Exploring the Potential of Multiple Use Water Services for Smallholder Farmers in the Western Middle Hills of Nepal

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(ABSTRACT)

Rural water systems (RWS) are commonly used to provide water to households for domestic uses (drinking, cleaning, washing, and sanitation) in developing countries. Water supply practitioners often classify these systems as single-use water systems (SUS) or multiple-use water systems (MUS). Smallholder farming communities in rural western hills of Nepal typically use such systems for both domestic and income-generating productive activities (e.g., agriculture, livestock, dairy, bio-gas, Rakshi), regardless of whether they were designed for single or multiple water uses. Therefore, this research frames both systems as providing multiple-use water services that enhance the productive activity and livelihoods of smallholders. Little is known on the factors that influence the productive activity of households in the western middle hills of Nepal and the impact these activities have on the technical performance of water systems (measured by duration of system breakdowns).

This research identifies the extent of water-related productive activities in rural Nepali households supported by single-use water systems (SUS) vs. multiple-use water systems (MUS), and explores the factors that enables households to engage in high-levels of productive activity. The vast majority of households were found to engage in small-scale productive activities no matter what the rural water systems were designed to support, and more than half of them earned an income from water-based activities. Households engaged in high-levels of productive activity farm as a primary occupation, use productive technologies, are motivated

to pursue productive activities, have received water-related productive activity training, and have received external support related to productive activities.

A multinomial regression was used to predict the factors associated with high levels of productive activities undertaken by small farms. A hierarchical regression model was then used to examine both household- and system-level variables that contribute to the breakdown of rural water systems, focusing on the duration of breakdowns. The predictors of water system breakdowns include social factors (household involvement in decision-making during water system planning and construction and a household's sense of ownership toward the water system), technical factors (the management capacity of the water user committee and activity level of the system operator), economic factors (income earned from water-based productive activities), and geographic factors (the distance from the village to the water source).

Finally, a conceptual model was developed to help identify strategies for implementing and scaling-up MUS. Scaling-up strategies for MUS begin with community participation in local government planning and budgeting. Under a new Constitution that went into effect in January 2017, newly formed local governments are to be provided with the funding and budget authority to determine local service priorities and how these services will be funded, designed, and implemented. The scaling-up of MUS would require local government officials, water system users, and private actors to develop the technical and institutional capacity needed to build and manage MUS, including the many support services needed by smallholder growers to realize its benefits.

This research also examines the potential approaches that could enable subsistence farmers to become viable commercial producers. While growers are typically risk-adverse producers, this research identifies the mediating factors that could expand the long-term engagement of these producers in commercial agricultural production. These factors include adequate access to year-round irrigation, the use of improved production technologies and practices, improved access to rural markets, and improved production skills.

The findings of this research will also be of value to Governmental, Non-Governmental Organizations (NGOs) and private sector actors who are looking to effectively mobilize their resources and expertise in support of smallholder farming in the hills of Nepal.

Exploring the Potential of Multiple Use Water Services for Smallholder Farmers in the Western Middle Hills of Nepal

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(GENERAL AUDIENCE ABSTRACT)

A vast majority of farmers in the western middle hills of Nepal are smallholders who often use family labor and follow traditional agricultural and water use practices. They have been traditionally using rural water systems to meet their multiple water needs alongside domestic uses (drinking, cleaning, washing, and sanitation). There is growing interest for these systems to also be used for small-scale productive activities such as growing vegetables and livestock production. Evidence shows that these activities are an important source of income for farming families. However, little is known on the conditions that are needed to expand these activities and improve livelihoods. This research identifies the conditions under which rural water systems can become productive and technically sound, and outlines the strategies that can be deployed to scale-up productive activities.

The research examines a broad range of perspectives (from rural farmers to development experts) on the limited commercialization of rural agriculture in the rural middle hills of Nepal and the potential approaches to promoting agricultural growth and commercialization among small landholders. The substance farmers were found to require both the means and motivation (i.e., extensive support services such as access to markets, input suppliers, irrigation and agricultural technologies, and production training) to become commercial farmers. Second, more than 90% of households were engaged in small-scale water-based production activities and more than half of them earned an income from these activities.

The research revealed the conditions that enabled these households to engage in high levels of productive activities. Further, the factors that affect water system breakdowns were investigated. Since farmers are engaged in small-scale production, the interlinkages between productive income and system performance were examined. Finally, the research explores how multiple-use water services have the potential to be scaled-up in the middle hills of Nepal and beyond. Successful scaling-up strategies begin with community participation in local government planning and budgeting. This activity needs to be supported by substantial capacity building among government officials, water system users, and private actors on the factors needed to expand the productive use of water. Broad implementation of multiple-use water systems also requires careful documentation and dissemination of their benefits to key state and non-state actors.

The results from this research can be used to identify appropriate households, communities, and water systems for programs focused on expanding water and agricultural productivity. Therefore, this research will have important implications for the Nepali government with regards to what policy, capacity development, and institutional arrangements need to be addressed to implement productive and sustainable rural water systems. This research can also be of special interest to Non-Governmental Organisations (NGOs) and private sector actors looking to effectively mobilize their resources and expertise relating to a smallholder farming in Nepal.

Dedication

To the smallholder farmers of Nepal.

Acknowledgments

I am grateful to the community of individuals and families that I interviewed during my dissertation field study. My research would not have been possible without their participation, openness, and support. I greatly appreciate the guidance provided by Dr. Floriane Clement with the International Water Management Institute (IWMI-Nepal) and Dr. Luke Colavito, Country Director for International Development Enterprises (iDE-Nepal) for their support, including the provision of workspace in the Pokhara office, a vehicle, and staff support. My thanks also goes to Bal Krishna Thapa, who provided logistic support and arranged meetings with provincial and district stakeholders. I would like to thank Rabindra Karki and Krishna Adhikari for setting up meetings with the Lele community to pre-test the survey instruments and for sharing iDE's available data that relates to this research. I greatly appreciate community leaders Bhakti Ram Devkota, Num Lal Devkota, Dinesh GC, Nar Bahadur Paudel, Jog Bahadir Disha, and Shiva Devkota for explaining their water systems and making me feel at home during the field work. Special thanks goes to Raju DC for digitizing hand-written community social maps using AutoCAD and to Him DC, Khadka Sunar, Gambar Thapa, Chetnath Tiwari, and Anita BK for their tireless support in organizing interviews and data collection.

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Personal Motivation

In 2012, Dr. Hall and I attended a MUS workshop at the Rockefeller Foundation's Bellagio Center in Italy that called upon academic institutions to expand their research on MUS [44]. This workshop laid the foundation for Dr. Hall and I to develop the research agenda that led to this dissertation. My doctoral research examines multiple dimensions of smallholder farming in rural Nepal, the factors influencing multiple uses of rural water systems, the relationship between MUS and system sustainability, and the public policy implications of MUS.

As an engineer and water resource management professional, I became engaged in the planning and development of rural infrastructure, first with single-use domestic water systems (SUS) and then with multiple use water systems (MUS) pioneered by International Development Enterprises (iDE-Nepal). iDE is a US-based international NGO where I was employed as a team leader responsible for implementing MUS projects in the hills of Nepal that serve smallholder farmers with domestic water and irrigation systems. The installed systems provided a range of support services to enable the production of vegetables, especially during the dry season, which helped to significantly improve livelihoods. While the success of the installed MUS stimulated interest among neighboring communities, donors, and certain government officials, the challenge of scaling-up MUS development is enormous in the face of competing sectoral interests, fractured government policy, inadequate funding, and a general lack of awareness of the concept. To advance MUS as a national program for economic development and poverty alleviation, I structured my research to address these challenges. I have taken a holistic approach to addressing socio-cultural, technical, geographic, and economic drivers for promoting small-scale productive activities through rural water systems in a smallholder farming context.

My previous engagement in the planning and development of MUS projects revealed the need to take a holistic approach to my research and to address the gaps in the literature on MUS in Nepal. A core motivation of my doctoral research has been to advance knowledge that enables donors, development organizations, and government agencies to enhance their planning and implementation of sustainable productive rural water infrastructure for smallholder communities in the rural hills of Nepal and in similar contexts in developing countries.

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List of Abbreviations

CPA Commercial Pocket Approach

CPWF Challenge Program on Water and Food

DCC District Coordination Committee

DoI Department of Irrigation

DWRC District Water Resource Committee

FEDWASUN Federation of Drinking Water and Sanitation Users Nepal

FGD Focal Group Discussion

GoN Government of Nepal

HH Household

HLM Hierarchical Linear Model

HVC High Value Crop

iDE International Development Enterprises

INGO International Non-Governmental Organisation

IRC International Water Supply and Sanitation Centre

IWMI International Water Management Institute

LG Local Government

LPCD litres per Capita per day

MLR Multinomial Logistic Regression

MoLD Ministry of Local Development

MUS Multiple-use Water System

NFIWUAN National Federation of Irrigation Water Users Association

NGO Non-Governmental Organization

NIT Non-conventional Irrigation Technology

RWS Rural Water System

SDGs Sustainable Development Goals

SIMI Smallholder Irrigation and Market Initiative

SUS Single-use Domestic Water System

USAID The United States Agency for International Development

VDC Village Development Committee

WASH Water Supply, Sanitation, and Hygiene

WI Winrock International

WUA Water Users Association

WUMP Water Use Master Plan

Chapter 1

Introduction

1.1 Overview

Globally, access to water supply in rural areas has been progressively improving over the past two decades. Rural coverage of safely managed water services increased from 22% to 43% between 2000-2017 [36]. This trend looks set to continue with Goal 6 of the Sustainable Development Goals (SDGs) that focuses on providing access to safe and affordable drinking water for whole populations by 2030. Since the UN's drinking water supply and sanitation decade (1981-1990), rural water supplies have become an important development priority. However, the focus has been on providing water for basic domestic use, which includes water for drinking, cleaning, washing, and sanitation at the household [49]. These systems employ a variety of acquisition, collection, and distribution practices to supply water from a source to the a household or community in an accessible from.

The vast majority of the systems in use today are single-use domestic water systems (SUS), which were planned, financed, and implemented for domestic purposes. The irrigation sector is another single-use domain that provides water for crop production through several technologies including surface channels, pumps, etc. International development agendas, including the SDGs have typically integrated rural water supply programs within the water supply, sanitation, and hygiene (WASH) domain.

In Nepal, the government has given a high priority to water supply, sanitation, and hygiene programs by adopting a WASH sector development plan which is aligned with SDG 6 [80]. This plan aimed to provide everyone in Nepal with basic WASH services by the end of 2020 and provide improved water services and achieve functionality and sustainability goals between 2021-2025, the time frame of the plan [80].

Historically, there has been an ongoing debate among WASH and irrigation professionals on whether or how rural water systems serve the interests of each sectoral actors [24, 49, 95, 108, 123]. While the WASH sector has a mandate to provide water to households for domestic uses, water for agricultural production is assumed to be provided by irrigation sector [8, 47, 74]. In fact, neither sector focuses on multiple-use water systems that support both domestic and productive activities due to their defined sectoral mandates. It is now becoming increasingly clear that rural users often use domestic water supplies and irrigation water for multiple purposes [94, 126]. For instance, rural domestic water systems often support livestock and agricultural production, among many other productive activities. Similarly, rural communities use irrigation water to support livestock and other uses. In practical terms, these informal uses turn the traditional domestic-only water systems into domestic-plus systems [47], and irrigation systems into irrigation-plus [18], despite the fact that these concepts do not fall within the scope of either sectoral domain. This evidence shows that a wide range of unplanned water-based productive activities take place at home or in adjacent to irrigation schemes because rural livelihoods are dependent on water. Since water-based small-scale productive activities are not typically implemented or seen by actors in the WASH or irrigation sectors, they have remained largely unaddressed by either sector [74]. This raises an important question: who bears the responsibility for supporting the productive needs of rural households?

Despite the existing sectoral boundaries, success stories on the design of multiple-use water systems (MUS) that support informal activities have come from individual MUS practitioners or NGOs, and often from donor supported initiatives [74]. These independent outsiders are not bound to sectoral approaches and can focus on flexible water-based approaches to improving livelihoods. However, the success of these actors is often isolated to the project area or a community where they work [74].

The public water sector in many developing regions has yet to pay serious attention to the fact that most rural water users need water for multiple uses at or around their homestead. However, the sectoral strategies, models, or practices undertaken by public actors (mainly WASH agencies) do not cater to this reality. Thus, research is needed to inform public agencies about workable strategies to promote water services that support multiple domestic and productive activities. While a growing body of research on the multiple-use water services approach in Nepal is emerging, prior studies have not explicitly sought to describe the various capacities and knowledge required at the different levels of government and among donors, I/NGOs, and interested external parties to implement and scale-up MUS. This research aims to address these gaps in a holistic way, by exploring the intersection of the water and agricultural sectors. The research views productive uses of water as essential to livelihoods in rural communities and considers MUS as an effective way to support and expand these activities.

The findings from this research support the claims from prior studies (discussed above) that most communities use SUS as 'de-facto' MUS. The study of SUS and MUS systems offered an unique opportunity to revel the factors that can enhance water-based productive activities and income, and improve the technical performance of rural water systems. The findings reveal the potential of MUS to reduce rural poverty. The set of recommendations proposed in Chapters 2, 4, and 5 provide a coherent approach that governments and water system implementers can adopt to advance the scaling-up of MUS in the middle hills of Nepal.

The following section reviews the literature on how rural households and farmers in Nepal use water. The concept of MUS is then explored from a global perspective, which is followed by a discussion of the emergence and development of rural water systems in Nepal. Next, the productive use of rural water systems, a central argument of this dissertation, is considered from a sustainability and policy perspective. These sections introduce the four principal research questions addressed in this dissertation. The research methodology and field work is briefly discussed in Section 1.5, but more details are provided in each of the four main chapters. The final section of this chapter outlines the structure of this dissertation

1.2 Smallholder Farming in Nepal

Nepali farmers have been involved in agriculture, livestock raising, and small-scale productive activities for hundreds of years. Agriculture plays a large role in Nepal's economy, which accounts for one-third of GDP, absorbs two-thirds of the labor force, and is the main source of livelihood for the majority of the population [27]. It is the primary occupation for the vast majority of the economically active smallholders and the poorest households. Rapid population growth and increasing urbanization in Nepal has put increasing demands on agricultural production [53]. The government, donors, and I/NGOs have spent significant resources trying to meet this demand by increasing agricultural production. However, the capacity of Nepali farmers to become productive commercial farmers is still limited [53]. Though the agriculture sector in Nepal has improved over the last decade, it has still not reached its potential when compared with the agriculture output of its neighbouring countries [79, 98]. Farmers engage mostly in subsistence activities and are typically risk adverse producers with inadequate and marginal land with minimal all year-round irrigation. Nepal's poverty reduction strategy (including the nation's 15^{th} five-year development plan (2019/20-

2023/24) recognizes that the agriculture sector is central to any attempt to increase rural poverty.

It is widely reported that climate change is already having discernible impacts in major climate-sensitive sectors including agriculture, water, and infrastructure. Water sources have been declining in the hills of Nepal [31, 35]. Eratic rainfall and changes in temperature have been contributing factors for decreasing crop yields for the past several years according to Nepali farmers [40]. These changes indicate the need for sustainable management of scarce water resources, especially for developing countries like Nepal with a substantial population of subsistence farmers. A 2005 study of Asian Development Bank (ADB) in Nepal showed that the prevalence of poverty in irrigated areas is half than that in rain-fed areas [9]. This implies that access to water for irrigation and productive activities can address poverty. Thus, access to land and water resources are critical factors affecting rural livelihoods [71].

Over past several decades, the Government of Nepal (GoN) has continually tried to improve agricultural production and productivity and commercialize farming. One key component of this agenda was the implementation of a 20-year Agriculture Perspective Plan (1995/96–2014/15). In addition, Nepal's agricultural strategy emphasized the need to transforming subsistence farming into commercial farming [11, 79], on the premise that such a transition is needed to achieve the national goal of a production-based economy. Despite these efforts, the gap between food demand and production has widened [22]. A number of studies have identified a range of agricultural production barriers in Nepal [7, 41, 76, 79]. However, there is limited research on the underlying factors that prevent small-scale farmers engaging in commercialized forms of agricultural production. Thus, a core research question is as follows: *What are the key challenges limiting agricultural production in the middle hills of Nepal and what strategies could promote the commercialization of smallholder farming?*

1.3 Multiple-use Water Services (MUS)

In response to growing evidence on how rural households use water to support productive activities, an international multiple-use water services (MUS) group with membership from over twenty-two developing countries was created to promote water systems that accommodate and support productive homestead-scale enterprises [24, 126]. The MUS approach that emerged from this research is discussed below.

In the 1990s and early 2000s, professionals in both the WASH sector (e.g., International Water and Sanitation Centre-IRC, c.f. (Moriarty, Butterworth, and Van Koppen [74]); and CINARA, Cali, Colombia) and the irrigation sector (e.g., the International Water Management Institute-IWMI, c.f. (Bakker, Barker, Meinzen-Dick, and Konradsen [8]; Polak, Adhikari, Nanes, Salter, and Surywanshi [87]; and Renwick [95])) realized that populations were using the single-use water systems they had been designing for other purposes as well. In 2004, representatives of these entities formed a Consultative Group on International Agricultural Research (CGIAR) to acknowledge and consider the emerging evidence. The group's final report was entitled "Models for implementing multiple-use water supply systems for enhanced land and water productivity, rural livelihoods and gender equity" [122, 125]. The research was undertaken in eight countries, including Nepal, and its collaborators coined the term Multiple-Use Water Services or Systems (MUS) to describe the construct they had developed [122, 125]. In this research, MUS refers to multiple-use water systems. International development organizations have now piloted MUS in more than 22 developing and underdeveloped countries in Africa, Asia, and Latin America [24]. Van Koppen et al.[122] defined MUS as,

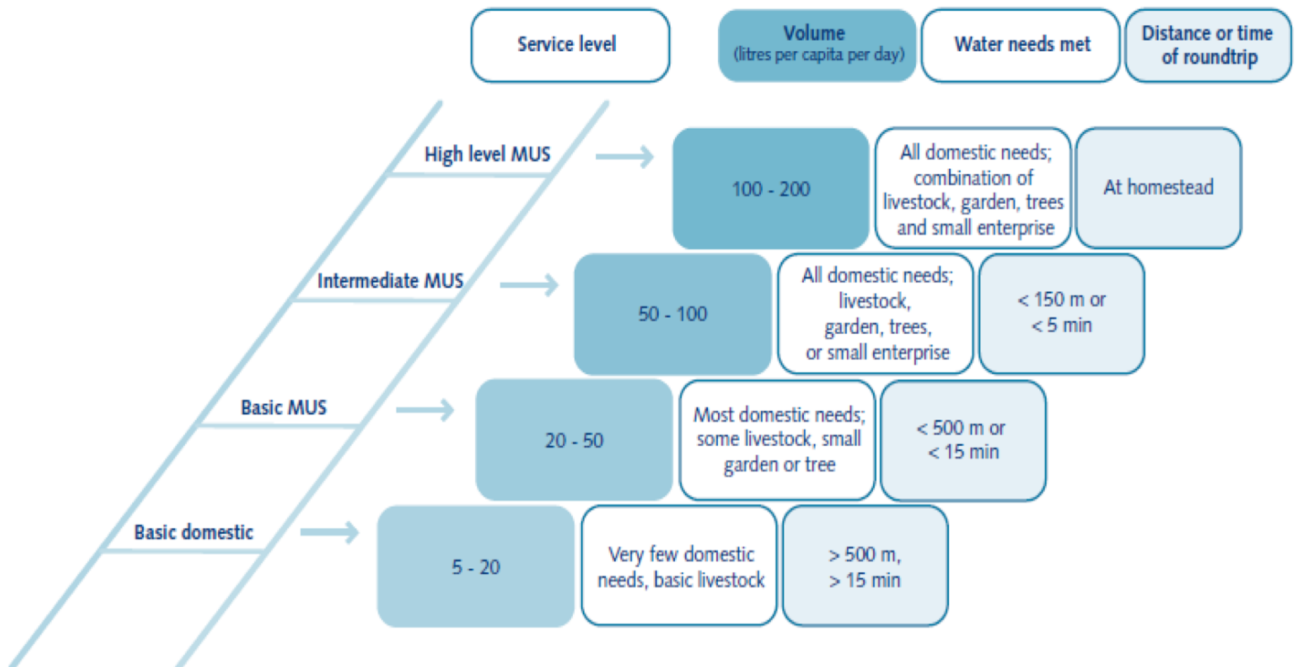
> "… a participatory, integrated, and poverty reduction focused approach in poor rural and peri-urban areas, which takes people's multiple water needs as a start-

> ing point for providing integrated services, moving beyond the conventional sectoral barriers of the domestic and productive sectors" (2006, p. v).

Others have defined MUS as a strategy for the planning, design, and management of water facilities to meet people's requirements for water use for various purposes [50, 124]. Accordingly, Clement et al.[25], Hall et al.[50], Sharma et al.[104], and Mikhail and Yoder [68] have emphasized that multiple-use approach result in improved health, food security, and livelihoods and promote gender equity for poor farmers in rural areas. These arguments emphasize that MUS closely aligns with the principles of community involvement, institutional development, and training, as well as physical design characteristics to achieve poor families multifaceted needs. Thus, there is growing recognition of the relevance of productive use of water in low income settings [44].

As Figure 1.1 suggests, water service levels run from basic domestic to high level MUS. The extent of water service depends on the amount of water available to households. A water supply system can be considered a MUS when domestic needs are met and sufficient water is available for productive uses. According to the ladder, a quantity of water between 50-100 liters per capita per day (lpcd) within a distance of 150 meters from a water access point implies that significant multiple uses of water can occur at the homestead. More generally, the ladder reflects that the livelihood impact of water services would be higher when users climb the ladder and multiple productive activities are allowed.

A water system can use a single technology or combination of technologies or infrastructure to serve the multiple water needs of users (i.e., the different water needs outlined in Figure 1.1) [108]. For instance, in Vinto, Bolivia, an irrigation and domestic water system used the same water collection and distribution facility (e.g., water intake, storage tank, and delivery pipe) [108]. Similarly, in a rural community in the Kaski district of Nepal, a gravity-fed piped water system and roof water harvesting system shared the same water tank that



Source: Smits et al.[108], Van Koppen and Hussain [119], Renwick et al.[96]

Figure 1.1: Multiple-use Water Services (MUS) Ladder

supplied water for both domestic use and vegetables production. Thus, MUS utilizes the water delivery approaches and technologies that are commonly used in the water sector.

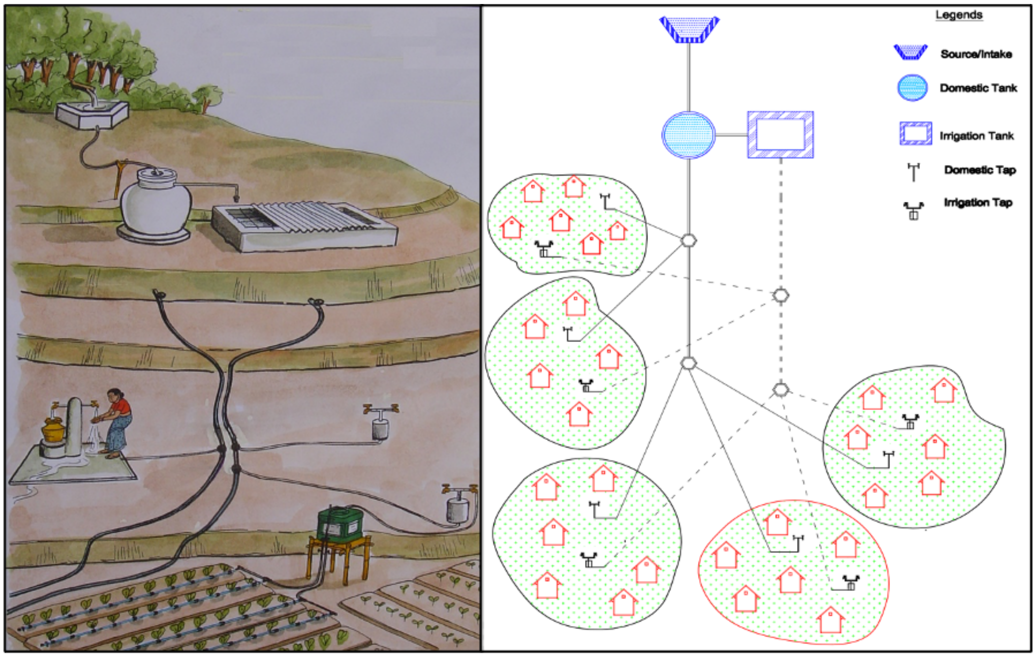
1.4 Emergence and Development of Single-use and Multiple-use Systems in Nepal

The first piped water supply systems in Nepal can be traced to 1895, along with the commissioning of the "Bir Dhara" system by the then Prime Minister Bir Shumsher JB Rana in Kathmandu [115]. This water system provided some public and private taps in a few locations of Nepal, mostly in Kathmandu [115]. Prior to the formation of the Department of Water Supply and Sewerage (DWSS) in 1972, the Department of Irrigation (DoI) was responsible for piped water supplies. Over the past several decades, the DWSS and numerous non-governmental organizations have assisted many rural villages with the installation of spring-fed piped water systems to provide water for domestic uses. These systems span a range of sizes serving urban, peri-urban, and rural communities utilizing gravity flow, pumping, or a combination of both [82]. The vast majorly of these systems are gravity-fed piped schemes, operated and managed by a water user committee. Most of these systems were designed from a single-use mind-set (i.e., to provide water for domestic uses only).

In the early 2000s, International Development Enterprises (iDE) led the initial installation of MUS in Nepal, with field-testing followed by the deployment of a pilot system in 2003 [68, 121]. iDE had previously developed micro-irrigation systems to improve the efficiency of vegetable production, but found that growers also had to carry water from remotely located water sources or use existing domestic water systems to irrigate their plots. To develop MUS, iDE engineers designed a 'hybrid model' by modifying the technical components of traditional domestic water systems by adding additional water irrigation tanks and off-takes to irrigate fields, which provided water for productive uses (mostly to provide drip irrigation for vegetables) [104, 134] (see Figure 1.2). The design prioritized drinking water as per government policy, but also efficiently provided water for increased vegetable production on "Bari" land (lands often close to households).

1.4.1 The Productive Use of Rural Water — Technologies and Practices

Water, as a basic human right, is typically supplied in rural areas in developing countries through traditional domestic single-use water systems that meet basic household needs for drinking, washing, cooking, and sanitation. However, a growing number of studies show



Source: G C and Colavito[40]

Figure 1.2: Multiple-use Water System (MUS) Schematic

that people in rural communities are using these domestic water systems to support a wide range of productive activities usually located in or around the household [47, 49, 68, 75, 121]. These productive uses include a range of small-scale activities that enable people to grow crops and vegetables, raise livestock, and engage in a variety of informal small-scale enterprises [50, 74]. Productive activities play an important role in livelihoods by making a significant contribution to household income, food security, improved nutrition, and health [25, 48, 68, 128].

A variety of technologies and practices are available to make water available in rural areas. For example, in Zimbabwe, boreholes with handpumps are used for domestic use, livestock, and community gardens; in Ethiopia, ponds are used for irrigation, livestock, and domestic uses; in Bolivia, groundwater-fed distribution networks provide services for domestic use and livestock production; in Nepal, gravity-fed piped water systems provide water for domestic use and irrigation; and in Colombia, communal surface water is piped to households for domestic uses, the irrigation of gardens, cattle production, and agricultural processing [108, 120]. This evidence shows that communities use their rural water systems (RWS) for multiple uses around homesteads, whether they are designed for single-use domestic water supply or dual-use (domestic and irrigation) [93]. A water abundant source is often used to meet people's multiple water needs [125]. When communities have limited access to water, possibly relying on an inadequate water source, they usually look for alternative sources to be used either in combination with or separately from an existing source.

As discussed above, productive uses of rural water systems is widespread. However, water-based productive activities do not take place automatically or are limited if the water service providers do not consider these activities in the design of water systems [74]. Further, the factors that enable the productive activities to occur in the Nepali context have yet to be carefully documented. This research fills this knowledge gap by conducting an in-depth examination of the extent to which, and conditions under which, rural households supported SUS vs. MUS engage in productive activities. Thus, a central research question is: *Does the design of rural water systems in Nepal impact the extent and scale of the water-based productive activities supported by the systems?*

1.4.2 Sustainability of Rural Water Systems in Nepal

The long-term sustainability of rural water systems has been a significant challenge in Nepal and elsewhere. Previous studies have shown that nearly half of the nation's rural water systems are not functioning well and need various degrees of repair and rehabilitation [15, 25, 38, 43]. One reason for this is the lack of consideration given to the productive use of water in the design of these systems [74]. If the implementing or oversight agency do not consider productive water demands of users in the design of a rural domestic water system, the end result may be reduced participation and ownership of the system by users [74]. These users in turn may extend water coverage to their homes using informal connections which may then create operational challenges for the water system – i.e., the system cannot supply the water demanded. Such illegal connections may contribute to system breakdowns or even create conflicts among water users [103]. In this context, water systems used for multiple uses may impact system performance and sustainability [107]. This involves a range of factors that affect water system performance and sustainability. At present, only anecdotal evidence exists on the factors that affect the performance of productive water systems in Nepal. Thus, an important question addressed by this research is: *What factors determine the technical performance of productive rural water systems in the middle hills of Nepal?*

1.4.3 MUS Upscaling in Nepal

The multiple use of water has proven to be a norm in developing countries, especially for rural water system users [126]. However, policy-makers and public water agencies or implementors have often discouraged or ignored this reality [74, 108]. Nepal has some of the first MUS projects [12] and the approach is increasingly known and accepted by stakeholders to its potential livelihood benefits [105]. Furthermore, a considerable body of knowledge on MUS has emerged that documents the multiple impacts of MUS [12, 25, 50, 68]. Despite these positive developments, MUS has gained hardly any institutional recognition or policy take-up within the Nepali government [24, 89]. In a similar vein, most of the MUS projects in Nepal are donor funded with little government buy-in [23]. There is also limited evidence and understanding of what makes MUS work in a rural community setting [93].

In 2015, the GoN endorsed a constitution and a new (federal, province, and local) governance system. The new constitution is likely to create a new pathway for the scaling-up of MUS.

Yet, efforts to realize the potential of MUS are still nascent. Thus, this research considers the following research question: *What strategies could be used to advance multiple-use water systems (MUS) in the middle hills of Nepal?*

1.5 Fieldwork

The fieldwork for this research was conducted between 2017 and 2018 in two stages that consisted of fieldwork preparation/sample frame development followed by data collection in the three sample wards (Annapurna-6, Waling-5, and Bagnaskali-1 of the Kaski, Syangja, and Palpa districts, respectively) in the western middle hills of Nepal (see Figure 4.1). First, between June and September 2017, general information was collected on the water sources, water systems, socio-economic and geographic characteristics, administrative boundaries, settlement patterns, and agricultural practices in the sample wards. During this first stage of the fieldwork, an assessment of 60 rural water systems located in these wards was also carried out. These data were then used to select the water systems for the in-depth study and to plan the logistics for the data collection. In the second stage that ran from October 2017 to July 2018, 202 household surveys, 50 key informant interviews, 10 focus group interviews, and 10 engineering assessments of the water systems were undertaken.

The western middle hill districts (Syangja, Kaski, and Palpa) were an ideal setting for the research. These three districts were identified as having 105 MUS developments (out of the 499 total MUS developments in Nepal up until 2019) that were among the first systems installed in Nepal. SUS developments were also widely available in three wards. Small-scale farmers in these wards also had a long engagement with a wide variety of water-based productive activities in including vegetables, the raising of livestock, and other small-scale income-generating activities. These farmers also had a mixture of experience with traditional

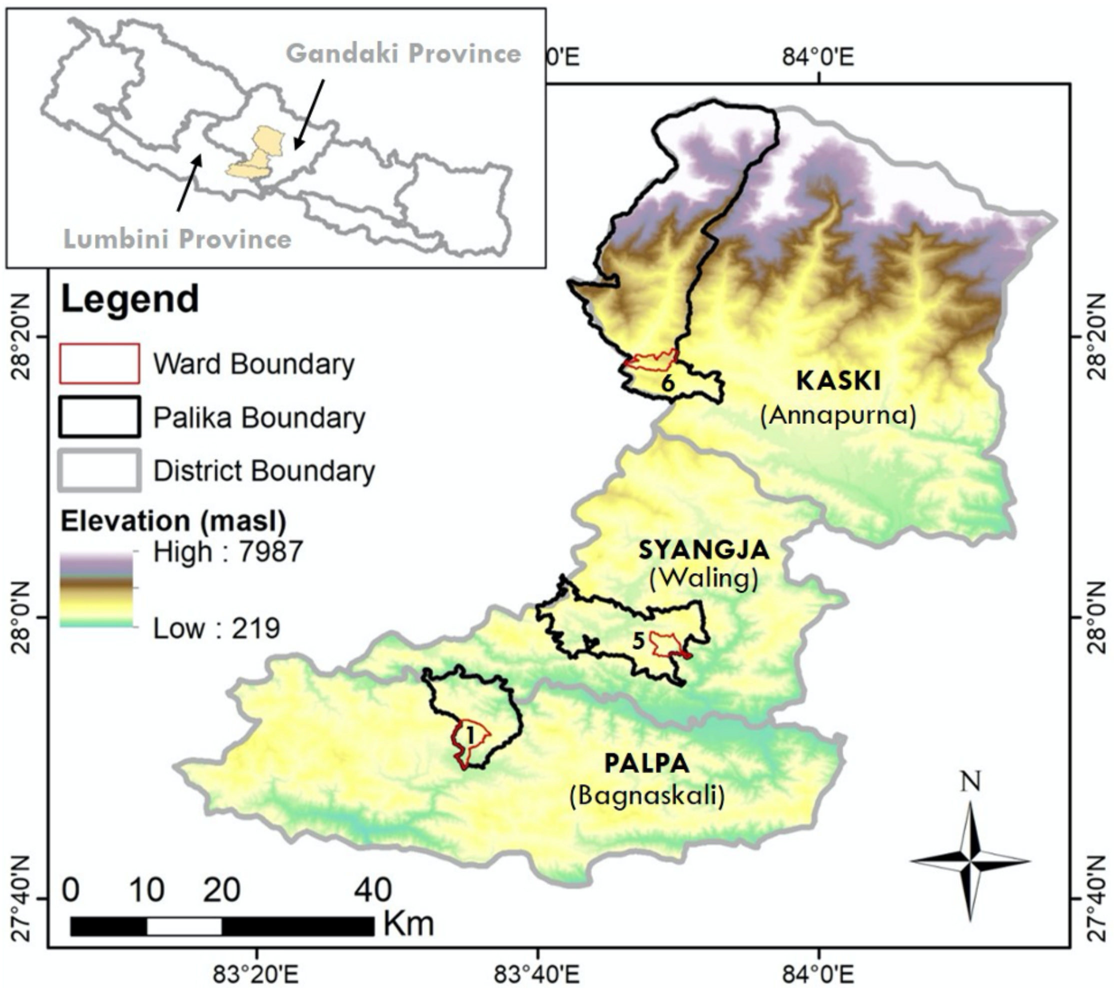


Figure 1.3: Study Area

and commercial production supported by both government and donor-funded programs.

Since this research seeks to deeply understand the potential of MUS in a smallholder farmer setting by capturing the local socio-economic, cultural, and geographic context, both qualitative and quantitatively research methods are used [28].

1.6 Dissertation Structure

The remainder of this dissertation is divided into five chapters. Figure 1.4 shows how the four research questions discussed above interconnect. A summary of the main research findings and conclusion is presented in Chapter 6. As Figure 1.4 indicates, the research first sought to discover the underlying challenges limiting agricultural production and identify the approaches that would enable farmers to become a commercial producer (Chapter 2). Interviews with key informants and heads of households provided information about their existing beliefs and attitudes towards production practices. These data were then used to answer the following questions:

- What are the underlying challenges limiting agricultural production and growth in the western rural middle hills of Nepal?
- What are the mediating factors that will address these challenges and promote the commercialization of smallholder farming?

Chapter 3 explores the extent to which, and conditions under which, the productive uses of water occurs in communities served by rural water systems. To do this, a multinomial logistic regression was used to examine the relationships between the levels of productive activities (high, low, efficient, and inefficient groups) and households socio-economic and geographical characteristics (independent variables). More specifically, the following questions were answered:

- What is the extent of water-related productive activities in rural Nepali households supported by SUS vs. MUS?
- What factors enable rural households in Nepal to engage in high levels of productive activity?

Chapter 4 examines water system performance measured against various social, technical, and geographical factors. The analysis used a hierarchical regression model that captured both household- and system- level variables. The empirical relationship between household productive income and the duration of breakdowns was also explored. This chapter answers the following research questions:

- What are the significant predictors of system breakdowns that prevent households from accessing water?
- To what extent does productive income predict water system performance?

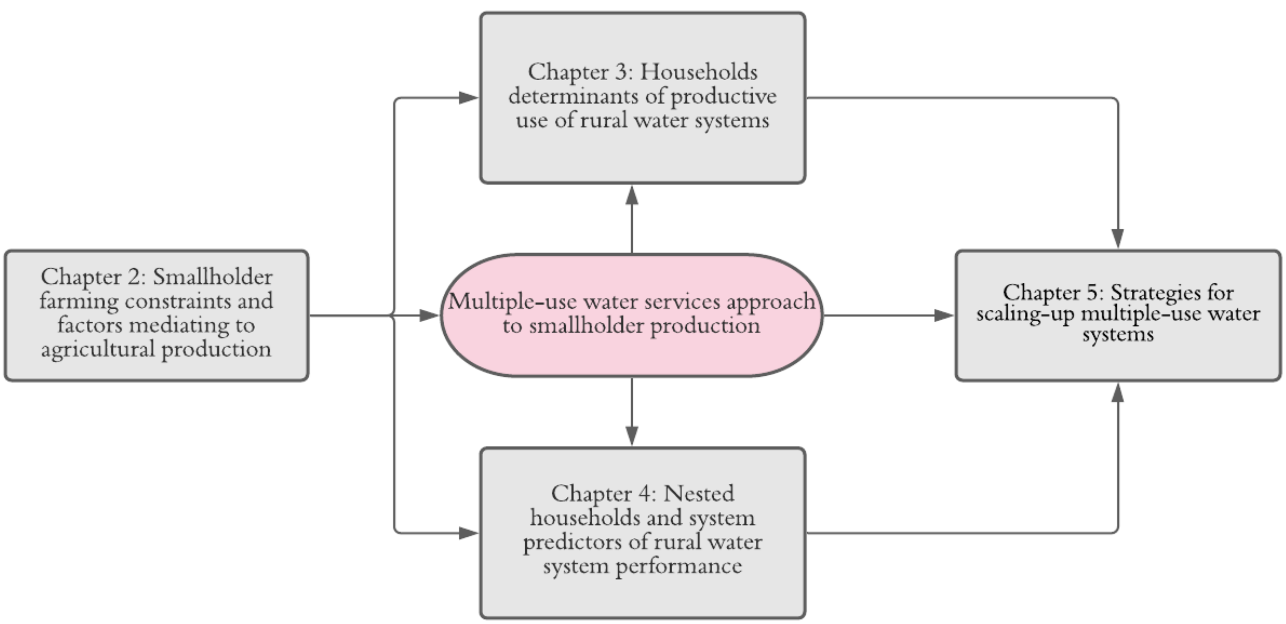


Figure 1.4: Organization of the Research Questions

Chapter 5 explores the challenges and strategies for scaling-up MUS in rural Nepal under the new national constitution that establishes a three-tier federal government (federal, provincial, and local) that went into effect in 2017. Rural water infrastructure projects are now governed by 460 newly formed local governments (i.e., rural and town municipalities) with revenue and budget authority transferred from the federal level, and support from donor agencies. Using an exploratory mixed-methods approach, this chapter considers the views of informed stakeholders regarding the emerging government structure and its impact on the institutionalization and scaling-up of MUS. This chapter answers the following research questions:

- How do key actors in Nepal view the scaling-up of MUS?
- How could MUS be incorporated into the emerging Nepali institutional and policy processes?

Chapter 2

The Commercialization of Smallholder Farming—A Case Study from the Rural Western Middle Hills of Nepal*

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2.1 Introduction

Nepal remains one of the poorest and least developed countries in the world despite more than five decades of formal development efforts. However, the country has witnessed significant progress in poverty reduction [27], living standards, food security, and infrastructure development [79]. Poverty reduced to 22% in 2015/16 from 41% in 1981 [79]. Nepal's per capita income increased from $491 in 2000 to $1034 in 2019 [2]. However, the poverty gap in rural areas is nearly twice than that in urban areas [2]. The high levels of poverty in the middle hills and mountains is due to the remoteness of communities and their lack of accessibility to markets and basic services [130]. The challenging geographic landscape represents a natural barrier to their development [27]. The 12 years of armed conflict (1994–2006), political instability during the transition from a monarchy to a multiparty democracy, and unstable governments during the past two decades have presented significant barriers to economic development. Rural poverty is also associated with slow growth in the agricultural sector and the rural economy [79].

The Government of Nepal (GoN) [79] classifies the rural farm population into three groups—small commercial farmers, subsistence farmers, and landless/near landless farmers. A majority of the farm population (53%) are landless/near landless farmers who each hold less than 0.50 ha of land. Collectively, they account for only 19% of the total available land. About 27% of the farmers practice ‘subsistence farming’ with land holdings of 0.5–1 ha, representing 28% of the total land available. One fifth (20%) of the rural families are ‘small commercial farmers’ with land holdings from 1 to 5 ha or above. These farmers own more than one half of the total land available [79]. The average farm size is 0.6 ha per household. Agricultural land per capita has also decreased due to the combined effect of several factors including inheritances, loss of agricultural land to urbanization, and the degradation of land [79]. Most farmers grow rice, maize, and wheat at a substance level. These crops are characterized by comparatively low yields compared to other countries in the region [27]. Samriddhi [101] shows that around three-fourths of farmers produce crops for home consumption. While it is clear that agriculture is vital to the Nepali economy, low investment in the sector has resulted in relatively low productivity when compared with comparable regions [27].

Agricultural commercialization is a complex and long-term process. Most studies consider commercialization in terms of the volume of marketable commodities [56]. In other words, a farming family is said to be commercialized if it is selling a significant surplus of its agricultural production. The GoN [79] defines agricultural commercialization as “the transformation from subsistence production (production for own consumption), to production for sale of surplus products and services.” However, the concept of commercialization is not limited to selling surplus products in markets. It must simultaneously consider both the production inputs and outputs as well as the decision-making behavior of farmers in production and marketing [56, 86, 128]. Thus, commercialized farmers need to focus on market demand when making production decisions instead of simply selling some the produce due to a production surplus.

The GoN has considered agriculture commercialization as one of the viable ways to reduce poverty and boost economic growth [101]. Agricultural development professionals have long argued that small farms, difficult terrain, limited access to farmer-friendly and low-cost agricultural technologies, a lack of all-weather road connectivity between the cities and rural areas, heavy reliance on seasonal rainfall, limited agricultural markets, and conventional farming practices remain the main challenges that hold the country in a state of poor agricultural productivity [98]. Another contributing factor is the low participation of the private sector in the agriculture sector [79]. In addition, the absence of year-round irrigation systems has limited the potential cultivation area. Climatic change and changes in the demand for agricultural products are additional factors that inhibit the growth of the sector [53]. Notwithstanding these challenges, the country is slowly moving towards market-oriented agricultural production [46].

One of the key strategies of the GoN has been to improve agricultural production and productivity and commercialize farming over the last three decades. To realize this strategy, the GoN has implemented several policies and programs. A 20-year (1995/96–2014/15) Agriculture Perspective Plan (APP) concluded with little progress [8]. Prior to this long-term plan, the GoN had given priority to agricultural development through the country's first 5-year development plan (1975–80) [101]. In 2016, the GoN initiated the Prime Minister Agriculture Modernization Project to enhance agricultural productivity and achieve commercialization of agriculture (with the allocation of Rs. 5.75 billion, USD $51 million). The GoN has also recently launched the Agricultural Development Strategy (2015–35) with support from the Agricultural Development Bank (ADB), as well as the 2018 “Roadmap to Prosperity”. These policies aim to promote the commercialization of agriculture and enhance the Nepali rural economy [54].

Development experts argue that the execution of these policies and programs has remained weak, as resources and institutional capacity needed for their delivery are limited. The GoN has also acknowledged that the leading stakeholders, particularly farmers, cooperatives, and private sectors, were not proactively involved in the development and implementation of existing policies and programs [79].

This chapter seeks to understand the institutional and technical barriers to expanding smallholder farming in the western rural middle hills of Nepal. The rural middle hills present an opportunity to study commercialization of smallholder farming due to the long engagement of farmers in cereal crops, high-value crops (such as vegetable crops that provide a higher return per unit of land and have a higher market demand than staple crops such as cereal crops), and livestock production. These farmers also have limited experience in selling these commodities in formal markets. This research aims to inform policy makers on appropriate policies that could advance the commercialization of smallholder farming in the region. The chapter is timely given the GoN’s efforts to develop hundreds of new polices in all sectors of the economy following the new federal constitution established in 2015.

The chapter is structured as follows. Section 2.2 presents the methodological approach and describes the study area and the data collection and analysis techniques used. The findings are presented and discussed in Sections 2.3 and 2.4. Section 2.3 is organized into subsections on the constraints to commercialization of agriculture, and the impact of remittances on agriculture and the role of women in agricultural commercialization. Section 2.4 then explores approaches to advance the commercialization of agriculture in the middle hills of

Nepal. The relationships between the socio-economic characteristics of households and crop incomes are presented in Section 2.5. Section 2.6 presents a series of recommendations and Section 2.7 concludes the chapter.

2.2 Methodology

2.2.1 Study Area

Nepal is a mountainous country located in southeast Asia, bordered by India and China. It is officially divided into three ecological zones—the Terai, the Hills, and the Mountains. It ranges from fertile plains in the south (57 m above sea level) to mountains in the north (up to 8848 m above sea level) [4]. The 2015 federal constitution of Nepal formed one federal, seven state, and 753 local governments (LG). These LGs were divided into 6743 wards [1]. They represent the lowest administrative unit of the government.

The research site is located in three wards (Annapurna-6, Waling-5, and Bagnaskali-1) of Kaski, Syangja, and Palpa districts in the western middle hills region of Nepal. Kaski and Syangja districts are located in Gandaki Province and Palpa in Lumbini Province as depicted in Figure 2.1. More than 1500 households live in these three study sites. Agriculture is one of the major occupations and sources of livelihood for a majority of the population in these areas. Typically, families grow cereal crops—rice, maize, wheat, and millet on terraced fields. In 2018, per capita income in this region was around USD $850 [42]. The major sources of income for these families include remittances (income from men working outside the country) (41%), jobs (22%), agriculture (excluding consumption) (15%), business (10%), pensions (11%), and government allowances (1%) [42]. Over three-quarters of the households kept animals with approximately six animals per family on average [42].

Agriculture and forestry are the dominant forms of land use in the region. Khet and Bari lands are the two common types of cultivated land. The Khet land often consists of leveled terraces that are primarily used for cereal crop production, and are located away from households. Whereas, Bari land is a small land area close to the homestead. The cultivated Khet lands depend mostly on monsoon rains from June to September with more than 75% of the annual rainfall occurring during this period [42, 117]. There are three distinct seasons in the middle hills: rainy, winter, and hot summer [13]. The elevation of the three districts included in this study range from 219 to 7987 m as shown in Figure 2.1. Landholdings are small and fragmented, which is a common phenomenon across the middle hills and mountainous region [16]. All three of the studied wards were located about 10 km from the district headquarters. Each ward was also located around 3 km from the nearest highway.

2.2.2 Data Collection and Analysis

The research for this chapter was conducted between October 2017 and July 2018. First, villages that met a preliminary set of criteria were shortlisted, primarily related to their use of rural water systems based on (1) data from an International Non-Governmental Organization and (2) their geographic location in the middle hills of Nepal. Second, the lead researcher visited the three shortlisted sites and assessed their access to agricultural markets; the water systems being used; experience with improved agricultural practices; involvement with cereal, high-value crops (HVC), and livestock production; and willingness to participate in the study.

The methodology consisted of household surveys, focus group discussions (FGDs), key informant interviews, and field observations. A total of 202 household surveys were conducted to gather data on the use of water for irrigation, the farmers' agricultural practices, their engagement and motivation in agriculture, and factors constraining production. Ten FGDs

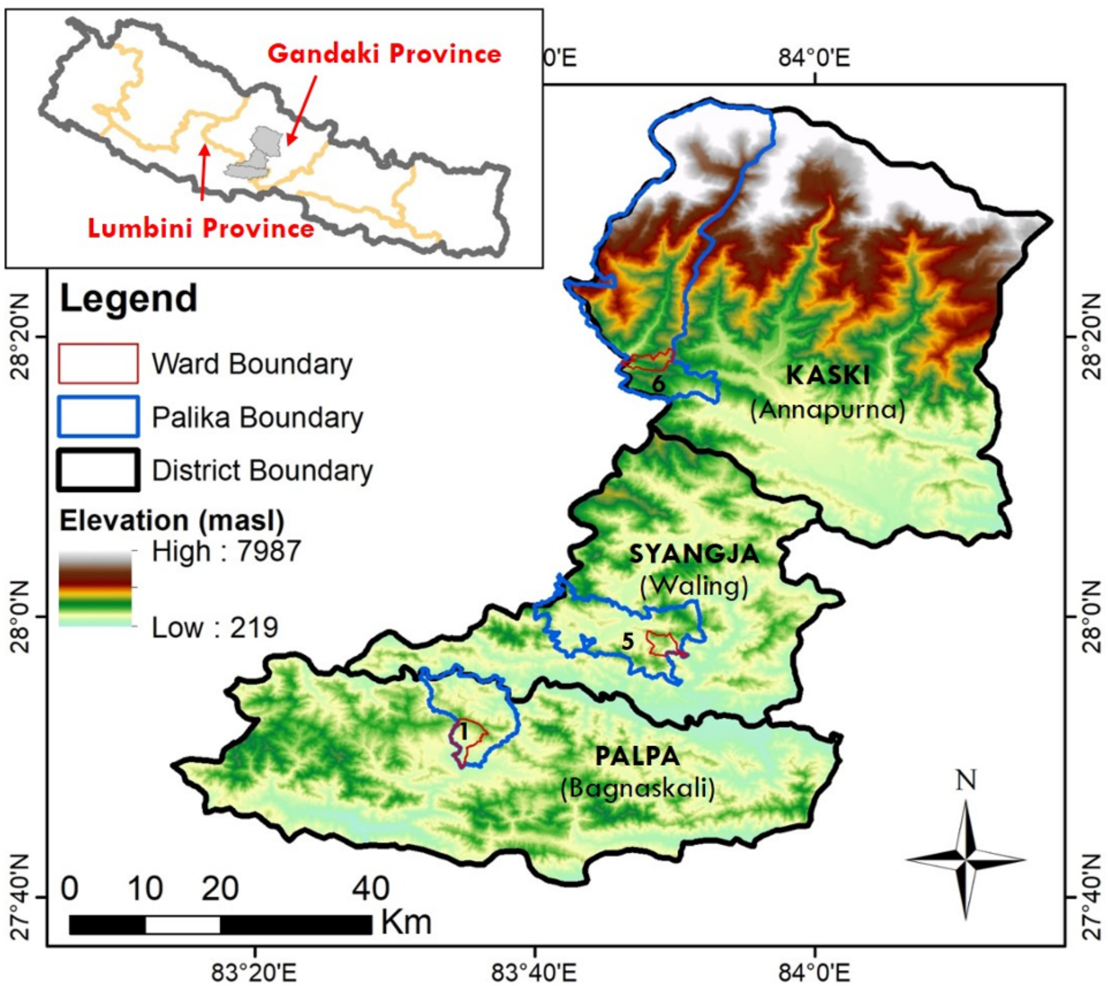

Figure 2.1: Study Area

with farmers (i.e mostly water committee and production group representatives) were undertaken to gather information on their experiences and beliefs relating to agricultural issues. The lead researcher provided different topics for discussion and the participants were given sufficient time to discuss each topic. The participants were then given time to present the results of their discussion. The farmers included in the FGDs were members of agricultural production groups and/or the community's water committee. The FGDs were designed to elaborate on the results obtained from the household survey.

Interviews with 50 key informants (KI) were also conducted. The interviewees consisted of government officials, elected representatives, local leaders, officials from agricultural cooperatives, agriculturists, and agriculture input suppliers (agro-vets). The key informants were identified through NGOs, municipalities, and conversations with lead farmers (farmers who have received extensive trainings and grow crops at a commercial scale). Key informants' perspectives are critical given their local agricultural knowledge.

The methodology consisted of a mixed-method approach that involved data collection and analysis using both quantitative (household survey) and qualitative methods (key informant interviews and FGDs). A 'hand coding' technique [28] was used to organize the qualitative data gathered from the key informant interviews and FGDs. The research was designed in a format that the household survey complemented the FGDs and KI data. Such integration of quantitative and qualitative methods [127] offered an effective way to understand the barriers to the commercialization of smallholder farming and how they might be overcome. The use of these methods permitted the triangulation of data around critical or emergent themes [21]. The responses received from the key informant interviews were classified into different themes through grouping and regrouping. The themes were then linked, as appropriate, to consolidate the explanations [100] and connect them with the challenges and opportunities facing efforts to commercialize smallholder agriculture.

2.3 Findings and Discussion

2.3.1 Constraints to Commercialization of Smallholders—Informant Perspectives

Nearly all the surveyed households were engaged in some kind of subsistence activity relating to growing vegetables, oilseeds, pulses, cereal crops, and fruits, rising livestock and poultry, and horticulture. However, more than three-quarters of the households (83%) were engaged with the cultivation of major cereal crops—rice, maize, and wheat. Almost all of the households (90%) grew vegetables, and more than half of the household (58%) sold them to vegetable collection centers, with the remainder either selling them to neighbors, hotels, or wholesalers who collect from their residence. Less than 4% of the households sold through all four of these options. Cattle, buffalo, and goats were raised by over two-thirds (70%) of households. A similar percentage of households (69%) kept chickens. Families were mostly subsistence producers living off marginal land of about 0.5 ha. Most households lacked access to year-round irrigation. These data reveal that agriculture is still a basic source of income for these communities. The following statement by a farmer highlights why most rural households rely on agriculture.

> "My grandfather and father were farmers. I started helping my father on the farm when I was just 15 years old. This is how I learned farming from an early age. I think my core skill is farming. I do not have the skills to work for an office or sit behind a computer for a high paid job. I enjoy working on my farm" [Interview, Farmer, December 2017].

More than one-third of the Khet lands were found to remain uncultivated throughout the year. Nearly half of the households reported that they lacked labor during the land preparation and harvesting time. Another one-third of families were not growing cereal crops in the dry season due to a lack of irrigation facilities. In most of the areas studied, only small amounts of wheat and pulses were grown during the winter dry months. Since the cultivated lands mostly depend on monsoon rains, the informant agricultural experts believed that regulated and controlled year-round irrigation would enable farmers to grow crops during three seasons in a year. While a vast majority of the households surveyed produce cereal crops for self-consumption, a little over one-third sold their surplus. Less than half of the households needed to buy rice, wheat, and maize for a majority of the year. These findings correspond to evidence that there has been a significant reduction in the production of cereal crops. For example, while the Kathmandu Post [3] reported that Nepal imported Rs. 51 billion (USD 451 million) of food grains, Rs. 28 billion (USD 248 million) of vegetables, and Rs. 37 billion (USD 327 million) of cooking oil in 2018, local agricultural experts argued that the current production of these crops is considerably lower than what is possible.

There was general agreement among the key informants that livestock raising and farming of cereal crops (rice, wheat, and maize) have been drastically reduced in the last decade. The household interviews revealed that livestock raising has declined by 15%–20% during this timeframe. The decline of raising livestock was found to be associated with a shortage of labor due to the outmigration of youths and a lack of pasture land, fodder, and open space for livestock (FGDs, production groups, November 2017). Additional barriers to raising livestock were poor nutrition and disease among animals [90]. In addition, more than half of the farmers interviewed complained that laborers were not willing to work on their farm due to the small financial incentives.

The informants reported there was minimal to no support from the government and NGOs for cereal and livestock production. However, the government and NGOs were providing production-related support for high value crops (HVC) for more than half of the households. There was only a small percentage of households (12%) who received technical support relating to livestock—e.g., how to use improved cowsheds, available veterinary services, etc. Most farmers reported they lacked access to a full range of inputs and technologies. In addition, interviews with some farmers revealed the lack of respect for farming as a disincentive to farm.

> “Farming profession is not well respected, rather perceived as a low-rank profession. This is a pity. All need to understand that farmers not only produce for

> themselves, they also produce for others, so they are shared property" [Interview, Farmer, November 2017].

Most of the households utilized their Bari lands for vegetable and livestock production. Bari lands were mostly irrigated with water systems designed for domestic uses, which constrains the growing of crops to a small portion (6.2%) of their Bari land. This result indicates that a large proportion of the Bari land could be brought into cultivation during the dry season if they had a reliable source of irrigation water. Less than one-fourth of the households had access to water to irrigate a larger area of Bari land. However, nearly one-half of these households limit crop production to small plots because they fear crop failures or low crop yields due to infestations and extreme weather. Farmers cultivating in marginal lands also increase the risk of land degradation and fertility loss due to mono-cropping (Interview, NGO Official, June 2018). These factors reinforce the lack of motivation among one-third of the farmers to produce crops on Khat and Bari lands.

In summary, the common reasons for reduced levels of crop production are the lack of a viable workforce, alternative off-farm sources of income, a limited return on crop-related investments, a shortage of inputs and fertilizers, the use of inefficient production techniques, and production risks associated with technology, irrigation, and marketing (FGD, January 2018). These factors collectively explain the constraints faced by smallholders when considering the commercialization of farming. Interestingly, over one-third of the farmers did report that they foresee a commercial and market-oriented future.

2.3.2 The Impacts of Remittances on Agriculture and the Role of Women in Commercialization

Agrilinks [85] reported that more than two million young Nepali, especially men, work outside of the country in low-skilled jobs. At least one youth male from more than one half of the households surveyed (54%) had out-migrated, mainly to the middle east for (mostly unskilled) employment. This male outmigration is associated with the critical shortage of farm labor. Remittances related to outmigration provide a significant cash inflow to households. It is estimated that migrants send $6.1 billion per year (54 million USD) (31% of GDP in 2014/15) home via remittances [79]. Low productivity, small farm size, and the low social status of farm-work are primary factors that have discouraged youths from getting involved with farming [3]. Labor migration has had a significant effect on land management and production in the middle hills of Nepal [57]. Remittances have resulted in improved food security and a decrease in dependency on farming [57, 113]. More than two-fifth (43%) of the households receiving a remittance reported that they spent most of it on loan repayments and consumption including food, education, health care, and upgrading their homes or building new homes. In reality, only a small amount of their remittance income was spent on agriculture. Samriddhi [101] has argued that these remittance incomes could be more productive if they were directed towards high-value agriculture.

Several migrant returnees interviewed for this study became engaged in commercial farming and livestock production. Each individual was considered to be a model farmer in their community, earning more than USD $12,000 per year. One of the returnees commented:

> "It was so hard to work in the hot of the Middle-East as an unskilled worker. I learned how hard it was to earn money. This made me realize that I would do something in my own country that I know and can do. After two years, I

returned to my village and took some loans from a cooperative and relatives for goat farming. It has become profitable. My family is happy and I am happy too" [Interview, Youth Farmer, June 2018].

Women were also found to play a crucial role in agricultural production and food security. Nepal has a relatively strong female labor force [27]. Despite the fact that the involvement of women in agricultural activities is very intensive [54], their contribution to agriculture has not been fully recognized. These responsibilities render women vulnerable to declining water supplies, climate variability, natural disasters, pest outbreaks, changing precipitation patterns, and other impacts from climate change [53]. Project planners often tend to limit women's involvement in the entire process of planning, programming, and implementation of development activities [Interview, Lead Women Farmer, July 2018]. As a result, such projects have either failed to meet their objectives or have made little impact on agricultural development [53]. The key informants favored women's participation because they already play a major role in producing, harvesting, and marketing many types of crops. The following statement from a key informant indicates how the role of women has changed in the community.

"The management of major crop production has traditionally been the male domain. Since most male youths have migrated to foreign countries for income, women are increasingly involved in crop and livestock production. Most people trust women now a days. This was not the case 10 years before. This shift is gradually breaking strict traditional divisions between the roles of men and women" [Interview, Social Activist, January 2018].

The limited presence of youths in the villages has negatively impacted socio-economic activities. For example, the work burden of women and elderly people related to household activities has increased. Similar findings were reported by Jaquet et al.[57]. Youth outmigration has required women to engage in agricultural and water groups, local water system planning and construction (e.g., the selection of water sources, locating taps and tanks, etc.), and trainings to increase their knowledge and capacity relating to agriculture and water management. These activities have led to shifting gender roles with women becoming entrepreneurial and engaged in extra-household activities. However, the key informant interviews and FGDs highlighted that women required training in value-added production, post-harvest handling, and agro-processing techniques. In addition, rural institutions need to be developed that provide agricultural services to women and opportunities to engage in decision making. For example, linking women's groups to credit sources in order to overcome the financial constraints that many female-headed households face would help overcome a significant entry barrier to small-scale agriculture [53].

2.4 Approaches to Commercialization

By carefully reviewing the perspectives of key informants on the technical approaches to promoting the commercialization of agriculture in the western middle hills of Nepal, six key themes were identified. These themes include production training and capacity building, access to irrigation systems, access to agricultural inputs, services and markets, the use of improved agricultural technologies and practices, risk reduction measures and approaches, and HVC and livestock intensive agriculture. Each theme is discussed below.

2.4.1 Production Training and Capacity Building

Interviews with the key informants revealed the need for comprehensive training on crop planning, improved agricultural practices, pest management, soil health improvements, crop harvesting and marketing, and the use of crop calendars by producers. Exposure visits to successful farms was also considered to be an important tool for capacity development (Interview, Local NGO Representative, June 2018). Such visits enable farmers to observe successful farms and interact with their owners. Some local elected ward representatives advised agricultural experts to develop need-based trainings that identify the users' specific knowledge and skills and address agro-climatic requirements. Farming families generally have limited skills in systematic record-keeping of their production and sales. As a result, many farmers did not know if they were making a profit or loss.

Farmers were found to need additional training on commercial planning and record-keeping, including income and expenditure records and unit cost calculations [53]. These activities are expected to empower farmers with the required technical knowledge and help them organize input supplies, improve the application and use of available technologies and practices, and enhance their access to markets for their products. In addition, the key informants recommended an increase in the number of women, marginalized, and disadvantaged groups included in new farmer groups and in the selection of farmer training programs. Farmers are organized into production groups, but in an *ad-hoc* way. As one local elected representative commented:

> "I urge the supporting NGOs to create local expertise by providing a complete basic training package to the groups and long-term ToT [Training of Trainers] trainings to selected farmers who could train other farmers as a service provider. Such a mechanism can promote activities at the local level even after the with-

> drawal of project support" [Interview, Local Elected Representative, June 2018].

A sustainable mechanism to train farmers would be to select lead farmers to receive ToT training so that they can pass on information and skills to other farmers [Interview, NGO Official, May 2018]. Such a locally transferable capacity development model can create a long-term approach that is collectively owned and managed by local people. It was recommended that programs focus on working with small farmers to prioritize and implement activities relating to crop diversification, commercialization, and productivity [Interview, INGO Representative, June 2018].

2.4.2 Access to Irrigation on the Farms

The topography of the middle hills of Nepal makes the development of irrigation systems costly and technically challenging [37]. In many cases, surface water sources are located below the settlements and require high-cost pumping technologies to lift water to communities. Besides the cost of these pumps, most installed systems suffer from poor operation and maintenance and have proved to be unsustainable. Studies in the region consistently find that it is unfeasible to access groundwater from a technical and financial perspective. Over the past decade, some efforts have been made, mainly by non-governmental and private sector organizations, to promote non-conventional irrigation technologies (NIT) such as drip irrigation and sprinklers for vegetable crops, but the pace of adoption by farmers has been slow [Interview, Local Dealer, December 2017]. One farmer remarked that:

> "Most farmers depend on rainfall for the crops. Some farmers want to grow crops that do not need irrigation or just a small rainfall would be sufficient. Three to four monsoon months matters much to farmers like me" [Interview, Farmer, November 2017].

A vast majority (89%) of the informants claim that the development of irrigation systems, will not only increase the cropping intensity of winter crops (i.e., wheat), but will also enable farmers to grow maize and other crops during the dry season. The yield levels of existing crops could also substantially increase. Agricultural experts anticipate that year-round irrigation systems would significantly increase farmer's motivation to engage in agriculture, especially those farmers who scaled down farming due to a fear of droughts or lack of irrigation water. Reliable irrigation during the dry months has tremendous potential to enable new income generating activities for smallholder farmers (Interview, Agriculture Expert, January 2018).

2.4.3 Access to Agricultural Inputs, Services, and Markets

The lack of access to appropriate direct farm inputs is seen as a significant constraint to enhancing the productivity of rural farmers. More than two-thirds (69%) of informants highlighted the need to provide improved access to agriculture inputs and technologies to smallholder households through a market-driven/private sector supply chain. This study found that most of the input suppliers were located in the district headquarters. Due to the rugged terrain and geographical constraints, a place to buy inputs is often not within comfortable walking distance from the communities. Moreover, most input suppliers have limited knowledge of their products and do not stock the proper inputs such as seed varieties, fertilizer, and pest control technologies. Most input providers were selling improved seeds, fertilizer, and equipment without any systematic training and lacked knowledge of plant protection methods and pesticide classification and uses [Interview, Agriculture Expert, January 2018]. Key informant experts recommended that input providers work with stockiest, exporters, and producer organizations to provide small-scale farmers with access to affordable fertilizers, chemicals, and quality seeds. More than two-thirds of the informants highlighted the need for a support program that would develop products and service packages tailored to the needs of identified markets and engage in demand creation activities. Such programs can develop linkages with a network of farmers groups and NGOs interested in demonstrating and disseminating information on the benefits of intensifying production using improved inputs and practices. One local agriculture supplier argued that:

> “To create sustainable supply, the government and project should invest in developing the capacity of manufacturers, assemblers, agro-vets, leaders, farmers, installers in the supply chain, and in ensuring that the supply chain generates benefits in terms of increased income from the production and/or sale of the products and services. To generate sustainable demand, the activities will need to launch a rural mass marketing campaign” (Interview, Local Agriculture Product Supplier, December 2017).

Most of the study villages were connected to a highway by rural gravel roads. Nearly half of the households were linked to a vegetable collection center and dairy that sold dairy products. There were no formal centers or markets for cereal crops and livestock. The key informants revealed the need for a profitable and expensive private sector supply chain (made up of manufacturers, distributors, agri-input dealers, and produce marketers) to produce, distribute, and sell affordable service packages and to profitably sell farm produce. As a political leader commented:

> “In our area, market access is weak for all kinds of production. To addresses this problem, a key intervention is the establishment of locally managed market facilities that link to traders and farmers. It is important to ensure that farmers gain access to information on market demand, price, and production. Development of local markets may overcome the uncertainty of sales and maximize income and

> profits from crops and livestock" [Interview, Political Leader, January 2018].

In summary, more accessible and competitive input and output markets would enable rural people to find their own way to agricultural production and provide more choices and opportunities. It was also recommended that the GoN develop livestock markets, well-equipped collection centers, and storage facilities in partnership with the private sector to improve the efficiency of the agricultural market [Interview, Local NGO, July 2018].

2.4.4 Use of Improved Agricultural Technologies and Practices

Traditional farming is widely practiced in the research area, which consists of indigenous production practices, conventional tools, and weather dependent seasonal crops. Local experts suggest that farmers may gain high yields if they use improved production practices and technologies. Some of these improved practices and technologies include crop selection and planning, nursery preparation, crop production and management, production technologies, post-harvest techniques, use of micro-irrigation technologies, and production and marketing trainings and services. These technologies and services, when combined together, were found to enable households to increase their income by NRP 44,500 (USD $445) per year from small-scale productive activities (excluding incomes from cereal crops), which is a significant income for a rural family [42]. In order for farmers to take advantage of improved technologies, the government should subsidize the needed technologies for lower-income segments of the population. Put simply, subsistence farmers need subsidies [101]. As a female farmer commented:

> "When I used a plastic house and hybrid seed, I become able to grow off-season vegetables. I also used drip irrigation to irrigate the vegetables. My vegetable farm has become successful. I earn more than NRP 100,000 [USD $900] per

year. My husband has returned home last year who was working overseas. The increased income is the reason why he returned home" [Interview, Female Farmer, December 2017].

Local NGOs working in the region argued that effective crop and livestock insurance is vital to motivate and engage rural farmers in agricultural production. Farmers face a series of challenges in developing and promoting crop and livestock insurance products and services that are suited for smallholder farmers [79]. Many of the farmers interviewed also lacked knowledge and awareness of insurance. Some of the cooperative and microfinance NGOs offer crop and livestock insurance services. However, these services are costly and narrow and are not receptive to the needs of farmers [Interview, Local NGO Official, June 2018]. Many of the insurers have a limited service network in rural areas. Therefore, insurance services need to be expanded and brought in line with international standards [79].

The NGOs and experts interviewed also highlighted the need for time series data on crop production and yields. Such data can help determine the appropriate crop choice for different micro climatic zones. These data can also inform the development of appropriate crop insurance products and services. In addition, necessary incentives such as promotion grants, awards, and revolving funds could play a key role in increasing the current level of agricultural production [Interview, Political Leader, June 2018].

2.4.5 Risk Reduction Measures

Most of the Nepali hills are characterized by fragility, marginality, and inaccessibility, making them vulnerable to the impacts of landslides, flooding, and climate change [4, 130]. Recent climate projections suggest that Nepal's agriculture and ecosystems will face many challenges over the coming decades due to climate-related variability such as water scarcity, declining yields, and outbreaks of pests and diseases [7]. A majority of local informants (57%) reported that they have experienced changes in rainfall patterns (such as less frequent, but more intense rainfall events and unpredictable and erratic rainfall patterns), increased frequency and intensity of floods, and longer dry spells and drought events. Several informant farmers reported a fear of production risks due to these extreme climatic factors.

> "In 2015, we had a big landslide that swept away several homes and destroyed crops. Hailstorms destroy crops every year. We never know when the crops will be destroyed. There is no guarantee that we will be able to harvest the crops and hard work evaporates instantly. This is a big frustration for a producer like me and many others hesitate to extend their agriculture because of these risks" [Interview, Lead Farmer, January 2018].

In addition, there is a sharply growing trend that farmers, especially the vegetable producers, depend on pesticides to grow their crops [97]. More than one-third of the farmers interviewed reported that the incidence of pesticide resistant insects is becoming more intense and alarming. Further, some of the experts interviewed linked this problem to the haphazard use of pesticides and the changing climate that create a favorable environment for these pest and insects.

Poor and marginalized households are more vulnerable than those with larger plots of land and a high household income [79]. Further, marginalized communities have fewer options to deal with environmental shocks and stresses. Therefore, opportunities to integrate and link adaptation interventions and mechanisms to the development planning processes at different levels are critically important. To deal with the impacts of disasters/risks, experts proposed adaptation activities that focus on resistant crop varieties, improved governance, and capacity building at the local level. Government and NGOs should train and encourage farmers to promote crops that are resistant to droughts and floods (Interview, Lead Farmer, December 2017). The experts interviewed suggested the promotion of adaptation strategies for the most vulnerable communities that center around improving access to agricultural technologies and services.

2.4.6 High-Value Crops (HVC) and Livestock—An Opportunity for Smallholder Farmers

High-value crops can provide higher income per unit of available water and land [Interview, Agriculture Expert, December 2017]. HVC can generally result in three or more times the net income obtained from traditional cereal crops [Interview, NGO Official, January 2018]. There was a common view among the key informants that the off-season production of HVCs generates a higher income than can be obtained from the main growing season.

> "I grow vegetables in a 500 sq. plot and keep six livestock (one cow, three goats, and two oxen). We have also some chickens. I sell surplus vegetables in the local market. I also sell some milk, goats, and chickens. They have been closely aligned with my family as an important source of income and livelihood. I want to produce vegetables in larger scale and keep more livestock, but I lack money and labor" [Interview, Farmer, June 2018].

HVC was also considered to be compatible with low technology greenhouses and locally appropriate and efficient micro-irrigation techniques (MIT) [Interview, NGO Official, December 2017]. According to some of the experts interviewed, these greenhouses enabled off-season vegetable production by creating heat in the winter. Those farmers using greenhouses to grow HVC, also described them as an effective way to protect against monsoon rain and hailstorms. Further, the combination of greenhouses with MIT technologies were found to be effective for HVC production.

According to the agriculture experts interviewed, variations in altitude are advantageous in growing high-value crops, not only for the main season crops but also for off-season production. When selecting a particular HVC for a particular site, a number of factors need to be considered: the location of the site; accessibility to markets; the local farmers' knowledge and experience; etc. (FGD, Syangja, January 2018). The FGDs also revealed that HVC are appropriate for smallholder and marginalized farmers, as these crops require less capital investment and provide a quick return to meet their more immediate needs. Reliable access to local markets with a cold storage facility would help attract farmers to HVC production.

The key informant interviews highlighted the potential for livestock, especially for goats and milk in the region. It is difficult to sustain rural livelihoods without keeping livestock (Interview, Community Leader, December 2017). More than one-fifth of the informants favored livestock production due to the higher financial return and high nutritional value. However, access to health services for livestock, a lack of proper breeding, poor animal husbandry practices, and rampant animal disease remain major challenges for farmers. Nepal's poor market access and road conditions create a challenge to deliver livestock feed to rural areas, which means farmers have to rely on local fodder products to feed their animals. Such isolation can put livestock holders at risk in rural areas [51]. Households need improved livestock sheds, available nutritious fodder, forage management knowledge, veterinary services, and improved livestock keeping and management practices to improve livestock productivity.

Utilizing Commercial Pocket Approach (CPA): A Model for the Commercialization of HVCs

With limited private sector investment and overstretched government extension services, Nepali farmers have suffered from low productivity and poor markets. As discussed in previous sections, agricultural production is primarily for subsistence and only a small portion of the crops grown are sold despite a strong demand. To overcome these challenges, International Development Enterprises (iDE Nepal), an International NGO, along with partner NGOs have promoted the commercial pocket approach (CPA) [6]. The CPA is a defined pocket area that is established to mobilize smallholder farmers to produce a marketable volume of HVC, sufficient to justify the creation of a community-managed collection center [26]. In addition, the private sector is encouraged to establish local extension agents (known as community business facilitators) to market essential inputs, equipment, and services through door-to-door services in coordination with production groups. The CPA approach envisions that a production group, i.e., farmers in the pocket area, is formed in every village within the collection center service area. The farmer groups elect their members to form a marketing and planning committee (MPC). The MPC then establishes a collection center to accumulate farmer produce for traders/byers. An MPC serves multiple functions such as organizing collection centers, mobilizing necessary agricultural inputs and extension services, developing linkages with the government and private sector to make their agricultural services available to farmers (e.g., trainings, access to credit, etc.), and advocating for needed rural policies and infrastructure such as water supply, agricultural roads, and collection centers, among others. The MPCs are expected to register and function as cooperatives.

When the volume of crops at a collection center increases, support services such as technical assistance, input supplies, marketing services, and education and leadership trainings are expanded for the producers. As a result of this growth, communities are likely to support the establishment of more rural collection centers and the marketing of agricultural products may extend from local markets to regional markets and beyond. One key informant described the CPA model as follows: "The key principle of the CPA approach is to focus smallholder vegetable production in a defined area that will create a demand for a range of input and marketing support services with an optional goal of engaging farmers in improved production activities. It enables the farmers to learn the principles of business enterprise such as records keeping, preparing a business plan, and production and marketing planning. Production groups also learn the principles of collective marketing and experience the institutional development of the cooperative/collection center they are associated with. The role of external agencies (i.e., NGOs) will be reduced when production groups within the commercial pocket become technically competent" [Interview, INGO Official, June 2018].

2.5 The Relationships Between the Socio-Economic Characteristics of Households and Agricultural Incomes

Table 2.1 shows how different household-level socio-economic factors and production practices are associated with the gross income from agricultural production (including livestock). Households that received an income from a government job or remittances report agriculture being a laborious task. As a result, they obtain a low level of income from agriculture. One-third of households reported being less motivated to pursue agriculture due to the required hard work. Interestingly, households with an income from government jobs and other secured sources of income were less engaged in farming and viewed agriculture as a difficult profession. While a majority of the households were engaged in improved crop production due to an external project, less than one-third of the households abandoned these practices after the project support had ended. More than half of the surveyed households used improved seeds, two-fifths sold crops in a formal market, and nearly one-quarter of the households applied Integrated Pest Management (IMP) practices or used low-technology greenhouses. More than one-third of the households used improved technologies and practices. Some of these households developed additional sources of water to irrigate their plots. Table 2.1 shows that households making a high income from agriculture used improved seeds (high yielding varieties), sold crops in local formal markets, and used non-conventional irrigation technologies (drip, sprinklers, manual water sprayers, etc.), surface or piped irrigation, and improved livestock production technologies.

While the households using improved technologies and practices sell crops in formal markets (e.g., collection centers, hat-bazar, etc.), the households growing traditional crops often sell to nearby hotels or informal markets. The use of agricultural technology and easy access to markets were considered as critical factors in commercial production. In addition, access to production, marketing, and post-harvest training enabled farmers to improve agricultural production and income. Households experiencing higher economic benefits from agriculture were found to engage in more production activities when compared with farmers that did not experience such financial gains.

Interestingly, more than one half (51%) of the households with women (aged between 15-50 years old) who were actively engaged in production activities were earning a high level of agricultural income (Table 2.1). These households were largely engaged in small-scale production activities such as HVC and livestock production and marketing and selling of dairy products. These production activities accounted for more than three-quarters of their total agricultural income. More than one half (55%) of the women interviewed also reported that outmigration of their husbands increased their role both in the household and with regards to small-scale agricultural activities. Notably, a majority of the women experiencing this situation also received a remittance and earned a high level of agricultural income. Women's increasing involvement in agricultural production groups and engagement in trainings were also found to increase their knowledge of, and capacity to engage in, small-scale agricultural production.

Table 2.1: Characteristics of Production Households

HHs Characteristics	**Gross Income (Cereal Crops, HVCs and Livestock)**		
	% of HHs with Ag.Income (>$801/year)	% of HHs with Ag.Income ($401–800/year)	% of HHs with Ag.Income (<$400/Year)
Women (aged 15-50) actively engaged in a HH's Ag. production activities (n = 99)	51	20	29
HH has reliable access to irrigation (n = 115)	50	26	24
Agriculture is the main HH occupation (n = 105)	47	30	23
HH receives production support from agencies (n = 94)	45	30	25
HH sells produce in a formal market (n = 85)	42	26	32
HH uses improved production technologies (n = 109)	41	34	25
HH member has received production/skills training (n = 121)	41	35	24
HH uses improved seeds (n = 117)	40	30	30
Small business provides an alternative off-farm sources of income (n = 37)	32	24	44
Main income source government job (n = 19)	29	25	46
Main income source—wage (n = 34)	23	31	46
HHs earning remittances (n = 109)	23	37	40

2.6 Recommendations

Based on the findings of this research, the following recommendations are proposed for the GoN and organizations working with rural farmers in the middle hills of Nepal to commercialize smallholder farming.

- **Overcoming the constraints to commercialization:** to increase a household's agricultural production skills and ability, the government and funding agencies should address the constraints to commercialization revealed in this study. For example, farmers holding less than 0.5 ha of land need direct support in the form of subsidies, tools and techniques, and capacity development. In contrast, farmers who are already undertaking commercial activities could benefit from business development training and other knowledge related to important areas such as health and environmental protection (e.g., the appropriate use of insecticides and pesticides).

- **Providing insurance services and loans:** users were found to fear risks such as production failures, pest infestations, low crop yields, limited availability of livestock fodder and space for grazing, and uncertainty of sales after production. These factors have discouraged smallholder farmers from undertaking commercial agricultural activities [42]. Therefore, any support strategy should address these challenges, including the provision of effective crop and livestock insurance services and agricultural loans to small commercial farmers.

- **Enhancing the role of the private sector:** in addition to the existing role of the private sector in providing agriculture inputs, the government should work to increase the role of the private sector in providing technical knowledge, business skills, and agro-enterprise development. Policies should recognize the role of private sectors as service providers. The sustained involvement of the private sector is critical to making agricultural services more effective.

- **Addressing outmigration:** labor shortages due to male outmigration and a lack of youth interest in agriculture have become a serious concern in the agriculture sector. It is important to engage returned youth (from outside of the country) in agricultural production by making agriculture more profitable and attractive. This concern should be addressed by government policies and programs.

- **Aligning agricultural programs with local micro-climate and farmer's needs:** the lack of agricultural programs that align with local micro-climates and farmer's needs is a factor constraining the advancement of the agriculture sector. Research is needed to understand the appropriate crops, production, and extension strategy for different micro-climatic zones, even within the middle hill regions.

- **Strengthening agricultural policies, projects, and programs:** the weak implementation of agricultural policies and short-term focus of agricultural policies and programs present barriers to agricultural development. Therefore, government and international development agencies should focus on implementing appropriate policies and long-term and sustainable agricultural development projects and programs. These efforts should also focus on enhancing effective governance from the federal to local level.

- **Supporting and protecting local production:** while agricultural production is highly commercialized in Nepal's neighboring countries (i.e., India and China), the subsistence level of agricultural production in Nepal increases production costs, making the farmers and customers dependent on imported foods and vegetables. Therefore, Nepali agricultural products are unable to compete with products from neighboring countries. Addressing this challenge will require a combination of a number of measures including low-cost production support to farmers and policy reforms and regulations that promote local production.

- **Valuing agriculture:** this research found that agriculture is considered a low-value profession among the public. Therefore, it is important to educate people on the value of farming and its role in growing the rural economy. The government could include this information in school and university education.

- **Mainstreaming the commercial pocket approach:** since the commercial pocket approach has been found to be an effective way to commercialize smallholder agriculture, the GoN and other organizations working in the agriculture sector should consider mainstreaming the approach in their projects and programs.

- **Considering household characteristics in agricultural development planning:** to increase household income and impact livelihoods, the GoN and other agriculture development agencies should consider household socio-economic characteristics (see Table 2.1) when developing their policies and programs.

2.7 Conclusions

The major finding from this study is that there is potential to commercialize smallholder farming in the middle hills of Nepal. To realize this potential, the following general technical approaches and practices are recommended: provide smallholders with adequate access to year-round irrigation, encourage the use of improve production technologies and practices, improve access to rural markets, and improve production skills. Small commercial farmers also require business planning skills to make their production viable. These strategies would expand the participation of subsistence and risk-adverse producers in commercial agricultural production. A unique opportunity is the commercialization of high-value crops, especially for smallholder farmers. High-value crops, which offer higher income per unit of land, are particularly important in areas of water scarcity. In general, the findings and recommendations advanced in this research align with the Government of Nepal's agricultural development strategies (2015–2035). If implemented, the recommendations hold the potential to considerably improve the livelihoods of marginal farmers.

Chapter 3

Does Rural Water System Design Matter? A Study of Productive Use of Water in Rural Nepal *

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3.1 Introduction

Access to water in rural areas has been rapidly improving over the past few years. In early 2000, International Development Enterprises (iDE) and its local partners pioneered multiple-use water systems in Nepal with the aim of providing water for domestic use and the irrigation of high-value vegetables [69, 134]. In view of the current practice of rural water services development in Nepal, RWS is generally classified as "by design SUS" or "by design MUS" [105]. The SUS design provides 45 litres per capita per day (LPCD) for domestic use. The MUS design provides year-round water based on the standard of 45 LPCD for domestic use and 400–600 litres/household/day (LPD) for vegetables grown near the homestead [40, 66]. SUS and MUS designs have many structural similarities; they divert water from a spring intake at an elevated location, typically a forested area, that is gravity-fed to a storage tank located above the community being served. Water is then piped to community taps or to individual households. Beyond water infrastructure, a core component of MUS is community engagement in learning to use micro-irrigation technologies, the selection of appropriate cultivation practices, and training on strategies to sell water-based products in local markets [40, 69].

Since early 2005, organisations such as the International Water Management Institute (IWMI), Winrock International (WI), the IRC (International Water Supply and Sanitation Centre), the Challenge Program on Water and Food (CPWF), and iDE, as well as academics, have undertaken research to understand the impact of MUS on water system functionality and sustainability [25, 69, 84, 107, 122, 124]. Similarly, several studies have been conducted on the impacts of SUS [14, 72, 129, 131] and MUS [12, 37, 40, 69, 92]. While this research has explored the extent of productive activities undertaken in rural communities and the factors and conditions that enable this activity, research focusing on communities in the rural hills of Nepal is limited. Those studies that do exist include [12, 25, 69, 93, 124].

Studies of rural water systems in developing countries have identified many factors that advance the productive use of water. For example, households with high water service levels have been found to generate more income than households with poor water access [95, 124], indicating that productive income is associated with the amount of water used. A global MUS assessment conducted by Renwick et al.[95] in Rural South Asia and sub-Saharan Africa found that each additional litre of water consumption for productive activities generated approximately \$0.5 to \$1.00 of income per capita per year. Therefore, improved access to water at the household level—e.g., improved water quantity and quality and reduced distances to the water sources [50, 58, 108]—can promote productive activities that improve livelihoods. In contrast, unreliable access to water discourages water-based activity.

The extent of productive water use and the associated income are also affected by several other factors, including: market access [87]; the nature and intensity of crop production, climatic and soil conditions, and commodity prices [40, 95]; access to inputs such as seeds, fertilisers, etc., and agricultural support services [40]; available land [25]; available capital [29]; and household knowledge in agricultural production [83], affordable agricultural production technologies, and access to agricultural information [87]. Productive activities in and around homesteads are also typically undertaken by women [39, 104] and provide households with an opportunity for livelihood diversification [118].

In Kenya, high productive activity was found to correlate with greater household wealth, a greater percentage of households with at least one literate member, and shorter distances to the nearest paved road [114]. In Senegal, improved water systems along with an effective institutional structure and capable water user committees were found to be necessary for the promotion of productive activities and income growth [73]. Household engagement in productive activities using water has also been found to be correlated with better technical performance of rural water supply systems [49].

The wide range of factors discussed above included technical, financial, and managerial aspects that can promote the productive use of water. However, this literature has not adequately reported on the factors that influence household income derived from productive activities in rural communities in the middle hills of Nepal.

This chapter focuses on understanding the factors that influence household income derived from productive activities in ten rural communities within the middle hills of Nepal. More specifically, the research focuses on answering the following questions: (a) What is the extent of water-related productive activities in rural Nepali households supported by SUS vs. MUS? and (b) What factors enable rural households in Nepal to engage in high levels of productive activity? This research should be of particular interest to the government of Nepal, which has a growing interest in water-based productive income through its recently launched five-year plan "Roadmap to Prosperity" that promotes the commercialization of productive activities to enhance the Nepali rural economy.

The following section presents the research methodology and provides a description of the study area and the data collection and analysis techniques used. The results section presents and describes the findings from the analysis, which is organised into sections on the household characteristics, the extent of productive activities supported by communities with MUS vs. SUS, and the factors that are associated with high levels of productive activity at the household level. The final two sections discuss the findings and conclude the chapter.

3.2 Methods

3.2.1 Study Area

The research site is located in three wards (Annapurna-6, Waling-5, and Bagnaskali-1) of Kaski, Syangja, and Palpa districts in the middle hills region of Nepal as depicted in Figure 3.1. Kaski and Syangja are located in Gandaki Province and Palpa in Lumbini Province. The wards are the lowest administrative-political body of Palikas (rural municipalities and municipalities). Several wards make a Palika. About 60% of the population in Nepal depends on subsistence farming [4]. Rural families typically grow rice, maize, and millet on terraced fields in the region [69]. The lands are often fragmented [30], and commercial farming is very limited in the region [59]. Most hill farmers depend on spring-fed piped systems for domestic use and seasonal rains for crops [38, 105]. Springs are the reliable and preferred source of domestic water for communities in the middle hills of Nepal because the cost of lifting water is often expensive, and groundwater is not economically accessible [38]. Since spring sources are being increasingly tapped and gradually depleted, their sustained use is becoming a challenge [39]. The depletion of spring sources is often due to a variety of biophysical (e.g., hydro-meteorological and land use changes) and social reasons (e.g., population growth, deforestation, haphazard construction activities) in the region [88].

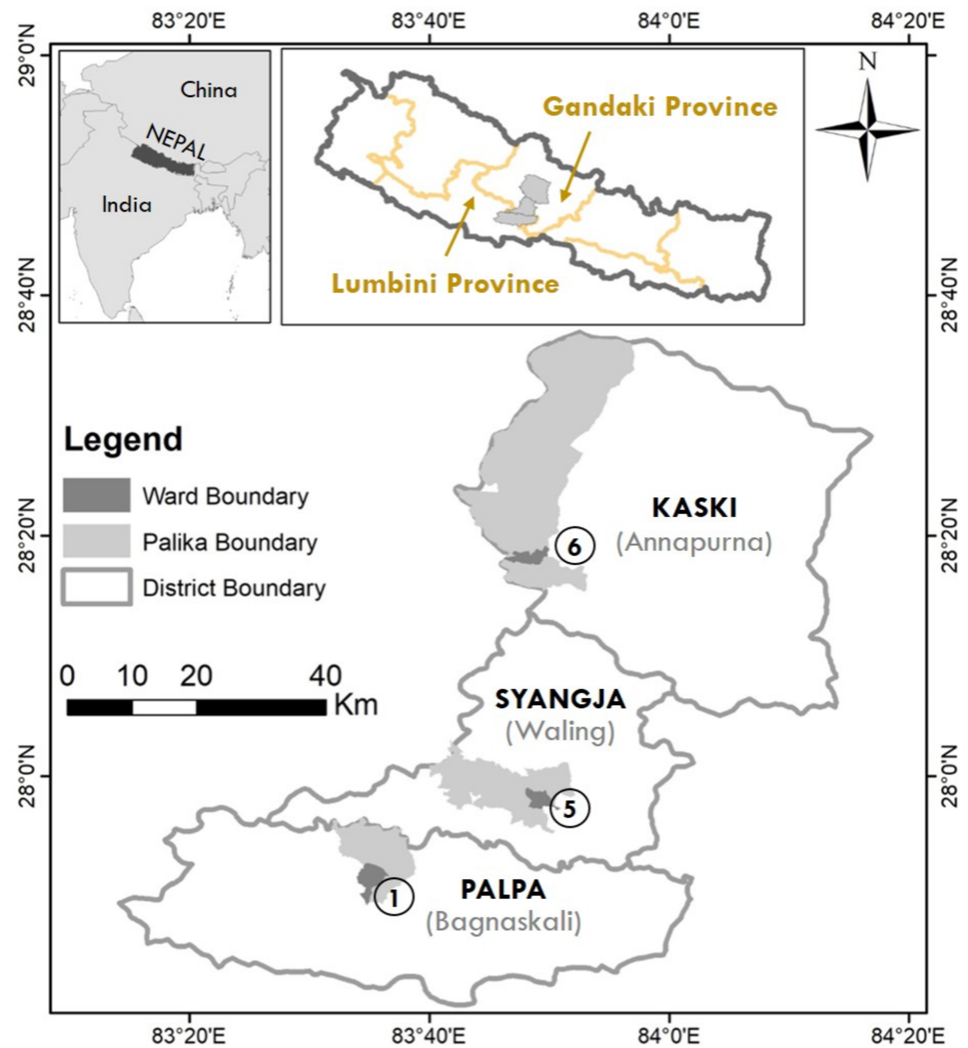


Figure 3.1: Study Area

3.2.2 Sampling Strategy and Processes

The fieldwork was facilitated by iDE, an organisation promoting MUS in Nepal. Communities and households are the focus of analysis for this study, and their selection followed a three-stage process developed by the research team. First, districts and rural municipalities within a large geographical area in the middle hills region were identified that contained both types of rural water supply systems: "by-design SUS" and "by-design MUS." Most districts within the middle hills have SUS developments and many have not experienced MUS development. By reviewing iDE's MUS data, three mid-hill districts (Syangja, Kaski, and Palpa) were identified as having 105 MUS developments (out of the 450 MUS total). SUS developments were widely available in these districts. Therefore, these three districts provided an ideal setting for the study where both MUS and SUS are used by communities.

The second stage of the selection process identified the wards within each district that contained the largest number of water systems with a sufficient number of systems that have been operational for several years. Purposive sampling utilizing a separate list of water systems prepared by the researchers in consultation with local NGOs, authorities, and community leaders was used to identify the following wards most appropriate for the study: Annapurna-6 of Kaski District, Waling-5 of Syangja District, and Bagnaskali-1 of Palpa District.

The third stage consisted of selecting the communities within these wards for an in-depth study of their productive activity. A rapid assessment was conducted of all the community water systems (20 MUS and 40 SUS) that existed within the three wards. This assessment led to the development of water system selection criteria and created the sample frame for the research. Water systems were excluded from the sample if they were serving fewer than 10 households, were shared by two or more villages, were partial systems (lacking tanks, taps, etc.), or were jointly serving users with a parallel system. These criteria helped exclude the less representative water systems. The sample frame, together with the criteria, informed the selection of 10 systems (5 MUS and 5 SUS) for an in-depth study. Of the ten systems, there were 3 MUS and 3 SUS from Annapurna-6 of Kaski District, 1 MUS and 1 SUS from Waling-5 of Syangja District, and 1 MUS and 1 SUS from Bagnaskali-1 of Palpa District. Each water system served a community averaging 21 households for a total of 213 households.

3.2.3 Data Collection

The fieldwork was conducted between 2017 and 2018. A total of 202 household surveys (from a sample population of 213) and ten focus group interviews were completed. The 11 households that were not interviewed had either migrated elsewhere or could not be reached at their home and were excluded from the analysis. The household survey included a structured questionnaire to assess a household's water-based productive activities, the related incomes, and its water consumption and to collect data to examine the socio-economic and geographic characteristics of productive activities in the region. Given the primary role of women in most household activities, including water collection, they were given priority for the interviews. In cases where two family members participated in an interview, only the participant with the greatest knowledge of their water system was listed on the survey sheet.

A focus group discussion among water users in each of the target communities was conducted to gain an understanding of user perceptions regarding productive activities, water-based incomes, and any associated interrelationships. These discussions were designed to complement the quantitative data received from the household survey. The focus group discussion was designed to be interactive. Each focus group consisted of 7–12 men and women selected from upper, middle, and lower income and geographical sections of the community. At the start of a focus group, the lead researcher explained the overall purpose of the study and read the questions to be discussed. Time was given to discuss each question while key discussion points were noted. The researchers then summarized the recorded discussion points and facilitated a discussion.

3.2.4 Classification of Households for Estimating the Determinants of Productive Activity

Table 3.1 shows that the MUS and SUS systems were providing water for uses beyond their designed uses. For example, 89% of SUS users, despite their systems being designed for domestic use only, use water for various productive activities including the irrigation of vegetables on their Bari lands. Similarly, 85% of the MUS users, despite their systems being designed for domestic use and vegetable production, also used water for livestock, dairy, Rakshi, and biogas.

Table 3.1: Distribution of Water System and Household Use within and beyond the Intended Design Purposes

Type of Rural Water System	**System/HH**	**Domestic Use Only**	**Domestic and Veg. Only**	**Domestic,Veg. and Other Prod. Activities**
MUS	System(n = 5)	0%	0%	100%
	Household (n = 109)	4%	12%	84%
SUS	System (n = 5)	0%	0%	100%
	Household (n = 90)	7%	4%	89%

Figure 3.2 supports the finding that there is a large continuum of productive activities for both MUS and SUS systems. These findings suggest that a distinction of high vs. low productive activity should examine factors other than the design of MUS vs. SUS when exploring the determinants of productive activities. Therefore, a system-level analysis of MUS (by design) and SUS (by design) is unlikely to reveal the factors influencing productive

activity. Thus, this research also undertook a household-level analysis using the "household clustering method" discussed below.

According to Hall et al.[49], the following two variables offer an appropriate measure of household-level productive activity:

- **Water Consumption:** Median volume of water, litres per household per day (LPD), used by households for productive activities from the water system; and
- **Productive Income:** Median household annual income (Nepali Rupee-NPR) from productive activities that use water from the water system.

Using the programming language R, four levels of households were identified and classified based on water consumption and income derived from productive activities. Figure 3.2 divides the surveyed households into the following four classifications (dependent variable):

- **High group:** Households who use a high quantity of water and generate a high income are defined as the high group, in which productive income > median income; LPD > median LPD.
- **Low group:** Households who use a low quantity of water and generate a low income are defined as the low group, in which productive income < median income; LPD < median LPD.
- **Efficient group:** Households who use a low quantity of water and generate a high income are defined as the efficient group, in which productive income > median income; LPD < median LPD.
- **Inefficient group:** Households who use a high quantity of water and generate a low income are defined as the inefficient group, in which productive income < median

income, LPD > median LPD.

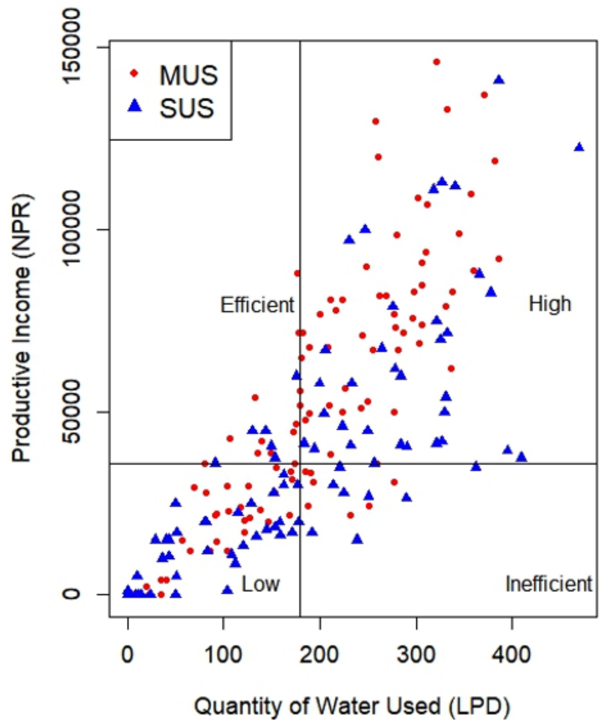


Figure 3.2: Household Water Consumption and Productive Income

Figure 3.2 shows that the high and low groups have a comparable number of households, 42% and 43%, respectively. The remaining 15% of households were evenly split between the efficient (7.5%) and inefficient (7.5%) groups. Table 3.2 provides descriptive statistics for the four groups. The t-test for high and low groups shows that water consumption and productive income are statistically significant ($p < 0.001$).

While the above classification analysis clearly shows a direct relationship between water consumption and income for households engaged in productive activities, it does not reveal the extent to which other factors contribute to that relationship. To identify the effects of these factors, a multinomial logistic regression model was developed to capture the relationship between group identity (as defined by the four groups above) and socio-economic and geographical characteristics. This predictive model allows the identification of the effects of

Table 3.2: Descriptive Statistics for Four Levels (Low-L, High-H, Efficient-E, and Inefficient-I) of Households

Varibale	**L**			**H**			**E**			**I**			**T-Test H vs L**
Varibale Name	N	Med	SD	N	Med	SD	N	Med	SD	N	Med	SD	*p*-value
HH Productive Income (USD/year)	86	150	117	85	720	271	15	440	144	15	280	62	<0.001
Water Used/ Consumption (LPD/HH)	86	74	62	85	279	64	15	153	22	15	225	48	<0.001

these factors at the household level in relation to a household's classification.

3.2.5 Independent Variables

Fifteen variables were included in the analysis that covered a wide range of household-level socio-economic and geographical characteristics (see Table 3.3).

Table 3.3: List of Independent Variables

Variable	**Question/Description**
Government job	Are one or more family members employed in a government job? Yes = 1, No = 0
Labour	Are one or more family members engaged in unskilled labour for cash income? Yes = 1, No = 0
Pension	Does anyone in the HH receive an income from a government pension or private source? Yes = 1, No = 0
Remittance	Do one or more members of the family receive a remittance? Yes = 1, No = 0

Variable	Question/Description
Wealth status	Does the respondent consider themselves? 1 = wealthy when compared to others in the community? 2 = as having the same wealth as others in the community? 3 = poor when compared to others in the community?
Ag. as a primary occupation of HH	Does the HH practice agriculture as their major occupation? Yes = 1, No = 0
External support in productive activities	Is the HH currently receiving any external support from an implementing agency or other organisation outside the community related to productive activities? Yes = 1, No = 0
Motivation in prod. activities	Did the HH respondent state that s/he was motivated to engage in productive activities? Yes = 1, No = 0
Prod. technologies	Did the HH use productive technologies (such as micro-irrigation, low tech greenhouses, improved livestock sheds and management, etc.) for at least two major productive activities— e.g., growing vegetables and raising livestock? Yes = 1, No = 0
Prod. training	Did anyone in the HH receive training related to water-based productive activities (such as high-value vegetable production, production of off-seasonal crops, livestock production and management, marketing of produce, etc.) during, before, or after the implementation of the project? Yes = 1, No = 0
Locality	In which region is the household located? 1 = Kaksi (Annapurna-6) 2 = Syangja (Waling-5)

Variable	Question/Description
	3 = Palpa (Bagnaskali-1)
Ethnicity	What is the caste group of the household? 1 = Upper, 2 = Janajati, 3 = Dalit
Availability of water for year-round productive use	Does the HH have access to water for year-round productive activities? Yes = 1, No = 0
Non-educated persons in the HH	What is the total number of persons with no formal education in the HH? (Numerical response)
Tap ownership	Do the households use a public or private tap? 1 = Private tap, 0 = Public tap

Multinomial logistic regression (MLR), a widely accepted research tool used in the rural water supply literature [55, 65, 102], was used to estimate the ratio of the probability of choosing a response category for each independent variable over the probability of choosing the baseline category. The response category in this work has four levels (low, high, efficient, and inefficient), with the low group being the baseline category (reference level). Group classification is shown in Figure 3.2 while Table 3.3 lists the independent variables. The MLR regression was chosen for two primary reasons. First, it is an appropriate model when the dependent variable is categorical and needs to be classified in two or more levels [33]. Second, it offers an effective way to test whether each independent variable has a probability of belonging in a particular group compared to the reference group [112]. Therefore, it shows the degree to which each group differs from the reference level and tells us the effect that each independent variable has on this classification and the effect size of this difference (relative to the reference group). Importantly, the model also allows us to identify which variables are statistically significant for defining the difference between the response and reference groups.

$$ln\left[\frac{p(Y)}{1-p(Y)}\right] = \beta_0 + \beta_i X_i + ... + \beta_n X_n \tag{3.1}$$

Where, p = probability of outcome/response, (Y)/1-p(Y) = odds of the outcome/response, β_0 = intercept (constant), β_n = coefficients for the n^{th} independent variable, Xn = nth predictor (independent) variable which can be categorical or continuous, and Y is a categorical dependent variable. Each regression coefficient represents the change in Y relative to a one-unit change in the respective independent variable (X). The data were analysed with the programming language "R". Statistics (z- stat and p-value) for the model, and the model coefficients were examined, and the statistical significance of each independent variable was assessed as a predictor of the difference in classification between high and low groups.

3.3 Results

3.3.1 Household Characteristics

The ten communities selected for the study supply water to 213 households with over 1,000 people within the three wards. The mean household size in the study area was 5.07 people per household. More than half the working-age male population (15–50 years of age) have migrated out of the communities to work in the Middle East and elsewhere. This age group accounts for more than 55 percent of the total sample population. The median age of all respondents is 48 years. Landholdings, referred to as 'khet' and 'bari' lands, average 0.5 hectares per household. Khet refers to cultivated land outside the community that relies on rainwater for irrigation whereas bari lands are smaller plots near the household that are used for cultivation, livestock, and other uses that rely on delivered water, especially during the dry season. We estimate that 85 percent of households own bari land and 67 percent of households own khet land, 24 percent of which is rented. Households are differentiated by a caste system that is no longer legally recognized: 53 percent of the households are upper caste (highest hierarchy of social group within the Hindu caste system/traditional system that includes Brahmin and Chhetri), 24% Dalits (lowest hierarchy of social group within the Hindu caste system), and 23% Janajatis (an ethnic group or tribe with traditional customs, distinct cultural identity, and their own language). The vast majority of families (97.5%) own their home, typically made of earth plastered walls (76%), an earth floor (79%), and tin roof (65%). Around one-fifth of respondents had no formal education. Eighty-five percent of the respondents reported owning a television, 18 percent a motorcycle, 98 percent a mobile phone, and 13 percent a refrigerator, while 86 percent used cooking gas and 15 percent used bio-gas. The mean per capita income of households in the study communities was $863 USD, which is less than the national average of $998 USD as of the fiscal year 2017/2018 [50].

Remittance from men working outside the country accounted for 41 percent of total income while jobs (22%), agriculture (15%), business (10%), pension (11%), and government allowances (1%) accounted for the remainder. Most households (79%) had livestock with an average of 5.8 animals per household. It is notable that only a fraction (6.2%) of bari lands are irrigated from the primary water system. In addition to piped water, 68.5 percent of households utilized a secondary water source for their needs. Almost all (99%) of households had private latrines, but fewer than 50 percent were water-base toilet units. Households have limited access to year-round secondary water sources within their residences. They rely on the primary water sources for activities around the homestead, and rainfall serves as a complementary source for irrigating vegetables and crops in and around the homestead during the four-month monsoon season (June to August).

3.3.2 Extent of Household Participation in Water-Based Productive Activities

Figure 3.3 shows the extent of productive activities for households located in MUS and SUS communities. The vast majority of households (MUS 96% and SUS 93%) were engaged in one or more productive activities and most of them (MUS 89% and SUS 85%) earned some income from these activities, which accounted for around 65% of the total agricultural income (from all types of crop and livestock). Similarly, more than three-quarters of the households (MUS 86% and SUS 80%) earned a regular income from productive activities. Thus, an equivalent proportion of MUS and SUS households engage in productive activities regardless of their system design. Of the 110 MUS households and 92 SUS households that were surveyed, nearly all (MUS 100% and SUS 97%) reported that they were dependent on their primary water system to undertake at least one productive activity. The remaining 3% of SUS households used a secondary water source for productive activity.

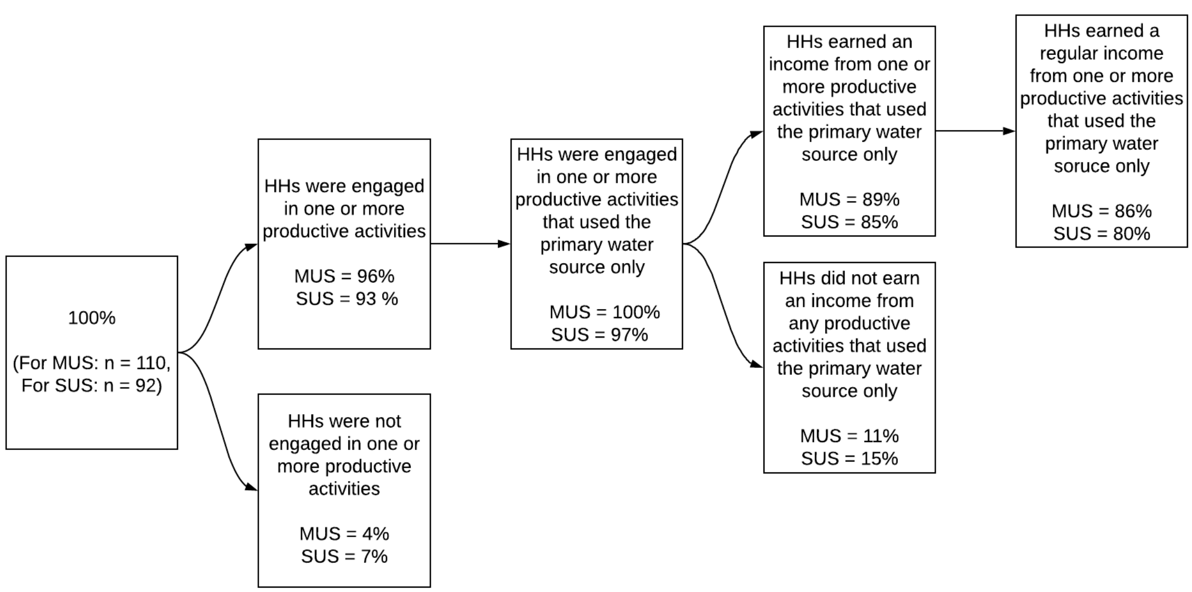


Figure 3.3: Extent of Productive Activity of MUS and SUS

More than half (MUS 56% and SUS 57%) of the surveyed households were using public taps for one or more productive activities, and the rest used a private tap. More than half of the households used a hosepipe to irrigate their bari lands, while one-third used micro-irrigation technology with the reminder (one–sixth) using buckets. Of the one-third of households using micro-irrigation, 37% were MUS and 8% were SUS households. With year-round productive activities, especially vegetable cultivation, rainfall was the primary source of water during the monsoon season, while the piped system served as a supplement to rainwater. Most of the users, either with a public or private tap, used a hosepipe to fill a water trough or small container to water animals.

The research found a wide range of water-dependent activities in the study area including vegetable gardens, horticulture (fruit trees, flower gardens), livestock (cattle, goats, chickens), dairy production, bio-gas, and Rakshi (locally made alcohol) production. A limited amount of work in construction, hotels, and religion was reported. Table 3.4 presents the following five water-based productive sources of income reported by households: vegetables, horticulture, livestock, dairy, and Rakshi. For both MUS and SUS communities, a majority of the households were involved in vegetable production, livestock, and dairy. Vegetable and livestock production were found to be the most practiced productive activity. Rakshi, horticulture, and bio-gas engaged a small percentage of households in MUS and SUS communities.

The annual median household income derived from water-based productive income was $360, which accounts for 9% of total median income ($3810). Around 94% of MUS and 80% of SUS households derived income from vegetable production. A comparison of mean income for vegetable production shows MUS households had nearly double the income of SUS households, $207 and $114, respectively. Whereas the mean income derived from each of the remaining four productive activities is similar for both MUS and SUS households. A com-

Table 3.4: Distribution of Household Participation in Productive Activities

Type of Rural Water System	**Productive Activity**	**% of HHs Participating in Activity**	**% of HHs Earning an Income from Activity**
Multiple-Use Water Systems (MUS)	Vegetables (n = 110)	94	75
	Livestock (n = 109)	80	45
	Dairy (n =109)	50	54
	Rakshi (n = 110)	31	9
	Horticulture (n = 110)	14	11
	Bio-Gas (n = 110)	6	-
Single-Use Water Systems (SUS)	Vegetables (n = 90)	80	46
	Livestock (n = 92)	79	58
	Dairy (n = 92)	53	45
	Rakshi (n = 92)	34	30
	Horticulture (n = 92)	27	20
	Bio-Gas (n = 92)	25	-

parison of mean annual productive incomes of MUS and SUS households was significant ($p > 0.05$). The water consumption for productive activities for MUS and SUS was not significantly different (median water consumption for MUS and SUS were 183 LPD and 166 LPD, respectively) (Table 3.5).

The higher income of MUS households was mainly driven by vegetable production reflecting the planning and support directed to farmers that created an efficient method for growing and marketing vegetables. The engagement of SUS households in vegetable production was influenced by neighbouring communities that had installed MUS water systems. With MUS households more focused on vegetable production, it is interesting to note that the two major activities of livestock and dairy production are slightly higher for SUS households. Nearly one-half (54%) of MUS and less than two-third (58%) of SUS households earned incomes from livestock; for dairy, the difference was 47 percent for MUS and 54 percent for SUS households.

These findings indicate that each one-litre per day (LPD) increase in water consumption in productive activities results in annual increased income of NPR. 248 ($ 2.48)—an increase of

Table 3.5: Descriptive Statistics for MUS and SUS

Varibale	MUS			SUS			T-Test MUS and SUS
Variable Name	N	Median	SD	N	Median	SD	P-Value
HH Prod. Income (USD/year)	110	446	360	92	290	318	<0.05
Water Consumption (LPD/HH)	110	183	105	92	166	121	0.6023

NPR. 295 ($ 2.95) for MUS and NPR. 207 ($ 2.07) for SUS households. These findings mean that households in MUS communities are one-seventh more productive than households in SUS communities. These findings are also consistent with Renwick et al.[95] and show that productive income in the surveyed households was largely associated with the volume of water used for productive activities.

In summary, most households used water for de-facto productive uses no matter what the systems were designed to support. However, this research has not found any evidence that households have compromised their basic domestic uses. Most households were using a mean of 171 LPD (34.2 lpcd) for domestic use, which was less than the designed 45 lpcd. Nonetheless, some households stored water to offset potential shortages due to system breakdowns, overuse by irrigators, or limited supply.

These findings challenge the current approach to rural water provision that views SUS and MUS differently. With this in mind, the following multinomial regression analysis focuses on identifying the key factors that differentiate households located in the high, efficient, and inefficient groups from those in the low group.

3.3.3 Determinants of Productive Activity

The multinomial logistic regression (MLR) analysis predicts the probable influence of independent variables on each of the household categories (the dependent variable). Thus, the model compares the low group against the other three groups (high, efficient, and inefficient) for each of the independent variables.

The following variables were found to be statistically significant predictors (positive) of the distinction between the high and the low groups (see Table 3.6): agriculture as a primary occupation of household ($p < 0.001$), external support in productive activities ($p < 0.05$), motivation to undertake productive activities ($p < 0.05$), the use of productive technology ($p < 0.001$), and water-related productive activity training ($p < 0.05$). The grow a variety of vegetables including tomatoes were the only significant predictors that had a negative effect on productive activities. None of the other variables considered in this study had a significant association (at a 5% confidence level) with the differentiation between the high group and the low group.

Table 3.6: Results of Multinomial Logistic Regression

Independent Variable	**Groups**	**Coefficients**	**Standard Error**	***P*–Value**
Government job	High	−1.9291	1.7648	0.2743
	Efficient	−0.3965	1.9142	0.8359
	Inefficient	−21.0261	0.0000	<0.001
Labour	High	0.1797	1.4275	0.8998
	Efficient	−0.4410	1.6702	0.7917
	Inefficient	−1.8557	1.2913	0.1507
Pension	High	−3.6721	1.5786	<0.05
	Efficient	−18.0673	0.0000	<0.001
	Inefficient	0.7863	1.1758	0.5036
Remittance	High	−0.7550	1.2452	0.5443
	Efficient	0.7307	1.2969	0.5732

Independent Variable	Groups	Coefficients	Standard Error	*P*–Value
	Inefficient	−0.3903	0.9043	0.6660
Wealth same as others	High	−1.2277	1.4491	0.3969
	Efficient	0.0101	1.4417	0.9944
	Inefficient	0.2487	0.8666	0.7742
Poor	High	−3.3077	2.0592	<0.05
	Efficient	−1.5937	2.1009	0.4481
	Inefficient	16.1432	0.0000	<0.001
Agriculture as a primary occupation of household	High	6.0541	1.4005	<0.001
	Efficient	3.0349	1.1189	<0.05
	Inefficient	0.4140	0.9907	0.6760
External support	High	2.8217	1.4022	<0.05
	Efficient	2.0424	1.3364	0.1264
	Inefficient	−0.3469	1.4103	0.8057
Motivation in productive activities	High	4.1844	1.6490	<0.05
	Efficient	2.2860	1.3170	0.0826
	Inefficient	−0.0672	0.7895	0.9322
Productive technologies	High	6.0123	1.9100	<0.001
	Efficient	4.6002	1.9337	<0.05
	Inefficient	3.7293	2.2136	0.0920
Productive training	High	2.8185	1.3993	<0.05
	Efficient	1.1038	1.1549	0.3392
	Inefficient	−0.5649	0.8934	0.5272
Syangja (Waling-5)	High	3.0586	1.9765	0.0509
	Efficient	3.9763	1.9706	<0.05

Independent Variable	Groups	Coefficients	Standard Error	***P*–Value**
	Inefficient	2.6513	1.7461	0.1289
Palpa (Bagnaskali-1)	High	1.7191	2.6421	0.0304
	Efficient	3.0846	2.6959	0.2526
	Inefficient	25.6955	0.7164	<0.001
Janajati	High	−0.3625	1.6714	0.8283
	Efficient	1.5318	1.8597	0.4101
	Inefficient	−23.9599	0.7164	<0.001
Dalit	High	−1.6731	1.5341	0.2754
	Efficient	0.0326	1.5573	0.9833
	Inefficient	2.3456	1.2595	0.0626
Availability of water for year−round productive use	High	1.1966	1.0925	0.2734
	Efficient	1.5094	1.1359	0.1839
	Inefficient	−0.0596	0.7442	0.9361
Non−educated persons in the household	High	0.5534	0.5798	0.3398
	Efficient	0.1668	0.6343	0.7926
	Inefficient	0.8334	0.4368	0.0564
Tap ownership	High	0.7900	1.3144	0.5478
	Efficient	0.0675	1.4161	0.9620
	Inefficient	0.2346	0.9281	0.8005

The MLR model also determines how the independent variables were associated with households in the efficient and inefficient groups when compared with households in the low group. Agriculture as a primary occupation of households ($p < 0.05$) and productive technology ($p < 0.05$) were the significant predictors of the efficient group as differentiated with the low group. Similarly, poor ($p < 0.001$) and Palpa ($p < 0.001$) households were significantly associated (positively) with the inefficient group relative to the low group, whereas Janajati ($p < 0.001$) households had a significant negative association with the inefficient group relative to the low group. The following results provide an important comparison between the high group and low group.

The MLR model results presented in Table 3.6 show that the odds of a household being in the high group relative to being in the low group increases (keeping all else constant) by 0.2 times for households engaged in labour compared to households not engaged as labour, 1.2 times when households used a private tap as compared to households who used a public tap, 2.3 times when households had access to water for year round irrigation compared to households without such access, 424 times when households practiced agriculture as the major occupation as compared to those whose major source of income is not agriculture, 15.7 times for households who received productive training compared to those who do not, 15.8 times when households were receiving any support related to productive activities as compared to households who did not receive such support, 21 times if they were located in Syangja (Walling-5) vs. Kaski (Annapurna-6), 64 times when households were motivated to engage in productive activities compared to those who were not motivated, and 407 times when a family used productive technologies compared to those who do not use technologies.

Conversely, the odds of a household being in the high group relative to the low group decreases (keeping all else constant) by 1.1 times when a family received a remittance, 1.4 times for Janajati vs. upper caste, 3.4 times for households who consider themselves as having the same wealth as other households vs. those that consider themselves as wealthier than other households, 4.3 times for Dalit vs. upper caste, 5.8 times when one or more of the family members is employed with a government job, 26 times for poor households vs. wealthy households, and 38 times when households received an income from a pension. The findings show that households with the lowest economic status and those with secured income from a reliable source (e.g., a remittance, pension, or government job) are less likely to be in the high group relative to the low group. In addition, households with similar economic status are less likely to be in the high group relative to the low group.

Importantly, an increase in productive training, motivation, and external support increases the probability of a household being in the efficient group and decreases the probability of it being in the inefficient group. As expected, the use of productive technology has greatly increased the chances of a household being in the high and efficient groups. Interestingly, households in the inefficient group tend to earn a low income but use a high volume of water. In contrast, households that own a private tap are more likely to be in the high group. Home owners prefer to own and control a water tap instead of sharing a tap with neighbours. According to the MLR model, households in the upper-class ethnic group are more likely to be in the high group than the households from the Janajati and Dalit caste groups. Households in the upper caste group have more access to land resources, tend to be culturally trained in agriculture, and have more knowledge relating to agricultural practices. Of the three wards located in each district, households in Waling-5 of the Syangja district are more likely to be in the high group due to their high level of engagement in raising livestock and dairy production. In addition, a higher percentage of households in Waling-5 are considered to be upper caste when compared with households in the other two wards (i.e., Annapurna-6 of the Kaski district and Bagnaskali-1 of the Palpa district).

As shown in Table 3.6, an increase in the number of non-educated persons in a household, being Dalits vs. upper caste, being Palpa (Bagnaskali-1) vs. Kaksi (Annapurna-6), and using private vs. public taps are more likely to put a household in the inefficient group relative to the low group. Importantly, Dalits are considered to be the most disadvantaged and less empowered caste group. Palpa (Bagnaskali-1) and Dalits households typically lack water management training compared to Kaski (Annapurna-6) and upper caste households or had limited access to productive-use training. This finding implies that Palpa (Bagnaskali-1) and Dalit households may benefit from the practical demonstration of technology and training in water management practices.

3.4 Discussion

This research provides empirical evidence of the extent of rural-water-system-based productive activities in communities in the middle hills of Nepal and the factors enabling these activities. The findings show that water-based productive activity is an income-generating opportunity for households. The water systems surveyed support nearly 94% of the households (MUS 96% and SUS 93%) in one or more productive activities, from which 87% of the households earned an income. This finding is similar to that of Hall et al.'s [49] multi-country study of the piped water systems in Senegal, Kenya, and Colombia where a majority of households (71%−75%) using a piped water system were involved in both domestic and productive activities and half of these households earned an income from these activities. Vegetable production, livestock raising, and dairy production were the most practiced water-based productive activities in the middle hills of Nepal. Most importantly, these small enterprises are the most reliable sources of income for these families. These small-scale productive activities and their benefits are widely realized in several developing countries [40, 69, 74, 84, 122]. The productive activities of the surveyed households increased annual median income by $360, which is significant for a subsistence farming rural family. In addition, a small proportion of the households were engaged in horticulture, biogas, and production of Rakshi.

Considering all water-based productive activity, the extent of the productive activity differed insignificantly between MUS and SUS households, while the median productive income of

MUS households ($446) was significantly higher than SUS ($290) households ($p < 0.05$). The difference in income can be explained by the contribution of vegetables. A previous study of 16 rural water systems in the middle hills of Nepal found that households gained an annual income $ 136 from the sale of vegetables [25]. Other productive activities (livestock, dairy, Rakshi, and horticultural crops) had a comparable contribution to family income across systems. In our study, the incorporation of vegetable production into the MUS planning process enabled users to develop irrigation technology, inputs, markets, and investment tools that resulted in increased levels of production and higher user income than those experienced by SUS users. At the homestead level, Renwick et al.[95] estimated 175–475 LPD was needed to meet productive uses for some livestock (7-17 cows), small gardens (25–200 sq.m), and small-scale enterprises. In our study, water consumption for productive activity falls towards the lower limit (i.e., 183 LPD for MUS and 166 LPD for SUS). The average number of livestock per household in our study was only 5.8, resulting in lower water consumption when compared to Renwick et al.'s [95] study. Research has found that significant levels of productive activities can occur by providing intermediate level MUS (> 175 LPD/household for productive uses) or high-level MUS (> 475 LPD/household for productive uses) [95, 120]. In a similar vein, Moriarty et al. [74] underscored that rural household engagement in economic activities is largely shaped by the availability of and access to water supplies. The extent of water consumption also differs between its use categories—e.g., to support large livestock, livestock at a commercial scale, irrigation of crops, etc. The results comparing MUS and SUS support our basic proposition that MUS households earned a higher income than SUS households. However, the extent of productive activity and water consumption (for productive activities) for MUS was not significantly higher than SUS.

A significant predictor of households being located in the high and efficient groups was the use of productive technology, which plays a key role in improved levels of production through the efficient use of water. For example, many households have installed micro-irrigation systems and low-tech greenhouses to boost production while conserving water. Similarly, livestock producers have improved production efficiency through technical training and new technologies such as improved animal-sheds, livestock feeders, water troughs, and new feed sources. These technologies and the associated technical assistance can significantly expand water-based productive activities. A majority of the households reported that these new technologies were instrumental in reducing the risk of crop failure or low production rates for livestock, dairy, and crops. Thus, the technical control of the piped water system (MUS and SUS) together with the application technologies (micro-irrigation technology, low-tech greenhouses, etc.) are associated with positive production gains per unit of water use. The application of appropriate water technologies can create multiple opportunities that need to be supported by a range of management options [134].

User motivation to pursue productive activities is a significant predictor of success. Users who had realised benefits from productive activities were found to be more motivated than those who benefited less. Additionally, households with government jobs were less engaged and thus less motivated to pursue productive activities. Households with lower economic status were more frequently located in the low group when compared with the high group. In addition, households engaged in year-round production were more likely to be in the high group. Uninterrupted and reliable access to water throughout the year was a necessary condition to enable year-round productive activity.

Households that received technical training in vegetable production, marketing of vegetables, improved livestock management, fodder production, and other small-scale water-based enterprises, were more likely to be in the high group. Agriculture and livestock service centres, NGOs, and local agricultural cooperatives provide a variety of agricultural and educational training programs directed at supporting the needs of the surveyed communities. These training programs were designed to improve the user's ability to increase production levels and establish marketing skills with the basic goal of improving rural livelihoods. The findings from this research provide empirical evidence that these training programs have been effective at increasing levels of water-based productive activity and improving household livelihood.

This study also suggests that certain productive activities are associated with a particular cultural group. For example, the higher caste group is more likely to grow vegetables, keep livestock, and sell dairy products whereas the production of Rakshi (locally made alcohol) was popular among the lower castes–the Dalit and Janajati households. The frequency of irrigation varied from one location to another due to variability in local micro-climatic conditions. The availability of fodder and geographical constraints also affected the raising of livestock. Syangja (Waling-5) and Palpa (Bagnaskali-1) were the most desirable locations for livestock, whereas Kaksi was the most desirable location for vegetable production. Each category of produce (vegetable, livestock, etc.) had different market requirements across these locations. These factors individually and collectively affect productive activities.

The results from the MLR model were largely consistent with findings derived from the focus group discussions with water users. There was uniform agreement that undertaking productive activities is an attractive option for households without a reliable source of income and who lack technical skills. The interviews highlighted how poor families that learned about commercial production techniques, technologies, and markets became small-scale entrepreneurs to better meet their family needs. Productive work was reported to be comparatively easier and more enjoyable than traditional agriculture due to the realization of income and livelihood benefits. The focus groups revealed that a small percentage of very wealthy families considered agriculture to be laborious, less profitable, and characterised by disappointment. Their production was primarily for home consumption with any leftovers being sold locally. However, these households could potentially enhance their productive activities through training and better use of appropriate technology.

Some families have limited or no access to bari lands or have unproductive land with limited ability to engage in productive activity. A study from the same region reported that households with sufficient bari land were more engaged in vegetable production and earned higher incomes from vegetables [25]. Water users reported that persons with higher educational attainment were found to be less engaged in productive activity as compared with persons with no formal education. They also revealed that users fear risks such as production failures, pest infestations, low crop yields, limited availability of livestock fodder and land for grazing, and market uncertainty. These factors have discouraged some users from undertaking productive activities. Therefore, future support strategies should focus on these challenges and recognise that women are largely responsible for water-based productive activities such as vegetable cultivation, livestock production, alcohol production, and the selling of products.

There were no constraints for most households in the study area to buying productive technologies and obtaining related productive services locally or from the district headquarters. Technologies were low-cost and either provided by NGOs, local governments, or self-purchased by the users in local markets. Most households had the ability to purchase these technologies. Therefore, the ability of households to develop productive activities depends more on their level of motivation than their poverty level.

The planning and design standard for MUS is to provide water for domestic use and vegetable production, whereas SUS is designed to provide water for domestic use only. However, the vast majority of households (89%) in SUS communities used their systems for unplanned small-scale productive activities. Thus, this research finds that communities do not limit the scope of their water use from a rural water system (RWS), regardless of its design. Therefore, rural water systems in the middle hills of Nepal are a de-facto multi-purpose infrastructure. This result is consistent with Van Koppen et al.[126] who state that "multiple uses of infrastructure is the rule, and single-use the exception." This conclusion is also supported by others [24, 47].

This chapter has addressed factors in rural water system planning and design that inform a system's ability to function as de-facto productive. Ideally, the design of MUS extends beyond supply infrastructure to include appropriate technologies (e.g., micro irrigation, water troughs, etc.), technical training, and access to productive activity support/services. In the middle hills of Nepal, SUS that are designed and built for domestic use only are adapted by users to accommodate small-scale productive activities. The failure to address these unplanned uses in advance may result in inefficient, inequitable, and unsustainable use and management of the water systems [95, 111]. While this de-facto multiple use of water has become an opportunity for rural households, it may bring risks to the sustainability of service provision [107] or cause technical and managerial problems [122]. More comprehensive research that explores links between de-facto productive use and system sustainability would be valuable.

3.5 Conclusions

This chapter provides empirical evidence on the extent of productive activity of MUS and SUS in the rural middle hills of Nepal. The research finds that the vast majority households (using MUS and SUS) are engaged in small-scale productive activities, from which more than three-quarters of the households earn an income. This indicates that water-based productive activities are critical to supporting rural livelihoods in Nepal. The research found that the productive activities and associated income were higher for MUS vs. SUS households, suggesting that integrated practices and services (productive training, technologies, and market linkages) offered in MUS could be transferred to SUS households to enhance the income earned.

Second, the research identifies the dominant predictors of high levels of productive activity. More specifically, households that farm as a primary occupation, use productive technologies, are motivated to pursue productive activities, have received water-related productive activity training, and have received external support related to productive activities have higher levels of productive activity. These factors also help explain why households served by SUS engaged in high levels of productive activity. Thus, while the design of rural water systems does influence what types of productive activities are undertaken and the income received from these activities, virtually all of the households in SUS communities were engaged in productive activities—making them 'de-facto MUS'. Put differently, the productive use of water in rural communities in Nepal is likely to be the norm, which implies that the Nepali government should design rural water services with these activities in mind.

The findings from this study are generally applicable in rural areas of Nepal or other developing countries with similar socio-cultural, economic, and climatic settings. However, additional research may be needed to identify additional variables unique to a particular area that would inform policy makers and water system planners and designers of the key factors that promote the productive use of water.

Chapter 4

What Factors Determine the Technical Performance of Rural Water Systems in the Middle Hills of Nepal?

4.1 Introduction

A typical rural water system in the hills of Nepal is gravity-fed, in which water from one or multiple spring sources is collected in a reservoir tank located above the community and then conveyed through a piped water system to tap stands. Water supply practitioners often classify these systems as either single-use domestic (SUS) or multiple-use (MUS) systems. The vast majority of the systems are conventional SUS, which were planned, designed, and financed for domestic use purposes. MUS in Nepal emerged during the early 2000s to support both domestic water needs and other productive uses such as irrigation for small vegetable plots. To develop MUS, engineers modified the technical components of traditional domestic water systems to provide water for productive uses such as additional water irrigation tanks and off-takes to irrigate fields [134]. The MUS designed by International Development Enterprises (iDE) are the most common in the middle hills of Nepal.

Prior studies have shown that communities use rural water systems to meet multiple water needs, regardless of system design [42, 126]. For instance, a study of piped water systems conducted by Hall et al.[49] in Senegal, Kenya, and Colombia, reported that a majority of families (71%−75%) were engaged in domestic use and small-scale productive activities (agriculture and home-based enterprises). A study of SUS vs. MUS systems in Nepal based on the dataset used in chapter 3 – revealed that more than 90% of MUS and SUS users were found to use water for various productive activities [42]. While the MUS systems supported slightly higher levels of engagement in productive activities, the water-based income earned by SUS households was less than that earned by households served by MUS. These results emphasize that, in practice, rural water systems are an income-enabling productive infrastructure regardless of whether the system is designed for MUS or SUS. However, the design features can influence the level of income generated from water-based activities.

Over the past decade, studies have reported on the poor functionality of domestic water systems in rural Nepal [132]. The non-functionality figures range between 30 and 40 percent in developing countries [106]. The high frequency of breakdowns is typically due to the poor condition of infrastructure, the lack of timely system maintenance, and the lack of an institutional arrangement that supports operation and maintenance [63]. Other factors affecting the technical sustainability of rural water systems include the system's age, the use of poor materials and workmanship during construction, a lack of post-construction support [63], the convenience of water-point locations [14], willingness to pay [45], and the availability of funds for operation and maintenance [20]. Further, the performance of water systems has been found to rely on system-level variables (such as improved water services, effective institutional structures, and capable water user committees and operators) [20, 73] and household-level variables (such as household participation in water system planning and decision making, payment for water services, and the contribution of labor to the construction of the system) [62]. A study of 1,500 households in Accra, Ghana, showed that family income, place of residence, and educational status were significant predictors of households access to reliable water supply [61].

Furthermore, the distance between a water source and a residence relates to the amount of water being used – i.e., more water is consumed the closer a household is to a water source. For instance, a cross-sectional study of community-based water supplies conducted between 2009 and 2011 in rural Kenya, revealed a 15-minute reduction (from 30 minutes) in water collection time following the construction of a water system, and an increase in the mean daily family water consumption from 82.6 to 99.0 liters per day [99].

Several studies have examined the critical role of users throughout system planning and project development, and during its operations and management. User groups can be organized to make key decisions about a project including the selection of water sources, pipeline routes, the location of water system components [42], the desired water service levels, and the amount of labor donated during system construction [62]. A study of 45 rural water projects in India concluded that community participation was critical to project success [91]. However, participation may not bring a sustained change unless the capacity of users to engage in the process is enhanced and they have an ability to influence decision-making. Effective community participation combined with the payment of tariffs made possible by increased income, empowers users to provide for ongoing system operation and management [25].

In general, inadequate capacity of water user committees [20] and a lack of appropriate tariffs [116] diminishes system performance and its sustainability. Thus, the extent and nature of responsibilities undertaken by water user committees is critical to the technical performance of systems [49, 63] including the adoption of user fees to pay for system upgrades and maintenance.

The above discussion indicates how technical, geographical, and socio-economic factors can affect the number and severity of system breakdowns, system performance, and the overall sustainability of the water system. However, few empirical studies explore the relationship between all these factors. Since the Nepali government plans to improve water service levels and the sustainability of water systems from 2021-2025, this study aims to provide policy makers and planners with critical information on the key factors impacting water system performance and whether/how these predictors relate to long-term sustainability of rural water systems.

The following sections describe the study communities, the research methodology, the model used in the analysis along with the key variables, the main research findings, and concludes with a discussion of the main findings.

4.2 Research Communities

This study was conducted in the three districts of Syangja, Kaski, and Palpa in the western middle hill region of Nepal. The region is geographically diverse with elevations in the districts ranging from 219 to 7,987 m as shown in Figure 4.1. The study concentrated on three wards – Annapurna-6, Walling-5, and Bagnaskali-1 in the Annapurna rural municipality of Kaski, the Walling municipality in Syangja, and the Bagnaskali rural municipality in Palpa. These wards (the lowest administrative unit of local government) are depicted in Figure 4.1. Agriculture remains the major economic activity in the region [41, 69]. Most families grow rice, maize, and wheat, which are typically grown for family consumption [110]. Rural households commonly grow a variety of vegetables including tomatoes, cucumbers, cabbages, chilies, bitter gourds, and cauliflowers and often raise livestock [41]. Average per capita income in these three communities was around $850 in 2018, which is below the national average of $998 [41]. The region receives an average annual rainfall of 1,500 mm and more than 75% of this rain occurs during the monsoon season, from June to September. Male out-migration, mostly to work in Middle East countries, is common especially in rural Nepal [110] and the resulting remittance significantly contributes to family incomes and livelihood.

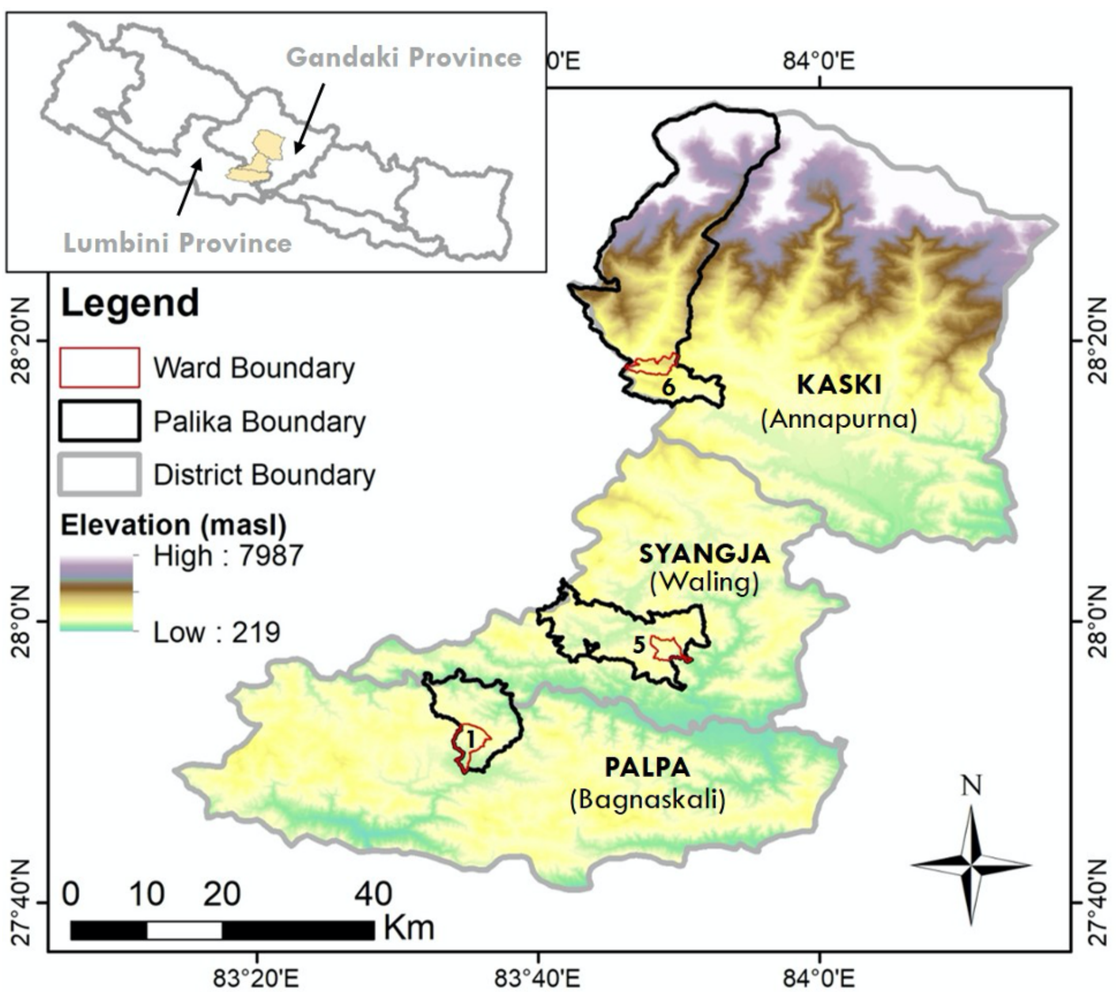


Figure 4.1: Study Area

4.3 Methods

The research for this analysis was conducted from June 2017 to July 2018 in two phases – fieldwork preparation (June and September 2017) followed by data collection in the three sample wards. The sample frame and each of the study techniques are discussed below.

4.3.1 Sample Frame

Using secondary data and consulting with local stakeholders, three middle hill districts were selected for this study that have a long history of domestic water systems and the greatest concentration of MUS systems nationally. Three sample wards were then selected, each having both domestic and multiple use systems. The lead author conducted a rapid assessment of 60 water systems across the three wards from which 10 systems (5 MUS and 5 SUS) were selected for the study. Water systems were excluded from sampling if they were: (1) serving fewer than 10 families, (2) shared by two or more neighboring communities, (3) partially functioning, and (4) operating in parallel with another system in the same community. Each water source feeding the 10 sampled water systems was visited and the following critical water system components were identified: the status of the water sources, the age of the system, its technical features, physical condition, and user data. GPS coordinates were recorded for each water source and water storage tank. Each of the 10 water systems served a village with an average of 21 households. A total of 213 households were surveyed as part of this study.

4.3.2 Households Survey

Structured interviews were conducted with 202 households out of the total 213 households that received water from the 10 water systems. Those households not surveyed were not available during the survey period. The paper-based survey focused on four topics: (1) household demographic and socioeconomic characteristics; (2) domestic and productive use of water and related income; (3) the physical condition and operation/management of the water system, which included the definition of the roles played by the water users association, system operators, and external support services; and (4) the household's involvement in water system planning and decision-making processes. The questionnaires were pre-tested with three households from Lele community in Lalitpur district.

After each interview, the respondent provided a tour of their water collection practices, vegetable plots, livestock, and other water-related activities undertaken by each family member. Given the widely practiced responsibility of women for household water collection and men for water system management, many household interviews included both male and female heads of household. However, the participant with the most water system knowledge was listed as the primary respondent. Because a large proportion of men migrate for work elsewhere, more than half of the respondents (57%) were women. A majority of the respondents were literate.

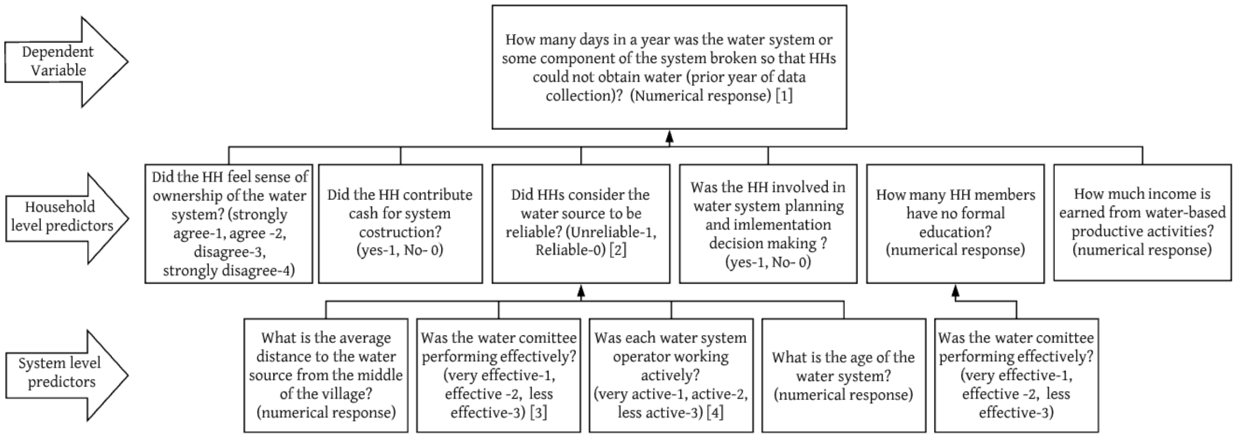
4.3.3 Engineering Assessments of Sample Water Systems

The major components (e.g., intake, tanks, pipelines, and taps) of the 10 sample systems were assessed to determine their physical condition and functional status. This examination also revealed the designed characteristics of each system and whether it was being adequately maintained. As a part of the assessment, water flow was measured and recorded in each system tap, along with its GPS location. While at each site, the system performance was discussed with water committees and system operators. This assessment helped identify the relevant system-level variables (e.g., the level of activity of the water committee and system operators) and provided background information on these variables.

4.3.4 The Model

Figure 4.2 presents the conceptual framework behind the model used to assess the technical performance of the water systems. The data were coded using appropriate scales and analyzed using the R programming language. Figure 4.2 illustrates the nesting of system- and household-level variables and their potential relationship with the dependent variable (the duration of system breakdowns). The relationship between these variables is further discussed in the following sections.

A hierarchical linear model (HLM) was used to identify the significant predictors of breakdown duration – i.e., the number of days in a year the water system was not functioning. HLMs are most commonly used to analyze variance in the response variables (dependent variable) when the predictors (independent variables) are at varying hierarchical levels [133]. In other words, the HLM model is appropriate when a data set contains nested relationships/structures as shown in Figure 4.2 – i.e., household-level predictors are a subset of system-level predictors. Thus, households served by the same system will have a common variance, so cannot be treated as truly independent of each other. Hierarchical models are effective in simultaneously capturing dependencies among households served by the same water system, and among individual households in general. HLMs are widely used in a variety of fields and disciplines to determine multilevel effects [5]. This analysis focuses exclusively on the application of the model to water systems, and captures the nested structure of the



Notes:
[1] Water system breakdowns are measured in terms of the duration of a breakdown. This dependent variable of technical performance captures the functionality of infrastructure such as tanks, taps, pipes, etc. and the impact of existing operation and maintenance practices.
[2] Since water system users are typically located far from a water source (intake), they do not know the exact status of water source at certain point of time or at different periods throughout the year. Thus, the reliability variable is based on their perceptions of the reliability of water sources and is defined as follows:
a) Unreliable: Users consider an unreliable water source/intake (e.g., due to flooding during the monsoon, intake blockages, lime deposits, or other reasons) to be the main cause of water supply disruptions.
b) Reliable: Users consider the water source/intake to be reliable and not the main cause of water supply disruptions.
[3] Water committee performance is defined as follows:
a) Very effective: Water committee meets at least once a month to discuss operation and management problems or issues related to the water system, develop a clear schedule for system operation (e.g., the schedule for opening/closing the main gate valve) that is followed, and address/resolve major issues with the users.
b) Effective: Water committee meets and discusses issues when a problem arises. The committee develops system operation schedules, but does not implement them as planned, and infrequently consults with users.
c) Less effective: Water committee neither meets regularly nor discusses issues when they arise. The committee does not develop system operation schedules. The committee chairperson or someone from the committee makes most decisions related to system operation and management.
[4] The water system operator's level of activity is defined as follows:
a) Very active: Operator(s) maintain/repair the water system in less than 48 hours when a problem is identified by the operator(s) or water committee. They operate the system in accordance with the schedule provided by the water committee. The operator(s) are formally appointed by the committee, work in consultation with the committee, and have the required maintenance tools.
b) Active: Operator(s) maintain/repair the water system within 48 to 72 hours when a problem is identified by the operator(s) or water committee. They are formally appointed by the committee and have only some of the required maintenance tools.
c) Less active: A water committee member or an individual (who is not officially trained) is the de-facto operator and spends more than 72 hours working to maintain/repair the system when a problem is identified. They do not have the required maintenance tools.

Figure 4.2: Model Diagram

data more appropriately than a regular multiple linear regression. The regression model is expressed as follows:

$$y_{ij} = \beta_0 + \beta_1 * x_{1ij} + ... + \beta_k x_{kij} + \gamma_1 * z_{1ij} + ... + \gamma_l * z_{lij} + \epsilon_{ij} \tag{4.1}$$

Where, $\gamma_1 = \eta_{01} + \eta_{11} * s^1_{1j} + ... + s^1_{mj} + \epsilon^1_j$

...

$\gamma_l = \eta_{0l} + \eta_{1l} * s^l_{1j} + ... + s^l_{mj} + \epsilon^l_j$.

In the above series of equations, y represents the dependent variable measured in household i and system j. The x represents the fixed effects, which are household-level variables. The z represents the random effects (modeled in this article as mixed effects, that include a fixed effect and a random effect component). The β represents the coefficients of the fixed effects and the γ represents the coefficients corresponding to the random effects. The hierarchical structure of the model where households (i) are nested within water systems (j) is captured by a series of equations that predict the random effect using system-level variables s^l_{1j}. Since there are l random effects in the household-level equation, there are potentially l auxiliary equations, with the system-level variables that predict each of the different random effects. For instance, in Figure 4.2, four system-level variables predict the perceived reliability of the water source by households, whereas only one system-level variable predicts the household-level education variable. Discussions with the water committees revealed that both household-level variables – i.e., the reliability of the water source and household education – were related to the performance of the water committee. For instance, an educated family may offer ideas to the committee on how to restore a broken system, help in decision making, or immediately report a system failure when discovered. Similarly, an effective water committee is expected to monitor the most vulnerable water system components (e.g., water source/intakes) and mobilize the needed resources and operators to fix any problems identified. In estimation terms, this nesting results in the estimation of interaction effects between system- and household-level variables along with main effects.

4.4 Results

4.4.1 Characteristics of the Water Systems and Households

This research considers rural water systems in the study area to be community-based public infrastructure, developed through demand-driven processes, and largely constructed and thereafter managed by its users. Engineers from the government or another oversight agency often set design standards and provide recommendations concerning the use of specific system components. Water users are typically involved in the construction of their systems, with engineering support and oversight provided by the government or local actor/NGO. Thus, local users and engineers were involved throughout the water system design and development process, cooperatively addressing the social and technical dimensions of each project.

An analysis of the surveyed households reveals that water systems became partially or fully non-functional due to several technical factors: the blockage of the water source intake (143, n = 192), air pockets and lime buildups in pipes (128, n =192), leaking pipes (99, n =192), broken fittings (96, n=192), water tank failures (75, n= 191), and broken pipes due to a landslide (61, n=191). These findings show that blockages of the water system intake were the most significant challenge to the regular supply of water to households. According to the respondents, this issue remains persistent in both dry and monsoon months. Most of the water sources (9 out of 10) were located uphill in forests. The average distance between the water sources and the middle of the villages was nearly 2,000 meters. These sources may suffer from several problems including flooding during the monsoon and intake blockages due to decaying leaves during the summer.

The age of the water systems varied between 7 to 18 years with a mean of ten years. It reportedly took four to seven months to complete the installation of the water systems.

Households participated in multiple forms of planning and management activities, and attended on average six meetings during the development of their water system. In these meetings, they discussed and made decisions about user roles in the implementation of the project, the formation of water committees, the procurement of construction materials, the registration of water sources, dispute resolution processes, and water system operational norms, among others. The respondents reported they contributed labor (136, n =193), cash (113, n=193), and local materials (86, n = 191) to the construction of their water system. They also provided support in terms of sharing design ideas, selecting the location of taps and the water tank, identifying pipeline routes, and making other decisions during consultative discussions. Most of the respondents recalled the contributions made by themselves or their family members. In some cases, the water committee was able to provide a record of the contributions made by the users.

Each community created a committee of 7 to 11 people to oversee the major administrative duties related to the operation and management of their water system. They also elected at least one woman into one of the five leadership positions (e.g., chairperson, vice-chair, secretary, joint-secretary, and treasurer). In most cases, the committees appointed an operator for major technical duties. The organizations implementing the water systems provided communities with operation and maintenance training and provided some maintenance tools. While users of four of the water systems pay flat fees each month, users in the other systems pay fees when they need to maintain their system.

The average number of days each household could not obtain water was 12 per year – most often due to a complete system breakdown or a component failure where a cluster of households are unable to access water. Each family used an average of 34 liters per capita per day (lpcd) for domestic use and 179 lpcd for productive activities (e.g., irrigating vegetables, raising livestock, producing alcohol, and bio-gas) from their water system connection.

About half of the households reported their production activities were compromised due to insufficient water. Some households used a secondary source (e.g., streams and springs not connected to the water system) for productive activities, especially for irrigating vegetables. For those households without a secondary water source, the system breakdowns presented a major challenge to irrigating crops, etc. When a system failed to supply sufficient water, households often carried water from public springs/spouts near to their homes for domestic use. The households characteristics are shown in Table 4.1.

Table 4.1: Characteristics of Sample Households

Total households	213
Number of respondents	202
Mean age of respondents (years)	48
% of male respondents	43%
% of female respondents	57%
Household size	5.07
Mean years living in the village	35
Mean annual per capita income of households (USD)	863
% of households that own their home	97.5%
% of households with cement/concrete floor	41%
% of households with concrete ceiling/roof	13%
Mean total land owned by households(hectare)	0.5
% of households with private tap connection	44%

4.4.2 Model Results

The hierarchical linear model was used to determine the significant predictors of breakdown duration. The fixed effects results are presented in Table 4.2 and random effects in Table 4.3.

Table 4.2 shows the relationships between the breakdown duration (dependent variable) and the independent variables. Three household-level variables – productive income ($p < 0.001$), a household's involvement in decision making processes ($p < 0.001$), and a household's low sense of ownership (strongly disagree, $p<0.001$) vs. high ownership (strongly agree) – significantly predicted the duration of breakdowns.

All else held constant, three system-level variables are significantly associated with the duration of a water system breakdown: a water committee's performance (less effective vs. very effective, $p<0.05$), the level of a system operator's activity (active vs. very active $p<0.01$ and less active vs. very active, $p<0.001$), and the distance to a water source ($p<0.01$). This finding shows evidence that the reliability of the water source is nested with the distance to a water source, the performance of the water committee, and the operator's technical activity.

Interestingly, water-based productive income is a significant determinant of the duration of a breakdown. This finding implies that there is potential for increased productive income to pay for recovery costs and important maintenance services. This finding aligns with other research that found increased income can improve system operation and management and enhance the resilience of a water system [25, 95].

As noted above, the model predicted that household involvement in decision-making significantly affects the duration of breakdowns. Thus, greater involvement of users in water system planning and decision-making leads to a more reliable water supply. This finding is consistent with previous research on water system sustainability, which suggests an association between user involvement in water system planning and system sustainability [32, 64, 116]. However, cash contributions towards the construction of water systems was not found to be significantly ($p = 0.549$) correlated with the duration of system breakdowns.

In general, the shorter the distance from households to the water source, the easier it is to maintain the water source/intake, allowing water to flow more reliably through the system. More distant water sources were found to present operational challenges, especially when the water sources were located in streams in forest areas far above the community. Given

Table 4.2: Summary of Hierarchical Multiple Regression (Fixed Effects)

Variables [a]	**Coefficients**	**Standard Error**	***p*–Value**
Productive income	-0.000061	0.000067	<0.001
Cash contribution for system construction	-0.1894	0.3160	0.5490
Sense of ownership of water system (strongly agree)			
Ownership (agree)	0.0514	0.3420	0.8800
Ownership (disagree)	0.7308	0.4633	0.1160
Ownership (strongly disagree)	1.9580	0.5810	<0.001
Involvement in decision making relating to project planning and implementation	-1.4730	0.4271	<0.001
Non-educated persons in the household	0.0774	0.3893	0.8430
Reliability of water source	2.9420	2.3060	0.2470
System age	-0.0849	0.0860	0.3350
Water committee performance (very effective)			
Water committee performance (effective)	-1.0170	0.8076	0.2100
Water committee performance (less effective)	2.0630	0.9686	<0.05
Level of system operator activity (very active)			
Level of system operator activity (active)	3.8960	0.6627	<0.01
Level of system operator activity (less active)	7.3550	1.5480	<0.001
Distance to water source from the community	0.0011	0.0003	<0.01
Interaction effects output			
Reliability of water source: System age	-0.4739	1.7110	<0.05
Reliability of water source: Level of system operator activity (active)	3.8960	0.9635	<0.01
Reliability of water source: Level of system operator activity (less active)	7.3550	1.5480	<0.01
Reliability of water source: Distance to water source from the community	0.00009	0.0005	0.8609
Reliability of water source: Water committee performance (effective)	-1.228	1.3180	0.3552
Reliability of water source: Water committee performance (less effective)	1.1060	1.3820	0.4245
Non—educated persons in the household: Water committee performance (effective)	-0.0467	0.4466	0.9202
Non-educated persons in the household: Water committee performance (less effective)	0.0552	0.4833	0.9090

[a] Variables have different scales.

the steep terrain, accessing water sources becomes even more challenging for the operators during heavy rain.

There is no statistical evidence ($p=0.247 > 0.05$) that source reliability is significantly associated with the duration of breakdowns. In addition, non-educated persons in the household ($p = 0.843 > 0.05$) and system age ($0.335 > 0.05$) were not found to be significant predictors of the duration of a breakdown.

The p-values for the interaction effects output results (Table 4.2) suggest that interaction between system age and water source reliability ($p < 0.05$), and the level of activity of system operators and water source reliability ($p < 0.01$) are statistically significant. These findings indicate that the duration of breakdowns derived from the reliability of a water source depends on system age and the level of a water system operator's activity. The duration of a breakdown significantly increases for unreliable water sources when system operators are not performing their operation and maintenance duties effectively. Conversely, the duration of breakdowns is predicted to decrease even for unreliable sources when system age increases. This implies that user experience for managing/operating the water sources is likely to improve over time. The interaction between non-educated persons in the household and the performance of the water committee is not statistically significant.

The random effects table (Table 4.3) indicates significant variation based on the reliability of a water source across localities (i.e., the three wards: Annapurna-6, Walling-5, and Bagnaskali-1). The intercept [1] and number of non-educated persons in the household show some variation across localities, but it is not statistically significant.

[1] The constant in the regression model is called the intercept. It represents the "baseline" effect on the dependent variable when all the other variables are taken to have value 0 (i.e., their effects are nullified). In this case, the random intercept represents the variation in the baseline effect across systems irrespective of the additional effects of other variables.

Table 4.3: Summary of Hierarchical Multiple Regression (Random Effects)

	Variance	**Standard Deviation**
Locality (Intercept)	0.10938	0.3307
Reliability of water source	3.14175	1.7725
Non−educated persons in the household	0.01216	0.1103
Residual	3.12064	1.7665

N= 171 ; Groups (Locality) = 3; REML criterion at convergence: 804

4.5 Discussion and Conclusion

This study identifies several factors that impact the technical performance of rural water systems in the middle hills of Nepal. One principal finding is the identification of significant household and system variables that predict the duration of system breakdowns. This study builds on previous research by incorporating a more holistic examination of social, economic, geographic, and management factors that affect system sustainability [32, 64, 91, 106]. The study used a hierarchical predictive regression model that captured both household- and system-level variables that contribute to system breakdowns. These include household involvement in decision-making during water system planning and construction and a household's sense of ownership toward the water system, the management capacity of the water user committee and activity level of the system operator, income earned from water-based productive activities, and distance from the village to the water source.

The study establishes three primary insights. First, household-level variables nested with system level variables (as shown in Figure 4.2), responded significantly to the dependent variable and produced meaningful results. In other words, the hierarchical modeling yielded a result that explains the local context. Similarly, variables with fixed effects and random effects are accounted for in the model. While the fixed effects are the only variables that individually predict the dependent variable, random variables interact with system variables to better predict the duration of breakdowns. Interactions between system and household-level variables enable the capture of a holistic analysis that can support the development of effective system planning and implementation strategies.

Second, the empirical evidence confirms that increased household productive income leads to a significant decrease in the duration of breakdowns. This reinforces the current debate that increased productive income enhances the ability of households to support system maintenance and upgrades [25]. Fundamentally, the development of sustainable community-managed water systems is dependent on initiating a partial transition from subsistence crop production to commercial agriculture and other income generation activities. As our model suggests, creating cash flow from water-based enterprises, such as vegetable production especially during the dry season when prices are higher, allows for the collection of user fees that support water system operations and maintenance while improving the livelihoods of poor and marginalized rural farmers. However, the organizational, financial, and technical skills of community leadership would need to be developed to realize this aim.

Third, all water systems considered in this study are community-managed infrastructure. In Nepal, as in other developing countries, the design and execution of participatory processes is a critical determinant for the effectiveness and sustainability of rural water systems. It is within this process that social, economic, engineering, and management variables are assessed by system users to produce design solutions. International and local NGOs facilitated the community engagement and training of water user committees during the planning and installation of the water systems. A key outcome from this process was the formation of a water user committee constitution that included the following basic elements: member composition, selection, and tenure; scope of authority (purpose and limitations); water allocation and conflict resolution; user fees and contingency fund; and employment and management of a system operator. The model results demonstrate that the duration of system breakdowns decrease with increased management capacity of water user committees. The deep level of user engagement and involvement in the study communities, combined with user fees and donated construction labor, created a strong sense of system ownership among system beneficiaries [62]. These findings help to develop robust community engagement and capacity building efforts during project selection, design, construction, and beyond.

Given the Nepali government's focus on providing access to water throughout Nepal, the model results contribute to the planning and development of technically sound and sustainably managed water systems. Various social, economic, engineering, and management predictors can be useful to produce effective design guidelines. This is especially important following the 2017 implementation of a three-tier federated governmental structure in Nepal, which empowers newly formed local governments to set budget priorities and exercise control over local development projects. Since these local governments typically lack technical expertise on productive rural water systems, they rely on international and local NGOs with experience developing water projects such as those analyzed in this study. It is recommended that local governments leverage the results from this study and begin to develop the technical and institutional expertise and financial resources needed to support sustainable community-managed productive rural water systems in Nepal.

Chapter 5

Thinking Beyond Domestic Water Supply: Approaches to Advance Multiple-use Water Systems (MUS) in the Rural Hills of Nepal

5.1 Introduction

Led by International Development Enterprises (iDE), Multiple-use Water System (MUS) installation began in Nepal in the early 2000s with field-testing followed by deployment of a pilot system in 2003 [69, 121]. Beginning in 2004, following successful pilot testing, International Development Enterprises (iDE) Nepal, Winrock International, and local partners implemented MUS in 19 of Nepal's 77 district[1] as a component of a USAID-funded Smallholder Irrigation and Market Initiative (SIMI). In 2008, Nepal's Ministry of Local Development (MoLD) officially allowed Village Development Committees (VDCs), the then lowest administrative unit of the Government, to invest in MUS development via agriculture

[1]Districts are a tertiary level of government in Nepal and are themselves subdivided into Palikas (municipalities). Nepal's seven states contain 77 districts.

block grants[2]. At the same time, however, separate government agencies (the ministries of Water Supply and Sanitation and Irrigation) with differing policy goals were then also independently providing overall drinking water and irrigation system investments; a fact that constituted a substantial barrier to MUS implementation. Indeed, governmental division of authority and lack of inter-agency coordination has greatly reduced Nepal's capacity to scale-up MUS to date. The national government has not, as of this writing, institutionalized MUS by assigning responsibility for its implementation to a specific ministry. That fact remains an important impediment to its diffusion to farmers today.

Previous studies have found that household garden plots and livestock production supported by rural water systems can contribute significantly to local economies [42, 73]. Successful MUS implementation in ten communities in the middle hills of Nepal, for example, increased those villages' median annual income by $156 per household when compared to households using a system designed solely for domestic water use [42]. In general, previous analyses have found that MUS can be effective in generating income and improving people's livelihoods [48, 69, 122]. As of 2019, iDE and its partners had facilitated the development of 499 MUS projects in 33 of Nepal's 77 districts. Together, those efforts now touch more than 80,000 people [52].

As a result, Nepal has emerged as an advanced international example of by-design MUS system development [121]. In February 2016, like-minded organizations within the country created a MUS Network for advocacy, learning, and mutual sharing concerning these initiatives. While the efforts of iDE and its partners have surely raised the profile of MUS in Nepal, its development to date has nonetheless largely been driven by donor-funds. Meanwhile, it has received little support or attention in national water policy dialogues and programs [24].

[2]Nepal's Ministry of Local Development had provided block grants to Village Development Committees before the nation's new constitution was implemented in 2017. The Ministry identified "small irrigation projects" under its agricultural development grant guidelines as a priority area for investment.

This lack of sustained consideration among national officials has made it difficult to establish the socio-political legitimacy of MUS [24]. In fact, this scenario reflects power disparities among the sectors involved, weak collective action among interested actors, and generally a low national political understanding and interest in small-scale water infrastructure. In short, strong socio-political legitimacy is required to institutionalize MUS and to create a space for policy change, which has been difficult to attain in Nepal to date.

Several authors have discussed approaches to encourage MUS scale-up in peri-urban and rural contexts [12, 69, 89, 122]. These authors have argued that above all, such water systems should be viewed first as an approach to service delivery, rather than as an engineering scheme [34]. In addition to this requisite, MUS also requires institutional development and social capacity building if it is to be fully realized. In fact, water professionals who have worked in the traditional hierarchical governance structure in Nepal have argued that increasing adoption of MUS demands a significant change in how government authorities have traditionally delivered water services. Such changes will need to address technical, institutional, financial, political, and geographical considerations.

Of these concerns, perhaps the most important is political; a well-functioning and accountable government is an important pre-condition for sustainable and replicable multiple-use water systems [67, 69]. Moreover, users will need support to manage integrated water services and to access markets and necessary technology once MUS have been established [69]. This demands a governing policy in which water services, production, and marketing activities are collectively addressed. In turn, accomplishing that goal requires coordinated efforts among all relevant public and private actors involved [40]. However, those stakeholders will need to develop a range of capacities to realize the goal. For instance, they often lack knowledge about appropriate planning and use of water resources, production systems, and related benefits.

Income from MUS - from water use in small-plot vegetable production [109] and livestock, dairy, bio-gas, horticulture, and alcohol production [42] - has the potential to provide financial and social benefits. Pradhan et al.[89] have contended that Nepali government policies need first to formally and broadly recognize MUS's economic and social development value, and create financial and institutional arrangements to support it. A critical aspect of securing that goal will be sharing information concerning the benefits of these systems with potential stakeholders. For example, there is evidence that the revenue from water-based production activities allows farmers to effectively maintain those systems [74]. Nonetheless, such a social, financial, and institutional shift cannot occur without reliable delivery of water [122], equal and effective user access to relevant information and technology [69], user participation [70] in MUS system planning and development, and adequate financing and coordination of actors across political and economic sectors [17]. These factors highlight the breadth of issues that Nepal's national and local governments and development agencies must consider when planning multi-use water system programs.

Nepal adopted a new constitution in 2015 aimed at reorganizing the government into a three-tier federal system, which formed one national, seven state, and 753 local governments (LGs[3]). The LGs were further divided into 6743 wards. LGs now have the authority to deliver basic public services such as education, health, agricultural extension, rural roads, and water and sanitation. The central government provided all basic services through district (DDCs) and village development committees (VDCs) until 2017. The national parliament passed the Local Government Operational Act in that year to define the obligations and functions of the country's new local governments. The adoption of a new federal structure has created an opportunity to integrate MUS into water policy at all governance levels. Nonetheless,

[3]LGs include municipalities (Palikas), constituent wards, and district coordination committees. A Palika can contain anywhere from 9 to 20 wards, all of which participate in a common planning and budgeting process.

that possibility can only be realized if such systems are successfully administered at the local level, which requires that the nation's new LGs possess sufficient resources, staff, and expertise to do so and that farmers also develop the necessary knowledge and wherewithal to participate.

While a growing body of research on MUS in Nepal is emerging, past studies have not explicitly sought to describe the various capacities and knowledge required at the different levels of government and among donors, I/NGOs, and interested external parties to implement and scale-up MUS. Accordingly, this chapter examines two broad questions: (1) what are the main challenges to wider adoption of MUS in the middle hills of Nepal and how do a sample of principal stakeholders view those concerns? and (2) what conditions, institutional arrangements, and support mechanisms do stakeholders perceive as important to attain more intensive adoption and successful implementation of MUS? In partial response to these questions, we developed a model for implementation and scaling-up MUS based on the results from both our fieldwork and analyses of previous MUS implementation efforts.

Section 5.2 outlines data collection and analysis methods. Section 5.3 examines the role of government and non-governmental institutions, including, I/NGOs, and for-profit service providers in MUS development and operation. Section 5.4 summarizes recommendations concerning MUS scale-up efforts and Section 5.5 offers our conclusions.

5.2 Method of Data Collection and Analysis

A cross-sectional research design and an exploratory mixed-methods approach was used to obtain the field data on which this analysis was predicated. We obtained three basic forms of information, outlined below.

5.2.1 Personal Interviews

The lead author interviewed 50 key informants at the community, state, and national levels during the period October 2017 to July 2018 (see Table 5.1). The key informants were selected using 'snowball sampling' in which the lead author asked those interviewed to suggest other individuals whom they thought could contribute to the study. Semi-structured interviews were used to understand the experiences and views of these stakeholders concerning MUS and whether and how it might be implemented more broadly in Nepal. The interviews averaged approximately one hour, and each was conducted at a location chosen by participants.

Table 5.1: Number of Personal Interviews by Type of Organizations

Type of organizations	**Central**	**State/District**	**Local**	**Total**
Government	3	1	3	7
I/NGOs	5	2	3	10
Water Supply Expert/Engineer	7	3	2	10
Water Users Association	-	-	5	5
Farmer Representatives	-	-	5	7
Collection Center/Cooperatives	0	2	2	4
Political Party Representatives /Cooperatives	1	1	3	5
Private Sectors/Cooperatives	-	2	-	2
Total	**16**	**11**	**23**	**50**

5.2.2 Focus Groups

Ten focus group discussions (FGDs) were convened with 10 water users association representatives (WUA). WUAs oversee the operation and maintenance of each MUS system according to locally adopted agreements. The lead author approached user group members, along with other water users, to form 7-12-member focus groups to obtain their perspectives on the productive use of water and MUS adoption and management in each of ten sample communities. Focus group participants were also asked to discuss the barriers that might limit the replication of MUS and for their views concerning how those issues might be overcome.

5.2.3 Household Surveys

Using existing rural water supply profiles and consultations with local stakeholders, three wards (Annapurna-6 of Kaski District, Waling-5 of Syangja District, and Bagnaskali-1 of Palpa District) were identified as having the largest number of long-operating MUS systems in Nepal. All 60 water systems within the three wards were visited to identify 10 that served more than 10 households each, had no parallel water networks serving them, and did not serve users located beyond their delimited boundaries. The resulting sample systems served 213 households with an average of 21 households per system. The lead investigator personally visited 202 of the 213 households and at least one adult individual from each responded to our questions. All interviews and surveys completed took place at the respondents' homes. The remaining 11 households were excluded from the survey because no one was at home when contacted.

The structured questionnaire helped develop a profile of each household's water-based production and marketing activities, incomes associated with them, and challenges linked to their planning and management.

5.2.4 Data Coding and Analysis

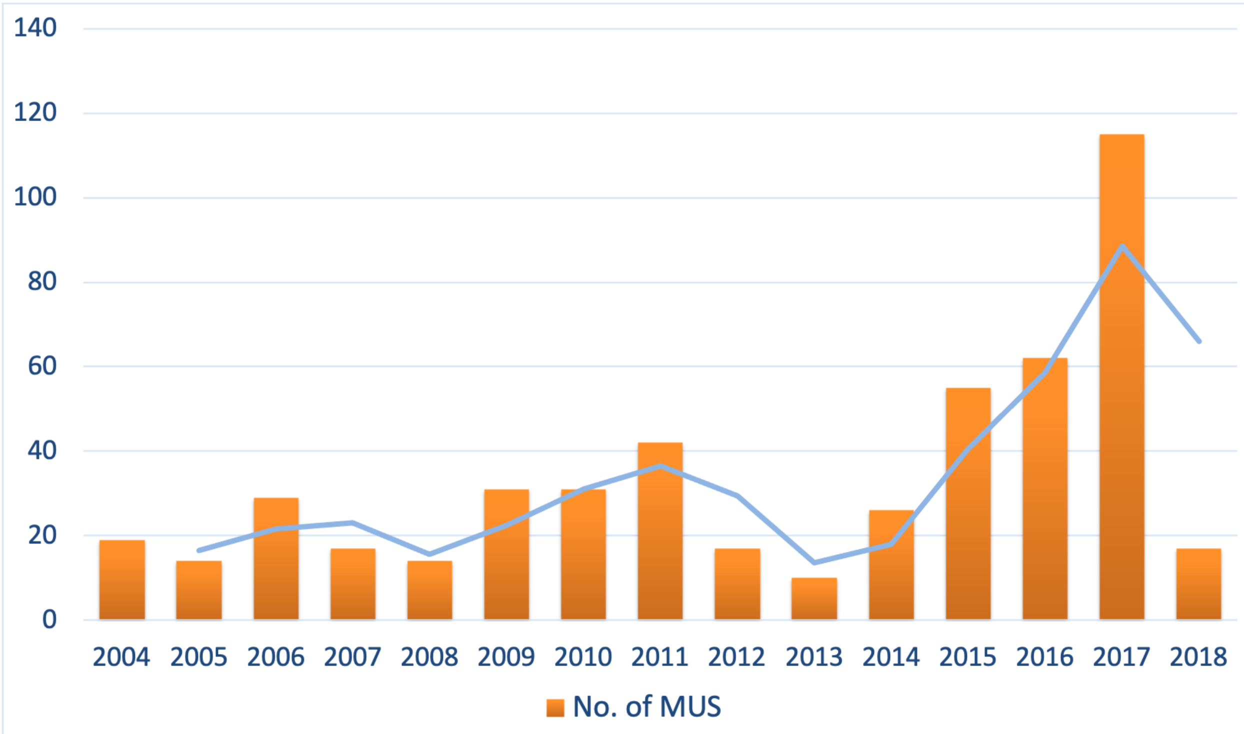
The responses obtained from the personal interviews and focus groups were hand coded [28] and the key variables and themes that emerged were triangulated with the results from the household survey and other relevant sources of information [127]. The interview and focus group responses were coded using a five-stage process suggested by Creswell [28]. We first i) reviewed each transcription carefully; ii) divided the text into topical themes; iii) gave each resulting grouping a name; iv) sought to aggregate across the identified codes to reduce overlap and redundancy; and v) settled on a group of themes that captured the major findings in each of our areas of interest. Unless otherwise specified when we reference our empirical work, the analysis that follows explores the findings through the key informants, who are identified by their role.

5.3 Findings and Discussion

5.3.1 Scale-up Challenges — Evidence and Stakeholder Perspectives

Securing adequate and consistent funding for MUS has been a central challenge to scaling up such efforts historically in Nepal and that concern remains key today. Figure 5.1 shows the number of MUS systems installed by iDE-Nepal and its partners between 2004 and 2018. The figure suggests that MUS development has risen or fallen each year with the availability of funding, primarily from external sources. While the Government of Nepal (21%) has provided significant financial support, MUS is currently disproportionately dependent on iDE and its international funders (30%). Other sources include community-based organizations and partner I/NGOs (8%), community/users funds (12%), and in-kind contributions from residential water users, such as unskilled labor and local materials including, sand, gravel, and stone (29%). This breakdown suggests that international donors remain the largest contributors to MUS development and implementation.

As Figure 5.1 suggests, iDE and its partners have implemented more than 11 livelihood-



Source: iDE MUS Data Sheet [52]

Figure 5.1: MUS Project Implementation in Nepal from 2004 to 2018

related projects that included MUS as a central component since 2004. These initiatives depended in part on *ad-hoc* government funding whose allocation arose from officials' awareness of this water system alternative and their previous ties to implementers, as highlighted in the following comment by an NGO staffer:

> "We had limited funds for construction. With two community leaders, we went to the local government office requesting funds. We gave a short presentation on MUS. After the presentation and conversation, the officials said they would check their budget to see if some funds could be allocated for MUS and asked us to visit them after 15 days. They provided the requested matching funds. We have a strong partnership with the local government, which has made it easier to generate matching resources" [Interview, NGO Official, December 2017].

iDE's support for local NGOs has been a critical catalyst for MUS development in Nepal. Once a jurisdiction commits to such an initiative and its planning is underway, iDE consults with central government officials and other potential partners to obtain matching support. This lengthy and uncertain approach to project development, in which public funding is secondary to donor support, is not a sustainable model according to a majority of those we interviewed. Three-quarters of our key informants argued that the limited scale-up of MUS in Nepal has arisen in significant part from the continued institutional siloing of government water-related responsibilities. For example, the Department of Irrigation (DoI) oversees only its namesake projects, the Department of Agriculture (DoA) only agriculture programs, and the Department of Water Supply and Sewerage Management (DWSSM) only water supply related initiatives. These institutions presently do not routinely coordinate their efforts, which would be essential for the successful implementation of MUS. Moreover, none of these authorities have formally recognized the productive capacity of rural water systems. That is, officials at all levels of governments continue to embrace a single-use view of water services provision. Consequently, our key informants contended that government decision-making is rarely based on evidence-based assessments of service needs. In addition, public agencies seeking to develop or improve existing water systems typically do not examine alternatives to traditional water service delivery approaches [Interview, Water Supply Expert, December 2017].

More broadly, our interviews suggested that key government decision-makers were generally not well informed about MUS or its livelihood impacts. This was so despite the fact that Water, Sanitation, and Hygiene (WASH) remains a major government development priority. Indeed, our key informants did not provide any evidence that the WASH sector has contributed to MUS development. Instead, those we interviewed who were active in that domain tended to view the productive use of water as a constraint on its supply for domestic uses. The MUS proponents interviewed did not accept this absolute opportunity cost argument, but nonetheless contended that the domestic needs of a community must first be met before other productive uses are considered. Most of the water supply experts/engineers we interviewed argued that this challenge could be addressed by engaging representatives of the relevant government agencies to review existing water system designs and use practices with an eye to whether they could support MUS.

While the major share of participants in our focus groups reported MUS as a potentially important asset for rural communities, half of those engaged expressed concerns related to the risks of water-based production. They specifically cited possible crop failure, pest infestations, poor market prices, and natural disasters as concerns. The government does not presently offer crop insurance programs to mitigate these risks [41]. Other obstacles to the wider adoption of water-based productive activities include the limited availability of livestock fodder and land for grazing, poor access to markets, and a lack of access to agricultural inputs, production technologies, and financial services. Lack of markets has discouraged many producers from adopting MUS because that fact allows them only to sell their produce to neighbors or in a nearby village, usually at lower prices than they could get in a vegetable collection center. Moreover, none of the growers contacted for this study had access to a facility to store produce prior to its delivery to markets.

5.3.2 Strategies for Scaling-up MUS

By combining the views of the key informants with the findings from the focus groups and household surveys, we identify a range of strategies that, if widely adopted, could encourage wider acceptance and use of MUS in the hills of Nepal. We have organized our discussion of these concerns into six categories of mediating factors, which we discuss in turn in the sections that follow: nascent local governments as the principal agents of governance responsible for MUS; government official, user, and private supplier capacity building; Palika multi-use water systems registration; improved coordination and collaboration among different sectoral actors and across levels of governance involved in water provision and management; more effective policy advocacy by MUS proponents and changes in national policy that formally recognize these systems and coordinate to support them among relevant departments; and sustained international donor support for MUS. These concerns are summarized in Figure 5.2 below, which illustrates a potential arrangement for scaling up MUS in the rural middle hills of Nepal. In this scenario, LGs would oversee the design and execution of approved projects based on own-source funding as well as federal (national government) and donor transfers. WUAs would implement LG-approved projects with the technical and facilitation support of local NGOs.

For this approach to work, all funders, including national and state governments as well as external agencies, would need to coordinate their policies and activities closely to support LGs. Palikas and water user association representatives would meanwhile also have to collaborate to ensure effective project implementation. We discuss potential arrangements for MUS scale-up in greater detail in the following sections.

Local Government as the Principal Governance Agent Responsible for MUS

The 2015 Nepal federal constitution charges all three tiers of government with some share of responsibility for water management [60, 78]. Schedule-8 (List of local-level powers) of the constitution and Clause 3 of the Local Government Operational Act of 2017 (functions, duties, and powers of local governments), grant LGs legislative and executive purview over service delivery for water supply, small hydropower projects, agriculture and animal husbandry, agro-products management, animal health, grower cooperatives, local support

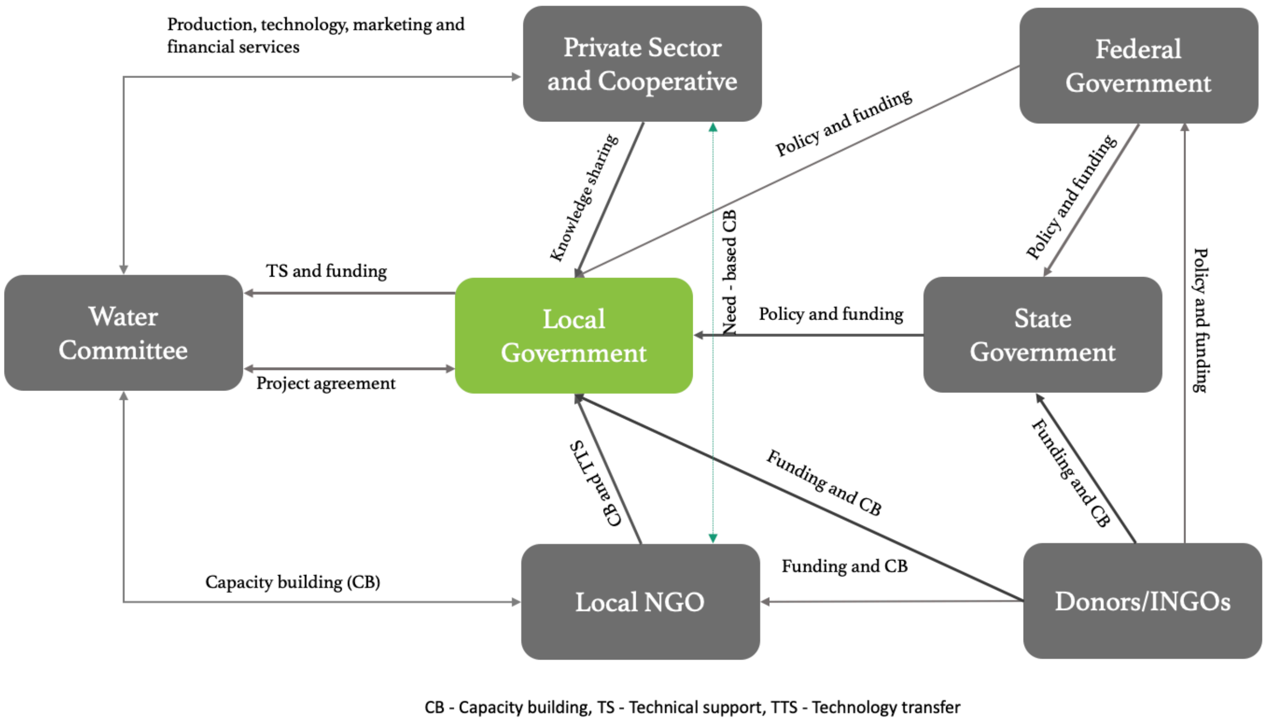


Figure 5.2: A Model for MUS Scale-up in Nepal

services and market management, environmental protection, and biodiversity, among other responsibilities. The federal and state governments are charged with overseeing large-scale water projects.

The Local Government Operational Act (2017) provided LGs authority to enact laws to guide water service needs in their jurisdictions, as long as those do not conflict with federal and state statutes [81]. This is to say that local governments possess the necessary formal authority to create laws, plans, and budgets to promote MUS on an *ad-hoc* basis. The constitution and the Local Government Operational Act (2017) called on those entities to plan, budget, and implement development programs within their capacity and resources [81]. Final budget authority for such initiatives rests with the relevant Palika assembly.[4]

[4]Villages are small geographical units of a ward and several wards together constitute a Palika. The Palika assembly is a decision-making body that includes the Mayor/Chairperson and the Deputy Mayor/Vice-chairperson of the municipal executive, ward chairpersons, and four members elected from each ward as well as members of the municipal executive elected from the Dalit and minority communities.

Most of the key informants (85%) interviewed argued that LG officials should take a lead role in MUS planning and implementation because they know local realities, needs, and resources the best. More particularly, these individuals also suggested that LGs should manage some MUS funding. According to a significant share of our focus group participants and key informants, this was so, in part, because they feared that if Palikas were not designated as chief project implementers, their leaders might well lose interest in, and refuse to accept ownership of, MUS design and realization. Put differently, local governments should lead the rural development agenda to ensure that that level of governance would become more responsible for addressing citizen's needs. Pradhan et al.[89] and Clement et al.[24] have also contended that LGs should be responsible for MUS development and should be granted sufficient decision-making authority and financial autonomy to address those aims. In light of these facts, MUS represents a new challenge for most Nepali localities and actors. As a result, existing staffs might not be able to oversee implementation of such water projects effectively because they lack resources, understanding and technical capabilities.

LGs Roles in MUS Scale-up

More generally, the vast majority our key informants contended that MUS should be fully institutionalized as a standard program within Nepal's local governments. These individuals argued overall that LG responsibilities should include: 1) an annual planning and budgeting process for MUS projects; 2) securing necessary resources for system development and realization; and 3) ensuring that farmers receive multiple forms of support to adopt and implement MUS. Each of these areas of potential LG MUS responsibility is discussed in greater detail below.

Annual Planning and Budgeting for MUS Projects

Prior to January 2018, when the new federal system went into effect, NGOs and VDCs implemented MUS projects on an *ad-hoc* basis. Now, however, LGs are at least formally well positioned to manage the planning and budgeting for such systems. To do so effectively however, those governments must provide villagers an opportunity to identify and rank their priorities for development through a need-based project identification process mandated by the constitution. Once a majority of residents have opted for a suite of potential initiatives, those must next be approved by the village[5] and Palika assemblies.

Securing Necessary Resources for MUS Development and Realization

The Nepali government's fiscal year begins with 1^{st} Shrawan (roughly mid-July) and LGs must prepare their annual budgets a year ahead of that date to secure sufficient time for review. However, the I/NGO planning cycle largely depends on donor approval of funding and subsequent sub-contracts to local NGOs. The mismatch of I/NGOs planning schedules with those of the government has created a challenge when efforts require combining resources from these sources. This suggests that I/NGOs could shift their planning system timelines to align them with those of local governments to allow pooling of funds for MUS LGs. Donors must also approve any such changes.

Farmers Must Receive Multiple Forms of Support to Adopt and Implement MUS

A large share of our key informants argued that farmers must receive training, access to inputs (seed, fertilizer, and technology), and marketing and lending services from cooperatives, private entities, or agency service providers for MUS to be implemented effectively. More than two-thirds of our household survey respondents also reported that MUS must include a range of services for farmers to help them scale-up production activities. These include crop production technologies (e.g. irrigation systems, integrated pest management, appropriate

[5] Legislative powers at the local level are vested in the village and the Palika assembly. A village assembly consists of the chairperson and vice-chairperson of the village executive, ward chairpersons, four members elected from each ward, and members of the village executive elected from the Dalit and minority communities [78].

seeds, low-cost greenhouses) and a number of additional services (agricultural input suppliers micro-credit, crop collection centers, and marketing). Roughly one third (35%) of the households who used three or more technologies/services reported an annual average income of $380 from the sale of vegetables, while the annual average income from vegetables for all households participating in the survey was $190. These results suggest that these services when used in an integrated way have a positive impact on productive income.

Government, User and Private Sector Capacity Building

Capacity Building of WUA

Most stakeholders understand and support the role NGOs play in helping user project committees (such as WUAs) develop agreements with them to manage the MUS development process, including engagement with support service providers such as micro-lenders, private suppliers, and cooperatives. Those managing any MUS project operating within a Palika will need to interact extensively with local and state officials and the district coordinating committee (DCC[6]).

Typically, a WUA oversees the development, management, and operation of a water system, guided by a locally adopted agreement. Establishing an effective institutional structure consistent with local customs and norms requires considerable facilitation skills and targeted capacity building. In addition to the operation and management of MUS, WUAs partner with local agro-vets and extension agents to provide training and technical assistance to farmers. Our focus group discussions with WUA members revealed that at least two system operators per water system need to receive 2-3 months of professional training to repair and

[6]The DCC is a nine-member elected body in each district assembly. Each district has several Palikas and its elected officials (by the people) elect 9 members to represent the Palika in the DCC. It coordinates and monitors the development activities of Palikas within the districts. It also plays a critical role in resolving conflicts between different Palikas and between Palikas and state governments.

maintain MUS systems. Because many young males work abroad, primarily in the Middle East, women assume much of the responsibility for smallholder crop production [42]. This informs a need to train women to serve as operators. A local NGO official experienced in MUS implementation explained:

> "We provided MUS installation, operation, and maintenance trainings to at least one man in each MUS community. We also provided a training completion certificate to them. It was disappointing that many of them went abroad for jobs. We also learned that the certificate we provided helped them to secure those jobs. We have realized that it is important to train at least one woman and one man as an operator per system" [Interview, NGO Official, December 2017].

Capacity Building of Local, State, and Federal Governments

Individual Palikas are now tasked with evaluating local water needs and establishing funding priorities to address them. Thus, it will be critical to engage and train Palika officials in developing such evaluations to ensure that productive uses of water, such as vegetable cultivation, are considered during their deliberations. Further, nearly half of our key informants (48%) confirmed the need to educate local officials on the engineering, agriculture, and social mobilization requirements of MUS developments. Understanding the support services and technologies necessary for such projects will allow Palikas to act on these needs. This suggests that MUS planning and implementation training should be provided to LG engineers. I/NGOs that have implemented previous MUS projects are well equipped to provide such assistance.

Three-fourths of our key informants reported that workshops, publications, and learning alliances involving government, NGOs, and other relevant stakeholders at the federal, state, and local levels constitute an important mechanism for sharing knowledge related to MUS. One MUS expert informant argued, for example, that, in his experience, the more officials understood the basic idea of MUS, the more receptive they were to it.

Capacity Building for Farmers to Create MUS

A majority of key informants (70%) reported there is substantial demand for this approach in communities whose growers had received an orientation to its characteristics and aims and who had undertaken a site visit to a successful project. Such visits have proven to be a compelling way to educate people about MUS and thereby expand interest in the approach.

Relevant training and visits to successful farms had equipped growers to become more effective commercial producers [Interview, NGO Official, December 2017]. This assistance occurred within farmer groups in communities and at collection centers or local agricultural cooperatives. In three successful MUS communities where collection centers or agricultural cooperatives were well established and private sector input suppliers and micro-finance institutions were accessible, nearly three-fourths of the household respondents suggested they were benefiting from production training and access to those services. This finding implies that WUAs need to ensure that farmers have access to specific capacity building opportunities related to the activities they will be responsible for. An agricultural input supplier (i.e., agro-vet) may demonstrate drip irrigation or hybrid seed varieties while a collection center representative might recommend a particular timing and quantity of crop varieties. Farmers seeking a production loan from cooperatives or micro-credit lenders should learn how to maintain records and track payment. In short, a wide range of service providers need to become engaged in the training of producers to equip them with the knowledge and skills necessary to become successful commercial farmers [Interview, Agriculture Expert, November 2017].

Capacity Building of Federations, Cooperative, and Private Sector Actors

More than two-thirds of the key informants (35) suggested that I/NGOs could educate the Federation of Palikas, leaders of cooperatives, and agro-vet staff members on the requirements for MUS. Agro-vets can also inform and orient NGOs and production groups on the availability of improved inputs and production techniques. The Federation of Palikas, an association of elected representatives serving in those bodies, can directly influence other actors as they consider MUS adoption. Cooperatives typically represent several farmer groups' interests and also provide credits for agricultural production. Agro-vets provide agricultural inputs and related services to MUS farmers.

Coordination and Collaboration among Different Sectors and Governmental Levels

More than half of the key informants (52%) identified horizontal coordination among agencies and vertical coordination among local, state, and federal agencies as being critical to effective and efficient MUS service delivery. A factor complicating this coordination is that government agency officials typically have a top-down mentality. Indeed, one of the primary barriers to successful implementation of the new constitution is a "centralised mindset," not only at the center of government, but also at the state level [Interview, Political Leader, December 2017]. Thus, it is important to overcome such a bias and respect local priorities and claims. For example, the state infrastructure, agricultural, social welfare, and environmental ministries will need to listen and support LG MUS priorities, rather than offer directions.

As noted above, all three levels of government—federal, state, and local—enjoy some measure of authority for water supply. This overlap has not yet been fully clarified by federal legislation and uncertainty about roles and responsibilities will likely continue until such can occur [10]. Infact, this situation gives the nation and states some control over LG policy-making. It is therefore important that the federal and state governments respect and support LG MUS-related policy decisions that meet the law and their accountability requirements. Under the new governmental system, the DCC will play a critical role in shaping policy as they are expected to mediate disagreements between LG officials and federal and state ministries. Hopefully, the DCCs will be able to resolve policy roadblocks and conflicts to MUS development by working closely with representatives of higher-level governments.

I/NGOs and government also must collaborate to share knowledge and good practices. A vast majority of the water supply experts (80%) suggested that MUS implementers should incorporate their efforts into a basin-wide examination of water sources through the preparation of water use master plans (WUMP) that set the development priorities for each water source. MUS can become a central part of the WUMP when such planning occurs [89, 93]. Indeed, I/NGOs can provide training to LG engineers and officials to integrate MUS into WUMP efforts. Such a strategy would require considerable collaboration among MUS and WUMP related organisations and approval from local and state ministry officials.

MUS Registration by Palikas

The Water Resources Act, 1992 (2049 BS) and the Water Resources Rules, 1993 (2050 BS) authorized District Water Resource Committee (DWRC)[7] to register water comittees or WUAs [77]. However, these government actions did not recognize MUS WUAs, because MUS is not yet formally recognized as a distinct approach to water delivery at any level of Nepali governance. As a result, unlike drinking water and irrigation WUAs, MUS WUAs have never found a space in national federations. This situation prohibited them from advocating

[7] Prior to 2015, the district water resource committees operated under the auspices of district development committees. These entities no longer exist in the current governance structure.

for MUS in national policy platforms. One of the experienced water supply experts argued that MUS promoters tend to focus on achieving MUS targets set with donors, rather than building the MUS capacities of WUAs [Interview, Water Supply Expert, December 2017]. In addition, there is no evidence that the MUS promotors effectively engaged DWRC in MUS planning processes.

Since DWRCs do not exist in the current governance structure, Palikas now manage MUS registration (water source and WUAs) but they do so inconsistently. That is, while some Palikas have formally registered MUS, others have declined to do so. Those that have refused have argued that these systems are not formally recognized in national government policies. iDE MUS guideline has highlighted the importance of securing such registration, but there are only a few examples of when this has occurred. As one Chairperson of a MUS WUA commented in an interview with us:

> "We went to the District Water Resource Committee to register our water source. Unfortunately, the committee refused to register the source with a name "multiple uses" added to it. They mentioned that the existing registration guidelines did not allow them to register the source. It was important for us to register the source to formally secure its ownership. Therefore, we registered the source without mentioning MUS" (WUA Chairperson, December 2017).

More than two-thirds of the key informants (70%) stressed the need to establish a clear and streamlined MUS registration process at the local level. Arguably, if MUS is formally recognised in policy, registration will be required at the same time. Similarly, Pradhan et. al [89] have argued that Palikas should formally assume responsibility for water system registration and/or renewal of water sources and user groups. However, it is not yet clear whether LGs will be willing to assume such a role without MUS first being recognized in national policy. This again suggests the important question of why MUS policy is not changing at the national level. We respond this specific concern in Section 5.4.

More Effective Advocacy and Changes in Policy

A large share of the key informants argued that the lack of a clear and supportive national government policy impedes MUS development. Taking MUS approaches to scale will require that responsible ministries change their strict approach to single-use domestic water supply [24], which serves the needs of the WASH sector, but fails to accommodate productive uses. This situation remains one of the biggest challenges in planning and funding MUS. A local political leader contended that governments limited understanding of economic benefits from small-scale productive uses and lack of stakeholders collective action to press the government to make that change has led to this situation [Interview, Political Leader, December 2017].

Upscaling MUS in Nepal also requires further documentation of the challenges and benefits of ongoing efforts [12, 40]. Indeed, a significant MUS information dissemination campaign is required to make government officials and political leaders aware of the advantages of this approach and thereby, hopefully, gain their support for a change in policy to support such systems. These materials should be packaged to appeal to a variety of target audiences. For example, state officials within the Physical Infrastructure and Development Ministry might be particularly interested in the design aspects of MUS, while the Land Management, Agriculture, and Cooperative Ministry would be more interested in the support services needed by farmers (e.g., production and marketing supports linked to MUS). Potential users could also use such information to make informed choices concerning their participation in MUS efforts. A highly experienced development professional involved in the devolution of irrigation management to local user associations argued in his interview that a MUS network or similar group could assume responsibility for sharing information with potential stakeholders [Interview, Water Supply Expert, January 2018].

This network could also advocate for needed local government policies by working closely with the Federation of Palikas [Interview , INGO Official, January 2018]. This group could also work with the National Federation of Irrigation Water Users' Association (NFIWUAN) and the Federation of Drinking Water and Sanitation Users Nepal (FEDWASUN) at the national level to advocate for needed policy changes and implementation practices, as shown in Table 5.2.

Table 5.2: Proposed Institutional/Policy Changes for Scaling up MUS

Current	**Proposed**
Primary funding from Donors	Primary funding from Nepali governments
Short-term project approach	Long-term program approach
INGOs/NGOs as major implementer	Local government as the major implementer and NGOs in a capacity development and supportive role
Sectoral coordination	Inter-sectoral coordination among actors in the WASH, agriculture, irrigation, rural infrastructure, and environmental sectors
WUA as the operational and managerial entity	Multi-functional user group (with the additional role of facilitating access to technology, support services, and markets)
MUS planning initiated by NGOs	LGs assume responsibility for planning and budgeting for MUS

MUS Funding by International Donors

As noted above, international donors remain the largest contributors to MUS development in Nepal. In practice, it is unlikely that localities will soon obtain adequate funding from the federal government as per their formal mandate due to its limited financial resources. In addition, the constitution and the Intergovernmental Financial Arrangements Act 2017 provide little guidance concerning which funding mechanisms should be used to support specific functions [19] . Further such a limitation can make LGs officials less accountable for their public service responsibilities. For instance, they can make funding decisions based on their own interests due to lack of clarity on what infrastructure or public functions to spend their funds on. As pointed out earlier, LGs have limited financial resources to implement these services including MUS. Given these constraints, a majority of the key informants and focus group participants argued that international donor contributions are now and will remain critical in the foreseeable future to ensuring adequate LG budgets for MUS planning and development in Nepal.

Schedule-5 (list of federal powers) and Schedule-6 (list of state powers) of the constitution grants federal and state[8] governments legislative and executive authority over foreign grants. National government policy currently bars local governments from signing aid agreements with international donors. However, LGs are charged with implementing donor funded public service projects (e.g., rural infrastructures, agriculture extension, rural water supply, etc.). More than half of our key informants (55%) advised that LGs should obtain donor's funds for hardware (i.e., water system construction) and seek the assistance of I/NGOs for software (i.e., capacity building) to ensure effective implementation of MUS projects.

5.4 Factors Mediating MUS Scale-up and Potential Ways to Address Them

This section provides an overview of strategies that together could chart a way forward for scaling up MUS in Nepal. Overall, government and I/NGO officials, and interested external parties and stakeholders active in pressing for MUS, should consider a range of technical, socio-cultural, and economic factors when advocating for its widespread implementation.

[8]According to the new constitution, the state government can exercise authority over foreign assistance with the approval of the federal government.

The various stakeholders involved possess differing resources, capacities, and knowledge of MUS. Furthermore, all of the actors now engaged face the very real challenge of developing these proposed systems amidst capacity constraints and while governmental responsibility allocations are being established.

We expect that local government capacity building and the related challenge of diffusing MUS knowledge to potential users will prove a long-term process. Making the proposed model shown in Figure 5.2 will require time and considerable training and team building to implement. The government at several levels will have to help foster such efforts. It is important to recognize that the success of these strategies will ultimately depend on the ability of localities to pursue them effectively, responsibly, and with accountability. It is equally important that federal and state governments and I/NGOs extend financial and technical support to local governments for the purpose.

5.4.1 Technical Factors: Capacity Building of Local Stakeholders in Planning, Design, Repair, and Maintenance of MUS

As we have noted, most LG leaders are most familiar with single-use domestic water systems concerning water services provision. Indeed, most local governments have had no or limited direct involvement in the planning and designing and management of MUS projects. Such officials, including engineers, need to develop a clear understanding of multi-use water system planning and design if this situation is to change. In turn, the NGOs now implementing MUS must work to help build LG capabilities to assume responsibility for their current efforts and do so on an ongoing basis to encourage the possibility of change.

Shifting MUS development responsibility from I/NGOs to LGs will likely require a transition period of several years, during which the knowledge gained from developing and refining the

MUS development during the past two decades can be shared with local officials. In this process, I/NGOs can play a critical role in supporting the government (at all scales) with MUS-related resources and expertise. External resources will be essential to support this capacity building effort.

5.4.2 Techno-economic Factors: Access to Market and Production Services

LG officials already possess knowledge and capacity concerning agricultural production activities. However, this knowledge has yet to be connected with MUS. Given the single-use water services provision mentality among most such leaders, it will take significant time for engineers and agricultural experts to understand and act on the need for the water and agricultural sectors to work together to advance MUS projects.

The provision of crop and livestock insurance, financial services, and credit from the private sector is likely to reduce the fear associated with MUS-based production such as production failures, low crop yields, and uncertainty of sales after production. These factors can, and often do, discourage users from undertaking water-based production activities [42]. A core aim of MUS is to encourage commercial-scale production through continued innovation and improvements in water supply systems. Meanwhile, farmers must be able to diversify their crops, spread farm production over the years, and take risks relating to stresses such as weather and market shocks. To achieve these goals, technology suppliers and service providers (technology suppliers, agro-vets, veterinary services, credit services providers, etc.) should establish/expand productive technologies and services supporting MUS. As suppliers make profits from their businesses, they can continue to provide their services to MUS farmers. In this sense, private sector involvement is likely to be critical to expanding MUS. In summary, the private sectors need to be harmonized with agriculture cooperatives that provide extension services. In the meantime, LGs must recognize these services as an integral component of their MUS program.

5.4.3 Socio-political Factors: Community and Government Awareness and Access to Knowledge and Information on MUS

For the concept of MUS to be widely understood by communities, LGs too will need to conduct technology demonstrations, information campaigns, and workshops at the grassroot level. Such activities should occur as localities develop the capacity to lead/support MUS outreach, which will likely be a long-term process.

Importantly, LGs have human resource constraints to deliver basic services. In partial response to this gap, I/NGOs may consider sharing their human resources with LGs as part of capacity building efforts. For instance, I/NGOs can play their familiar role of working with communities to assess water needs, supply sources, create opportunities for crop production, and provide technical support. In addition, they can play a critical role in advocating for policies and procedures to accommodate MUS among local governments.

At the state and local level, collaboration among MUS-related groups could take the form of a “MUS group” within the Palikas’ Federation. Such a group could integrate knowledge and best practices related to WASH, the productive uses of water, and support services and advocate for MUS among state and local government officials. At the national level, the “MUS network” could establish coalitions with kindred organisations with the objective of educating government officials (through workshops, trainings, information campaigns, etc.) on the role of MUS in alleviating poverty in the rural hills of Nepal. It is essential that state and national leaders support local elected officials if MUS is to be more widely adopted.

5.4.4 Economic Factors: Financial Resources and Mechanisms for MUS Funding

We have argued that donor contributions will continue to be necessary for scaling up MUS. In our view, government funding for these systems should increase substantially compared to previous levels, while a larger portion of donor and INGO MUS resources should be devoted to relevant stakeholder capacity building.

Currently, all MUS projects are donor-driven and implemented over a 3-5 year period. Until adequate national and state MUS policies are established and the basic institutional capacity of LGs to advance such water systems is developed, I/NGOs will need to continue implementing MUS in an *ad-hoc* way with financial support from donors. It is important that both I/NGOs and donors recognize their long-term role in advancing MUS by transitioning this role to LGs as soon as appropriate. Local governments may be able to facilitate the work of I/NGOs by creating mechanisms to pool financial resources from multiple sources. Thus, a strong official commitment to the decentralization mandated by the nation's new constitution, along with government and donor willingness to work towards a unified disbursement mechanism for support funds, will be essential for effective MUS scale-up.

5.4.5 Institutional Factors: Appropriate Policies and Institutions for Effective Planning, Implementation, and Promotion of MUS

It is important that federal and state governments uniformly recognize MUS as a standard approach to rural water service development. However, such policies are unlikely to materialize until government officials at all levels fully understand and accept MUS. In addition, MUS WUAs traditionally function as the operation and management entity for such systems. We suggest that the Nepali government develop a policy that allows such groups to work as a multi-functional entity. This entity could facilitate the linkage of MUS users with agricultural technology, support services, and markets. Notably, LGs officials are new and will require skills to effectively engage in these policy arenas. I/NGOs and donors could lobby the national government to enact these policy changes.

5.4.6 Cultural Factors: Addressing Traditional Practices, Rooted Cultural Understanding, and Lack of Interest in Adopting Innovative Practices

A number of the key informants informed us that federal and state government officials may obstruct delegating responsibility for MUS to local governments due to their many years of working in a thoroughly centralized governance framework. Most LG officials simply follow federal instructions. Key informants also contended that that many government officials are risk averse, preferring to take conventional approaches to project development, rather than pursue innovations that might fail. Most government officials are historically trained to implement sectoral projects (i.e., domestic water system) (See Appendix A). For instance, they consider MUS challenging because it spans multiple sectors (engineering, agricultural, and social mobilization dimensions). This finding, also discussed in previous sections, highlights the importance of educating government officials on the multi-dimensional aspects of MUS development.

Importantly, the policy (discussed above) will not change until much larger numbers of Nepali government officials embrace the idea that people need, and can use, water for multiple uses. Thereafter, change is likely only to come with time and experience as MUS systems demonstrate their potential to change the lives of rural communities.

5.5 Conclusion

This article has examined MUS development in the middle hills of Nepal during the past 15 years. Under the new Nepali Constitution, local governments (LGs) can now play larger roles to advance MUS. However, until formally supportive national and state policies are established and LGs have developed the basic institutional and cultural capacity to advance them, the landscape for MUS is unlikely to be a dynamic one. Further, for communities to be receptive to MUS, local officials should strive to create an enabling environment for collaboration and partnerships among the infrastructure (water supply), agriculture, economic development, and social welfare sectors at the local and state levels. Making the new decentralized governance structure function effectively will itself require time and considerable capacity development efforts at all levels of government, quite part from the required changes necessary to implement MUS more broadly within Nepal. After carefully describing the challenges and opportunities that confront leaders and advocates wishing to scale-up MUS implementation in Nepal, a series of recommendations designed to advance such efforts at all levels of government are outlined.

Chapter 6

Summary of Findings and Conclusion

This research focused on understanding the factors that enable rural water systems to become more productive and technically sound. It also explores strategies to scale-up MUS for smallholder farming communities, reduce poverty, and promote rural economic development. This chapter provides a summary of main findings from this research and discusses the main contributions, study limitations, and suggestions for future research.

6.1 Research Question 1: *What are the key challenges limiting agricultural production in the middle hills of Nepal and what strategies could promote the commercialization of smallholder farming?*

The study found that nearly one-third of farmers have left their agricultural lands (mainly the khet lands) barren or only partly cultivated and a similar proportion of the households were not motivated to engage in agricultural activities. This lack of motivation was found to be connected with limited access to irrigation water, poor production systems, a lack of access to markets, a low return on investment, the low social status of farm-work, the incidence of crop infestations, and fear of production risks due to extreme climatic conditions. The study also found that remittances from out-of-country workers remained an important factor limiting farm production due to labor shortages. The major finding from this study is that there is potential to commercialize smallholder farming in the rural middle hills of Nepal. To realize this potential, the government and agriculture program implementers need to address the following technical approaches and practices: provide adequate access to year-round irrigation; promote the use of production technologies and practices; improve access to rural markets; improve production skills; and improve access to input suppliers and other service providers. This research also confirms that, for agricultural production to be profitable, households must produce high-value crops in conjunction with appropriate technologies and practices. Households that receive an income from government jobs, private sources, and remittances reported agriculture being a laborious and difficult task. These findings provide an important background for the subsequent research questions.

6.1.1 Contribution

The study identified a set of initiatives, approaches, and practices that the Government of Nepal and other stakeholders could advance to promote the commercialization of smallholder farming in the rural western middle hills of Nepal. Addressing these mediating factors has the potential to (re)engage rural households in farming activities. This approach is consistent with the Government's current Agriculture Development Strategy (2015-2035) that aims to commercialize smallholder agriculture and promote rural economic development. The implementation of this strategy will rely on the recent devolution of budget authority and transfer of funds to local governments.

6.1.2 Limitation and Future Research

The study focuses on identifying the mediating factors that enable small-scale farmers to become commercial producers. However, the sites studied and methodological approaches used were limited by the selection of appropriate water systems. More generally, the study focuses on production, but it does not consider how consumption patterns might affect the production and marketing of agricultural products. In addition, the research assumes that existing markets would be able to accommodate an increase in production, but future research should examine the market's ability to support the transition from subsidence farming to market-oriented commercialized production. This research should also examine the food supply chain and intermediate actors that influence local, regional, and national markets.

6.2 Research Question 2: *Does the design of rural water systems in Nepal impact the extent and scale of the water-based productive activities supported by the systems?*

More than 90% of households were found to engage in one or more water-based productive activities including growing vegetables and horticulture crops, raising livestock, and producing biogas and Rakshi (locally-produced alcohol), regardless of the system design, i.e., SUS vs. MUS. Considering all water-based productive activity, the extent of the productive activity differed insignificantly between MUS and SUS households, while the annual median productive income of MUS households ($446) was significantly higher than SUS ($290) households. The difference in income can be explained by the contribution of vegetable production, especially during the dry season when prices are high. Despite the difference in productive income, the amount of water used by the MUS and SUS households was not significantly different (183 LPD for MUS and 166 LPD for SUS). Since the SUS vs. MUS classification was not found to be a significant determinant of the extent of productive activity, the households were reclassified as having high or low levels of productive activity based on the quantity of water used for these activities and the associated earned income. The analysis then identified the factors that enabled a high level of productive activity to occur. They include households that farm as a primary occupation, use productive technologies, are motivated to pursue productive activities, have received water-related productive activity training, and have received external support related to productive activities. Important, but less dominant, predictors include wealth status, income from government jobs, remittances, and tap ownership. The analysis revealed that SUS can be considered as 'de-facto' MUS. In other words, these results challenge the current approach to rural water provision that views SUS and MUS as functionally different services.

6.2.1 Contribution

The identified predictors indicate that expanding the design of rural water systems in Nepal to include those factors described above is likely to result in higher levels of productive activity and improved livelihoods. MUS implementers, government officials, and responsible stakeholders should design rural water services with these determinants in mind. The findings from this research will also help planners of rural water systems to identify households likely to participate and benefit from MUS development.

6.2.2 Limitation and Future Research

Income and water consumption data used in the study were self-reported by the surveyed households. This may lead to some inaccuracies within these data despite efforts to gather these data as accurately as possible. To try and reduce errors, households were asked to measure water-use for domestic and productive uses for at least 2-3 days before interviews. They were also trained to measure water flow for accuracy. For the income records, households were asked to calculate their water-based income from the prior year so that it could be reported during the interview.

Productive income and water consumption for each of the surveyed households were used as key indicators in defining high or low levels of water-based productive activity. However, high-performing farmers reported several related benefits such as time savings, health benefits, new social relationships, and nutritional benefits that were not included in the factors that contribute to a high level of productive activity. Future research is needed to measure the impact these benefits have on motivating farmers to commercialize their crop production. Moreover, the study addressed productive income as water system-based income but did not capture the contribution of rainfall to production. Future research could distinguish household crop production and income during the monsoon season compared with the dry season when prices are the highest.

The farming communities surveyed for this research are typical for the middle hills of Nepal, with each containing 10-35 households and being isolated from market centers. The findings from this study may not be applicable to larger communities or those located in peri-urban settings. It would be useful to conduct similar research in larger gravity-fed schemes that serve larger populations.

6.3 Research Question 3: *What factors determine the technical performance of productive rural water systems in the middle hills of Nepal?*

Three household-level and three system-level predictors of the duration of water system breakdowns were identified. The significant household-level predictors include: (1) a sense of ownership towards the water system; (2) user involvement in decision-making during the planning and implementation of the water system; and (3) income earned from water-based productive activities. The significant system-level predictors include: (1) distance from the village to the water source; (2) the performance of the water user committee; and (3) the water system operator's level of activity. In addition, the study captured the interactions between household- and system-level variables. The empirical relationship between household productive income and the duration of breakdowns is a novel finding within the rural water supply sub-sector.

6.3.1 Contribution

Given the government's focus on providing water supply throughout Nepal, the model results contribute to the planning and development of technically sound and sustainably managed water systems. Various social, economic, engineering, and management predictors were analyzed to help identify effective design guidelines. In addition, the model results predict that increased household water-based productive income is significantly related to the duration of breakdowns. This reinforces the current finding that increased productive income enhances the ability of households to support system maintenance and upgrades [25, 95]. In summary, the findings inform rural water supply practitioners that a viable financial and institutional framework is essential for the sustainable operation and management of rural water systems.

6.3.2 Limitation and Future Research

The study considers the reliability of water sources (as perceived by community members) as an important factor influencing a system's technical performance. There is a growing concern that mountain springs are declining/drying up in the middle hills of Nepal. Scientific research that captures the long-term reliability of these water sources would be useful. Moreover, the study did not capture water quality as a factor of system performance and/or operation and management. Future research should examine the relationships between water quality and water system technical performance.

The study predicted that families with higher water-based productive income had more reliable water access. However, it did not explicitly examine whether the increased financial gains were related to system repair and maintenance. Productive income can help farmers secure essential support services such as marketing, water saving technologies, low interest credits, and input suppliers that were outside the scope of this study. This insight can be investigated through new research.

The study has not examined if productive income was affected by system breakdowns. Future research is needed to examine whether or how system breakdowns contribute to income losses due to interrupted access to water for productive uses.

6.4 Research Question 4: *What strategies could be used to advance multiple-use water systems (MUS) in the middle hills of Nepal?*

Under a new Constitution that went into effect in January 2017, newly formed local governments are provided with the funding and budget authority to determine local service priorities and how these services will be funded, designed, and implemented. Since rural municipalities have little technical capacity, donor funding through international NGOs will continue to facilitate development of rural water systems. The challenge to scaling-up MUS development will require a systematic public information initiative involving provincial ministries, local governments, political parties, and allied organizations such as the Federation of Palikas (rural and urban municipalities). The following six key strategies, if widely adopted, could encourage wider acceptance and use of MUS in the middle hills of Nepal: establish nascent local governments as the principal agents responsible for MUS; build MUS capacity among government officials, water system users, and private actors; require multi-use water systems to be registered by Palikas; improve coordination and collaboration among different sectoral actors and across levels of governance involved in water provision and management; advance more effective policy advocacy by MUS proponents and change national policy so that it formally recognizes MUS; and sustain international donor support for MUS. However, the process for scaling-up MUS begins with community participation in the local government planning and budgeting process, where donor funding can be critical.

6.4.1 Contribution

The study recommended that the actors supportive of MUS should consider a range of technical, socio-cultural, and economic factors when advocating for its widespread implementation. Those findings addressed policy questions arising from the adoption of a three-tier federal governance system, a transition that is still nascent and unfolding. Therefore, the findings of this research will have important implications for the Nepali government with regards to what policy, capacity development, and institutional arrangements need to be addressed moving forward. Moreover, the MUS implementation and scale-up strategies identified in the study will also help funders and I/NGOs to understand their role in advancing MUS in Nepal.

6.4.2 Limitation and Future Research

The research used a cross-sectional (a singular point-in-time) method to draw strategies for effective implementation and upscaling MUS in the rural middle hills of Nepal. Given a wide range of respondents chosen from different levels (local, province, and federal) and walks of life, some technical questions were posed to only some of the informants. This reduced the "n" for certain variables of interest. The focus groups and household surveys were designed to complement key informant perspectives. In addition to the extensive use of surveys, project files were examined to identify the technical design, funding sources, and operational characteristics of each system being studied. These systems were built or upgraded through a donor funded intervention prior to the restructuring of governmental service delivery where money and decision-making authority is granted to local governments. It would be interesting to research water systems constructed under the authority of local governments to determine how they compare with the guidelines developed from the current study. This proposed study would sample systems from each hill region where the development of piped water systems is common. This large "n" follow-up research would evaluate the change in financial and institutional capacities and socio-cultural practices with reference to the recommendations presented in this research.

6.5 Personal Thoughts—Transforming the De-facto Water Systems to Planned Systems?

MUS practitioners argue that rural water systems become multiple use systems when people adapt to meet needs beyond planned uses [49, 108]. This argument is confirmed by this research. Arguably, one can view this as a free-rider issue. According to Renwick et al.[95], intermediate level MUS is reached when between 157-475 liters per day per family is provided by a water system. Accordingly, the systems included in this study could be classified as intermediate level MUS with 183 liters per day for MUS and 166 liters per day for SUS. At this intermediate level, water should be able to support a small scale-enterprise such as a few livestock or small farming plot [95]. It is my view that SUS, even when accommodating productive uses, have obstacles that need to be overcome because the system is built around single-use planning, budgeting, and management provisions.

The previous discussion raises a question about whether it is realistic to design and implement a planned system to meet a range of prospective water needs. My experience as a development professional and water resource development engineer, suggests there are challenges to implementing a strictly planned system. First, it is hard to accurately estimate water demand due to the variability of water user needs. Second, an existing water infrastructure is a dynamic system, which changes as users upgrade from street taps to household taps, or add new users and technology or secure a new water source. Such changes affect the water supply and new operational norms may be needed. In my view, rural water systems should be designed with flexibility in mind so that extensions and other modifications become easy to accommodate. Water system implementers should focus on creating simple construction methods so that a trained system operator can make most system modifications without outside technical assistance. This simplicity of design is likely to make the system more resilient and sustainable.

A well-designed MUS enables the development of productive activities while providing sufficient water for domestic uses. Notably, MUS households generated higher incomes than SUS users because they received technical assistance along with access to marketing services, appropriate inputs, micro-credit, etc. In the end, smallholders served by MUS were able to substantially increase their income and improve their livelihoods. Establishing participatory and inclusive decision making processes around the provision of water creates an opportunity to plan a water system that addresses all users multiple water needs. For instance, listening to women, adolescents, elderly individuals, differently able (i.e., disabled) persons, and disadvantaged groups (low incomes, ethnic, and lower caste groups) would help the water system implementers address a community's specific water needs. The design factors/principles highlighted in this research also provide a framework that could make the promise of MUS achievable.

The study findings show that scaling-up the MUS approach has been and will continue to be a challenge because MUS actors have differing access to resources, capacities, and knowledge of the approach. Community leaders, government officials, NGOs, and private sector actors involved with MUS communities need to understand, act, and transfer the knowledge that will promote further MUS development. It is important to recognize that the success of these strategies will ultimately depend on the ability of localities (including local governments) to pursue them effectively, responsibly, and with accountability. Overall, I believe this research provides a pathway to implementation and scale-up MUS in Nepal.

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Appendices

Appendix A

Chapter Five — Supplementary Material

A.1 Sectoral Development Priorities

- **Economic development:** Agriculture, industry and commerce, tourism, cooperative, and financial sector;
- **Social development:** Education, health, water supply and sanitation, promotion of culture, gender equality, and social inclusion;
- **Infrastructure development:** Roads and bridges (including suspension bridges), irrigation, building and urban development, energy, micro and small hydropower (including renewable energy);
- **Environment and disaster management:** Forest and soil conservation, watershed management, environmental protection, climate change, waste management, sanitary landfill sites, water-induced disasters, disaster, and emergency vehicles;
- **Social development and service delivery:** Human resources development, institutional capacity building, institutional infrastructure, token system, and use of electronic messages in service delivery; and

- **Financial management and governance:** Revenue mobilization, financial discipline/governance, financial risk minimization, public audits, social examination, internal audit and internal control mechanism, and information and communication management.