the home (measured in hours). It is hypothesized that longer time spent in fetching water positively influences the adoption of MUWS.

2.5. Model specification

Binary logistic regression model: Adoption of MUWS system. The objective of the research was to understand the degree and the trend of the relationship between dependent and independent variables with regards to adoption of MUWS system at the household level. Since the adoption of MUWS is a dichotomous variable, with the options of adoption or non-adoption, the binary logistic regression model was applied as the most appropriate tool to investigate how each independent variable affects the probability of the occurrence of events (Long & Freese, 2006). MUWS adoption in the study area is influenced by a set of independent variables and is specified as follows:

$$\mathrm{Ln}[P_i/(1-P_i)] = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots\ldots\ldots + \beta_k X_{ki}$$

where the subscript i means the ith observation in the sample. P is the probability that a farmer adopts the MUWS system and (1 − P) is the probability that a farmer does not adopt MUWS system. β_0 is the intercept term and β_1, β_2, ………., β_k are the coefficients of the independent variables X_1, X_2, ………., X_k.

Linear regression model: Extent of area under vegetable production. Since the dependent variable 'area used for vegetable production' is a quantitative variable, the stepwise linear regression model was considered to be an appropriate analytical tool for this analysis. This model has a high ability to incorporate the effects of each independent variable on the dependent variable. Although the economic benefits from vegetable production could influence MUWS adoption, the area under vegetable production might be influenced by several factors. Each adopter of MUWS has different areas of land under vegetable production. In the Nepalese context, farmers are smallholders and land is utilized in parcels for various purposes such as cereal production, vegetable production, agroforestry and small private forest. Due to the country's current situation of youth migration in relation to employment, lands are left fallow due to labour shortage (Chaudhary *et al*., 2020). It is imperative to assess factors that determine the extent of area under vegetable production. Thus, the extent of MUWS measured as the area under vegetable production by individual farmers is influenced by a set of independent variables specified in the following model:

$$Y = b_0 + b_1X_1 + b_2X_2 + \dots\dots\dots + b_nX_n$$

where Y, the dependent variable, is the area under vegetable production, b_0 is the intercept, and b_1, b_2, ………., b_n are the coefficients of the independent variables X_1–X_n.

3. Results and discussion

3.1. Characteristics of MUWS adopters and non-adopters

Chi-square tests showed that there were significant differences in education and caste of the respondents with respect to adopting MUWS. Illiteracy was significantly higher (72%) among non-adopters ($p < 0.05$). For those who were literate, the education levels at higher secondary and above were significantly higher for adopters ($p < 0.05$). For caste, *Dalits* and *Bhramin/Chhetri* were significantly higher among adopters than non-adopters. Water was shared by households and significantly higher among adopters ($p < 0.001$). The water volume used per day was significantly higher among adopters ($p < 0.001$). Since water was shared among households and the volume of water used was also higher, a significantly higher number of respondents paid water tariffs among adopters compared to non-adopters ($p < 0.001$). Water sufficiency for domestic uses during the dry season was significantly higher among adopters ($p < 0.001$), while access to water purification was significantly higher among non-adopters ($p < 0.05$). The economic benefit from vegetable farming, access to water and the water quality supplied for drinking purposes were significantly higher among adopter farmers (Table 2). Non-adopters of MUWS were dependent on small shallow wells and traditional pond water, where water quality was relatively poor. Thus, a significantly higher number of non-adopters have access to water purification as it is directly related to their health.

3.2. Determinants to MUWS adoption

The binary logistic regression showed the indicators, magnitude and statistical significance of the estimated parameter for adoption as shown in Table 3. The log likelihood is 136.55 and overall, the model correctly predicted 96.6% of the variation in the adoption behavior of the farmers. The magnitude of the regression coefficient indicates that positively influencing factors contribute more to the decision to adopt MUWS than the negatively influencing factor.

Table 2. Description and summary statistics (mean and percentage) of the variables used in the binary logistics model ($n =$ 150).

Variables	Description	Adopters	Non-Adopters	Significance
Adoption	Dependent variable: adoption of MUWS	92	58	
Education[a]	Education of the respondent (%)			
	Illiterate (%)	28	72	0.037[d]
	Primary education (%)	26	74	0.090
	Secondary education (%)	49	51	0.092
	Higher secondary and above education (%)	71	29	0.016[d]
Caste[a]	Caste of the respondent (%)			
	Dalit (%)	75	25	0.008[d]
	Janajati (%)	57	43	0.816
	Bhramin/Chhetri (%)	53	47	0.012[d]
Household size[b]	Total household members (in number)	6	5	0.707
Total landholdings[b]	Total landholdings owned by the respondents (ha)	0.26	0.21	0.092
Landholdings under vegetables production	Area under vegetable production (ha)	0.051	0.012	0.845
Agricultural crops[a]	Agricultural crops grown	65	35	0.134
Occupation[a]	Occupation of the respondent (%)			
	Agriculture (%)	55	45	0.275
	Business (%)	62	38	0.981
	Service (%)	62	38	0.954
	Remittance (%)	66	34	0.514
	Wage Labour (%)	64	36	0.812
Household sharing tap[a]	Water tap stand shared by households	61	39	0.000[c]
Water tariff[a]	Water tariff	73	27	0.000[c]
Water volume[b]	Daily water use (liters)	292	174	0.000[c]
Water storage system[a]	Availability of storage system for collected water	61	39	0.954
Water insufficiency[a]	Water sufficiency for domestic uses in dry seasons	73	27	0.000[c]
Water purification[a]	Access to water purification	30	70	0.008[d]
Food sufficiency[a]	Food sufficiency for the whole year	61	39	0.929
Economic benefit[a]	Economic benefit from vegetable farming	74	26	0.000[c]
Time spent[b]	Time spent in fetching water (hours)	1	2	0.115
Water access[a]	Access to water	66	34	0.001[c]
Water quality[a]	Quality of water used for drinking purposes	61	39	0.007[d]

[a]Dummy variable.
[b]Continuous variable.
[c]$p < 0.001$.
[d]$p < 0.05$.

The model output revealed that seven of the seventeen variables significantly influenced the adoption of MUWS. Five variables, namely: household sharing tap, water tariff, water volume used, water storage system, and water sufficiency during dry season have significantly positive influence on the adoption of MUWS (Table 3), and two had a significant negative impact: namely: Caste (*Dalit*) and access to water. When water is shared among households, farmers have an inclination to shift from SUWS to MUWS.

Table 3. Maximum likelihood estimates of the MUWS adoption model.

Variables	Coefficient	S.E.	Sig.	Odds ratio
Illiterate	−0.113	0.183	0.163	0.893
Primary education	−1.500	0.415	0.148	0.223
Secondary education	1.326	0.758	0.588	3.767
Higher secondary and above education	0.336	0.660	0.918	5.335
Caste (Dalit)	−2.629	0.443	0.004*	0.111
Caste (Janajati)	−1.814	0.489	0.998	0.261
Caste (Bhramin/Chhetri)	0.682	0.834	0.531	4.063
Household size	0.611	0.401	0.127	1.813
Agricultural crops	−2.831	0.679	0.200	0.063
Occupation (Agriculture)	3.379	1.237	0.723	12.344
Occupation (Business)	0.151	2.119	0.827	1.090
Occupation (Service)	3.743	1.885	0.724	12.837
Occupation (Remittance)	3.316	1.841	0.756	11.537
Occupation (Wage Labour)	13.072	1.894	0.689	53.067
Household sharing tap	1.175	0.434	0.007*	3.237
Water tariff	5.081	2.984	0.007*	18.696
Water volume (liters)	0.012	0.006	0.045**	1.189
Water storage system	7.967	3.983	0.008*	21.000
Water insufficiency for domestic uses in dry seasons	5.608	1.983	0.005*	15.004
Access to water purification	−2.585	0.804	0.082	0.075
Food sufficiency	3.129	1.518	0.203	1.609
Economic benefit from vegetable farming	−2.427	1.240	0.053	0.060
Time spent in fetching water (hour)	1.341	0.461	0.338	1.666
Access to water	−5.862	1.783	0.021**	0.006
Water quality	1.491	0.654	0.130	6.323
Constant	−2.331	28.405	0.935	0.975

Hosmer and Lemeshow Test: Chi-square = 9.12, d.f. = 8, Sig. = 0.63, −2 Log likelihood = 136.558, Cox & Snell $r^2 = 0.562$; Nagelkerke $r^2 = 0.80$; overall percentage of right prediction = 96.6%; sample size = 150 households.
$^*p < 0.01$, $^{**}p < 0.05$.

When the water user group imposed monthly compulsory water tariffs, users tended to be more likely to adopt MUWS. The odds ratio also explained that compulsory water tariff puts almost 19 times greater likelihoods of MUWS being adopted. During group discussions, farmers mentioned that when they pay tariffs, they feel ownership to MUWS, which does not happen in SUWS as there is no tariff and ownership. Likewise, when farmers' water demand per day is higher and when they have proper water storage system at home, farmers tend to adopt MUWS to fulfill the water demand. The other factor that strongly motivated farmers to adopt MUWS was that MUWS provided water at least for drinking purposes during the dry season as otherwise water supply from SUWS system was lean during such periods. In contrast, those in the *Dalit* caste tended not to adopt MUWS had a significant negative influence on the behavior of farmers towards the adoption of MUWS. Inequitable access to water has influenced farmers to choose MUWS.

Characteristics of farmers, nature of innovations, and social circumstances influence the adoption of any agricultural innovation (Rogers, 1995). Results of this study reveal that caste is the most significant factor influencing MUWS adoption. The *Dalit* caste is the so-called lower caste in Nepalese context. In communities with high numbers of *Dalits*, they do not tend to adopt the MUWS system. This may be linked with the landholdings they own. Historically the upper castes tend to be more engaged in agriculture, as they own larger parcels of land compared to middle and lower caste people.

Studies showed that landholding has significantly influenced the adoption of new technologies either by influencing the amount of cash income that farmers are able to accrue by cultivating commercial crops or because farmers with more land can more easily bear risks of crop failure, and afford expenditure on farm machinery (Waithaka *et al*., 2007; Kassie *et al*., 2009; Nepal & Thapa, 2009; Raut *et al*., 2011). In contrast most *Dalits* own only small landholdings, cannot bear the risk of failure of commercial crops, and they typically cannot afford farm machinery. However, the scenario has been changing recently as lower caste people are beginning to adopt vegetable farming due to the direct benefits it offers (Tiwari *et al*., 2008). It seems in future, *Dalits* will tend to adopt MUWS as it enhances water for productive purposes.

Inequitable access to water has influenced farmers to adopt the MUWS system. Discussion with the key informants of the water user group mentioned the reasons behind installing MUWS were: assistance to underprivileged ethnic groups through vegetable production and commercialization; to minimize conflicts over water use; and to provide better water accessibility near households. Farmers in the area reported inequitable water access has been a main reason for water conflict, which they said has been reduced by MUWS. Farmers also reported that a non-governmental organization (NGO) called iDE Nepal financed and implemented MUWS, and later communities have created user groups for operation and maintenance.

The high water consumption for drinking and other household activities would indicate more demand for water and may result in water scarcity, hence the likelihood of adoption is positive. The high water use was directly related to the household size and farm size. In this study the average household size was similar between adopters (six) and non-adopters (five). The finding is consistent with a study by Zhang *et al*. (2019) in which it was reported that adoption of water-saving irrigation technologies are influenced by farm size. It is plausible in future that water supplied from MUWS can be one of the best adaptive measures for communities to cope with predicted increasing water scarcity.

The results of the binary logistic regression model showed that water insufficiency for domestic use during dry seasons and water storage system has a significant positive influence on the adoption of MUWS. The odds ratio showed that increasing water insufficiency during dry season led to 15 times greater odds of MUWS being adopted. The impact of climate change on the quantity and quality of water resources as a drinking water source is of global importance (Mishra, 2014). It has already been reported that 73% of the springs in the Nepalese mountains had a decreased flow, while 12% had dried up over the past 10 or more years (Poudel & Duex, 2017). Springs are the primary source of domestic water supply for rural communities in the Himalayan region, and when they dry up or have reduced flows water shortages become a major environmental threat (Vaidya, 2015; Poudel & Duex, 2017). These conditions apparently regularly result in serious water shortage during the dry period (Tambe *et al*., 2012). Hence, the increasing water insufficiency and need for adequate drinking water in dry periods increased adoption of MUWS. Some farmers are already adopting measures such as installing tanks at water sources, installing pipes for drinking water, and reducing the water supply to livestock to adapt to drinking water shortages. Likewise, irrigation water shortage is being addressed by adopting measures such as constructing water retention ponds, establishing a schedule to take turns to accessing water, etc. (Poudel & Duex, 2017), as MUWS can have capacity to reduce both drinking and irrigation water shortages. Its adoption is positively influenced by availability of water during dry periods and availability of a water storage system.

One of the features of MUWS is that the water is being shared among the water user group members. In this study, each MUWS system has one water storage tank near the community. From the storage tank, water was distributed among households using individual pipelines; two households shared water from each pipeline. Water overflowed from the storage tank and the runoff water was collected in a pond near the community. These ponds are renovated natural ponds. The collected water in the pond was used for irrigating farms mainly for vegetable production. Key informants interview revealed that a few water users were collecting vegetables produced by the members and selling to local markets. Hence water sharing by households had a positive influence on the adoption of the MUWS system. The monthly water tariff collected from each member of the water user group was used for operation and maintenance of the MUWS. These funds supported the regulatory mechanism of the MUWS system, reduced water conflicts, and gave farmers more confidence that the funds would support maintenance of the MUWS. Among the respondents using MUWS having water tariff rates, a majority of the respondents (82%) reported water tariff rates to be reasonable; however, the remaining respondents (12%) found the water tariff rate to be high and inequitable (i.e., the rate was the same for all households, but households with more land or more livestock used more water). Therefore, farmers preferred water tariff rates based on the amount of water used (meter readings) for all the consumers to prevent excessive use of water beyond the capacity of the water source. This shows that the respondents were concerned that overuse of water might have negative effects on sustainability of their water resources.

3.3. Factors influencing the extent of vegetable production enhanced by MUWS system

The stepwise linear regression model included nineteen independent variables. R and R squared values increased with the addition of independent variables and significantly explains the model (Table 4). The final model with three independent variables, namely agricultural crops grown, total landholdings and water quality supplied by the scheme, explains 65% of the variation in the extent of the area under vegetable production. The area under vegetable production varied from one household to another. The agricultural crops grown by farmers among the three variables explained 78% of the variation indicating the very important role in influencing the extent of vegetable production (as shown in Table 4). The income generated from vegetable production was spent for various household needs. The highest proportion of household expenditure was on grocery (27%), followed by education (20%) and goat farming (20%) (see Figure 2).

Of the three significant factors, the agricultural crops grown appears to be the most significant, with increase in crops grown, there was increase in the extent of area under vegetable production (Table 5). The total landholdings was the second most important variable, with a unit increment leading to an

Table 4. Summary of the extent of vegetable production model.

Model	R	R square	Adjusted R square	Standard error of the estimate
1	0.643[a]	0.514	0.408	0.624
2	0.717[b]	0.615	0.504	0.571
3	0.733[c]	0.657	0.521	0.521

[a]Predictors: (Constant), Agricultural crops grown.
[b]Predictors: (Constant), Agricultural crops grown; Total landholdings.
[c]Predictors: (Constant), Agricultural crops grown; Total landholdings; Water quality supplied by the scheme.

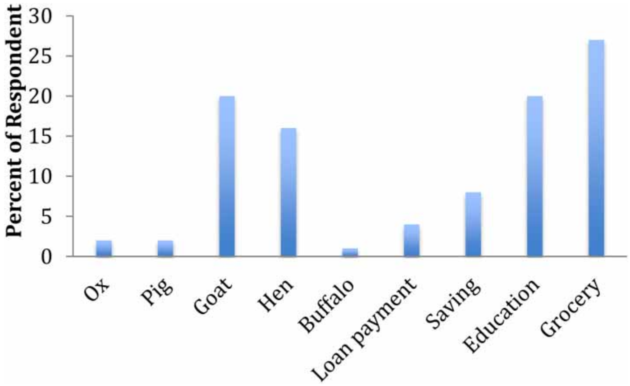

Fig. 2. Household expenditure of economic benefit obtained from income generated through vegetable production.

Table 5. Coefficients of independent variables in the extent of vegetable production model.

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	1.082	0.192		5.646	0.000
Agricultural crops grown	1.067	0.147	0.546	7.239	0.000*
Total landholdings	0.201	0.045	0.338	4.483	0.000*
Water quality supplied by the scheme	−0.175	0.085	−2.059	−2.059	0.042**

*$P < 0.001$; **$P < 0.05$.

increase in the extent of area under vegetable production by about 0.33 units. The results of this study reveal that a unit increase in the water quality had a negative change by about 2.0 units in the area under vegetable production. This is a rational correlation, which was expected. During the informal discussion with farmers, they perceived that the good quality water is needed mainly for drinking purposes and possibly for other domestic purposes, while the quality of water collected in pond was only used for vegetable production.

During key informant interviews, respondents were worried about the fallow land due to a shortage of labour and a reduction in interest for the agriculture profession. In the Nepalese context, this view is also supported by Chaudhary *et al*. (2020) and Shrestha *et al*. (2019), who indicated that the majority of youth migrate within and outside the country, for employment in areas other than agriculture resulting in arable lands being left fallow. To mitigate the loss of farm labor due to migration, adequate water for irrigation should be a high priority to keep as much land as possible in vegetable production.

4. Conclusion and policy recommendations

As indicated above, this study analyzed various determinant factors that influence a farmer's decisions about whether to adopt MUWS. Households where water was from a shared tap with a water storage system were able to use more water, including during the dry seasons, and favored tariffs based on water use to help ensure good maintenance of the systems tended to favor MUWS. However, people in the Dalit caste and those who already had good access to water, did not tend to want to adopt MUWS. This study shows that agricultural crops grown, total landholdings, and water quality explain the variation in the area under vegetable production. Thus the socio-economic condition, access to resources and the institutional context affect the adoption behavior of farmers.

The relative significance of motivating factors may vary in different socio-economic and agro-ecological conditions. However, agriculture and policy intervention at provincial/national level should highlight the importance of adoption of MUWS and its benefit in terms of economy and food security. Therefore, based on the results of this study, the following policy recommendations are made: (1) further evaluate, with multidisciplinary research, the socio-economics, motivating factors, constraints and challenges in adopting the water management technologies in Nepal water; (2) include studies of water conservation, including water source protection programs at the watershed scale; (3) incorporate result of this study to help build capacities of communities for sustainable water management and water security.

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Data availability statement

All relevant data are included in the paper or its Supplementary Information.

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