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STATUS OF AVAILABILITY AND ACCESSIBILITY OF SAFE GROUNDWATER SOURCES IN TRIPURA

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Abstract

The availability of clean and dependable water supplies is a necessary condition for long-term growth and development. Safe groundwater is water that is fit for consumption and other domestic purposes without having any significant risk to health in its long-term exposure. Safe water availability and accessibility are inextricably linked and vary spatially. The rationale behind this study lies in exploring the status of availability and accessibility of safe and reliable groundwater sources in the households of Tripura. The study area comprises hills and piedmonts, intermontane synclinal troughs, flood plains, terraces and tillas. The random sampling technique was used to gather primary data on the status and availability of groundwater sources. The results show that about 16% of households consume water from unprotected dug wells sources. In the research area, groundwater is highly enriched in iron content and manganese in some proportion due to the ferruginous nature of rocks containing aquifers. The households in the hills, piedmonts, terraces and tillas suffer from seasonal scarcities of safe groundwater. A greater number of wells dry up, especially during the dry season when there is a decline in the water table. Other notable problems observed in the study area include poor maintenance of tube wells/bore wells and broken water delivery points. The study prioritizes the physiographic regions in Tripura to draw plans for access to safe groundwater sources.

Keywords*:* Groundwater, Physiography, Water availability, Water accessibility, Health issues

Introduction

Groundwater is an integral part of the hydrological cycle and one of the most vital resources for millions of people's drinking, domestic, industrial, and agricultural requirements. About half of the world's drinking water is estimated to come from groundwater (Gronwall and Danert, 2020). About 85% of the population in India depends on groundwater for drinking, and boreholes have become more prevalent over the past several decades for drinking water supplies. (Ali et al., 2019). Groundwater resource offers a dependable supply of drinking water to both rural and urban areas, but its utilization, availability and accessibility are hindered by a variety of factors (Wakode et al., 2014; Khan and Jharia, 2017; Mridha et al., 2020). The groundwater resources in India are shaped by both physical and socio-economic conditions (Kulkarni et al., 2015). Groundwater flow and occurrence are governed by various parameters, including rock type and structural attributes, topography, land use/land cover, drainage network and climatic conditions. The local physiographic features directly influence the groundwater's spatial availability (Kudamnya et al., 2021). Access to clean groundwater in rural areas is also restricted by physical constraints such as inadequate infrastructure, limited yield, and low groundwater quality. The political and social variables also affect people's ability to acquire water for daily needs (Mseli et al., 2019).

Groundwater is a vital resource that millions of people worldwide rely on for a range of water needs, but maintaining its safety and accessibility presents severe challenges in the face of rising demand, overexploitation, pollution, and climate change. Every community's socio-economic development heavily relies on sustainable water supply availability (Che et al., 2018). As a result, the availability of clean and dependable water supplies is necessary for long-term growth and development (Asonye et al., 2007). Safe groundwater is water that is fit for consumption and other domestic purposes without having any significant risk to health in its long-term exposure. Safe drinking water indicates an "improved water source" to households, which includes household connections, public standpipes, boreholes, protected dug wells, protected springs, and rainwater collectors. It is also important to note that "access to clean drinking water" is a provision of at least 20 litres per person per day from an "improved source" within one kilometre of the user's residence. According to WHO and UNICEF's estimates, in 2019, one in three people worldwide did not have access to clean drinking water; 79 per cent of people drink from unimproved sources, and 93 per cent drink from surface water residing in rural regions. More than 884 million people lack a source to secure consumable water, and as a result, poor drinking water is responsible for 72 per cent of diarrheal deaths. Safe drinking water can assist in decreasing or eliminating fatalities caused by water-borne diseases, as well as improve the quality of life all over the world (Lawson, 2011).

Groundwater is the most used resource in Tripura. Although there has been some research on groundwater quality in Tripura, no studies examine the differences in safe groundwater accessibility and availability sources across various physiographic regions. It is observed that the demand for safe water from the protected sources of groundwater, such as tube wells/bore wells, is a major issue in some regions of the state, particularly the hills and piedmonts, compared to other physiographic units. Access to clean and safe groundwater is also frequently hampered by these regions' malfunctioning water delivery points. Even when these sources are available, they are sometimes non-usable because of the poor quality due to heavy iron concentration in water.

In terms of groundwater accessibility, the people residing in the hilly areas have to travel further in order to fetch water as compared to the lesser travel time encountered by the residents of other physiographic units. During the dry period, households are compelled to obtain water from wherever it is found and mostly rely on unsafe dug wells in the hills and piedmonts, as well as terraces and tillas. Safeguarding groundwater supplies should be the top priority in terms of human health (Song et al., 2020). Therefore, this study was formulated to get comprehensive information about the availability and accessibility of safe groundwater sources to meet the needs of households inhabiting different physiographic areas in Tripura. The study seeks answers pertaining to (i) types of groundwater sources available in the major physiographic units and (ii) accessibility of groundwater in terms of the time and distance needed to get safe drinking water.

Study Area

Tripura is a landlocked state with a total population of 36,73,917 persons (350 persons/km^2) as per the 2011 census (Fig. 2) and 41,65,000 as per the projections in 2023 (Directorate of Economics and Statistics, 2024). The study area is located between 22º56' N to 24º32' N latitudes and 91º10' E to 92º21' E longitudes with a land area of 10,492 km^2. Geological formations, such as the Surma, Tipam, Dupitila, and Recent groups, are the main four types of formations found in the study area. Tripura has a varied topography, including hills and piedmonts, an intermontane synclinal trough, flood plains, terraces, and tillas (Fig. 1). The anticlinal hills in the research area run north-south parallel to one another, forming broad valleys with erratic rivers and streams and undulating hillocks. The landscape gets steeper as you move eastward from the west. The drainage pattern in the State is sub-parallel. The anticlinal hill ranges serve as watersheds from which different drainage channels develop, fill in valleys, and eventually empty into Bangladesh. Major rivers in the State are Juri, Longai, Fenny, Muhuri, Gumti, Haora, Khowai, Dhalai, Manu and Deo.

A humid subtropical climate characterizes Tripura, with an average temperature range from 10°C to 35°C. With an average annual rainfall of 2200 mm, the southwest monsoon provides the majority of the rain throughout the monsoon season, which begins in June and lasts until September. During the monsoon season, water swells in most of the major rivers of the state. Evergreen forests mostly dominate the study area. The study area also has several vegetation types, including bamboo, cane, savannah, moist deciduous, and grassland forests. The dense concentration of population is mainly observed in the city and towns of synclinal troughs, whereas in the hills and piedmonts, they are dispersed (Fig. 2).

In the study area, groundwater mainly occurs in the Tipam and Dupitila formations in rocks of sandstone and shale. The Tipam formation's sandstone, which has a far higher permeability than Surma or Dupitila sandstone, is the main source of water. Having abundant rainfall from the southwest monsoon, the geology, as well as the geomorphology of the State, is favourable for auto artesian conditions within synclinal valleys. Flood plains with younger alluvial soil generally influence groundwater recharge due to high infiltration. Therefore, groundwater development occurs mostly in the synclinal trough, flood plains and adjacent anticlinal hills. However, there are issues with regard to the accessibility and availability of reliable and safe groundwater sources. In rural areas where groundwater treatment is not regular, it causes many waterborne diseases. Besides malfunctioning water delivery points, the lack of maintenance of tube wells and protected dug wells also hinders the household's access to safe water sources.

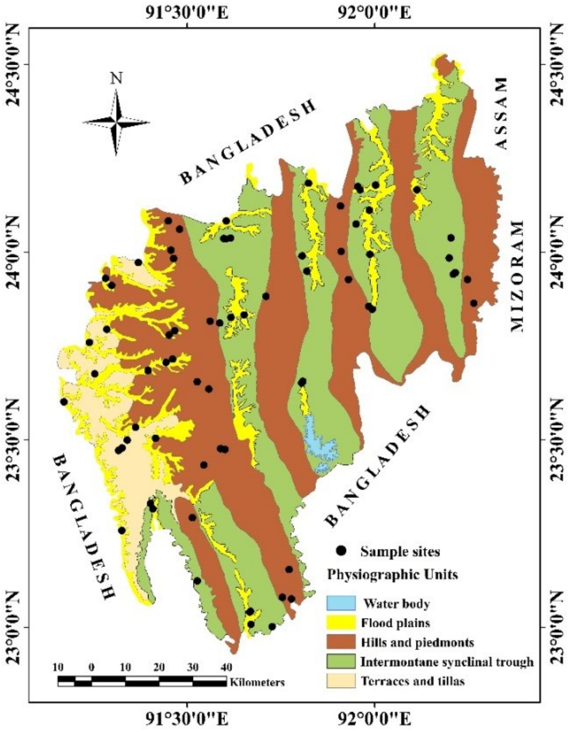


Fig. 1 Physiographic units and sample distributions in the study area

Materials and methods

This study used primary data to assess the availability and access to safe groundwater sources in Tripura. Questionnaires were used to generate primary data about the availability and accessibility of safe water sources from households of diverse physiographic units. The study employed a multi-stage sampling technique integrating both purposive and random sampling methods to ensure a representative and diverse sample. The prepared physiography map was superimposed over the district boundaries in the first stage. Secondly, the physiographic areas of the respective districts have been narrowed down to the blocks to locate the villages that fall within the maximum area dominated by each physiography. In the third stage, at least five villages from each physiographic unit were selected randomly. Unlike the administrative units, the physiographic units were not defined by discrete boundaries; hence, selecting households within the diverse physiography was challenging. Therefore, finally, the sample size of households, i.e. 650, which forms the basic unit of study, was determined using Yamane's formula at a 95% confidence level and 5% margin of error to determine the minimum sample size needed to achieve a desired level of confidence and precision in the study's results. The Central Groundwater Board, Northeastern Region, Guwahati, was consulted as a secondary source to obtain information on the usage patterns of groundwater.

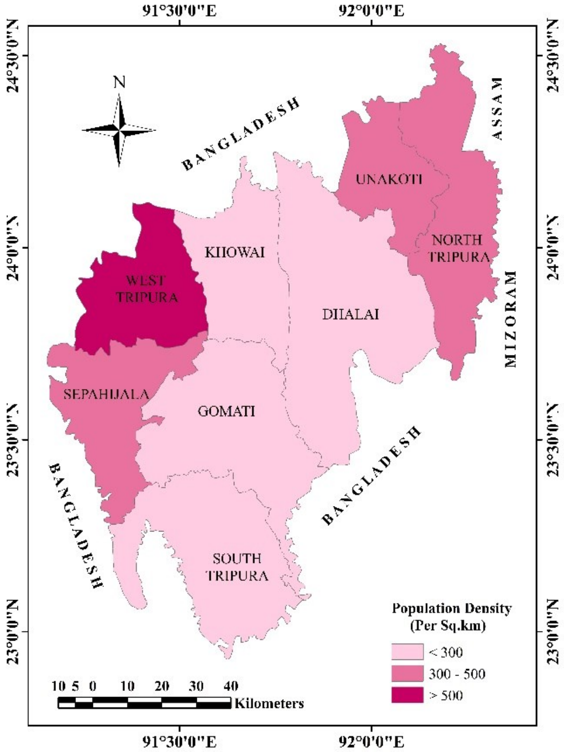


Fig. 2 Population density in Tripura

Results and Discussion

Pattern of Groundwater Utilization

Groundwater utilization pattern refers to the uses of water for different purposes. The socio-economic condition of households determines the pattern of groundwater utilization. Additionally, physiography also influences the consumption pattern of groundwater. The households that are far away from the water collection sources usually use groundwater for drinking purposes only. In the study area, the district-wise pattern of groundwater utilization reveals that groundwater is used mostly for domestic purposes, such as drinking, cooking, washing clothes, bathing, animal use and house cleaning. The water requirements of individuals residing in rural areas are generally for these basic needs, whereas people living in urban areas use water in a variety of ways. The utilization of groundwater for irrigation is only observed in the plain areas of Khowai, West, Sepahijala and South Tripura districts (Fig. 3). Government-led irrigation projects and infrastructure development initiatives influenced groundwater utilization patterns in these districts. Due to the hilly terrain, the rest of the districts do not depend much on groundwater for irrigation.

The State benefits from ample groundwater resources, primarily due to the monsoonal rainfall, which helps recharge the aquifers. In hilly areas, the rugged terrain makes it challenging and expensive to access groundwater for irrigation purposes, leading to limited utilization of groundwater for domestic purposes. Areas adjacent to hills and piedmonts hold substantial potential for groundwater availability, and shallow aquifers in the plains and flood plains allow for relatively easy groundwater extraction.

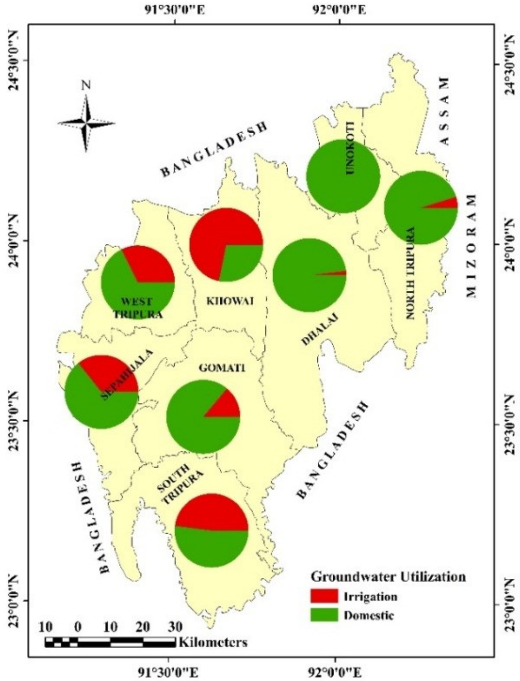


Fig. 3 District-wise groundwater utilization. Source: Central Groundwater Board, North Eastern Region, Guwahati

Sources of Safe Drinking Water

Availability of potable drinking water is a pressing need, as 30% of urban dwellers and 90% of rural dwellers still rely entirely on untreated surface or groundwater

(Palanisamy et al., 2007). Access to improved drinking water sources is a key requirement and a basic human right for everyone's health and hygiene. In the study area, tube wells, hand pumps, protected dug wells, protected spring water and piped water into the home offers an improved source of drinking water. Unimproved sources of water include unprotected dug wells, surface streams, ponds, reservoirs and water supplied through tankers.

Tube well/bore wells represent the primary water source in the flood plains, terraces and tillas. These groundwater sources were preferred due to their reliability and accessibility, especially in flat terrain where groundwater can be easily extracted. In the hills and piedmonts, and intermontane synclinal toughs, the major source of drinking water comes from public taps (Fig. 4). In hilly regions, the dispersed nature of households and the challenging terrain make it difficult and economically unfeasible to install deep tube wells or bore wells. Groundwater availability is also limited to specific areas along low-lying bordering anticlinal hills. Consequently, public tap water systems have become the more viable option for providing water to communities in these regions by the government. The dependence on public tap water in intermontane synclinal troughs and flood plains was caused by the extensive aquifers and groundwater reserves due to their relatively flat terrain and high permeability of soils. The dense concentration of the population also makes it more feasible and cost-effective to establish centralized water supply systems, such as public tap water networks, to serve a larger number of people. Shallow hand pumps, tube wells, and bore wells can also be installed relatively easily in the plains, allowing groundwater extraction to supply public tap water systems.

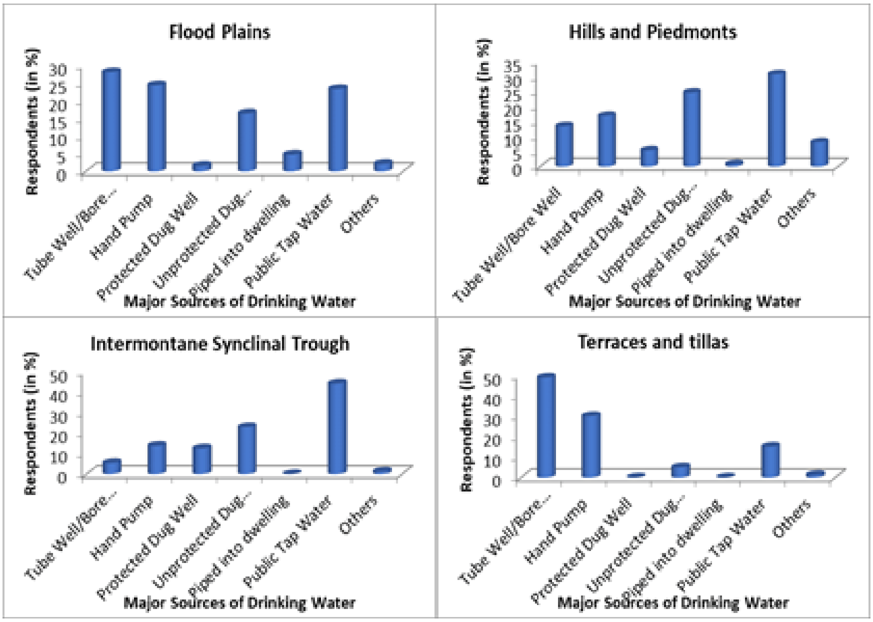


Fig. 4 Drinking water sources in different physiographic units in Tripura

It has been found that despite improved water sources in the State, there are still inequalities in accessing safe groundwater sources across the region. This indicates disparities in infrastructure development, economic factors, and geographical constraints that affect access to safe and reliable water sources. Furthermore, Fig. 4 illustrates that many households rely on unprotected dug wells for water consumption across all physiographic units. This reliance on unprotected sources poses potential health risks due to contamination and highlights the need for interventions to improve water quality and accessibility, particularly in areas where safer alternatives are less accessible.

Accessibility to Safe Drinking Water

Distance plays a critical role in terms of the collection and usage of water. It may also be indirectly linked to stress and burden associated with water collection. Water must be available when needed, and people who travel longer distances to get to a water source use less, negatively impacting consumption and hygienic standards (Manyanhaire et al., 2009). The study depicts that most households collect water within a travel distance of less than 100 m (Fig. 5). This shows the availability of water sources within a safe distance due to the government-operated tube wells, individually owned handpumps and public tap supply. However, the situation is slightly different in the hills and piedmonts, where a sizeable percentage of households, about 25%, is required to travel a distance of more than 100-200 m. Travelling a distance of more than 100 m in hilly terrain can be very tiring as well as challenging. It was also observed that about 2.31% of households travel beyond one km to fetch water. Groundwater sources, particularly the public tap supply in hilly terrain, were not uniformly distributed and were located at greater distances from residential areas than flat or plain regions. The terrain makes it challenging to install public taps in close proximity to all residents. As such, residents need to trek long distances, often uphill or downhill, to reach water sources. This prolonged travel time adds a burden to the overall time spent collecting water and impacts daily routines and productivity.

Seasonal Water Scarcity

Water scarcity is a seasonal phenomenon in the study area, particularly in the hills, piedmonts, terraces, and tillas. According to the respondents, water scarcity happens mostly during the dry season from the month of March till the onset of monsoon. Due to this seasonal scarcity, households in hilly areas endure a significant problem as they spend considerable time searching for water, while those in terraced regions face relatively less. However, households of the flood plains and intermontane synclinal troughs remain unaffected by such difficulties. Approximately 40% of the respondents mentioned that they have to spend lots of time in search of water, which becomes a severe problem during the dry season (Fig. 6). In hilly regions, terraces, and tillas, severe water shortages occur during the pre-monsoon season due to lack of rainfall to replenish the subsurface aquifers and limited water storage capacity. Without significant rainfall to recharge the groundwater sources, groundwater level declines, leading to shortages in water supply. Additionally, the public tap supply system faces significant strain during the dry season, leading to prolonged waiting times for households to access water. Therefore, seasonal water scarcity-induced problems tend to increase the workload of the women in the hills, piedmonts, terraces and tillas (Fig. 7). In addition, the respondents are also exposed to the risk of consuming untreated water during seasonal water shortages as they are forced to rely on shallow groundwater sources (Fig. 8). About 30.61 and 31.25% of respondents from the hills and piedmonts, as well as terraces and tillas, agree that the risk of drinking untreated water is a severe issue.

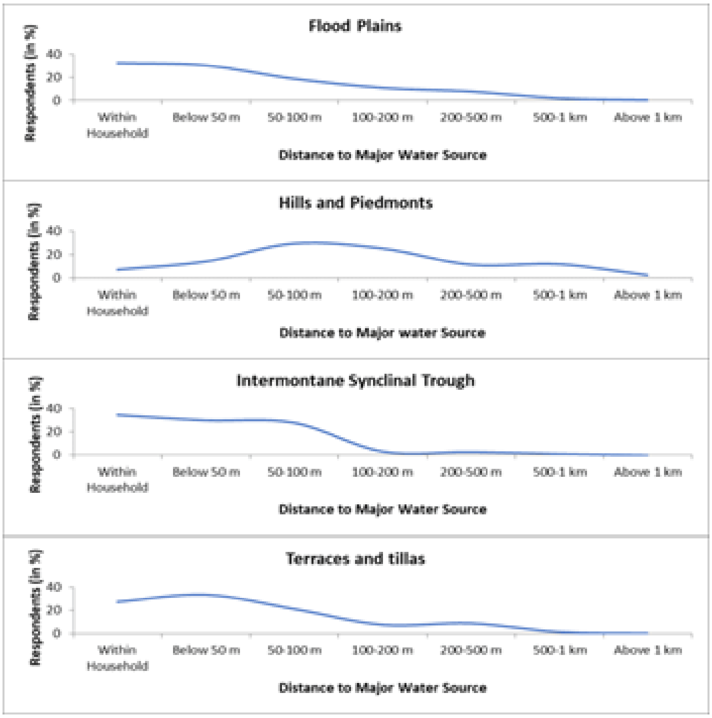


Fig. 5 Distance to access safe groundwater sources in Tripura

Water Collection and Quantity

According to the WHO, a person should have access to 50 to 100 litres of water daily to cover all of their basic requirements and prevent any health hazards. The amount of water available for improved hygiene practices depends significantly on how much time and effort goes into gathering water (Manyanhaire et al., 2009). The duration it takes to collect water, the time of day it is collected, the volume of water collected per trip/day, and the number of household members involved all have an impact on the quantity of water collected. In the study area, water collection by 47.79% of households is undertaken mostly at any time of the day as per their needs. Physiographic variations on time spent to collect water reveal that more than 70% of the households take 10-15 mins to collect water in the flood plains, terraces and tillas. The households in the intermontane synclinal troughs take about 15-20 mins to collect water (Fig. 9).

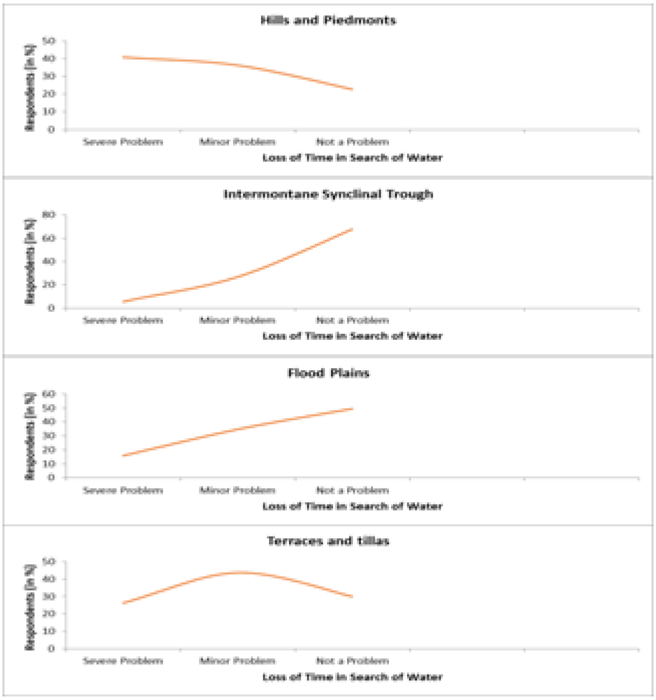


Fig. 6 Time spent to search for safe water resources in different physiographic units

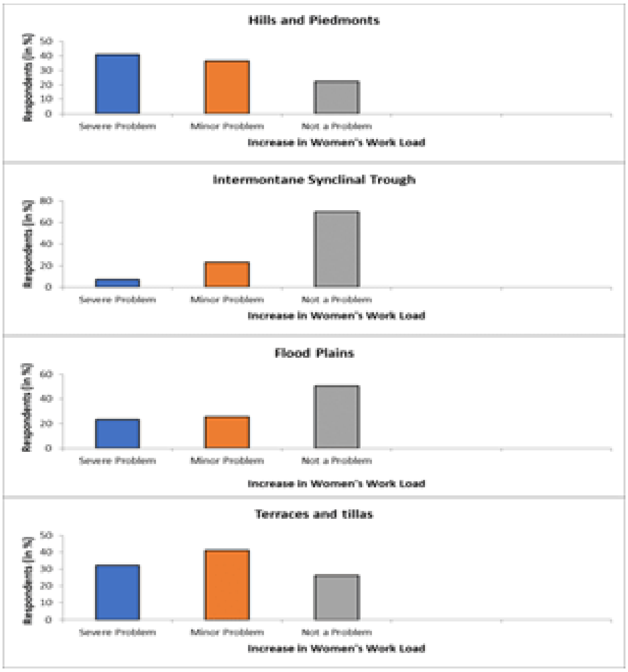


Fig. 7 Women's workload due to seasonal water scarcity in different physiographic units

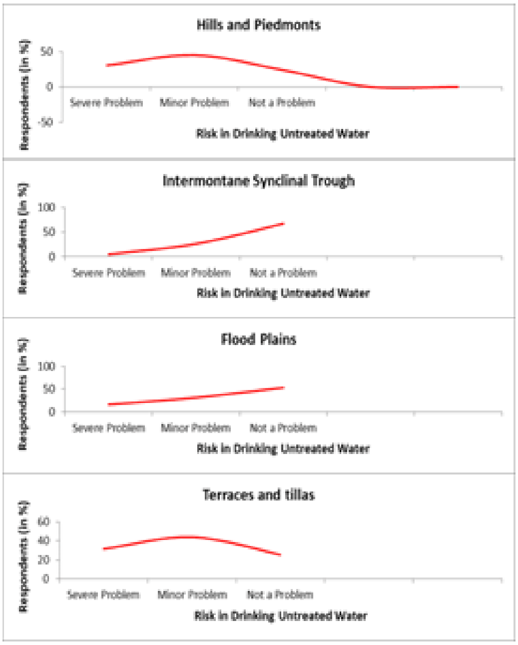
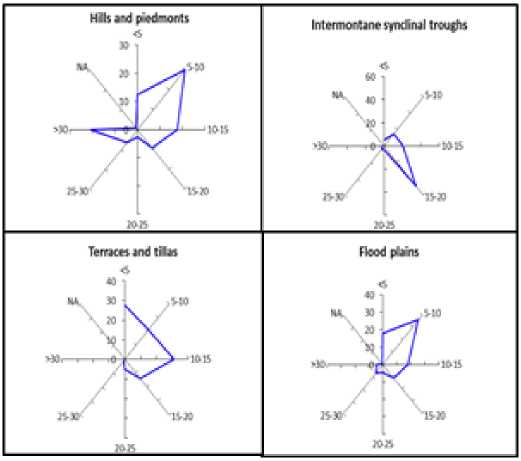


Fig. 8 Risk of drinking untreated water in different physiographic units



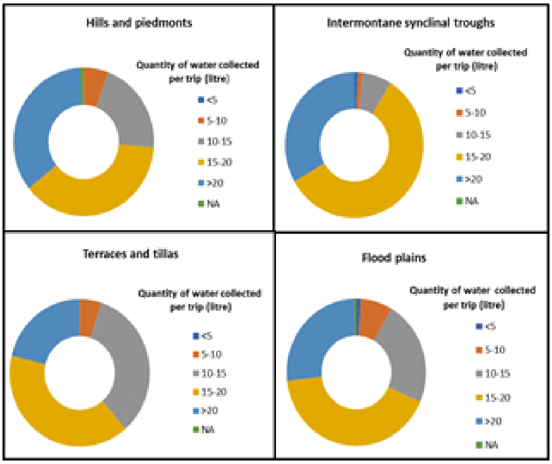


Fig. 9 Time taken to collect water (in min) Fig. 10 Quantity of water gathered per visit

On average, the household members fetch 15-20 litres of water in a single trip, and more than 50 litres of water is collected by households in a day (Fig. 11). Among the units, the availability of government-provided wells and also privately owned groundwater sources in the terraces and floodplains results in less time consumption as well as a sufficient amount of water collected. In the hills and piedmonts, people have to travel significant distances to reach water collection points that are far away from residences, resulting in travel time exceeding 30 minutes.

Groundwater is predominantly used for domestic purposes in the State, indicating its importance for basic human needs such as drinking, cooking, and sanitation. The availability and accessibility of safe groundwater are of utmost importance since they determine an individual's well-being. Access to reliable and safe groundwater sources is, therefore, essential for the health and socio-economic status of a community. The provision of safe, reliable, and cheap water deprives a person of basic human rights, wreaking havoc on one's health, destroying opportunities and undermining one's dignity. As a result, the United Nations recognizes access to safe, sufficient, acceptable, cheap, and physically accessible water for personal and domestic use as a basic human right.

Conclusion

The study reveals disparities in the availability and accessibility of safe groundwater sources across different physiographic units in Tripura. The study indicates that the State's groundwater resources largely depend on physiography and the southwest monsoon. Different physiographic units utilize groundwater sources variably due to the availability of public and private water systems. Tube wells form the major source of drinking water in the flood plains, terraces, and tillas, whereas households in the hills, piedmonts, and intermontane synclinal troughs are found to be covered by public taps. Still, a significant percentage of households consuming water from unprotected dug wells can be noticed in all the physiographic units. Hills and piedmonts suffer from a lack of water availability due to seasonal water scarcity and poor aquifers. Women often bear the brunt of water scarcity in these regions, spending significant time and effort on water collection, especially during dry periods. Poor maintenance of water supply points, irregular water supply, and water contamination issues (e.g., high iron concentration) contribute to the challenge of ensuring safe water sources for households.

Seasonal variations in water availability exacerbate these challenges, with dry periods leading to declining water levels in wells and increased difficulty in accessing safe water sources. The findings suggest that a significant percentage of households, particularly those in hilly areas, lack access to safe, reliable, and physically accessible groundwater sources, thus being deprived of their basic human right to water. The study underscores the critical importance of addressing disparities in groundwater availability and accessibility, particularly in ensuring access to safe water sources for all segments of the population of the State, and highlights the need for targeted interventions to mitigate the challenges identified, especially in marginalized hilly areas.

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