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Preliminary Assessment of Rinchulum Watershed in Paro, Bhutan: A Pathway Towards Evidence-based Conservation

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***Abstract*-- The Rinchulum watershed in Paro, Bhutan, is a critical socio-ecological system, supporting local livelihoods, agriculture, and multiple ecosystem services. However, increasing anthropogenic and natural pressures threaten its ecological integrity. This study presents a preliminary assessment of the socio-economic patterns, watershed's biophysical features, conservation initiatives, and emerging threats, based on field observations, geospatial analysis, and stakeholder inputs. The study findings indicate that ongoing rapid infrastructure expansion, farm road construction and unsustainable extraction of forest resources for economic gain have jeopardized watershed stability and community resilience. The study identifies priority areas for targeted management and provides evidence to guide context-specific conservation strategies. The study results emphasize the urgent need for integrated management that safeguards ecological sustainability while supporting community well-being, strengthening water governance in Bhutan.**

Keywords **- Watershed management, ecosystem functioning, hydrology, watershed degradation, integrated conservation, and socio-economic.**

I. Introduction

Water is an essential resource for sustaining human population, socio-economic livelihoods, and ecosystem functioning. Although the majority of the earth's surface is covered with water, 'escalating anthropogenic pressures, driven by materialism and individual gain, have transformed water resources into a critical scarcity, undermining the integrity of socio-ecological systems and threatening the sustainability of human societies' (Dorji, 2023). 'Access to safe and clean water is one of the most essential requirements for humankind and a recognized fundamental right' (Chathuranika et al., 2023); yet, anthropogenic pressures and climate-driven disturbances such as droughts, wildfires, flash floods, climate change, and socio-institutional changes threaten both human and ecological water security.

Bhutan, a carbon negative country, is endowed with abundant fresh water resources in the form of glaciers, lakes, wetlands, rivers, streams and springs, which play a critical role in sustaining hydrological functions, ecosystem services, and socio-economic livelihoods.

Bhutan has one of the highest per capita water resources availability in the world with 94,500 m^3/capita/annum (Tariq et al., 2021), and a per capita mean annual flow availability of 109,000m^3 (Lhamo and Chhetri, 2022). However, the distribution of water resources in Bhutan is highly uneven, with some regions experiencing surplus while others struggle with chronic shortages, leaving vast tracts of fertile land fallow and intensified conflicts over equitable water access and shared ownership across urban and rural areas.

A recent nationwide *'Assessment and Mapping of Water Sources in Bhutan'* found that, of 7399 water sources assessed, 0.9% had completely dried, 25.1% were in progressive decline, and 73.8% remained stable (Phuntsho et al., 2023). The findings indicate a concerning trend of declining water sources in a geographically small but ecologically diverse country like Bhutan. Similarly, the Rinchulum watershed located within the jurisdiction of Dopshari Block Administration in Paro District Administration (*Figure 1*) is experiencing intensified pressure from anthropogenic activities such as logging, farm road construction, infrastructure development, and forest resource extraction.

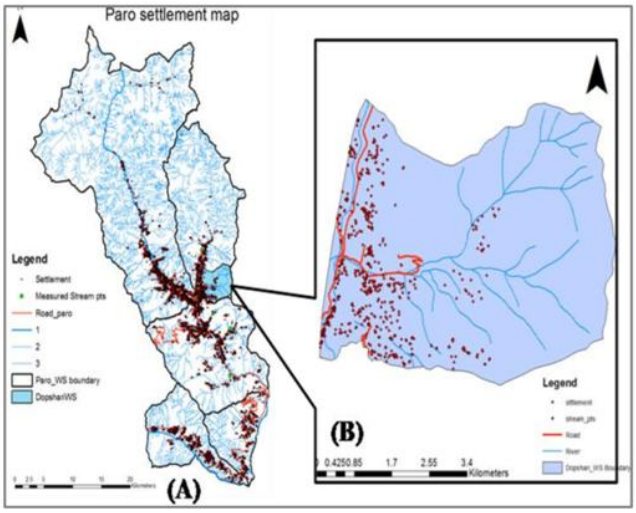

Figure 1: Map of Study Area

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These land-use dynamics are anticipated to progressively degrade both the availability and quality of hydrological resources, posing significant risks to domestic water supplies and irrigation-dependent agricultural systems in surrounding communities unless effective management interventions are enacted.

II. Study Objectives

The study aims to assess patterns of socio-economic status, water resource access, utilization, and management by local communities of Dopshari Block in Paro District, Bhutan.

The specific objectives are to:

- Examine the status and drivers of watershed depletion, and the mechanisms and practices through which communities access, utilize and manage water resources; and
- Identify priority areas for targeted management to guide the development of context-specific conservation strategies.

III. Methodology

The study used a mixed-methods design, combining quantitative and qualitative approaches. Primary data were collected within 11 months (January–November 2025) period through in-person surveys, Key Informant Interviews (KII), and Focus Group Discussions (FGD) with Local Government officials, community-based Water Users' Associations (WUAs), and local communities of Dopshari Block. Secondary data were obtained through a systematic review of relevant reports and case studies.

The data were systematically recorded, organized and analysed using SPSS, Microsoft Excel and Word, while GIS and CorelDRAW were used to generate 3D conceptual layout of hydrological system. Findings are presented descriptively and graphically to elucidate patterns of water resource status, access, utilization, and management.

IV. Results And Discussion

4.1 Socio-economic and Livelihoods

The Rinchulum watershed falls under the jurisdiction of Dopshari Block in Paro District, comprises of 21 villages with 619 households and a total population of 3180, the majority of whom are engaged in farming (Paro Dzongkhag, 2025). The local economy is predominantly agriculture-based, with 417.34 acres of dry-land cultivation, 519.90 acres of wetland paddy fields, 651.30 acres of vegetable production, 175.76 acres of fruit cultivation, and substantial dairy production.

These livelihood systems exhibit a high degree of hydrological dependence, with the Rinchulum watershed functioning as the principal source of water provisioning services that sustains both agricultural productivity and household needs.

Figure 2 indicates that agriculture constitutes the primary source of livelihood in the study area, followed by livestock rearing, employment, and small-scale business ventures. At the subsistence level, communities engaged in supplementary occupations such as daily wage labour during paddy cultivation and local construction work. Notably, the majority of the households depend heavily on consistent water supply, underscoring the critical role in sustaining agriculture productivity, livestock management and overall livelihood resilience.

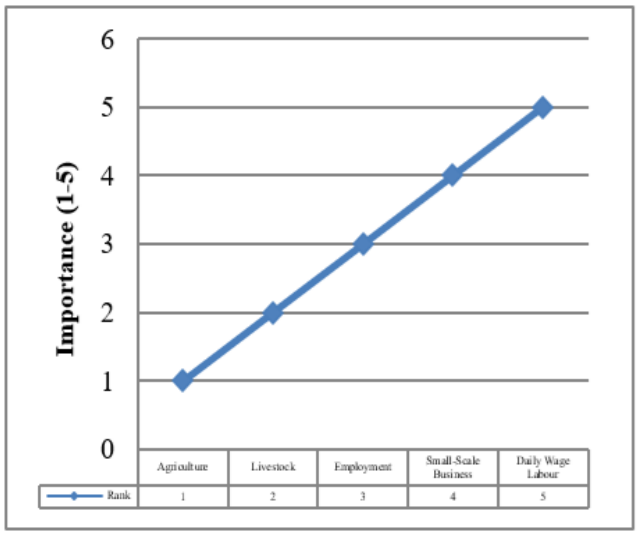

Figure 2: Sources of Livelihoods

4.2 Main Sources of Water

The study delineates three principal sources of water, namely river, stream and spring, which collectively serve as the primary supply systems for local communities. *Figure 3* reveal that 98% of households rely on tap water supplied from government-supported water reservoir connected from Rinchulum stream, while only 2% of households access water directly from nearby perennial stream and spring through self-connections. For irrigation, 100% of households access water from Dochu River and Rinchulum Stream. However, households report recurrent winter shortages in drinking and domestic supply, highlighting seasonal vulnerability despite established water infrastructure.

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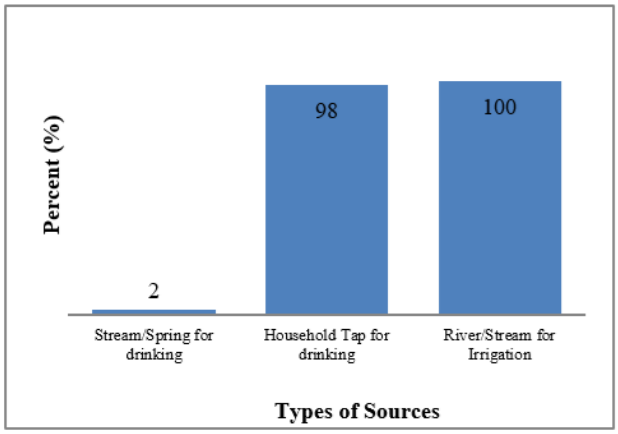

Figure 3: Main Sources of Water

4.3 Major Consumers of Water Resources

The study identifies three primary categories of water consumers within the study area. As shown in *Figure 4,* 50% of respondents perceive local communities as the largest consumers, followed by schools and offices by 30% of respondents, while hotels and religious institutions account for the smallest share of consumption by 20% of respondents. These findings indicate that households and community-level activities are the main competitors for finite water resources. Water use is primarily associated with domestic needs, livestock, and agricultural activities, with demand varying according to livelihood patterns and location-specific requirements. Furthermore, emerging new hotels and resorts are expected to intensify competition of water, potentially exacerbating resource pressures in the near future.

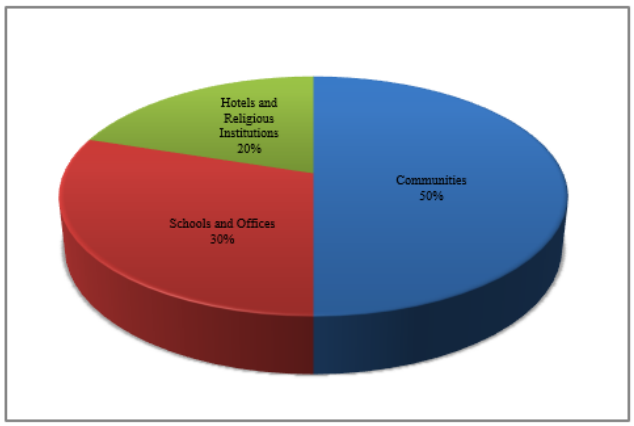

Figure 4: Percentage of Respondents

4.4 Average Discharge and Current Status of Rinchulum Sub-watersheds

The Rinchulum watershed in Dopshari receives an approximate annual accumulated rainfall of 684.5mm in 2024, classifying as moderately water-sufficient region (NCHM, 2025), indicating limited but reliable water availability for local uses. Its hydrological system is supported by four sub-watersheds of Rinchending, Samakha, Nysena and Damchena as shown in *Figure 5*, which collectively contributes to its water availability and ecosystem resilience.

Table 1 presents annual mean spring discharges across the Rinchulum sub-watersheds, with Nysena recording the highest flow with 67.35 liters/second, followed by Samakha with 7.69 liters/second, Damchena with 3.26 liters/second, and Rinchending with 1.44 liters/second. Further, the main stream which originates from Rinchulum watershed exhibited an annual average discharge of 79.74 liters/second *(=0.08m^3/s)*, classifying it as a small stream category *(10-100 liters/second)* according to international hydrological standard (Briney, 2025). However, it represents a relatively high-flow, medium-size stream category *(<5-10 liters/second)* in the context of the Bhutan's Himalayan region (WMD, 2016), and as per the ICIMOD's Protocol for Reviving Springs in the Hindu Kush Himalayas (Shrestha et al., 2018). This discharge magnitude reflects a hydrologically significant watershed capable of sustaining base flow throughout the dry season, indicating relative resilience. Nevertheless, seasonal fluctuations, particularly increased flows during the monsoon can affect water availability, emphasizing the need for continuous monitoring and targeted management to ensure year-round water security.

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Table 1: Annual Average Discharge of Springs in the Rinchulum Sub-watersheds (2025)			
Sub-Watersheds	**Springs**	**Discharge Qty. (Lit/Sec)**	**Beneficiaries**
Rinchending	Maksa-1/Palikha	0.17	Rinchending Community
	Maksa-2	0.14	Rinchending Community
	Maksa-3	0.14	Rinchending Community
	Seriphu	0.99	Shari Community
	Sub-Total (1)	**1.44**	
Samakha	Chubana	7.16	Shari, Kempa and Juka Communities
	Samakha	0.24	Samakha Community
	Awagen	0.29	Samakha Community
	Sub-Total (2)	**7.69**	
Nysena	Shingdacha	0.97	Six Senses and Ozen Resorts
	Bjakarp	1.64	Jishigang Community
	Dorizekha	1.31	Dorizekha Community
	Nyesina	60.00	Kempa and Shari Communities
	Ritsamlum	0.98	Bara and Juka Communities
	Basikha/Hinglumpa	1.47	Bara and Juka Communities
	Tsaygolum	0.98	Bara Community
	Sub-Total (3)	**67.35**	
Damchena	Chorten Dangrim	0.46	Damchena Community
	Damchegoma/Saydotsawa	0.63	Damchena Community
	Damchena/Tongchuganey	0.66	Chujakha and Uma Resort
	Dobamo	0.60	Jishigang Community
	Dachopsawog	0.24	Damchena and Jishigang Communities
	Chudungdung	0.67	Jishigang Community
	Sub-Total (4)	**3.26**	
	Total Discharge	**79.74**	

Figure 5: Sub-Watersheds of Rinchulum Watershed

4.5 Determinants of Rinchulum Watershed Degradation

The Rinchulum watershed is experiencing significant challenges in sustainable water resource management, driven by multiple interrelated factors. *Figure 6* highlights four perceived primary determinants of watershed degradation, which collectively exacerbate water scarcity, compromise water quality, and undermine social cohesion within dependent communities.

The study indicates that 50% of respondents perceived forest degradation from unsustainable legal and illegal timber extraction as the primary contributor to watershed decline followed by infrastructure development, including resorts and farm roads, was perceived by 30% as a secondary contributor, while 10% attributed degradation to climate change impacts such as drying water sources and poor waste management along the popular *Druk Path Trek*[i], collectively reducing water quality.

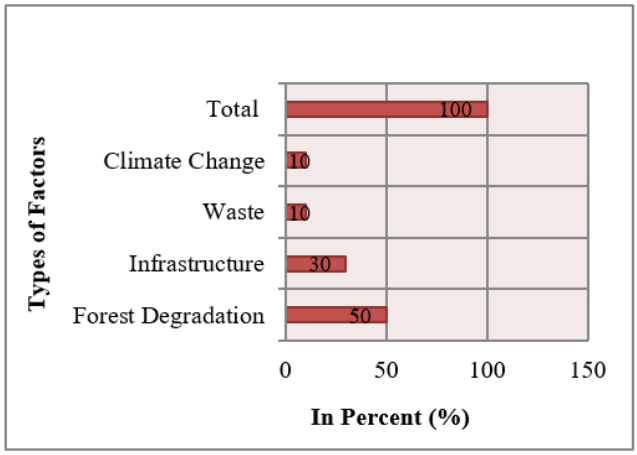

Figure 6: Perceived Factors of Degradation

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4.6 Anthropogenic and Natural Stressors of Rinchulum Watershed Degradation

The forest below Jela *Dzong*[ii] functions as a critical water catchment, regulating monsoon rainfall and controlling surface runoff, but its integrity is increasingly threatened by anthropogenic pressures, including farm road construction, timber extraction, unplanned water tapping, and poor waste management, which are closely correlated with declining watershed health.

Table 2 highlights five key drivers of degradation across Rinchulum watershed and its sub-watersheds. Legal and illegal extractions of timber are widespread in all the sub-watersheds of Damchena, Nysena, Samakha, and Rinchending, significantly contributing to the drying of water sources.

Farm road construction in Damchena sub-watershed, which connects Damchena and Jishigang villages has intensified surface runoff and accelerated soil erosion within the catchment. Forest fires across all sub-watershed of Damchena, Nysena, Samakha, and Rinchending has let to substantial vegetation loss, while forest pests and diseases in sub-watersheds of Damchena and Nysena further reduce vegetation cover and disrupt recharge zones. In addition, inadequate waste management in Damchena sub-watershed has resulted in environmental pollution and declining water quality. Collectively, these anthropogenic and natural stressors are closely correlated with reduced watershed resilience, emphasizing the urgent need for integrated and sustainable management interventions.

Table 2: Consolidated List of Issues at Rinchulum Watershed

Drivers of Degradation	Effects on Watershed	Location of Sub-watersheds
Legal and illegal extraction of timber	Drying of water sources	Damchena, Nysena, Samakha and Rinchending
Farm road construction	Surface runoffs/erosion	Damchena
Forest fire	Elimination of vegetation cover	Damchena, Nysena, Samakha and Rinchending
Forest pest and disease *(bark beetle infestation in blue pine)*	Elimination of vegetation cover and impede recharge areas	Damchena and Nysena
Poor waste management	Environment pollution and deterioration of water quality	Damchena

4.7 Governance and Management of Water Resources

Effective water governance in Bhutan requires a management system that ensures equitable and sustainable allocation while minimizing risks of conflict, degradation, and pollution.

Figure 7 presents Bhutan's multi-tiered water governance and management system, wherein the Department of Water provides national level leadership and technical oversight, supported by allied departments and agencies. At the local level, District and Block Administrations, together with community-based WUAs, facilitate participatory decision-making and implement strategies for equitable and sustainable access. Consistent with Bhutan's broader water governance and management system, the study area likewise prioritizes water resource management, with Block Administration, civil society organizations (CSOs), and community-based WUAs serving as key actors in conservation and collective stewardship.

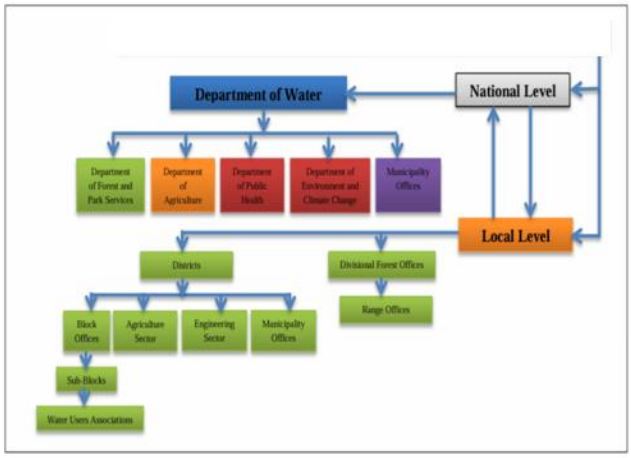

Figure 7 Governance and Management in Bhutan

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V. Conclusion And Recommendations

Achieving universal access to safe water is increasingly jeopardized, as climate change and human-driven pressures are strongly correlated with rising water insecurity (Hamlet et al., 2020). The study concluded that watershed degradation is closely linked to patterns of water access, utilization, and management. The study established that while Block and District level interventions have enhanced water availability by mitigating shortages, degradation and pollution, but ongoing rapid infrastructure development and unsustainable timber extraction continue to threaten watershed stability and long-term resilience. The findings emphasize the urgent need for integrated management that aligns ecological sustainability with community well-being, strengthening water governance in Bhutan.

The following are recommendations for possible improvement and ensuring sustainable management of water resources:

The study found that widespread legal and illegal timber extraction is a major driver of water source depletion. Restoring degraded areas through native tree plantations and demarcating critical watershed zones can protect these watersheds and facilitate their ecological recovery.

The study found that farm road and new resorts construction, often in violation of environmental regulations, have intensified surface runoff and accelerated soil erosion in the watershed. Strengthening regulatory enforcement, penalizing violators, and implementing a payment for environmental services (PES) scheme can help protect the watershed from further degradation.

The study observed that recent forest fires and pest infestations in blue pine forests have caused significant vegetation loss and disrupted recharge zones. Implementing springshed management and strengthening community-based WUAs can enhance biodiversity, improve groundwater infiltration, and support the sustainable management and use of water resources.

The study found that water quality has declined due to pollution from the open dumping of solid waste by trekkers. Enforcing proper waste management along the Druk Path Trek trail and ensuring trekkers comply with regulations, while supporting sustainable tourism; can protect water resources from further contamination.

Disclaimer/Author's Note: The findings of this study may not be sufficient and fully representative, as they are derived exclusively from respondent's responses and field-based basic information.

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[i] The Druk Path Trek is a popular 5–7 day high-altitude trek in Bhutan, connecting Paro and Thimphu, renewed for its scenic landscapes, monasteries, lakes, and mountain panoramas.

[ii] A Dzong is a combined fortress, monastery, and administrative center unique to Bhutanese culture.