

Urban Water Scarcity and Water Governance: A Study of the Bandarawela Municipal Council Area, Sri Lanka

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ABSTRACT

Urban water scarcity is an increasingly pressing challenge in secondary towns across the developing world, where physical water endowments are often adequate, but governance, infrastructure, and equity failures translate into chronic household-level insecurity. This study examines the nature, causes, and consequences of urban water scarcity in the Bandarawela Municipal Council (MC) area, a highland town of 36,651 residents in Sri Lanka's Uva Province. A mixed-methods design combined a structured household questionnaire survey of 68 respondents, selected through simple random sampling across all 14 Grama Niladhari Divisions (GNDs), with secondary water-consumption data obtained from the National Water Supply and Drainage Board (NWSDB) for 2025, Bandarawela Municipal Council, and qualitative field consultations. The results reveal severe spatial inequity in water distribution: per-capita daily consumption ranged from 3.6 litres in Wewathenna to 221.2 litres in Thanthiriya, and 61.8 percent of households received fewer than 12 hours of piped water per week. Seventy-five percent of households reported experiencing water shortages, predominantly during the February-April dry season, with consequences including disrupted household activities (57.4 percent), increased expenditure (41.2 percent), water-related illness (32.4 percent), and psychological stress (22.1 percent). The Uma Oya Multipurpose Development Project was identified by 36.8 percent of respondents as a direct trigger of well and spring depletion. The findings indicate that scarcity in Bandarawela is predominantly institutional and economic rather than hydrological in origin, driven by fragmented governance, deteriorating infrastructure, agrochemical pollution, and the near-total absence of rainwater harvesting despite annual rainfall of approximately 1,497 mm. The study recommends coordinated investment in water infrastructure rehabilitation, the establishment of an Integrated Urban Water Governance Committee, and the promotion of rainwater harvesting and groundwater protection to support more sustainable and effective water management in the area.

Keywords: water scarcity; urban water governance; water supply equity; sustainable water management; Bandarawela; Sri Lanka

INTRODUCTION

Water is one of the most fundamental natural resources on Earth, often described as the “lifeblood of the planet” (UN-Water, 2021). As an inorganic compound essential to all known forms of life, water constitutes a major component of the Earth’s hydrosphere and functions as a universal solvent that sustains the biochemical processes underlying living systems (Gleick, 1993; Chaplin, 2001; Ball, 2008). Water circulates continuously through the hydrological cycle of evaporation, condensation, precipitation, seepage, and runoff, maintaining climatic balance and replenishing the groundwater reserves on which terrestrial and aquatic ecosystems depend (Shiklomanov, 1993; UNESCO, 2020). Access to clean and safe water is therefore recognized as a critical determinant of public health, sustainable development, and economic productivity (WHO & UNICEF, 2023).

Despite water covering roughly 71 percent of the Earth’s surface, freshwater accounts for only about 2.5 percent of total global supply, and the great majority of this fraction is locked in glaciers, ice caps, and deep

groundwater that is largely inaccessible (Shiklomanov, 1993; Gleick, 1993). Pressure on the remaining accessible freshwater has intensified in recent decades as a result of population growth, urbanization, industrialization, agricultural demand, and climate change (Vörösmarty et al., 2010; IPCC, 2022), a pressure that is no longer confined to arid regions but increasingly affects areas with relatively high annual rainfall (Grey & Sadoff, 2007). Water scarcity is broadly defined as a condition in which available freshwater is insufficient to meet the aggregate demand of a population within a given area and time period (Falkenmark & Rockström, 2004), encompassing both physical scarcity, where natural availability is genuinely insufficient, and economic scarcity, where water is physically present but inaccessible because of inadequate infrastructure, weak institutions, or financial constraints (UNDP, 2006; UN-Water, 2021). Falkenmark's (1989) widely used thresholds classify a region as water-stressed below 1,700 m³ of renewable freshwater per person per year, scarce below 1,000 m³, and absolutely scarce below 500 m³, although these benchmarks have been criticised for overlooking variation in use efficiency and seasonal distribution (Rijsberman, 2006).

Globally, urban water scarcity has become a genuinely worldwide phenomenon. Approximately 3.6 billion people, nearly half the world's population, currently live in areas experiencing water scarcity for at least one month a year, a figure projected to rise to between 4.8 and 5.7 billion by 2050 (WWAP, 2019; UN-Water, 2021). Among the global urban population, close to a third live in water-scarce conditions, with roughly one in eight residents facing perennial scarcity (Flörke et al., 2018; He et al., 2021). Asia, home to more than half the world's population but only about 36 percent of global renewable freshwater, is among the most water-stressed regions on Earth (ADB, 2013), and South Asia in particular faces mounting pressure from population growth, agricultural water use, groundwater depletion, and the impact of climate change on monsoon rainfall and glacial systems (Immerzeel et al., 2010; IPCC, 2022). Sri Lanka, although a tropical island with a mean annual rainfall of approximately 1,850 mm, experiences pronounced spatial and seasonal unevenness in rainfall distribution, and the hill country and intermediate zones, including the Uva Province, occupy a transitional climatic position in which moderate but highly seasonal rainfall does not guarantee year-round water security (Panabokke & Perera, 2005; Jayatilaka et al., 2003; DSD, 2024). Across the country, piped water coverage stands at approximately 47 percent of the population, leaving a substantial share of households dependent on unprotected wells, rainwater harvesting, and other informal sources vulnerable to seasonal variability and contamination (NWSDB, 2025).

It is against this backdrop that the Bandarawela Municipal Council area, located in the Badulla District of Uva Province at an elevation of approximately 1,230 metres, presents a compelling case of urban water insecurity. The town's water is drawn primarily from springs, streams, and reservoirs in the surrounding mountain terrain; however, population growth driven by rural-urban migration, expanding economic activity, and land-use change has steadily intensified domestic, commercial, and institutional demand on a system that was never designed to accommodate such pressure (NWSDB, 2025; World Bank, 2016). Field survey data collected for this study indicate that approximately 75 percent of households across all 14 GNDs experience water shortages, and 61.8 percent receive less than 12 hours of piped water per week, well below the continuous-supply standard implied by the WHO benchmark of at least 50 litres per person per day for basic domestic needs (WHO, 2017). Secondary data from the NWSDB reveal an extreme disparity in distribution, with annual supply ranging from 3,347 m³ in Wewathenna to 201,500 m³ in Thanthiriya, and per-capita daily consumption ranging correspondingly from 3.6 to 221.2 litres (NWSDB, 2025). This spatial inequality is compounded by deteriorating infrastructure, declining groundwater levels reported by 54.4 percent of respondents, adverse impacts on rivers and wetlands reported by 73.5 percent, and agrochemical and solid-waste pollution identified by 60.3 percent and 30.9 percent of respondents respectively as the principal sources of water contamination.

Urban water scarcity does not arise from a single cause but from the compounding interaction of population growth and urbanisation, climate variability, environmental degradation and land-use change, deteriorating infrastructure and non-revenue water losses, agricultural demand, pollution, and governance failure (Vörösmarty et al., 2010; UN-Water, 2021). Non-revenue water losses commonly account for 30 to 50 percent of total production in developing-country utilities, simultaneously reducing supply and raising the operating costs of already under-resourced institutions (Kingdom et al., 2006). Weak water governance — the fragmentation of responsibility across agencies, inadequate cost recovery, and limited community participation is widely regarded in the literature as being as important a driver of urban water crises as physical hydrology,

particularly in developing-country contexts (Grey & Sadoff, 2007; Rogers & Hall, 2003; UNDP, 2006). The consequences of scarcity extend across public health, where inadequate access is linked to waterborne disease and, globally, to an estimated 1.4 million deaths annually (WHO & UNICEF, 2023); food security and agricultural productivity, given that agriculture accounts for roughly 70 percent of global freshwater withdrawals (FAO, 2020; Postel et al., 1996); household and municipal economic activity, with the World Bank (2016) estimating that scarcity could cost some regions up to six percent of GDP by 2050; social equity and gender, since women and girls disproportionately bear the burden of water collection and household water management (Mehta, 2005; UN-Water, 2021); and environmental sustainability, through the degradation of rivers, wetlands, and aquatic biodiversity when withdrawals exceed natural recharge (Vörösmarty et al., 2010; Millennium Ecosystem Assessment, 2005).

In Bandarawela specifically, the Uma Oya Multipurpose Development Project has been identified in both the literature and this study's field evidence as a significant contributor to localized groundwater depletion, with subsurface tunnelling activities linked to the drying of previously reliable wells in areas such as Bindunuwewa and Ambegoda (Wijayarathne, 2018; Fernando, 2019; CEA, 2020). Water governance in Sri Lanka is distributed across multiple institutions: the Ministry of Water Supply, the NWSDB, the Department of Irrigation and Mahaweli Authority, the Central Environmental Authority, the Water Resources Board, and local authorities such as the Bandarawela Municipal Council, whose overlapping mandates and limited coordination constrain the coherence of local water management (GWP, 2000; UN, 2015). Local authorities, as the level of government closest to residents, play a critical role in land-use planning, stormwater management, sanitation, and community engagement in water governance, yet frequently face constraints of financial resources, technical capacity, and inter-agency coordination that limit their effectiveness (UN-Habitat, 2020). While the existing literature has established water scarcity as a global environmental and developmental challenge, most Sri Lankan research has concentrated on large metropolitan centres such as Colombo, Kandy, and Galle, leaving secondary highland towns such as Bandarawela considerably under-researched with respect to their specific supply dynamics, infrastructure limitations, and governance arrangements. Existing studies also emphasise engineering and demand-supply solutions over the household-level and community experience of scarcity, and rarely apply spatial analysis tools such as GIS to examine intra-municipal distribution patterns.

It is within this gap that the present study is situated. The main objective is to critically investigate water resource availability, distribution patterns, the socio-economic impacts of water scarcity, and sustainable management strategies in the Bandarawela Municipal Council area, addressing four specific research questions: (1) what water sources are available within the Bandarawela MC area; (2) how is water distributed, and what quantities are supplied to different areas; (3) how does water scarcity affect the community within the MC area; and (4) what are the key factors contributing to water scarcity, and how can community-based approaches support sustainable solutions. Correspondingly, the sub-objectives are to identify and assess available water sources; examine the distribution system and evaluate quantities supplied across areas; analyse the socio-economic impacts of scarcity on the community; and identify the causes of scarcity while evaluating community-based solutions for sustainable management.

This study is significant on several grounds. It moves beyond aggregate statistics to examine how water shortages affect the everyday lives of residents, their cooking, cleaning, hygiene, and livelihoods, and thereby places lived experience at the center of the analysis alongside technical and infrastructural considerations. It is significant for water governance, since Bandarawela's water management involves multiple institutions, whose coordination gaps this study seeks to expose and address. It is significant for social equity, since water scarcity does not affect all residents equally and low-income households in particular bear a disproportionate burden. It is significant for future planning and policy, since the evidence generated can support local and national decisions on infrastructure investment, catchment protection, and demand management.

METHODOLOGY

This study adopted a mixed-methods research design, integrating quantitative and qualitative approaches to develop a comprehensive understanding of water scarcity and water governance in the Bandarawela Municipal Council area. The use of multiple data sources allowed triangulation, whereby findings generated through

different methods could be compared and integrated, strengthening the reliability and depth of the results (Bryman, 2016; Creswell, 2014). The quantitative component centered on a structured household questionnaire survey measuring water consumption patterns, the frequency and duration of shortages, the diversity of sources used, and the socio-economic impacts of scarcity on household well-being. The qualitative component complemented these findings through informal consultations with Municipal Council officers, National Water Supply and Drainage Board (NWSDB) officials, and community representatives, together with direct field observation of water infrastructure and natural water bodies.

Study Area

The study area is the Bandarawela Municipal Council, located in the Badulla District of Sri Lanka's Uva Province, approximately between 6°45' to 6°57' N and 80°55' to 81°03' E, at an elevation of roughly 1,200 to 1,500 meters above sea level. This highland position gives the area a temperate climate distinct from lowland Sri Lanka, with maximum temperatures of approximately 23 - 27°C and minimum temperatures of 15 - 18°C across the year (Climates to Travel, 2024). Rainfall follows a bimodal monsoon pattern, peaking above 300 mm per month in October and November under the northeast monsoon, with a pronounced Uva dry season between June and September during which monthly precipitation falls to 60 -75 mm as fohn-type winds descend the eastern slopes of the central highlands (Meteorological Department of Sri Lanka, 2023; Jayatilaka et al., 2003). The rugged, dissected topography channels rainfall into a network of small, largely rain-fed streams that are highly sensitive to seasonal variation, while also complicating the construction and maintenance of distribution infrastructure across the municipal area (DSD, 2024; Panabokke & Perera, 2005).

The municipal area comprises 14 Grama Niladhari Divisions (GNDs), Ambegoda, Bandarawela East, Bandarawela West, Bindunuwewa, Diganathenna, Eththalapitiya, Gediyaaroda, Inikambedda, Kebillewela North, Kebillewela South, Kinigama, Mahaulpatha, Thanthiriya, and Wewathenna, with a combined population of 36,651 persons (19,107 female, 17,544 male), unevenly distributed as summarized in Table 1. Land use across the municipality is dominated by home gardens, with a concentrated urban core, scattered paddy and tea cultivation in peripheral divisions, and limited forest reserve that nonetheless plays a disproportionate role in sustaining catchment hydrology (DSD, 2024; Perera & Dissanayake, 2018; FAO, 2020).

Table 1. Population of Bandarawela Municipal Council by Grama Niladhari Division

GN Division	Population	GN Division	Population
Ambegoda (67C)	2,689	Eththalapitiya (67)	2,655
Wewathenna (67G)	3,096	Gediyaaroda (67K)	2,511
Bindunuwewa (67B)	1,633	Mahaulpatha (66D)	1,475
Kebillewela North (67D)	2,775	Kinigama (66)	1,964
Bandarawela West (65B)	3,382	Kebillewela South (65A)	1,517
Bandarawela East (65G)	3,518		
Inikambedda (65E)	3,982		
Thanthiriya (66G)	2,705	Total	36,651

Source: Divisional Secretariat Department, Bandarawela Resource Profile (2024).

Research Design and Sample Size

A mixed quantitative-qualitative research design was adopted (Figure omitted from text; described narratively). The sample size for the household survey was calculated using the standard statistical formula for estimating proportions, $n_0 = Z^2p(1-p)/e^2$, which is widely applied in social and environmental research to

determine the minimum number of respondents required for statistically reliable results (Cochran, 1977). A 90 percent confidence level ($Z = 1.645$), a conservative population proportion of $p = 0.50$, and a margin of error of $e = 0.10$ were adopted, since no prior study offered an estimate of the true proportion and this assumption maximises the required sample size (Israel, 1992). Substituting these values, $n_0 = (1.645^2 \times 0.5 \times 0.5) / 0.10^2 = 67.65$. Because the target population is finite ($N = 36,651$), the finite population correction $n = n_0 / [1 + (n_0 - 1)/N]$ was applied, giving $n = 67.65 / [1 + (66.65/36,651)] \approx 67.53$, rounded up to a final sample size of 68 households. Given the small ratio of n_0 to N , the correction had only a marginal effect on the required sample (Cochran, 1977).

A sampling frame was constructed from household records for the 14 GNDs, with each household assigned a unique identification number, and the 68 households were selected using simple random sampling, ensuring that every household had an equal and independent probability of selection (Bryman, 2016). This approach minimizes selection bias and strengthens the representativeness of the sample across the socio-economic, spatial, and demographic diversity of the study area (Creswell, 2014), providing a statistically defensible basis, at the stated confidence level and margin of error, for generalising the survey findings to the wider municipal population.

Data Collection

Primary data were collected through three complementary methods. A structured household questionnaire survey, administered to the 68 sampled households, captured household water sources, consumption patterns, the frequency and severity of shortages, coping strategies, and perceptions of water management. Informal, semi-structured stakeholder consultations were held with Municipal Council staff, NWSDB officers, and community representatives to contextualise the survey findings within institutional and administrative realities. Direct field observations of pipelines, storage reservoirs, overhead tanks, community water points, and surrounding environmental conditions were used to validate self-reported survey responses and to inform the GIS-based spatial analysis.

Secondary data were obtained from several institutional sources. Monthly water consumption records disaggregated by GND and by consumption sector (domestic, commercial, institutional, religious, and government) were obtained from the NWSDB for the full twelve months of 2025, documenting a total annual supply of 1,109,655.9 m³ across the 14 GNDs. Infrastructure and service-coverage data were obtained from the Bandarawela Municipal Council, and demographic, land-use, and household water-source information were obtained from the Divisional Secretariat Department through the Bandarawela Resource Profile (2024). These were supplemented by published reports from UN-Water, WHO, UNICEF, the World Bank, and peer-reviewed research on urban water governance and scarcity in South Asia, providing a comparative and theoretical framework for interpreting the local findings.

Data Analysis

Quantitative data from the household survey and institutional records were analyzed using descriptive statistics, frequencies, percentages, and averages to summarize and compare water-related variables across the sample and across GNDs. Per-capita daily water consumption for each GND was calculated as: monthly consumption (m³) = annual consumption $\div$ 12; and per-capita daily consumption (L/person/day) = [monthly consumption (m³) $\times$ 1,000] $\div$ [days in month $\times$ population]. Consumption levels were benchmarked against the WHO minimum of 50 L/p/d for basic needs, the WHO adequate urban range of 100–150 L/p/d, and the Sri Lankan national urban water supply standard of 100 L/p/d (WHO, 2017; NWSDB, 2025).

A Normalized Water Supply Index (NWSI) was developed to evaluate spatial equity in distribution, calculated as $NWSI = [\text{total twelve-month consumption (m}^3\text{)} \div \text{population}] \times 1,000$, expressed as m³ per 1,000 population. Spatial analysis was conducted using Geographic Information Systems, applying overlay and hotspot techniques to examine the relationship between population density, water consumption, and the distribution of water-supply infrastructure and land use. Qualitative data from field observations and stakeholder consultations were analyzed thematically, with recurring issues grouped into categories including

the causes of shortage, household coping strategies, institutional support and development interventions, and social and environmental impacts, allowing the integration of quantitative, spatial, and qualitative evidence into a single analytical framework.

RESULTS AND DISCUSSION

Available Water Sources

Water sources within the Bandarawela MC area fall into four broad categories: piped municipal supply, well-based groundwater, surface water and rainwater harvesting, and supplementary sources such as bowser delivery. Piped tap water within the house is the dominant formal source, serving approximately 6,527 registered units, followed by protected wells in or outside the garden (1,029 households) and unprotected wells (1,100 households). Rural community water projects supply 673 units, bowser-delivered water serves 393 units, public wells serve 153, tube wells serve 2, and natural surface sources such as lakes, rivers, and streams serve 17 units. Notably, rainwater harvesting is entirely absent from the recorded source data, and bottled water accounts for only 5 units (DSD, 2024).

This apparent diversity of sources conceals a more troubling uniformity: across all 14 GNDs, small-scale rural water project schemes function as the near-universal backbone of supply, regardless of population size or infrastructure capacity. Classification of GNDs by dominant source reveals a three-tier structure. A first tier of well-served divisions, including Bandarawela West, Inikambedda, Gediyaroda, Kebillewela North, Diganathenna, and Thanthiriya relies predominantly on piped supply. A second, transitional tier — Ambegoda, Wewathenna, Bindunuwewa, Kinigama, Kebillewela South, and Eththalapitiya depends on a mixture of piped water, safe wells, and rural water projects, indicating partial but unreliable infrastructure coverage. A third, vulnerable tier most notably Bandarawela East and parts of Mahaulpatha depends heavily on unprotected wells and multiple informal sources, reflecting acute infrastructure deficiency and elevated exposure to water-quality risk. The near-total absence of rainwater harvesting, despite the area’s annual rainfall of approximately 1,497 mm and its predominantly residential built environment, represents a substantial and currently unrealised opportunity for supply diversification and climate resilience (DSD, 2024; Panabokke & Perera, 2005).

Distribution and Quantity of Water Supplied

Table 2 presents total NWSDB-recorded water consumption for 2025 across the 14 GNDs. The data reveal a highly unequal distribution: consumption ranged from 3,347.4 m³ in Wewathenna to 201,499.9 m³ in Thanthiriya, with Thanthiriya and Bandarawela West together accounting for more than one-third of the entire municipal supply of 1,109,655.9 m³. This concentration reflects the central location, higher population service coverage, and greater density of commercial, institutional, and government connections in these divisions. A middle tier Mahaulpatha, Eththalapitiya, Kinigama, and Diganathenna recorded moderate annual volumes of roughly 40,000 to 102,000 m³, while Ambegoda, Bindunuwewa, Inikambedda, Wewathenna, Gediyaroda, and Kebillewela South recorded critically low volumes, several below 10,000 m³ annually.

Table 2. Total Water Consumption by GN Division, 2025 (m³)

GN Division	Q1	Q2	Q3	Annual Total
Ambegoda (67C)	10,175.0	10,182.1	10,224.3	40,869.8
Wewathenna (67G)	835.2	844.2	815.5	3,347.4
Bindunuwewa (67B)	11,307.3	11,467.7	12,125.1	47,147.7
Kebillewela North (67D)	37,566.5	37,576.6	27,894.4	140,320.4
Bandarawela West (65B)	51,200.9	52,556.5	40,516.9	197,849.1
Bandarawela East (65G)	29,750.9	30,086.5	37,192.8	127,940.9

GN Division	Q1	Q2	Q3	Annual Total
Inikambedda (65E)	8,267.0	9,023.3	9,060.8	35,791.1
Thanthiriya (66G)	50,894.7	49,278.5	50,655.8	201,499.9
Diganathenna (67H)	13,651.3	14,371.6	13,325.3	57,661.2
Eththalapitiya (67)	17,604.4	18,156.8	18,737.7	71,909.4
Gediyaroda (67K)	1,872.3	1,928.8	1,913.4	7,583.5
Mahaulpatha (66D)	25,056.7	24,456.8	25,094.8	100,382.5
Kinigama (66)	16,504.6	16,321.4	17,409.3	70,690.3
Kebillewela South (65A)	1,515.8	1,776.1	1,757.2	6,662.8
Total	276,202.6	278,026.9	266,723.2	1,109,655.9

Q1 = Jan–Mar; Q2 = Apr–Jun; Q3 = Jul–Sep. Source: NWSDB Reports (2025).

Monthly consumption across the municipality remained relatively stable through most of the year at 80,000–100,000 m³, with a marked dip in January, a gradual rise to a mid-year peak around July, a decline in August–September coinciding with the onset of monsoon rainfall, and a recovery toward a year-end peak near 98,000 m³ in December, likely reflecting both the dry-season increase in demand and heightened festive and tourism-related activity. The roughly 13,500 m³ gap between the lowest and highest months underscores the need for flexible storage and distribution management capable of accommodating seasonal peaks (NWSDB, 2025).

Per-Capita Consumption and Spatial Equity

Table 3 converts total consumption to per-capita daily figures, benchmarked against the WHO minimum of 50 L/p/d and the Sri Lankan urban standard of 100 L/p/d. The results show an extreme range, from 3.6 L/p/d in Wewathenna to 221.2 L/p/d in Thanthiriya a ratio exceeding 61 to 1 within a single municipal authority. Several divisions, including Thanthiriya, Mahaulpatha, and Bandarawela West, exceed 150 - 220 L/p/d, largely reflecting concentrations of commercial, institutional, and government water use rather than purely domestic demand, while Wewathenna, Gediyaroda (8.6 L/p/d), Kebillewela South (11.8 L/p/d), Inikambedda (39.9 L/p/d), and Ambegoda (42.0 L/p/d) fall well below the WHO minimum, indicating serious accessibility constraints.

Table 3. Per-Capita Daily Water Consumption by GN Division, 2025

GN Division	Population	Annual Total (m ³)	Avg. L/person/day
Ambegoda (67C)	2,689	40,869.8	42.0
Wewathenna (67G)	3,096	3,347.4	3.6
Bindunuwewa (67B)	1,633	47,147.7	82.8
Kebillewela North (67D)	2,775	140,320.4	164.5
Bandarawela West (65B)	3,382	197,849.1	173.7
Bandarawela East (65G)	3,518	127,940.9	98.7
Inikambedda (65E)	3,982	35,791.1	39.9
Thanthiriya (66G)	2,705	201,499.9	221.2
Diganathenna (67H)	2,749	57,661.2	56.3
Eththalapitiya (67)	2,655	71,909.4	77.6

GN Division	Population	Annual Total (m ³)	Avg. L/person/day
Gediyaroda (67K)	2,511	7,583.5	8.6
Mahaulpatha (66D)	1,475	100,382.5	199.0
Kinigama (66)	1,964	70,690.3	97.6
Kebillewela South (65A)	1,517	6,662.8	11.8
Total / Average	36,651	1,109,655.9	91.2

Source: NWSDB Reports (2025).

The Normalised Water Supply Index confirmed this disparity with mathematical precision, ranging from 1,084.53 m³ per 1,000 population in Wewathenna to 74,899.01 m³ per 1,000 population in Thanthiriya. GIS-based spatial analysis of population density, water consumption, and water-source availability (Figure 1) revealed a clear pattern in the urban wards of Bandarawela. Bandarawela West, Bandarawela East, Thanthiriya, and Gediyaroda recorded the highest population densities, reaching up to 7,306 persons per km². These highly populated areas also recorded high levels of water consumption. However, despite this high demand, they continued to depend on less secure water sources, including rural water projects and unprotected wells. In Thanthiriya, surface water was also an important water source.

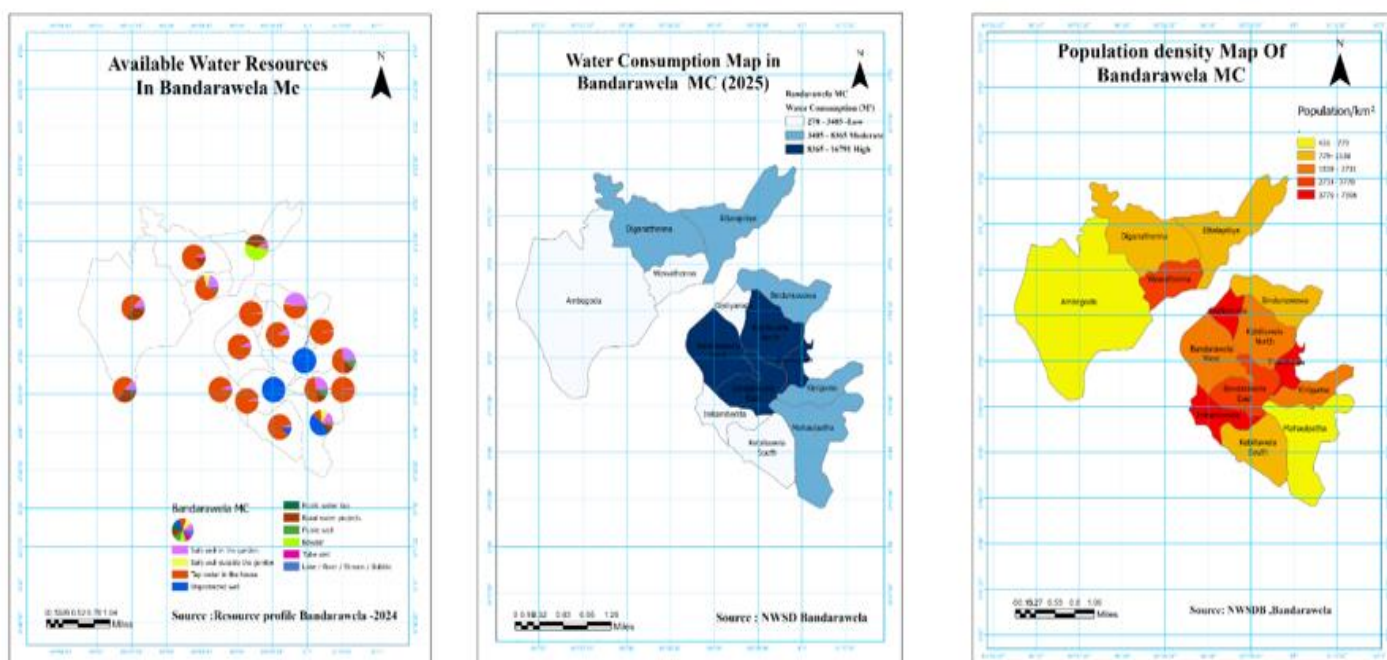


Figure 1: Spatial Distribution of Water Resources, Water Consumption, and Population Density in Bandarawela Municipal Council, 2025

Population density in some highly urbanized wards is relatively high, but these areas record the lowest levels of water consumption in the municipality. This may indicate problems with water supply rather than genuinely low water demand. Transitional wards such as Bindunuwewa and Eththalapitiya show a strong dependence on bowser tanker deliveries, suggesting that existing formal and rural water supply networks are not sufficient to meet the growing demand. As a result, emergency water supply has become a regular practice. In contrast, peripheral wards such as Ambegoda, Diganathenna, Kebillewela South, and Mahaulpatha have relatively low water consumption and depend mainly on rural water projects, with limited access to formal piped water networks. This limited infrastructure may make these areas more vulnerable to future increases in water demand associated with urbanisation and tourism development.

Household Experience of Water Scarcity

In Bandarawela Municipal Council 68 households was used as a sample for the study, as a result 75.0 percent reported personally experiencing water shortages, confirming that scarcity is a widespread community-level condition rather than an isolated phenomenon, the 25.0 percent who reported no scarcity were concentrated in the better-served central divisions, consistent with the NWSI findings. Among affected households, 70.6 percent experienced shortages predominantly during the February–April dry season, corresponding to the inter-monsoon dry spell, 17.6 percent reported year-round scarcity, concentrated in the structurally underserved divisions of Wewathenna, Gediyaaroda, and Kebillewela South where per-capita supply remains critically low regardless of season; and 11.8 percent reported irregular scarcity linked to localized infrastructure breakdowns rather than a consistent seasonal or structural pattern.

Weekly supply-hour data confirm a deeply inadequate and intermittent supply regime: 36.8 percent of respondents received only 6–12 hours of water per week, and a further 25.0 percent received as little as 3–6 hours; only 22.1 percent received more than 12 hours, and just 16.2 percent enjoyed continuous 24-hour supply, concentrated in better-served central divisions. In total, 61.8 percent of the sample received fewer than 12 hours of piped water per week, a finding that points directly to structural inadequacy in the distribution network and to an urgent need for pipe rehabilitation and expanded storage and reservoir capacity.

Socio-Economic and Environmental Impacts

The survey findings indicate that water scarcity has had significant socio-economic and environmental impacts on households. The most commonly reported impact was the disruption of daily household activities, particularly cooking, bathing, laundry, and sanitation, which affected 57.4 percent of respondents. This finding is consistent with the limited availability of piped water, as most households receive water for fewer than 12 hours per week. Damage to agricultural and home-garden productivity was reported by 35.3 percent, reflecting the embeddedness of the Bandarawela economy in tea and vegetable cultivation, where dry-season water scarcity translates directly into reduced household income. Increased water-related expenditure driven by bowser purchase costs and rising NWSDB tariffs was reported by 41.2 percent of respondents, disproportionately burdening low-income households with the fewest alternatives. Psychological stress and family tension attributable to chronic water insecurity were reported by 22.1 percent, and disruption to communal and social events such as funerals and weddings, where water access is a cultural as well as practical necessity, was reported by 10.3 percent.

Public health impacts were substantial: 32.4 percent of households confirmed experiencing water-quality-related illness, including gastrointestinal disease and skin conditions, with impacts concentrated in divisions most dependent on unprotected wells, Bandarawela East, Mahaulpatha, and parts of Ambegoda and Kebillewela South. Two contamination pathways plausibly explain this pattern: direct infiltration of agricultural runoff and waste leachate into unprotected wells, and back-flow contamination within the piped network during the low-pressure or no-flow periods that are structurally common where supply is intermittent (Howard & Bartram, 2003; WHO, 2017). Although systematic gender-disaggregated data were not the primary focus of the questionnaire, qualitative evidence consistently identified women and girls as disproportionately responsible for water collection, with time costs estimated at 1.5–3.5 hours per day in the most severely underserved divisions, time diverted from education, income generation, and rest (Mehta, 2005; UN-Water, 2021).

Environmental impacts were widely reported: 73.5 percent of respondents observed adverse effects on local rivers, streams, and wetlands, including reduced flow and drying of seasonal streams; 54.4 percent reported a perceptible decline in groundwater levels; and 57.4 percent reported reduced vegetation and green cover. These self-reports are broadly consistent with secondary evidence of declining well and borehole counts in Bindunuwewa and Mahaulpatha and rising bowser dependency in Eththalapitiya. Agrochemical contamination, cited by 60.3 percent (n = 41) of respondents as the leading pollution source, aligns with the area's dependence on tea and vegetable cultivation (Jayasinghe et al., 2020; Perera & Dissanayake, 2018), while improper solid-waste disposal was cited by 30.9 percent (n = 21).

A recurring and geographically specific finding was the community identification of the Uma Oya Multipurpose Development Project as a driver of worsening water scarcity, particularly in Bindunuwewa, Ambegoda, and Eththalapitiya. In total, 36.8 percent of respondents specifically identified the project's subsurface tunnelling as the trigger after which their water situation deteriorated, and a further 13.2 percent cited general construction activity; only 50.0 percent reported no perceived linkage. Respondents from Bindunuwewa described previously functioning wells drying up after tunnelling began, compelling reliance on the intermittent NWSDB supply, while a respondent from Ambegoda described a decline in the flow of a spring that had traditionally served the community. These accounts are consistent with the documented hydrogeological effects of large-scale diversion tunnels, which can intercept and redirect subsurface flows and depress local groundwater tables in adjacent areas (Wijayarathne, 2018; Fernando, 2019; CEA, 2020).

CONCLUSION

This study set out to investigate water resource availability, distribution patterns, socio-economic impacts, and sustainable management strategies in the Bandarawela Municipal Council area, drawing on a structured household survey, NWSDB consumption records for 2025, GIS spatial analysis, and qualitative field evidence. The findings demonstrate that the municipality's water supply system is diverse in appearance but fragile in practice, resting almost universally on small-scale, ageing rural water project schemes with no formal backup or redundancy, and characterised by the near-total absence of rainwater harvesting despite an annual rainfall endowment of approximately 1,497 mm.

The analysis of NWSDB consumption data revealed spatial inequality of a severity that is difficult to justify on any governance standard: per-capita daily consumption ranged from 3.6 litres in Wewathenna to 221.2 litres in Thanthiriya, a disparity of more than 61 to 1 within a single municipal boundary, confirmed with mathematical precision by the Normalised Water Supply Index. The household survey confirmed that this inequality translates into a pervasive and daily lived reality for most residents: three in four households reported experiencing water shortages, 61.8 percent received fewer than 12 hours of piped water per week, and the consequences extended across disrupted household activities, increased expenditure, water-related illness, psychological stress, and disproportionate burdens on women and girls. The Uma Oya Multipurpose Development Project emerged as a specific and geographically concentrated driver of well and spring depletion in Bindunuwewa, Ambegoda, and Eththalapitiya, a finding corroborated by both quantitative and qualitative evidence yet, to date, without any formal institutional acknowledgement or redress.

Taken together, the evidence points consistently to governance, equity, and infrastructure investment rather than absolute physical water scarcity as the central and binding constraint on water security in Bandarawela. The municipality possesses a natural hydrological endowment capable, in principle, of meeting current and near-future demand; what is lacking is the institutional coordination across the six or more agencies with overlapping water-related mandates, the infrastructure integrity required to deliver water reliably and equitably, the environmental stewardship needed to protect the catchments and groundwater systems on which supply ultimately depends, and the community governance structures required to translate the considerable local knowledge and willingness to participate that this study documented into systematic influence over planning and investment decisions. Addressing this crisis durably and justly will require sustained, coordinated, and adequately resourced action across supply infrastructure, demand management, environmental protection, and institutional reform, guided by the principle that access to safe, sufficient, and affordable water should not depend on a household's proximity to the commercial center of the municipality.

RECOMMENDATIONS

The recommendations proposed here stem from the research findings and aim to contribute to more equitable, sustainable and climate resilient water management in the Bandarawela MC area. Implementing institutions will need to work closely together to successfully implement these recommendations, including the Bandarawela Municipal Council, National Water Supply and Drainage Board (NWSDB), other national and provincial institutions, and communities.

A rehabilitation, extension and upgrading programme should be carried out systematically throughout the 14 GNDs, starting with the most underserved. The five most underserved areas are: Wewathenna, Gediyaaroda, Kebillewela South, Ambegoda and Kinigama. All divisions should aim to gradually reach and exceed a supply level of 100 litres per person per day within the next five years. Technical inventories should be conducted to identify damaged and aging pipes, leakage, insufficient reservoir capacity, pumping constraints and household connection gaps. The outcome of this exercise can feed into a publicly available investment plan outlining priorities, budgets, institutions responsible and target dates for implementation.

Households affected by the disruption of traditional water sources associated with the Uma Oya Project should also receive greater institutional attention. In areas such as Bindunuwewa and Ambegoda, an independent and transparent mechanism should be established to assess affected water sources and household impacts. Hydrogeological assessments, appropriate compensation, alternative water supply arrangements, and continued community monitoring should form part of this process.

Rainwater harvesting should be promoted as an important supplementary source, particularly in underserved communities. Municipal support could include subsidies for low-income households, training for local technicians, and the incorporation of rainwater harvesting systems into appropriate building approval requirements. Demonstration systems at schools, health centers, and community facilities could further encourage wider adoption.

The protection and monitoring of groundwater resources should also be strengthened. A municipality-wide monitoring programme could include selected monitoring wells, regular water-quality testing, appropriate regulation of groundwater extraction, and protection zones around important wells and springs.

Improved institutional coordination is essential for addressing the fragmented governance identified by the study. An Integrated Urban Water Governance Committee could bring together the Municipal Council, NWSDB, Water Resources Board, Central Environmental Authority, Department of Irrigation, Divisional Secretariat, and community representatives from the 14 GNDs. Regular meetings, publicly available performance reports, and independent review would improve accountability and enable water-supply inequalities to be monitored at the GND level.

Demand management should complement improvements to water infrastructure. Water audits of major institutional and commercial consumers, effective leak detection and repair, appropriate tariff structures that protect basic household needs, and continuous public awareness programmes could help reduce unnecessary consumption. Schools, religious institutions, community organisations, and local media could play an important role in promoting responsible water use.

Finally, the watersheds, catchments, springs, streams, and riparian areas that support Bandarawela's water resources should be systematically mapped and protected. Catchment restoration, riparian planting with locally appropriate species, and the integration of water-resource protection into municipal land-use planning would strengthen long-term water security. Community Water Committees at GND level should also be established and connected with the proposed governance committee and NWSDB area office. Recognizing communities as active partners rather than passive recipients of water services would strengthen local accountability and contribute to more equitable and resilient water governance in Bandarawela.

REFERENCES

1. Arnell, N. W., & Gosling, S. N. (2016). The impacts of climate change on river flood risk at the global scale. *Climatic Change*, 134(3), 387–401. <https://doi.org/10.1007/s10584-014-1084-5>
2. Asian Development Bank. (2013). Asian water development outlook 2013: Measuring water security in Asia and the Pacific. Asian Development Bank.
3. Ball, P. (2008). *Water: A biography*. Farrar, Straus and Giroux.
4. Bryman, A. (2016). *Social research methods* (5th ed.). Oxford University Press.

5. Central Environmental Authority. (2020). Environmental impact assessment report: Uma Oya Multipurpose Development Project. Ministry of Environment, Sri Lanka.
6. Chaplin, M. F. (2001). Water: Its importance to life. *Biochemistry and Molecular Biology Education*, 29(2), 54–59. <https://doi.org/10.1111/j.1539-3429.2001.tb00070.x>
7. Climates to Travel. (2024). Climate: Bandarawela, Sri Lanka. <https://www.climatestotravel.com>
8. Cochran, W. G. (1977). *Sampling techniques* (3rd ed.). John Wiley & Sons.
9. Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). SAGE Publications.
10. Department of Meteorology, Sri Lanka. (2023). Climate of Sri Lanka. Department of Meteorology.
11. Divisional Secretariat Department. (2024). Bandarawela resource profile 2024. Divisional Secretariat, Bandarawela.
12. Falkenmark, M., & Rockström, J. (2004). Balancing water for humans and nature: The new approach in ecohydrology. Earthscan.
13. Fernando, S. (2019). Hydrological impacts of the Uma Oya tunnel project on groundwater in the Uva Province [Research report]. University of Peradeniya.
14. Flörke, M., Schneider, C., & McDonald, R. I. (2018). Water competition between cities and agriculture driven by climate change and urban growth. *Nature Sustainability*, 1, 51–58. <https://doi.org/10.1038/s41893-017-0006-8>
15. Food and Agriculture Organization of the United Nations. (2020). The state of food and agriculture 2020: Overcoming water challenges in agriculture. FAO.
16. Gleick, P. H. (1993). *Water in crisis: A guide to the world's freshwater resources*. Oxford University Press.
17. Global Water Partnership. (2000). Integrated water resources management (TAC Background Paper No. 4). Global Water Partnership.
18. Grey, D., & Sadoff, C. W. (2007). Sink or swim? Water security for growth and development. *Water Policy*, 9(6), 545–571. <https://doi.org/10.2166/wp.2007.021>
19. He, C., Liu, Z., Wu, J., Pan, X., Fang, Z., Li, J., & Bryan, B. A. (2021). Future global urban water scarcity and potential solutions. *Nature Communications*, 12, 4667. <https://doi.org/10.1038/s41467-021-25026-3>
20. Howard, G., & Bartram, J. (2003). Domestic water quantity, service level and health. World Health Organization.
21. Immerzeel, W. W., van Beek, L. P. H., & Bierkens, M. F. P. (2010). Climate change will affect the Asian water towers. *Science*, 328(5984), 1382–1385. <https://doi.org/10.1126/science.1183188>
22. Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Impacts, adaptation and vulnerability*. Cambridge University Press.
23. Israel, G. D. (1992). Determining sample size (Fact Sheet PEOD-6). University of Florida Institute of Food and Agricultural Sciences.
24. Jayasinghe, H. A. S. L., Ariyawansa, R. G. S., & Dissanayake, C. B. (2020). Agricultural non-point source pollution and its impacts on water quality in rural-urban fringe areas of Sri Lanka. *Ceylon Journal of Science*, 49(2), 113–125.
25. Jayatilaka, C. J., Sakthivadivel, R., Shingi, P. M., & Makin, I. (2003). A suggested framework for the second generation of irrigation management transfer in Sri Lanka. International Water Management Institute.
26. Kingdom, B., Liemberger, R., & Marin, P. (2006). The challenge of reducing non-revenue water (NRW) in developing countries (Water Supply and Sanitation Sector Board Discussion Paper No. 8). World Bank.
27. Mehta, L. (2005). *The politics and poetics of water: Naturalising scarcity in western India*. Orient Longman.
28. Millennium Ecosystem Assessment. (2005). *Ecosystems and human well-being: Wetlands and water synthesis*. World Resources Institute.
29. National Water Supply and Drainage Board. (2025). Monthly water consumption records: Bandarawela Municipal Council — Grama Niladhari Division disaggregated data, January–December 2025. NWSDB, Bandarawela Regional Office.

30. Panabokke, C. R., & Perera, A. P. G. R. L. (2005). Groundwater resources of Sri Lanka. Water Resources Board of Sri Lanka.
31. Perera, L. A. S. R., & Dissanayake, C. B. (2018). Water quality assessment and pollution source identification in the hill country streams of Sri Lanka. *Journal of the National Science Foundation of Sri Lanka*, 46(3), 347–360. <https://doi.org/10.4038/jnsfsr.v46i3.8481>
32. Postel, S. L., Daily, G. C., & Ehrlich, P. R. (1996). Human appropriation of renewable fresh water. *Science*, 271(5250), 785–788. <https://doi.org/10.1126/science.271.5250.785>
33. Rijsberman, F. R. (2006). Water scarcity: Fact or fiction? *Agricultural Water Management*, 80(1–3), 5–22. <https://doi.org/10.1016/j.agwat.2005.07.001>
34. Rogers, P., & Hall, A. W. (2003). Effective water governance (TEC Background Paper No. 7). Global Water Partnership.
35. Shiklomanov, I. A. (1993). World freshwater resources. In P. H. Gleick (Ed.), *Water in crisis: A guide to the world's freshwater resources* (pp. 13–24). Oxford University Press.
36. UNESCO. (2020). The United Nations world water development report 2020: Water and climate change. UNESCO Publishing.
37. United Nations. (2015). Transforming our world: The 2030 Agenda for Sustainable Development (A/RES/70/1). United Nations.
38. United Nations General Assembly. (2010). The human right to water and sanitation (Resolution A/RES/64/292). United Nations.
39. UN-Habitat. (2020). World cities report 2020: The value of sustainable urbanization. United Nations Human Settlements Programme.
40. UNDP. (2006). Human development report 2006: Beyond scarcity — Power, poverty and the global water crisis. United Nations Development Programme.
41. UN-Water. (2013). Water security and the global water agenda: A UN-Water analytical brief. United Nations University.
42. UN-Water. (2021). The United Nations world water development report 2021: Valuing water. UNESCO Publishing.
43. Vörösmarty, C. J., McIntyre, P. B., Gessner, M. O., Dudgeon, D., Prusevich, A., Green, P., Glidden, S., Bunn, S. E., Sullivan, C. A., Liermann, C. R., & Davies, P. M. (2010). Global threats to human water security and river biodiversity. *Nature*, 467(7315), 555–561. <https://doi.org/10.1038/nature09440>
44. World Bank. (2016). High and dry: Climate change, water, and the economy. World Bank Group.
45. World Health Organization. (2017). Guidelines for drinking-water quality (4th ed., incorporating the first addendum). WHO Press.
46. World Health Organization & United Nations Children's Fund. (2023). Progress on household drinking water, sanitation and hygiene 2000–2022: Special focus on gender. WHO & UNICEF.
47. World Water Assessment Programme. (2019). The United Nations world water development report 2019: Leaving no one behind. UNESCO Publishing.
48. Wijayaratne, L. H. P. (2018). Uma Oya diversion project and its impact on the environment and livelihoods: A review. *Sri Lanka Journal of Advanced Social Studies*, 7(1), 1–18.