

SMALL WATER STORAGE SYSTEMS FOR CLIMATE-RESILIENT AGRICULTURE: DANG VALLEY IRRIGATION PROJECT

PETITS SYSTÈMES DE STOCKAGE D'EAU POUR UNE AGRICULTURE RÉSISTANTE AU CLIMAT : PROJET D'IRRIGATION DE LA VALLÉE DE DANG

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ABSTRACT

Nepal, despite abundant water resources, struggles to meet year-round water demand because of highly seasonal rainfall and uneven distribution of rivers and groundwater. The Dang Valley in western Nepal exemplifies this paradox, where fertile land and favorable agroecology are constrained by water scarcity during the dry season. Small water storage systems have emerged as a practical way to capture excess monsoon runoff and use it during lean months, thereby enhancing irrigation, domestic water supply, and climate resilience. These decentralized, cost-effective structures—earthen dams, ponds, and reservoirs—are transforming agriculture by enabling multiple cropping seasons, diversifying production, and increasing yields by more than 50 percent. Farmers who were previously limited to subsistence farming are now adopting commercial models, supported by improved water reliability and scientific inputs.

The Dang Valley experience demonstrates that storage dams not only improve agricultural productivity but also strengthen community institutions through Water User Associations (WUAs), fostering participatory governance, resource mobilization, and financial sustainability. Secondary benefits include groundwater recharge, fisheries, biodiversity restoration, eco-tourism, and enhanced livelihoods for disadvantaged groups. While challenges such as sedimentation, leakage, and climate-induced risks remain, proper design, watershed management, and adaptive operation can mitigate these threats.

The economic and environmental returns are significant: cropping intensity has doubled, household incomes have risen, and local ecosystems have been revitalized. Importantly, these interventions embody Integrated Water Resources Management (IWRM) principles by balancing human needs with groundwater recharge and empowering local communities. The Dang Valley case illustrates that small storage dams are more than technical infrastructure; they are institutional innovations that build resilience, promote equity, and provide sustainable pathways for climate-resilient agriculture. As Nepal confronts increasing climate variability, scaling up such systems offers a viable strategy for water security and rural transformation.

Keywords: Water storage systems; Groundwater recharge; Water User Associations (WUAs); Sedimentation; Integrated Water Resources Management (IWRM).

RESUME

Malgré des ressources en eau abondantes, le Népal tente désespérément à répondre à la demande en eau tout au long de l'année en raison des fortes précipitations saisonnières et d'une répartition inégale des cours d'eau et des nappes phréatiques. La vallée de Dang, situé à l'ouest du Népal, illustre parfaitement ce paradoxe : ses terres fertiles et son environnement agroécologique favorable sont limités par la pénurie d'eau pendant la saison sèche. Les petits systèmes de stockage d'eau ont été créés comme un moyen pratique pour capter l'eau excédentaire de ruissellement de la mousson et de les utiliser pendant les mois de pénurie d'eau, améliorant ainsi l'irrigation, l'approvisionnement en eau à usage domestique et la résistance au changement climatique. Ces structures décentralisées et

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rentables — barrages en terre, étangs et réservoirs — transforment l'agriculture en permettant plusieurs cycles de culture, la diversification de la production et l'augmentation des rendements de plus de 50%. Les agriculteurs, qui se limitaient auparavant à une agriculture de subsistance, adoptent désormais des modèles commerciaux, soutenus par une meilleure fiabilité de l'approvisionnement en eau et des contributions scientifiques.

L'expérience menée dans la vallée de Dang prouve que les barrages de stockage améliorent non seulement la productivité agricole, mais renforcent également les institutions communautaires grâce aux Associations des usagers de l'eau (AUE), favorisant ainsi la gouvernance participative, la mobilisation des ressources et la viabilité financière. Il convient de noter que les avantages secondaires comprennent la réalimentation des eaux souterraines, la pêche, la restauration de la biodiversité, l'écotourisme et l'amélioration des moyens de subsistance des groupes défavorisés. Bien que des défis tels que la décantation, les fuites et les risques liés au changement climatique persistent, une conception adéquate, une gestion des bassins versants et une exploitation adaptative permettent d'atténuer ces menaces.

Les bénéfices économiques et environnementaux sont significatifs: l'intensité culturelle a doublé, les revenus des ménages ont augmenté et les écosystèmes locaux ont été revitalisés. Il est important de noter que ces interventions expriment les principes de la gestion intégrée des ressources en eau (GIRE) en équilibrant les besoins humains avec la réalimentation des eaux souterraines et en autonomisant les communautés locales. Le cas de la vallée de Dang démontre que les petits barrages de stockage sont plus que de simples infrastructures techniques; ce sont des innovations institutionnelles qui s'appuient sur la résistance, favorisent l'équité et ouvrent des voies durables pour avoir une agriculture résistante au changement climatique. Alors que le Népal fait face à une variabilité climatique croissante, le renforcement de tels systèmes constitue une stratégie viable pour la sécurité hydrique et la transformation rurale.

Mots-clés : Systèmes de stockage d'eau; Réalimentation des eaux souterraines; Associations des usagers de l'eau (AUE); Décantation; Gestion intégrée des ressources en eau (GIRE).

Introduction

Nepal is often described as a water-rich country, yet paradoxically, it struggles to meet its own water needs. The problem is not the total volume of water but its timing and distribution. Most rainfall occurs during the monsoon season, while the dry months leave rivers depleted. This imbalance has long constrained agriculture, which depends on reliable water supplies throughout the year. The Dang Valley in western Nepal provides a vivid example of both the challenges and opportunities of irrigation development. Through small water storage systems, the valley is learning how to transform agriculture, strengthen community institutions, and build resilience against climate change.

Water Resources in Nepal

Nepal's rivers, glaciers, and rainfall provide enormous amounts of water. However, despite a high aggregate water endowment, only about one-tenth of the water arising within or transiting Nepal can be used within the country. The main reason for this is that precipitation is limited to a short season: four-fifths of precipitation (rain and snow) fall in just the four months of the monsoon, when runoff is enormous and engorged rivers carry most of the water away downstream into India. But then in the dry season, river flows plummet.

A factor that mitigates this pronounced seasonal variation is the considerable natural storage in frozen freshwater bodies in the high mountains and the annual meltwater, which provides some base flow. However, even the larger rivers carry only about one-tenth of their annual flow during the dry season, and many smaller rivers originating from lower elevations dry up completely. In many areas, the only access to year-round water is from surface water bodies, such as lakes, and from groundwater. These resources, however, are very unevenly distributed across the country.

This uneven availability of water between seasons and regions is being exacerbated by climatic changes, notably rising temperatures and changes in precipitation patterns.

The Dang Valley

The Dang valley of Western Nepal is an oval-shaped inner Dun valley stretched between the Mahabharat and Churia hills. The topography of the valley comprises river valleys, alluvial fans, flood plains, flat terraces, and hilly sloping lands intersected by numerous streams and rivers. The valley relief is almost flat with a gentle slope from north to south, draining to the Babai River, which flows from east to west along the edge of the valley (Figure 1). The elevation of the Dang valley varies from 600 m to 900m above mean sea level, with an average slope of 2 to 5 m per kilometer from North to South. The major land use patterns of the Dang valley are forest, agriculture, and non-vegetative areas. The northern part of the valley is covered with forest land, which is the source of rivers and streams. Rainfall averages 1661 (Table:1) millimeters annually, but most of it falls between June and September. This seasonal concentration of rainfall creates both opportunities and challenges for farmers.

Rainfall and Precipitation in Dang

The maximum temperature ranges from 21°C to 34°C while the minimum temperature ranges from 6°C to 22°C. The rainfall occurs mainly during the monsoon, which starts from June and lasts until September. The average annual rainfall of the Dang valley is 1661 mm. The mean monthly temperatures and rainfall of Tulsipur (station No. 508) are presented in Table 1. The climate of Dang Valley is suitable for growing all kinds of sub-tropical crops, including paddy, wheat, maize, potato, peas, green vegetables, and mustard.

Table 1 Mean Monthly Temperatures and Rainfall of Tulsipur (station No 508)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Tmax. °C	21.2	23.6	28.6	32.7	33.3	33.3	30.6	30.3	29.4	29.4	26.7	22.7	28.5
Tmin. °C	6.4	8.5	12.6	17.7	20.6	22.3	22.5	22.0	19.8	16.6	11.6	7.8	15.7
Rainfall (mm)	24	26	15	23	79	277	429	384	289	95	10	11	1,661

Existing Irrigation Systems and Government Plan

Farmers in the Dang Valley have long relied on Farmer Managed Irrigation Systems (FMIS). These traditional networks divert water from streams and rivers, enabling cultivation during the monsoon season. However, they provide little or no water during the dry months, limiting farmers to one crop per year. The total command area of FMIS in the valley is about 17,000 hectares, but productivity remains low due to seasonal water shortages. This situation has kept farmers dependent on subsistence agriculture, with limited opportunities for diversification or commercialization.

To address these challenges, the Department of Water Resources and Irrigation prepared a plan to provide year-round irrigation to the entire valley. The plan combines several approaches:

- **Diversion:** Inter-basin transfers
- **Surface:** Rehabilitation of FMIS
- **Storage:** Construction of small dams
- **Lift Systems:** Surface and Groundwater
- **Non-Conventional Methods:** Ponds, rainwater harvesting, and wetlands Together, these measures aim to irrigate 56,000 hectares, transforming agriculture in the valley.

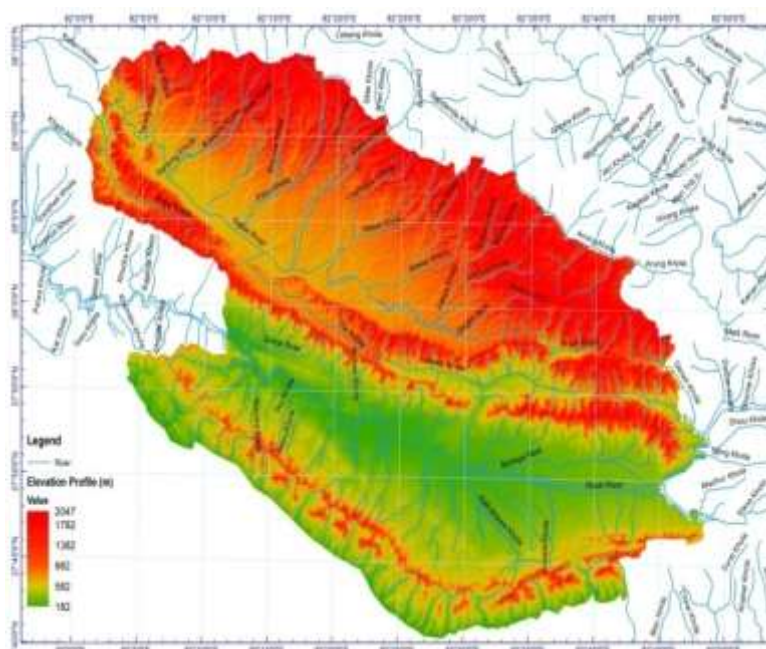


Figure 1: Topography and River Systems of Dang Valley

Existing crops and yield

The existing yields of the project are 2.10-2.25 t/ha for monsoon paddy, 1.60-1.80 t/ha for wheat, 1.75-1.85 t/ha for maize, 0.65-0.70 t/ha for pulses, 0.60-0.70 t/ha for oilseeds, and 7-8 t/ha for potato. It is expected to increase to 4.0 t/ha for monsoon and early paddy, 3.20 t/ha for wheat and maize, 1.10 t/ha for oilseeds and pulses, 14-15 t/ha for potato and vegetables after the implementation of the project. And overall annual cropping intensity is around 145%. Based on agroecology and soil conditions, the crop yield could be doubled simply by providing irrigation water.

Planning of the storage Irrigation Project

Small water storage dams can play a vital role in mitigating seasonal water scarcity by capturing excess monsoon runoff for utilization during dry periods. They facilitate irrigation, support livestock and domestic water supply, enhance groundwater recharge, and contribute to local climate adaptation and the resilience of livelihoods, which makes them a key adaptation measure in the context of climate change. As decentralized and cost-effective solutions, such structures are particularly important in rural and peri-urban areas of Nepal.

In practice, small storage dams have been implemented in many areas of Nepal through government programs and local initiatives, especially in regions where water is scarce. These dams are often utilized for small-scale irrigation and for community domestic use. Recent efforts in small storage dam construction in Nepal focus on enhancing water security and mitigating dry-season shortages.

The sources of all dams do not have abundant water during the dry season. So, storage types of projects are designed to store surplus water during the monsoon to irrigate the winter and spring crops during winter and dry weather. With the construction of dams across the river, with adequate water for irrigation, the focus is on providing year-round irrigation.

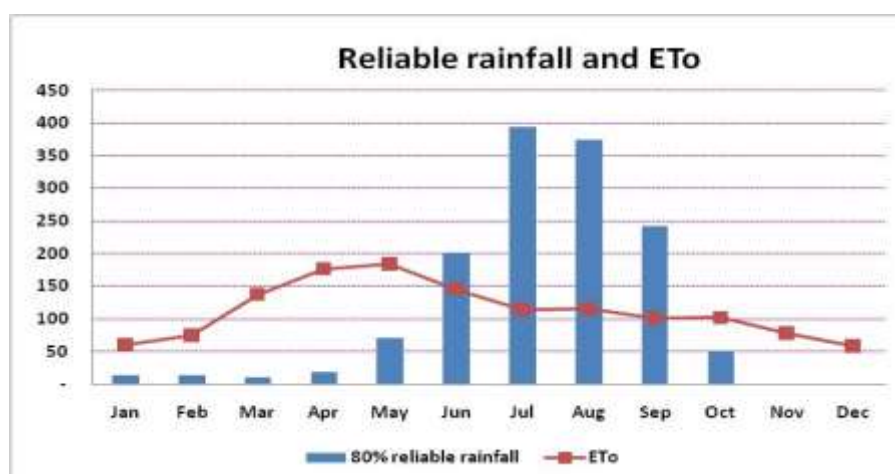


Figure 2: Reliable Rainfall and Evapotranspiration

During winter and summer, the stored water could be utilized for irrigation, while during the monsoon, existing sources of water could be beneficially utilized. Figure 2 above shows the 80% reliable monthly rainfall and evapotranspiration in the Dang Valley. The four months in a year have excess rainfall, and excess water is stored and will be utilized in the rest of the months in a year where effective rainfall is less compared to the evapotranspiration requirement.

Constructed Facilities

Earthen dams are constructed in relatively small watersheds (a few square kilometers). The watersheds are generally forest-covered, and the amount of sediment in the stream is relatively low. The flow in the stream is completely blocked by the earthen dam of heights ranging from 10 to 15 meters. A spillway is provided to expel the extra discharge, providing a freeboard of about two to five meters, depending on the size of the dam. The Ghorahi Sub-Metropolitan City, located in Dang, has recently transformed its landscape by constructing 44 artificial reservoirs that cover around 60 hectares of land, utilizing low-cost technology, simply an earthen bund and spillway. These small-scale storage dams, including the *Karjahi* reservoir found in Ghorahi-17, were developed to address the impacts of climate change by harvesting rainwater to recharge groundwater and ensure year-round irrigation for more than 935 hectares of farmland.

Likewise, in the western Dang valley in Tulasipur municipality, several storage facilities have been constructed, some are in operational phase, and many are in development phase. The *Kuioresota* storage at just been in service for the last 3 years, serving a command area of 150 ha, changes the cropping pattern from a single monsoon crop to three high-value crops in a year. The water springs in the vicinity have better flow throughout the year. In addition to agriculture, this project has stimulated local economic growth. The creation of these wetlands has contributed to the establishment of local businesses, which include shops and resorts, while contributing to biodiversity restoration and attracting a variety of bird species. The spillway of *Kuioresota* has been connected to the traditional surface canal, which is also beneficial by getting the silt-free water and avoiding the diversion structure to the traditional canal. The watershed of the source River is forest. Local communities have experienced the increment of wildlives in the forest due to the availability of water. In the West *Rauniyapur* village, the constructed storage facilities are a blessing for the disadvantaged poor community. Their livelihood is being enhanced by more crops and more income. They could get water for their domestic use from their dug wells before the project; the dug wells generally dry up during the dry season.

In the *Dangisharan village*, the storage facilities have been completed (Figure 3), and irrigation systems are being developed. After a few years of completing the storage project, the village spring known as *Baghechira Dhara*, which had been dry in recent years due to climate change and was previously used

for domestic water supply, has now regained full flow. As a result, villagers are receiving domestic water before irrigation water.

These projects demonstrate how small storage dams can transform agriculture and strengthen communities.



Figure 3: Photograph Showing Storage Facilities at Dangisharan village in Western Dang

Water Management and System Operation

Most of the storage schemes have only recently been completed, and many are being developed. So it is still too early to make categorical comments about the performance and issues faced. Up to now, most of the schemes seem to be success stories. However, some earthen dams seem to have some stability problems with some piping from the embankment. Also, in some cases, the collection at the storage point seems to be insufficient to meet the needs. The expectation is that the reservoir will be filled in due course of time.

The operation of this earthen dam is quite simple. The water gets filled up to freeboard, and excess water gets spilled from the escape structure. Escape structures at some systems are linked with traditional FMIS, which seems like an additional benefit. For irrigation purposes, the water is pumped to an overhead tank in case of lands located above the storage level and flows through canals by gravity in case of lands below the storage level. The distribution system is done with a uPVC pipe system with an Alfa valve for outlets. Only one valve is operated at a time for irrigation of the field. The Water Users Association (WUA) set a rule for collecting irrigation service fees based on the hour of operation, and in some cases, on a unit of electricity consumption and on a rotational basis.

Agricultural aspects

The soil and climate in the area are suitable for high-value agricultural crop production. Soil is mainly sandy loam and clayey loam, and the soil depth is sufficient for all types of crop cultivation. This clearly

indicates the prospects for enhancing the cropping intensity to three crop seasons and crop diversification to include more profitable crops. Most of the farmers of the completed schemes are farming three crops. Common crops grown in the area after irrigation service has been initiated are wheat, Musuro, mustard, rice, etc. Agriculture zones are being developed in the area for vegetables like cucumber, tomato, onion, and garlic (Figure 4). So, by the development, both at the farm and household level and at the level of the economy, there is a rise in agricultural productivity and production due to the assurance of more and better-controlled agricultural water supplies.



Figure 4: Photograph showing Tomato Farming at Western Dang

Institutional aspects

Irrigation systems strengthen community institutions by creating Water Users Associations (WUAs), fostering collective decision-making, and embedding local governance structures that manage water distribution, conflict resolution, and resource sustainability. They not only improve agricultural productivity but also build organizational capacity, enhance social cohesion, and empower marginalized groups through participatory management. This developed system follows the same principles. Farmers' level of interest and commitment of the stakeholders, as well as their willingness for further intervention and their commitment to managing the developed system, is high. WUAs have developed their bylaw for resource collection, mobilization, and operation and maintenance of the system. WUAs have the capacity to run their office, can collect and mobilize local resources for operation, maintenance, and management of their system.

Risks involved and measures for minimizing the risks

However, experiences from Nepal indicate that many of these structures encounter various challenges such as sedimentation, leakage, insufficient spillway capacity, and limited maintenance. These issues often arise due to inadequate attention to hydrological variability and climate risks during the design and implementation stages. Construction of a storage dam is one of the most efficient means to cater to the "seasonal variations and climatic irregularities seriously impeding the efficient use of river runoff".

Dam designers work on the assumption that historic hydrological variables such as average annual flow, annual variability of flow, and seasonal distribution of flow are a reliable guide to the future. As global temperatures increase, however, there are likely to be significant changes in seasonal and annual rainfall patterns and other factors affecting stream flow. More extreme storms and increasingly severe

floods will have major implications for dam safety. So, the main risk of the construction of dams across the river is that of their failure. This may result in loss of properties and even casualties. Due to climate change, if there is a high-intensity concentrated rainfall in any area, then such a failure may occur. The second risk is that of filling up the dam, which may gradually reduce the storage capacity. Proper design of the dam and necessary watershed management to control dam siltation should be carried out to minimize these risks.

Opportunities

Opportunities for conjunctive use: There are ample opportunities for integrating the different options. The first option of having a storage reservoir provides avenues for both lifting water and supplying water through gravity flow. Likewise, as per the local users and officials, there is a significant rise in water tables in the vicinity of the dam. So, by expanding groundwater utilization facilities, the synergy of conjunctive use can be achieved by integrating those options by combining surface water with groundwater.

sustainability of the system: Since most of the storage schemes have only recently been completed, it will take some time for us to learn about their sustainability aspects. Some earthen dams have been found to face a piping problem. However, up to now, the problem has not seemed to be too serious, as the embankment has been fixed by changing the soil material. Also, in some cases, the collection at the storage point seems to be insufficient to meet the needs. The silt inflow does not seem to be too high, so the reservoir is not expected to be filled too soon. Contract for fish harvest from the reservoir is also expected to be a good source of steady income for WUA.

Investments necessary: Earthen dams are being constructed at a very cost-effective price in this project. The investment is a very reasonable price compared to all the benefits that it is able to generate. Moreover, things like watershed management have not been properly considered in the earlier estimate. Hence, these should also be considered in the days to come. **Economic return from the system:** There is no doubt that the improved system will deliver multiple benefits. The cropping intensity is expected to double, and agricultural yield to increase by more than 50%. Additionally, it opens new avenues for income generation, like contracts for fish, development of tourist spots, etc.

Contributions to the local economy: The changes brought by this intervention are the income level of the farming community and, eventually, the living standard of the people living within the area. Environmental benefits in the system due to storage, apart from ecological benefits and attraction points for tourists. Wildlife like deer, wild boar etc has been increased due to the favorable conditions created by the dam.

Environmental adverse impacts: Serious adverse environmental impacts are not foreseen. Since the topography is sloping, no waterlogging, no water quality, and pollution issues are expected.

Importance of Implementing the IWRM Principle and Climate Change Context

Small storage dams are essential for strengthening Integrated Water Resources Management (IWRM) and building climate resilience in Nepal, given the country's diverse terrain and highly variable climate. These decentralized systems allow water to be stored locally, reducing flood risks during intense monsoon periods while ensuring a reliable supply during the dry season. By maintaining environmental flows through groundwater recharge and empowering community-based Water User Associations (WUAs), storage dams put IWRM principles into practice and directly safeguard communities against climate-related extremes.

Beyond water security, assured year-round irrigation from storage facilities has transformed agriculture. Farmers who traditionally practiced subsistence farming are able to adopt commercial farming models, supported by scientific inputs and modern technologies. This shift has enhanced productivity, diversified cropping patterns, and increased household incomes.

Impact of irrigation facilities

The water in the reservoirs is mainly being used for irrigation purposes and for drinking purposes for livestock. Additionally, the storage water provides multiple secondary benefits like fish cultivation, ecosystem services, temperature control, groundwater recharge, etc. Some are being used as habitat for migratory birds. There are significant benefits from multiple-use storage projects at the head of an irrigation system, especially when complementary sources of income, such as fish farming, can be realized.

There is considerable value in the age-old concept in Nepal of “one village one pond”, community-managed and bringing benefits to the whole community. In a water-abundant area, there are generally several storage options available with different trade-offs, and the challenge is to choose the most viable option from the socio-economic, environmental, and sustainability viewpoints. But in dry areas like the Dang Valley, their impact seems very positive. These cases of earthen dam construction in Dang valley have not only established the fact that it is feasible but also proved that it is capable of providing multiple benefits. They illustrate how storage is beneficial both from economical as well as an environmental point of view. Hence, this concept needs to be promoted, and the government should continue to support its construction wherever feasible. Some attention should also go in this direction so that the needs of the community can be more properly met. Further wider expansion, a detailed master plan needs to be prepared for Dang Valley, considering the possible options based on the lessons of completed schemes.

Although it is early days yet, these small schemes present many characteristics of success. The more assured water supply allows farmers to cultivate three crops a year, double the previous intensity. Yield can increase by 50% or more. The level of interest and commitment of stakeholders is high. O&M is in the hands of WUAs. Fees are collected, and the schemes are financially self-sustaining.

Conclusion

The experience so far suggests that small earthen dams and hill ponds are accessible and affordable technologies, likely to be both profitable and sustainable under farmer management. The fact that these dams also provide storage for multiple uses increases their value to the community. The experience of the Dang Valley shows that small water storage systems are more than just technical solutions. They are institutional innovations that empower communities, strengthen governance, and build resilience. By capturing excess water during the monsoon and using it during the dry season, these systems make agriculture more productive, livelihoods more secure, and communities more cohesive. As Nepal faces the challenges of climate change, small storage dams offer a practical, affordable, and sustainable path forward.

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