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Implications of Limited Water Availability for a Small Farm in Western Nepal

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Abstract

In Nepal and other developing nations, mixed farming – combining livestock and cereal crops – enhances income and food security. However, these systems face challenges from various factors such as population growth, urbanization, and water scarcity, among others. Though there are several researches in Nepal on water availability and water allocation using a model-based approach, it is still a major concern on a small farm scale which is a source of livelihood for many smallholder farmers. The poorest and most at-risk groups are the ones most affected by food and water scarcity. Rapid urbanization and changing lifestyles further strain water resources, leading to water insecurity. Therefore, it is even more important to use the limited available water resources wisely and efficiently and adhere to proper water management practices. Consequently, research in this field is gaining increasing importance due to diminishing water supplies and growing consumer competition. It is imperative to efficiently and responsibly utilize our limited water resources and adhere to sound water management practices for sustainable growth. This research addresses the lives and livelihoods of smallholder farmers in Nepal. Results reveal variations in discharge rates among four water sources, with water scarcity evident for irrigation in most months, except for May, based on the current cropping pattern. Moreover, there is an urgent need for efficient methods of managing water resources and agricultural fields to enhance the efficiency of water utilization. This not only boosts the amount of available water but also opens up possibilities for growing valuable crops, ultimately improving the well-being of small-scale farmers. This study collected both primary and secondary data through fieldwork, including stakeholder consultations, survey design, and a combination of qualitative and quantitative approaches. The findings shed light on Nepal's climate adaptation and mitigation strategies, emphasizing the need for more precise agriculture water management.

Keywords

Climate Change, Crop Water Requirement, Demand, Net Irrigation Requirement, Water Availability

1. Introduction

In Nepal, mixed farming systems, which blend livestock with cereal crop cultivation to boost income and provide a safety net against food shortages, are prevalent, as in many other developing nations [1]. These systems help farmers diversify their risk, optimize their workforce, and improve output quality. Yet, they face persistent and intense challenges, including factors like water scarcity and climate change among others.

Water scarcity, impacting more than half of the world's population for at least one month per year [2], is an emerging problem. By 2025, an estimated two-thirds of the global population could experience water stress [3]. Rapid urbanization and changing lifestyles further strain water resources, leading to water insecurity [4]. In Nepal, where the majority of the 26.4 million people are impoverished and over 80 % reside in rural areas [5], the situation is particularly challenging. A study conducted by the International Labour Organization (2019) revealed that the vast majority of vegetable production in Nepal is attributed to smallholders. Specifically, 3.2 million holdings engaged in vegetable cultivation represent 69 % of all Nepalese households. According to the Food and Agriculture Organization of the United Nations, 2.7 million smallholder farms are responsible for producing 70 % of the country's food supply, with nearly five family members participating in the operations of each household farm. Furthermore, Nepal's Agriculture Development Strategy (2015-2035) aims to enhance food production by promoting increased productivity in micro, small, and medium-sized agro-enterprises, including those led by women, youth, and disadvantaged groups [6].

Effective management of Nepal's water resources to meet year-round agricultural, livestock, and residential demands remains a significant challenge. While plains rely on large and medium irrigation systems, as well as shallow and deep tube wells, hilly and mountainous areas depend on rivers, rivulets, and springs, managed by medium and small-scale irrigation systems and water supply programs. The presence of numerous rivulets and springs in Nepal presents opportunities for smaller irrigation and water delivery systems in rural areas with water scarcity.

Although irrigation consumes ten times more water globally than all other uses combined, proper crop management can save up to 100 % of water when temporarily fallowing farmland [7]. Despite research on water availability and allocation in Nepal using model-based approaches, concerns persist at the small farm scale, which sustains many smallholder farmers. Given the predominance of smallholder farmers in Nepal and their significant contribution to the national Gross Domestic Product (GDP), research in this area gains increasing importance amid declining water supply and growing consumer competition. Utilizing limited available water resources wisely, practicing efficient water management, and adhering to sustainable growth principles are critical [8].

This research addresses essential questions, including the status of water availability, its impact on crop production, its effects on the lives and livelihoods of smallholder farmers, and potential solutions to these challenges.

2. Material and Methods

2.1 Study Area

The study area (Coordinates: 28°26’30.5" N, 81°52’10.9" E) is situated in Gurbhakot Municipality in Surkhet District of Karnali province (Figure 1). According to the 2011 Nepal Census, the total population of the municipality is 43,765 of which 19,882 men and 23,883 women, and the total area of the municipality is 228.62 square kilometers. People living in the municipality earn their living through trade, industry, tourism, commercial agriculture, and animal husbandry. The municipality has residences of all kinds of castes especially high residences of Brahmins, Chhetri, Magar, Rai, and Dalits. The communities of this region use the Nepali language as their mother tongue, while the Magar language is also prevalent. Although there is arable land in this area, due to the lack of irrigation, and the lack of modern technology, the people here are engaged in other activities and migrating to India. The farmers with a varying range of landholdings in this community mainly produce rainfed wheat, maize, pulses, and some vegetables in their backyards for self-consumption. They also rear animals, mainly goats along with cows, oxen, chickens, and pigs for their personal use as well as alternative income by selling them in the nearby market once or twice a year. Most of the men of the locality are outside the village as migrant workers as the food production is not sufficient to sustain more than 3-4 months of the year. While most of the farming is rainfed, some of the water sourced from the nearby spring for drinking purposes is used for the occasional irrigation of vegetables. Because of water scarcity, an increasing number of farmers are leaving their land uncultivated. Nevertheless, some farmers have adopted water-efficient technologies such as drip and sprinkler systems, and they also store excess water from their drinking water supply in drums and other structures. These practices enable them to cultivate vegetables for household consumption. The total area is 137 hectares and the total cultural command area is about 70 hectares.

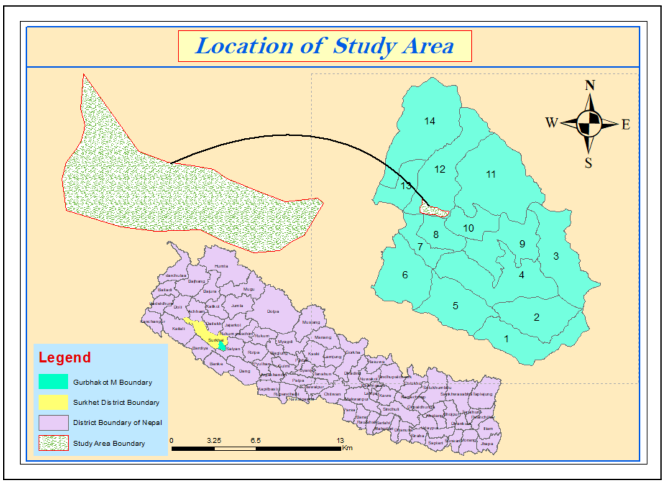

Figure 1: Location and details of study area

2.2 Methodology

The methodology starts with measuring the necessary data in the field as well as collecting data from institutions and literature and then calculating the various water demands using different methods. The domestic and livestock demands are estimated by the guidelines provided by the Department of Water Supply and Sewerage Management (DWSSM). Irrigation demand was estimated using the CROPWAT software. Water availability and source mapping were assessed primarily based on field surveys. Secondary data were also used where appropriate. Field survey and data collection were done followed by a couple of field visits to the selected site of the district and conducted semi-structured and key informant interviews with the government staff, Non-Government Organization staff, Community Based Organization staff, Junior Technical Assistance (JTA), cooperatives, and farmers. A questionnaire was prepared both in English and Nepal for a better understanding of farmers and completed at the site. The questions are targeted to collect information about water availability and its sources in the past and the current conditions as well as crop parameters. With the help of the availability of sources indicated by local stakeholders, discharge through each source was measured by the Area-Velocity Method. For the sampling techniques, all of the farmers were surveyed following the participatory approach as the study area was very small. For the identification of water demand: domestic, livestock, and irrigation water demand were considered. The crop water requirement is the amount equivalent to crop evapotranspiration. The crop evapotranspiration is the product of crop coefficient and reference evapotranspiration and was calculated using the FAO Penman-Montieth method.

The FAO Penman-Monteith equation for the determination of reference evapotranspiration (ET_0) is given by:

$$ET_0 = \frac{0.408 \cdot \Delta \cdot (R_n - G) + \frac{\gamma \cdot 900}{T+273} \cdot u_2 \cdot (e_s - e_a)}{\Delta + \gamma \cdot (1 + 0.34 \cdot u_2)} \quad (1)$$

Where:

ET_0 = Reference evapotranspiration (mm/day)
R_n = Net radiation at the crop surface (MJ/m^2/day)
G = Soil heat flux density (MJ/m^2/day)
T = Mean daily air temperature at 2 meters height (°C)
u_2 = Mean daily wind speed at 2 meters height (m/s)
e_s = Saturation vapor pressure (kPa)
e_a = Actual vapor pressure (kPa)
Δ = Slope of the vapor pressure curve (kPa/°C)
γ = Psychrometric constant (kPa/°C)

All the input data like climate file, crop file, field management file, and physical parameter were prepared and the model was run to know the net irrigation requirements. The root zone depletion was not allowed to deplete below 50 % Readily Available Water (RAW) content in the case of maize, wheat, millet, lentil, peas, and mustard while back to field capacity plus 50 mm water depth in case of paddy for flooding. The planting and harvesting date of the selected crop as per farmer respondent is shown in Table 1.

For the CROPWAT model, the following data were given as input

1. Climate Data For the determination of ETo, long-term average data of rainfall, maximum temperature, and minimum temperature were taken as suggested by Solangi et al [9]. The station considered was Mehalkuna (Lat: 28.42, Long: 81.84, and Elevation: 464 m). The reference evapotranspiration was estimated using the FAO Penman-Montieth method.

2. Crop Data The major cultivable crops in the study area are paddy, wheat, maize, mustard, millet, lentil, and green peas. The date of planting and harvesting of crops is considered for the present study. The crop coefficient and other parameters were adjusted according to the local condition. FAO paper 56 presents a procedure to calculate ETc using three Kc values that are appropriate for four general growth stages (in days) for a large number of crops. In the single crop coefficient approach, the effect of crop transpiration and soil evaporation are combined into a single Kc coefficient. Similarly, for the yield response to crop, FAO paper 26 helps to get data. However, the CROPWAT default value itself was derived from FAO so the default data are taken and adjusted as required.

3. Soil Data For the soil data, soil from 8 different locations following the soil sampling techniques was collected from the study area at 30 and 60 cm and mixed to make the final two layers. The textural analysis of soil was done in the central material testing laboratory by sieve and hydrometer analysis at the Pulchowk campus. The soil in the study area was found to be silty loam; the default soil was selected and adjusted as required.

4. Crop pattern Crop patterns were identified in the study area through a farmer's survey and validated with the government cropping pattern employed in the study. A cropping pattern consisting of the planting date, crop coefficient data files (including Kc values, stage days, root depth, depletion fraction) the area planted (0-100 % of the total area) and a set of typical crop coefficient data files were provided in the program. The planting and harvesting dates of selected crops are presented in table 1.

Table 1: Planting and harvesting date of selected crops

Crop	Planting date	Harvesting date
Maize	21-Mar	16-Sep
Millet	6-Jun	17-Oct
Mustard	20-Oct	6-Feb
Paddy	6-Jul	7-Nov
Wheat	23-Nov	12-Apr
Lentil	28-Nov	20-Mar
Peas	23-Nov	12-Mar

CWR and IWR compute due to the following formula, on account of the model.

$$CWR = ETo \times Kc$$

$$IWR = (ETo \times Kc) - ER$$

Where,
CWR is Crop Water Requirements
ETo is a Reference Evapotranspiration
Kc is the Crop Coefficient
IWR is Irrigation Water Requirements, and
ER is an Effective Rainfall

As the overall surface irrigation efficiency lies between 30-40 % in Nepal. So, irrigation efficiency was set at 35 % as there were losses in the field as well. After analyzing the demand and supply side as well as the field scenario, some pertinent measures were considered for adaptation. Following methodological framework was followed as shown in figure 2.

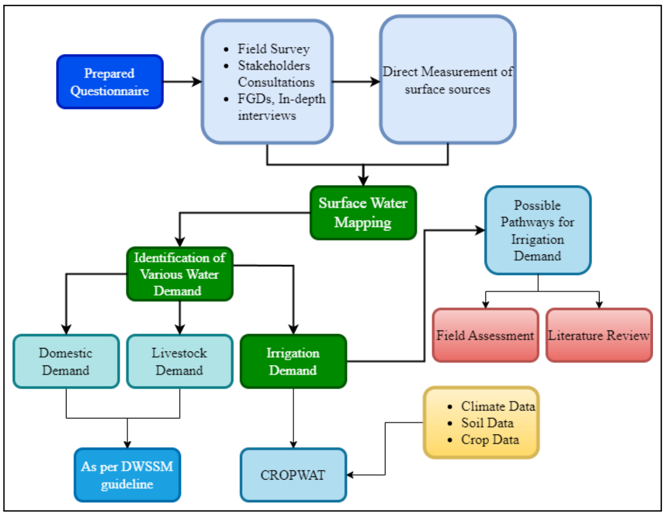

Figure 2: Methodology framework for this study

3. Results and Discussions

3.1 Surface water availability

A field survey was conducted to gather social as well as technical data which was required for this study and total demand was estimated in the study area. A total of 16 surveys were implemented including farmers, stakeholders, and Government officials. The major crops grown in the study area were rice, maize, wheat, mustard, peas, lentils, and millet. There were four sources with continuous flow throughout the year as indicated by the survey respondents. There was a spring source named as Source I with a constant rate of flow. At the intake, there are two ponds: one rectangular and another cylindrical. But both these ponds are dry which needs maintenance. There was another small conservation pond built to store water for irrigation. The capacity of the pond was around 0.083 million liters. Out of the total water available (0.0285 million liters/day), 3455 lit/day were estimated for domestic and livestock demand, remaining water is for agriculture. The major crops grown with this water are paddy, wheat, mustard, and vegetables. Similarly, there was another spring source named Source II of which discharge during March is 2.5 liters per second, i.e., 0.216 million liters/day is available. There is a pond to store this water, however, due to the construction of roads, the canal was disrupting the regular flow to the farm. The capacity of the pond was found to be 0.189 million liters. The pond water was used for irrigation and 19 households (HHs) benefitted from this pond. The major crops grown with this water are paddy, wheat with cowpeas, mustard, and some vegetables. There was another spring source named Source III. The discharge from the source was 6 liters per second i.e. 0.518 million liters/day. As seen, there was a huge irrigation potential but it lies just 10 meters above the Bheri River. The lowlands can be irrigated with this amount of water. Some farmers are lifting water from the source through diesel pumps, however, due to the high cost of pumping farmers are looking for alternative ways for irrigation. The major crops grown with this water are paddy, lentils, cowpeas, and vegetables. There was another spring source named Source IV and the discharge through the source was 6 liters per sec i.e. 0.518 million liters/day. This source was feeding six different canals in rotation however there was no intake built. The discharge at canal intake to Kiteni was measured as 4 liters per second and is fed in rotation, once a month in the dry season and a week in the wet season (paddy). The canal to Kiteni was benefitting 50 HHs. The major crops grown with this water are paddy, wheat with cowpeas, mustard, lentil, and vegetables. The location of water sources in the study area is shown in Figure 4 below:

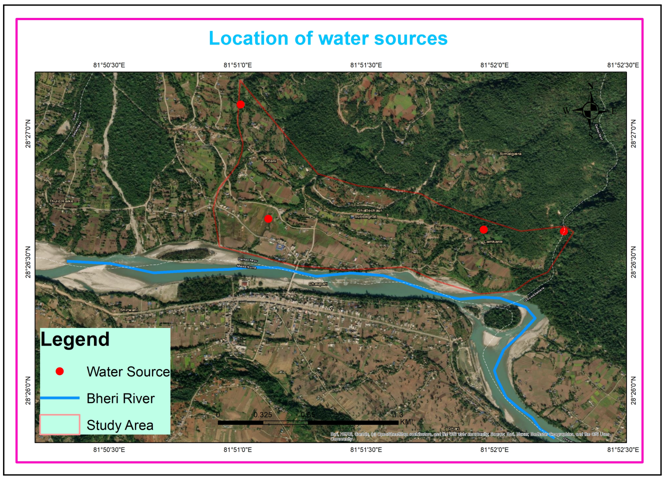

Figure 3: Location of water sources in the study area

3.2 Water demand

Various water demands were considered according to the site conditions (Table 2). There was a separate drinking water supply source that fed each household. The total water available from four different sources, after allocating water for domestic and livestock demand, was found to be 1.1 million lit/day however the total net scheme irrigation requirement for the current cropping pattern with major crops: maize, wheat, rice, peas, millet, mustard and lentil was found to be 24.68 million lit/day. The results show that the water is deficient in June, July, and August from sources I and II and March, June, July, August, and September. However, the available water from source IV is only adequate for May in the current cropping pattern. This is because there is a lot of fallow land in the field during May. So, evaluating the supply versus demand side, there seems to be a huge water deficit of 23.57 million liters/day. This study shows that the water in the study area was found to be deficient especially while planting paddy as it requires about 950 mm of net irrigation in the entire cropping season.

Table 2: Water Demand in lit/day

SN	Demand	Water Requirement
1	Domestic	2600
2	Livestock	855
3	Loss and Wastage	520
4	Irrigation	24683443

Alternate wetting and drying (AWD), a water management approach primarily utilized in rice cultivation as a substitute for the constant inundation typically employed during planting and the growth period, which entails the periodic flooding and subsequent drying of the soil in the field, resulting in a reduction in water consumption might be an alternative option for paddy in the study area [7].

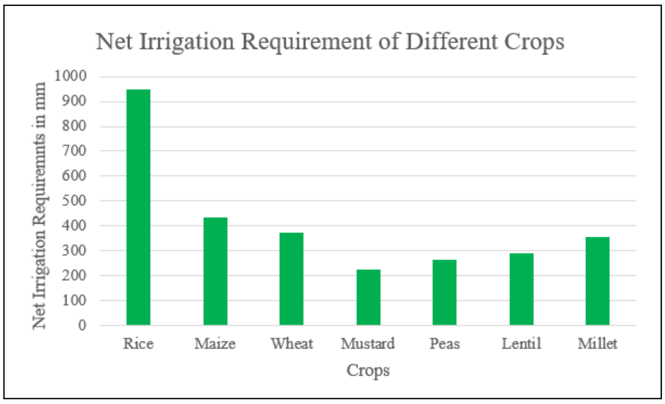

Figure 4: Net Irrigation Requirement of selected crops

As seen in figure 4, the major crops that require less amount of water are mustard, peas, and lentils. However, alternate wetting and drying for paddy and high-value crops with micro irrigation technology like drip and sprinkler irrigation may be good options for agriculture water and field management strategies in the study area.

3.3 Possible Pathways

Based on actual results found from the study. The following pathways will enhance the lives and livelihood of smallholder farmers in the selected site.

- Water in the study area was found to be a deficit for the current cropping pattern however surface water availability may change with time so proper management of water like irrigation scheduling i.e when and how much to irrigate and farmyard manure management may be a good option for efficient use of water.
- Although there are several perennial surface sources in the study area, water conveyance efficiency was very low as there was lots of leakage in the pipelines, canal, and intake structure. So, maintenance of all these infrastructures will even increase the availability of water for future use.

- Concept of deficit irrigation, micro irrigation technologies, conservation agriculture, agricultural water, and farmyard management will not only increase water availability but also sustainable use of resources to reduce pressure on the environment.

- Rainwater harvesting, collection, and storage of rainwater for various uses, such as irrigation, domestic water supply, and groundwater recharge, is vital as it reduces the burden on conventional water sources, mitigates flooding, and provides a local and reliable water supply, particularly crucial in regions facing water scarcity or erratic rainfall patterns, ultimately promoting water conservation and environmental sustainability.

- No-till farming involves the cultivation of crops over consecutive years without disrupting the soil through plowing, thus keeping crop residues in their original positions. This approach has the advantage of boosting the organic content in the soil, resulting in enhanced absorption of rainfall or irrigation water. Additionally, this method can decrease soil temperature and limit evaporation by providing shade and reducing the impact of wind on water evaporation.

- Introducing drought resistance crops and shifting of cropping calendar as there were lots of crops grown between Nov to Feb which requires almost 50 % of net irrigation requirements.

- Crop shifting entails substituting a crop with higher water demands for one that necessitates less water. A key factor to ponder is the alteration in revenue generation, ideally involving the replacement of a less profitable, water-intensive crop with a more valuable crop that demands less water.

- Apart from all of these technical issues, there is a serious problem of water sharing between the upstream and downstream sections so such issues should be solved at the local level to increase equal access to water.

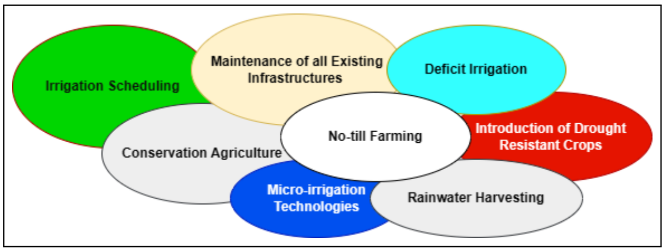

Figure 5: Pathways for fulfilling future water demand

Additionally, the majority of farmers aspire to transition from subsistence farming to commercial agriculture by incorporating high-value crops such as vegetables, spices, and fruits. This shift aims to enable them to generate cash income through sales in nearby markets, offering several potential benefits. These advantages include increased profits per unit of land, access to broader markets, and the prospect of enhanced standards of living for farmers.

4. Conclusions

This research evaluated the opportunities and bottlenecks for irrigation and other water uses in the study area using a system approach. The overall conclusions of the study are summarized below:

- Four surface water sources were identified in the study area, each maintaining a consistent flow throughout the year. The total water available from four sources is estimated as 404.6 million liters/year with the discharge (in million liters/year) from individual sources as 10.4, 78.8, 189.2, and 126.1 respectively.

- After fulfilling domestic and livestock demand, water scarcity for irrigation is apparent in the months of June, July, and August from sources I and II and March, June, July, August, and September from source III. However, the available water from source IV is only adequate for May based on the current cropping pattern.

- There is a pressing need for effective water as well as field management techniques to improve water use efficiency. This not only increases water availability but also creates opportunities for cultivating high-value crops, ultimately enhancing the lives and livelihoods of smallholder farmers.

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