Ecosystem Based Adaptation for Increased Water Availability: A Case Study from the Hills and Mountains of Nepal

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Abstract

Water scarcity is a pressing issue in Nepal's rural hill communities, worsened by climate change, irregular rainfall, and unplanned infrastructure. This study examines the impact of Ecosystem-based Adaptation (EbA) strategies on water availability and soil moisture in Dolakha, Salyan, and Achham districts. Using a participatory approach, data were collected through household surveys (n=392) and focus group discussions (FGDs) to assess community perceptions of EbA interventions, particularly conservation pond construction and rehabilitation. Results show that EbA measures significantly improve water availability and soil moisture, with perception scores ranging from 6.12 to 6.84 on a 10-point scale. Additionally, reduced time spent collecting water benefits women and children, improving their quality of life. These findings underscore the need to integrate EbA strategies into government policies and development programs, providing a sustainable solution to water scarcity and climate variability while enhancing community resilience.

Keywords: Climate change, ecosystem-based adaptation, water conservation

INTRODUCTION

Nepal is one of the most climate change-vulnerable countries in the world. In response to this, the country has been reforming policies and implementing climate change mitigation and adaptation strategies. Key initiatives include the National Climate Change Policy (2019), the National Adaptation Plan for 2021-2050 (MoFE 2023), the Second Nationally Determined Contribution (NDC), and climate-resilient, gender-responsive adaptation plans (MoFE 2020).

Irregular rainfall patterns in Nepal are severely impacting the livelihoods of farmers, particularly in rural areas. Water shortages are prevalent during the pre-monsoon season (March to May) and the post-monsoon and winter seasons (October to February) (GFDRR 2021). To address the vulnerability caused by these erratic rainfall patterns, there is a pressing need to establish a year-round water supply. Water conservation ponds are effective adaptation strategy, as they capture rainwater, replenish groundwater reserves during the monsoon, and help reduce soil erosion and surface runoff, especially on landslide-prone slopes (Koirala 2021). Moreover, these ponds ensure water availability during dry periods, which is vital for traditional rural livelihoods like livestock farming and crop cultivation.

They also support new activities, such as fish farming, and help stabilise and revegetate gullies, enabling small-scale cultivation of fodder, vegetables, and fruit trees along the pond boundaries. Additionally, conservation ponds reduce the time women spend on fetching water (FAO 2014).

Springs and wells (*Kuwa*) are crucial water sources in the hills and mountains of Nepal. In the Hindu Kush Himalaya (HKH) region, temperatures are projected to rise by more than 2°C on average by 2050 (Shrestha *et al.* 2019). Nepal is predominantly mountainous, with about 43 per cent of its total land area classified as hills. The varied landscapes in these hilly regions create niche micro-climatic habitats that support diverse ecological zones and farming systems (Shrestha *et al.* 2015).

Rural villages in the hills and mountains face significant challenges regarding water availability for drinking and irrigation. Factors such as unplanned infrastructure development, changes in land use practices, prolonged drought, and erratic rainfall due to climate change have contributed to decreased water yield. Traditional knowledge-based water management practices, which include the use of local resources and techniques like water conservation ponds, bioengineering methods for water source protection, and planting trees near water sources to enhance yield and control erosion, have declined over the past decades. There could be many reasons for the decline but major ones could be the lack of inter-generational knowledge transfer, out migration from rural areas to urban centers (Koirala 2021), changes in community structures and decreasing collective efforts.

The socio-ecological systems refer to the interconnected and dynamic interactions between human societies and their natural environment. These systems encompass the way communities in the hills interact with, depend on, and manage natural resources while adapting to environmental, social, and economic changes. To adapt to climate adversities and build resilience in this socio-ecological systems, local communities have initiated various ecosystem-based adaptation (EbA) approaches for water management (CGED-Nepal 2024). These include promoting efficient water use through harvesting, storage, source protection, and efficient usage. Several EbA measures have proven effective in building the adaptive capacity of local communities by offering simple and affordable technologies.

Among many, the EbA II project implemented from March 2019 to April 2025, led by the Government of Nepal, MoFE, GEF, and UNEP, with funding from Least Developed Countries Fund (LDCF) to reduce climate vulnerability in Nepal. It focuses on the mid-hills (Achham, Salyan) and high-hills (Dolakha), implementing ecosystem-based adaptation measures to restore forests and rangelands, reducing community sensitivity to climate change. The project in Nepal focuses on integrating ecosystem-based solutions to address climate change impacts, while enhancing biodiversity conservation and improving community resilience. The project emphasises the role of natural ecosystems in mitigating the effects of climate change, such as floods, landslides, and droughts. By restoring and protecting ecosystems like forests, wetlands, and watersheds, EbA approaches aim to reduce vulnerability and enhance adaptive capacities of local communities, especially in marginalised and vulnerable regions. Water conservation is one of the main achievements of the project. This paper provides evidence of the efficiency of EbA measures, such as recharge ponds and conservation ponds, in terms of increased water availability and infiltration in the EbA II project implemented in Dolakha, Salyan and Achham districts of Bagmati, Karnali, and Sudur Paschim Provinces of Nepal using a participatory approach. Proper documentation of how these measures improve water yield is essential for replicating them elsewhere.

This study aims to assess and analyse the effectiveness of EbA measures in enhancing water availability and yield, as well as their socioeconomic benefits for rural communities in the hills and mountains of Nepal. The research seeks to provide evidence-based insights on the impact of these measures and to generate recommendations for scaling up and integrating EbA practices into local and national climate adaptation strategies.

Objective of the study

The general objective of this study was to assess the impact of EbA interventions on water availability and soil moisture improvement in the EbA II Project areas.

The specific objectives of the study were (i) to evaluate the impact of EbA interventions on water availability in the springsheds of Dolakha, Salyan, and Achham districts; (ii) to assess the improvement in soil moisture levels resulting from water conservation and management measures under EbA interventions; and (iii) to analyse community perceptions regarding changes in water availability and soil moisture in the targeted areas.

STUDY METHODS

Study area

The EbA II project supported local communities in constructing and rehabilitating 92 conservation and water recharge ponds across the project districts (Table 1). For this study, five conservation ponds and their beneficiary communities were randomly selected from Dolakha and Salyan districts, and six from Achham district. The list of conservation ponds in the EbA II project sites is provided in Table 1.

Table 1: Water conservation pond constructed in EbA II project districts

Water Conservation Pond Construction						
District	**Unit**	**2021**	**2022**	**2023**	**Total**	**Sample**
Dolakha	Number	6	12	6	24	5
Salyan	Number	7	7	5	19	5
Achham	Number	18	21	10	49	6
Total		31	40	21	92	16

The list of water conservation ponds and community chosen for the detailed household survey is presented in Table 2.

Table 2: List of water conservation ponds and community selected for study

District	Municipality	Ward	Place
Dolakha	Shailung	4	Mathillo Gaon Jogidanda
	Shilung	4	Pokharidanda
	Bhimeshwor	9	Mane
	Kalinchowk	6	Okhreni
	Kalinchowk-5	5	Bandethali
Salyan	Kumakh	2	Danda Pipal sim Narayan Takura
	Kumakh	2	Kiya Khola, Danda Kateri
	Bangaad Kupinde	1	Samaila
	Bangaad Kupinde	5	Sano Barule
	Bangaad Kupinde	7	Deutipujne
Achham	Sanfebagar	13	Babla
	Ramaraoshan	5	Badapani
	Ramaraoshan	6	Basanta, Bhatakaatiya
	Ramaraoshan	6	Sherapatalkharka, Bhatakaatiya
	Mellekh	6	Jhadigau, Sodsha
	Mellekh	6	Dudhimela, Sodsha

Sample size

The survey was conducted in October 2023. From the total of 92 water conservation ponds constructed with the support of the EbA II project, 16 ponds were randomly selected-five each in the Dolakha and Salyan districts and six in the Achham district. This selection was made to ensure geographic diversity and manage logistical and resource constraints while maintaining statistical relevance for the study.

Research methodology

Before initiating data collection, an extensive literature review was conducted. This review primarily included national policies, programs, and archival research. The research methodology employed both quantitative (household surveys) and qualitative (FGDs and key informant interviews) methods.

A total of 392 households were surveyed across the three districts using pre-designed questionnaires, representing 10 per cent of the total beneficiaries (3,920) of the EbA II project. Table 3 summarises the proportional distribution of surveyed households across the three districts, ensuring a representative sample.

Table 3: Distribution of surveyed households

District	Total beneficiaries	Surveyed Households	% surveyed
Dolakha	1250	125	10%
Salyan	1260	126	10%
Acham	1410	141	10%
Total	3920	392	10%

Additionally, 16 FDGs were conducted. The household survey aimed to gather local perceptions on the effectiveness of EbA interventions in increasing water yield and soil moisture. The questionnaire included a variety of multiple-choice and open-ended questions.

To avoid interviewer bias and to maintain a cost-effective approach, a self-administered questionnaire was used. For data analysis and reporting, both quantitative and qualitative data were triangulated to provide a comprehensive analysis. Microsoft Excel was used for data entry and analysis.
We applied basic statistical methods, such as calculating the mean, standard deviation, and confidence interval (CI). The CI test was used to estimate the range within which the true population mean is likely to fall, with 95 per cent confidence. This was done using the formula provided by Triola (2020) for cases where the population standard deviation is unknown.

Equation 1

$$CI = \bar{x} \pm z \cdot \frac{s}{\sqrt{n}}$$

Where:

- $\bar{x}$ is the sample mean,
- z is the critical value from the standard normal distribution (1.96 for a 95% confidence level),
- s is the sample standard deviation,
- n is the sample size.

RESULTS

Major water related problems of the study sites

The household survey and FDGs revealed that climate change poses numerous challenges related to water resources in the study areas. The major problems identified include:

a. Dry spells: The respondents reported that the precipitation patterns within the study areas have changed. They also highlighted the consequences of these altered patterns, including more frequent and severe dry spells. These shift have led to critical issues such as drying water sources and water scarcity, which has significantly impacted agriculture, drinking water supplies, and ecosystems.
b. Water Scarcity: The respondents observed noticeable changes in precipitation patterns, with prolonged droughts leading to significant water scarcity in the study areas.
c. Floods: The participants mentioned that occurrence of more intense rainfall patterns are increasing and flooding, leading to frequent sediment deposition in the downstream of watershed.
d. Changes in Water Availability: The availability of irrigation water during the crop cultivation period is also a major issue. As a result, participants noted a decline in agricultural productivity.

Community contribution for water conservation/management

Community contributions are crucial for achieving sustainable water conservation and management goals, as they leverage local knowledge, resources, and collective action to effectively address water-related challenges. Participants reported their involvement in various water conservation and management activities. Their key contributions include constructing conservation ponds, regularly maintaining existing water sources, building water storage tanks, planting vegetation near water sources, maintaining water channels, and protecting water sources.

Benefits of water conservation/ management activities

Water conservation activities in the study areas are benefiting various stakeholders. Participants noted that local communities are the primary beneficiaries of these efforts, as they help ensure reliable access to clean water for drinking, sanitation, and household use, especially during dry seasons when water sources may be scarce. They also reported improved agricultural productivity and significant enhancements to livelihoods for many community members.

Furthermore, 71 per cent respondents highlighted that protecting and conserving water sources has positively impacted ecosystems and wildlife. Similarly 62 per cent respondents mentioned that women and girls, who are responsible for collecting water for drinking, cooking, washing, hygiene, and raising livestock, have experienced direct benefits from these conservation activities, leading to a significant reduction in their workload.

Program sustainability

When asked about program's sustainability, 71.5 per cent respondents indicated that the community is willing to voluntarily construct additional water conservation ponds. They also plan to contribute to the maintenance of existing ponds, expansion of pond sizes, and protect other water sources. Additionally, other members of the community, such as livestock herders, will apply their acquired knowledge and participate in water conservation efforts. Local communities also expressed their intention to coordinate with rural or municipal authorities to incorporate additional ponds, catchment protection activities, and budget allocations into their annual development programs.

Perception of local people on the increment of water availability and soil moisture after the construction of conservation pond

Dolakha

Out of the total of 125 respondents, 85 (68%) responded that the community is willing to voluntarily construct additional water conservation ponds.

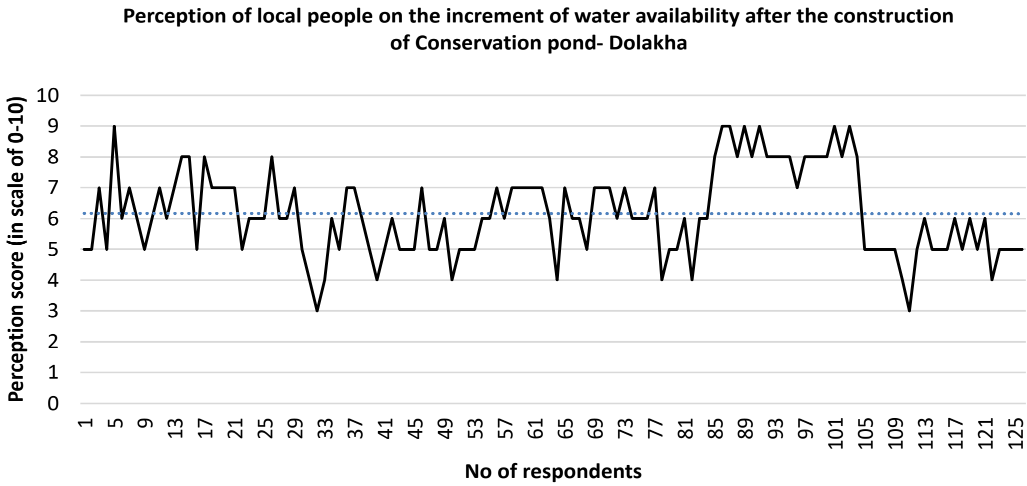

Figure 1: Perception of local people on the increment of water availability after the construction of conservation ponds in Dolakha district

The household survey shows that the local residents believe there has been a significant improvement in water availability (at 95 % confidence level) following the construction of conservation ponds. When asked to rate the improvement in water yield on a scale from 1 to 10 (with 1 indicating no improvement and 10 indicating very good improvement), the average score from 125 participants was 6.48, with a standard deviation of ± 0.062. While calculating the CI using equation 1 the CI ranges from 6.469 to 6.491. Both limits exceed the mid value of 5 in 1 to 10 scale. Thus, the result demonstrates a statistically significant positive community perception of improvement in water availability.

Similarly, when asked about the rating of improvement in greenery on a scale from 1 to 10 (with 1 indicating no improvement and 10 indicating very good improvement), the average score from the 125 participants was 6.405, with a standard deviation of ± 1.338. While calculating the CI using equation 1 the

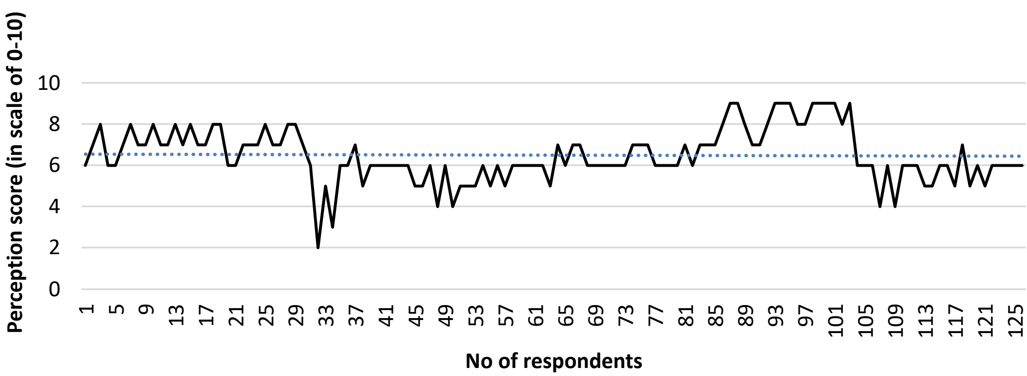

Figure 2: Perception of local people on the improvement of greenery after the construction of conservation pond in Dolakha district

CI ranges from 6.170 to 6.640. Both limits exceed the mid value of 5 in 1 to 10 scale. Thus, the result demonstrates a statistically significant positive perception of local people on improvement in soil moisture after the construction of conservation ponds.

Salyan

A total of 126 community members shared their perceptions of water availability in the village after various activities were implemented. On a scale of 0 to 10, the average score given by respondents was 6.12, with a standard deviation of ± 1.413. This indicates that the local communities perceive a significant increase in water yield in the watershed following the construction of conservation ponds. While calculating the CI using equation 1, the CI ranges from 5.873 to 6.367. Both limits exceed the mid value of 5 in 1 to 10 scale. Thus, the result demonstrates a statistically significant positive perception of improvement in water yield after the construction of conservation ponds.

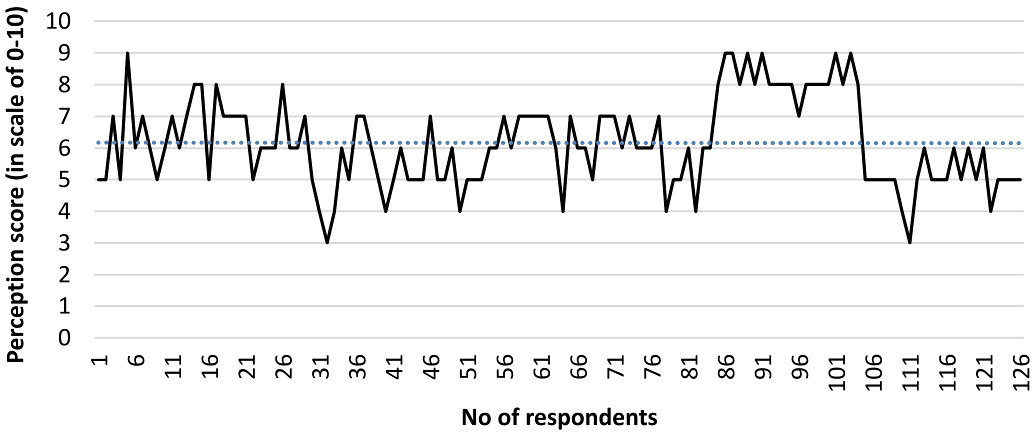

Figure 3: Perception of local people on the increment of water yield after the construction of conservation pond in Salyan district

Similarly, when asked regarding the improvement in greenery on a scale from 1 to 10 (with 1 indicating no improvement and 10 indicating very good improvement), the average score from the 126 participants was 6.14, with a standard deviation of ± 1.289. While calculating the CI using equation 1 the CI ranges from 5.915 to 6.365. Both limits exceed the mid value of 5 in 1 to 10 scale. Thus, the result demonstrates a statistically significant positive perception of improvement in soil moisture after the construction of conservation ponds.

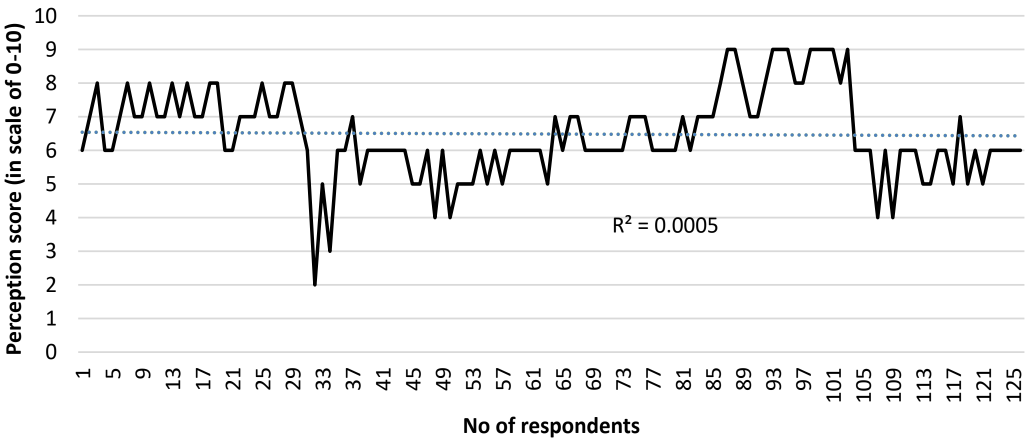

Figure 4: Perception of local people on the improvement of greenery after the construction of conservation pond in Salyan district

Achham

A total of 141 community members shared their perceptions of water availability in the village after various activities were implemented. On a scale of 0 to 10, the average score given by respondents was 6.84, with a standard deviation of ± 1.441. While calculating the CI using equation 1 the CI ranges from 6.602 to 7.078. Both limits exceed the mid value of 5 in 1 to 10 scale. Thus, the result demonstrates a statistically significant positive perception of improvement in water availability after the construction of conservation ponds.

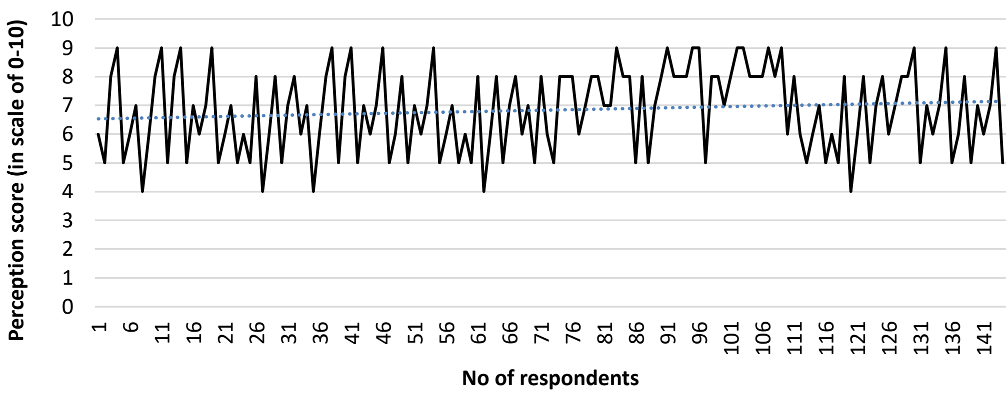

Figure 5: Perception of local people on the increment of water yield after the construction of conservation pond in Achham district

Similarly, when asked the participants to rate the improvement in soil moisture and greenery on a scale from 1 to 10 (with 1 indicating no improvement and 10 indicating very good improvement), the average score from the 141 participants was 6.84, with a standard deviation of ± 1.418. While calculating the CI using equation 1, the CI ranges from 6.610 to 7.075. Both limits exceed the mid value of 5 in 1 to 10 scale. Thus, the result demonstrates a statistically significant positive perception of improvement in soil moisture after the construction of conservation ponds.

Figure 6: Naula Samrrakshan Pokhari of ward no 13, Babla, Sanfebagar Municipality, Achham

Figure 7: Dudhimela Conservation Pond of Sodasa, Mellekh-6, Achham

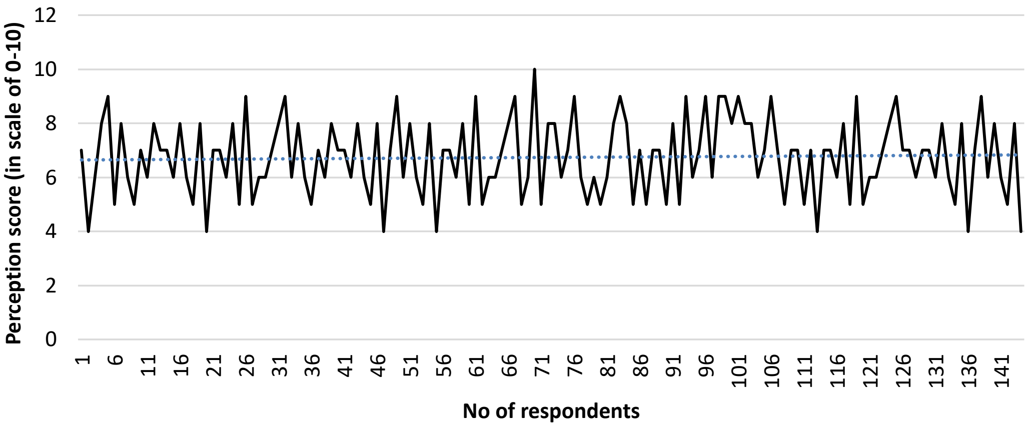

Figure 8: Perception of local people on the improvement of greenery after the construction of conservation pond in Achham district

DISCUSSION

The findings of this study underscore the critical role of EbA interventions in enhancing water availability and soil moisture in the hill and mountain districts of Nepal. This discussion interprets the results in the context of the general and specific objectives, providing insights into the impacts, challenges, and future implications of the interventions. Impact of EbA interventions on water availability and soil moisture improvement

The general objective of assessing the impact of EbA interventions on water availability and soil moisture improvement was met through a combination of quantitative and qualitative data collection methods. The data indicate that EbA measures, particularly the construction and rehabilitation of conservation ponds, have positively influenced water resource availability and soil moisture levels. This aligns with global evidence on the effectiveness of nature-based solutions in addressing water scarcity and climate variability (Garcia-Herrero 2022).

Improvement in water availability

The household survey and FGDs revealed that the construction of conservation ponds have significantly enhanced water availability in the springsheds of Dolakha, Salyan, and Achham districts. The average perception scores for water availability improvements ranged from 6.12 in Salyan to 6.84 in Achham, reflecting widespread community acknowledgment of increased water yield. The findings are similar to those of Thiaw (2013), which demonstrated that EbA interventions help mitigate the impacts of erratic rainfall and prolonged dry spells, thereby ensuring a reliable water supply for drinking, irrigation, and other livelihood activities.

Improvement in soil moisture

The study also highlights the role of EbA measures in improving soil moisture levels. The perception scores for soil moisture and greenery improvements were consistent across districts, with Achham reporting the highest average score of 6.84. Enhanced soil moisture has resulted in increased agricultural productivity, improved vegetation cover, and reduced erosion, all of which contribute to the sustainability of local ecosystems. These findings are similar to those of Liniger et al. (2011). These benefits underscore the importance of integrating soil and water conservation strategies into adaptation planning.

Community perceptions of EbA benefits

Community perceptions provide critical insights into the socio-economic impacts of EbA interventions. Participants reported reductions in the time and effort required to collect water, particularly benefiting women and children. This finding is in line with the report of secretariat of the Convention on Biological Diversity (SCBD 2009) which highlights the social benefits of EbA interventions, including improved water availability and reducing the burden on women and children responsible for water collection in many regions. FGDs emphasised the broader benefits of conservation ponds, including increased biodiversity, enhanced groundwater recharge, and stabilisation of gullies. This finding is in line with the findings of the report on building a common vision for sustainable food and agriculture: Principles and approaches by FAO (2014). This report highlights the contribution of water conservation practices, such as pond construction to ecosystem services like biodiversity enhancement, water resource management, and land stability. The community's willingness to contribute to the maintenance and expansion of these interventions reflects a strong sense of ownership and recognition of their value.

CONCLUSION AND WAY FORWARD

Water scarcity remains a pressing challenge for rural hill communities in Nepal, compounded by climate change, erratic rainfall, and unplanned infrastructure development. This study has demonstrated how EbA strategies, particularly the construction and rehabilitation of conservation ponds, can effectively address these challenges by enhancing water yield, improving soil moisture, and contributing to agricultural productivity.

Community perceptions, supported by both qualitative and quantitative data, underscore the tangible benefits of these interventions. Respondents from Dolakha, Salyan, and Achham districts reported significant improvements in water availability, soil moisture, and greenery. Women and children, in particular, have experienced reduced workloads associated with water collection, improving their overall quality of life.

The findings highlight the importance of incorporating EbA measures into local and national development policies as sustainable solutions to water resource management. By fostering community engagement and leveraging local knowledge, these interventions can enhance resilience against climate variability while supporting livelihoods and biodiversity.

The success of the EbA II project provides a model for replication in other vulnerable regions, emphasising the potential for ecosystem-based strategies to mitigate climate impacts and sustainably manage water resources for the long term.

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