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Assessing Water Deficit Induced Water Stress of Households and their Welfare in Small Cities of Nepal

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Abstract

This study investigates water deficit-induced stress in 12 small cities within Nepal's Marshyangadi River Basin, crucial for sustainable water management amid global water scarcity concerns. Employing the Milankovitch Theory, it explores Earth-Sun relationships and their impact on long-term climate changes, shaping societal adaptation strategies. Utilizing the Water Deficit Model, the study unveils the multifaceted consequences of water scarcity of Gandaki Province's Marshyangdi River basin. The study employs a comprehensive design, sampling 317 households across diverse ecological zones and elevations. The study finds the existing month-long water deficit in these cities to the higher water demand of households, along with water stress in the cities of Himal and Terai more than in the Hill. Water deficit is higher in Himal than in Hill and Terai because of lower water availability in Himal (below average 0.9). The people of Himal and Terai have extremely high stress but the people of Hills are comfortable without stress, except in Bandipur for drinking and cleanliness. In the 20 litres per capita per day water, water stress is found mixed. Five small cities in Himal and Terai are extremely stressed, meanwhile, 7 small cities in the Hill are not stressed, except two cities, Bandipur and Marshangdi. Relatively, the water deficit in the Hill is less than Himal and Terai. Similarly, in 20 liters per capita per day water, it is good for households but most cities have extreme water stress. The Hill's water stress is lower than that of the Himalayan and Terai. By WHO's standard (50 liters-100 liters per day per capita), all cities are extremely water deficient and critically water stressed. The findings reveal a direct correlation between water deficit and stress, impacting survival, hygiene, and living standards. The study concludes that despite *ample water resources, poor governance and inadequate policies contribute to extreme water deficit, challenging SDG targets and living standards. It urges urgent action, accountability, budgeting, and a comprehensive plan for water poverty reduction.*

Keywords: Water Deficit, Water Stress, Adaptation, Small Cities, Nepal
JEL Code: Q25, Q52, Q53, Q56, O18

1. INTRODUCTION

The water deficit is widely accepted as a big issue in the world in the context of water security and welfare (Khanal et al., 2020). UNICEF (2023) notes that 4 billion populations, two-thirds of the world's population have extreme water deficit. About 50 percent of those populations live in those countries where water availability is inadequate. UNICEF (2023) projects half of the world's population facing water scarcity by 2025. Global Water Institute (2023) projects the displacement of 700 million by 2030. By 2040, the water stress level will be extreme. Thus, the UN states that 2.3 billion populations live in stressful countries. By 2040, the growth of the water deficit is projected extremely critical in the world. This projection has two arguments: climate change and disasters deteriorating water availability and the growth of population and cities-led water demand. Firstly, IPCC (2001), Stern (2006) and UNFCCC (2018) project the complication of climate catastrophe that is declining rainfall and erratic rainfall is further observed rising warming and drought. The frequency of natural disasters is expected higher. In both cases, declining water availability will increase water scarcity-led deficit. Secondly, the growth of population and cities-led water demand is expected a higher level because of higher literacy, health and cleanliness awareness, and rapid urbanization. By 2050, water demand in Sub-Saharan Africa is expected to skyrocket by 163% - 4 times the rate of change compared to Latin America, the second-highest region, which is expected to see a 43% increase in water demand (World Resource Institute, 2023). It increases water deficit more in urban cities than in rural cities. In the developed countries, it is moderate, although their water consumption is more than WHO's standards. It is critical to meet drinking and cleanliness in the developing countries, although they have water availability in the absence of proper water distribution and management. Therefore, water deficit depends on the level of water availability and scarcity. It is validated by UN (2022) with 884 million populations not having access to safe drinking water. It is found in agriculture in which 3.2 billion populations live. Further, it affects 73 percent of total population in Asia. Large populations live in water stress countries (Majumdhar, 2015).

In 2022, Nepal is identified for water scarcity and stress, along with Lebanon, Pakistan, Afghanistan, Syria, Turkey, Burkina Faso and Niger (concernusa, 2022). This water deficit-induced stress is because of the higher demand for water not only for clean drinking water but also for irrigation for agricultural production and others (Phuyal et al., 2019). There are 83 percent of the population are exposed in the Middle East and North Africa and 74 percent in South Asia. Besides, it will be a big economic loss that is 31 percent of the global GDP (i.e. 70 trillion USD). In four countries, it accounts a half of the exposed GDP by 2050 (Jonman et al., 2012). Therefore, water deficit- induced stress is expected a big complex issue in South Asia, particularly in Nepal. In Nepal, water deficit led water stress exists across the country. It is surprising and interesting because Nepal is rich in water availability but the cities are suffering from water deficit and stress, along with economic losses in terms of disruption of agricultural, industrial and household activities. DWSSM (2019) and MoF(2019) report that 51.69 percent of the population uses piped water and 48.31 percent of the population uses non-piped water. Maskey et al. (2023) cover this issue in the cities of Kathmandu valley with dimensions of equity, quality, and affordability. Further, the study explains its existence. Furthermore, it covers health hazards from this issue. However, it studies only three municipalities based on 40 key informants-based qualitative assessments, although it is relevant. It raises a question of reliability and validity. Considering water stress, Pandey (2021) identifies variables including impacts of climate change and haphazard urbanization on the supply side and increased population, and changing lifestyle patterns and socioeconomic practices on the demand side are constantly putting pressure on water resources and urban water security. This is cross-sectional data of eight cities in Nepal.

Differently, Mishra et al. (2021) mention water stress as the cause of water deficit, along with water quality focusing more on water security. The study is city-centric but review-based. Studying water inequity issues in water distribution and water quality among the core and peripheral wards of Dhulikhel, a mid-hill town of Nepal, Maskey et al. (2020) find out socioeconomic, environmental, technological, and governance-related factors are causing inequity in water distribution and then water deficit-led stress. Its method is a mixed one but a descriptive one. Capturing the linkage between climate change and water availability, Adhikari et al. (2017) and Dahal *et al.* (2019) found erratic precipitation patterns causing water availability and security issues, along with water deficit and stress. This study is purely hydrological. Further, Dahal *et al.* (2020) examine it in the Karnali region. The study finds the lowest observed precipitation and irregularities in precipitation determining the future water availability for agriculture, hydropower, ecosystem functioning and the availability of its services to the people living in the Karnali River Basin (KRB) as well as in the downstream region. Furthermore, Saraswat et al. (2017) argue institutions and governance to solve water deficit-led stress in Kathmandu. Singh et al. (2020) comprehensively note water deficit induced stress and insecurity as attributed to:

(i) water governance issues; (ii) inappropriate urban planning, and to some extent, unable to account for the floating population, such as tourists; and (iii) the scourge of climate change which could worsen the situation further. Short-term coping strategies to meet water demands often involve unsustainable solutions, such as groundwater extraction, with long-term repercussions. However, long-term strategies for water sustainability by the governments have been beneficial while others are yet to show success.

McManus (2021) argues water deficit and scarcity as the result of critical water management at local level for future adaptation and water availability. Ojha et al. (2019) focus more on indigenous and scientific knowledge to improve local adaptation to address water deficit-induced stress. Pradhan (2012) observed that local households and communities are adapting, and will continue to adapt, through actions that are independent of structured programs and policy. These actions are sometimes referred to as' autonomous', as opposed to planned, responses to climate change to build local resilience to water deficit-induced stress. Assessing costs and benefits of the selected climate adaptive and equitable water management practices and strategies (CAEWMPS) in Dhulikhel Municipality and Dharan Sub-metropolitan city of Nepal. Rai et al. (2019) focused on adopting appropriate strategies to tackle problems related to water shortage under city-specific contexts. In the synthesis, the above literature has made known the status, drivers and adaptation of water deficit-induced stress at the national and local levels, along with the linkage with climate change. However, this literature has not covered well water deficit-led stress in the cities of the Marshyangdi water basin, particularly the emerging small cities. So, there is a research gap creating a scope to be studied further in Nepal.

This study aims to analyze water deficit-induced water stress in 12 small cities in the Marshyangadi River Basin's three ecological belts - Himal, Hill, and Terai. Beyond surface-level examination, the study examines the complex dynamics of water deficit in the targeted area and assesses water stress levels in small cities. The ultimate goal is to provide insights beyond observation and comprehensive policy recommendations to stakeholders and policymakers. This study is relevant to climate change and the Sustainable Development Goals because developing countries like Nepal face severe water-related challenges. The research seeks to enrich water management and sustainability discussions by illuminating these issues.

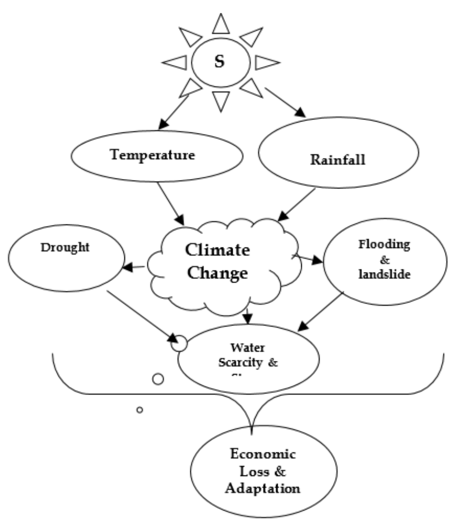
This paper comprises the following sections: Section 2 details the methods and data, Section 3 presents the study results, Section 4 discusses findings, and Section 5 concludes the paper.

2. RESEARCH METHODS

2.1.Theoretical/Conceptual Framework

This study is basically based on the assumption of the relationship between the sun and the earth. This assumption is explained by the Milankovitch Theory. This theory hypothesized the long-term, collective effects of changes in Earth's position relative to the Sun are a strong driver of Earth's long-term climate, and are responsible for triggering the beginning and end of glaciation periods (Ice Ages) (Buis, 2020). This hypothesis argues that the Sun changes the Earth's climate including temperature and rainfall. When temperature of the Sun changes, rainfall will change in the Earth, along with the pattern of temperatures. It results the so-called climate change. When mean rainfall increases, flooding will happen. In the reverse, drought induced water scarcity and stress happen. In both cases, the society will experience economic loss on one side and on the other side explore adaptation methods in both cases to minimize economic loss and vulnerability (Figure 1). This is a scientific fact in the world (IPCC, 2001; Gleick, 2000; Solomon, et al., 2007; Adams and Peck, 2008; and IPCC, 2018). The society expects the stability of climate change by employing adaptation in the short run period and mitigation in the long run for a better, safer, and beautiful life and security of livelihood in the future.

Figure 1: Conceptual Framework



2.2. Study Area

Located in Gandaki Province, Nepal, the study covers Marshyangdi river basin. This basin of 4787 sq. km. spreads 150 km long situating between $27^0 50'42''$N to $28^0 54'11''$

latitudes and $83^0 47'24''$E to $84^0 48'04''$E longitudes (Figure 1). This basin starts from Annapurna trans-Himalayan range and ends at low land of Chitwan. In the basin, water is rain-fed. Its level is steady in both monsoon (rainy) and winter (dry) seasons. Ecologically, it ranges from the cold high-alpine type to the hot and humid tropical type. Its mean slope is about 29.42°degrees. The basin is highly exposed to climatic variables, particularly rainfall. The cluster of dense small cities is highly vulnerable to flooding, landslides, and droughts. Therefore, rainfall varies across the different landscapes. The study area is highly relevant because of two major reasons: a) DHM (2022) reports that the basin has erratic rainfall and adverse effects at the catchment areas; b) the study area has different elevations from 200 meters to 7800 meters. In the elevation, the study area covers four districts of three ecological zones as follows: Manang from the Himal (high altitude), Lamjung, and Tanuhu from the Hills (middle altitude), and Chitwan from the Terai (low altitude). In these districts, there are 12 emerging small cities as municipalities.

2.3. Data

Using explorative cum descriptive research design, the study areas of the Marshyangdi river basin cover four districts including Manang, Lamjung, Tanahu, and Chitwan in the elevation range of three ecological zones (Himal, Hill, and Terai) from 415 meters to 3600 meters. Covering 12 small cities (9 rural municipalities, 1 metropolitan city, and 2 municipalities) in the study areas, total households were about 47060, with 254124 populations (CBS, 2011). This total household (47060) was considered as the population of this study. Out of population (47060 households), a sample size of 317 households was drawn at a confidence level of 95% and a margin error of 4 % using the sampling technique of Daniel (1999). Firstly, the sample size was clustered into two stages. In the first stage cluster, the sample was distributed into four districts cluster, including Manang, Lamjung, Tanahu, and Chitwan. Similarly, in the second stage cluster, the sample was further distributed into 12 small cities (Chame, Nashong, Neshyang, Dordi, Marsyangdi, Anbukhaireni, Bandipur, Devighat (Rural Municipality), Besishahar, Bhanu, Gaidakot (Municipality) and Bharatpur (Metropolitan City) with respect to the above five district clusters. In accordance with the river basin areas, wards areas of 12 cities were selected. After completing the clustering sample, the respondent's individual household was selected by random sampling method for proper representation by removing biasness and technical error. The supplementary data sets of rainfall are collected from desk review from June 1 to June 20, 2021. The desk review includes a) The 15th Five Years Plan Development (2018|19-2022|23; b) Sustainable Development Goal: Roadmap (2016-2030); c) Statistics Pocket book, Central Bureau of Statistics (CBS), d) Nepal Living Standard Survey III, Central Bureau of Statistics (CBS), and e) Economic Survey, Ministry of Finance (MoF).

2.4. Water Deficit Model

Water scarcity causes water stress in the community in various ways, including a) uneasiness, b) discomfort, c) staying in queue, d) spending hours and hours' time only for water collection, e) using physical efforts, and f) spending extra money for drinking water. In urban areas, these by-products of water deficit may be a big constraint to urban life of households, where the family size is small in which husband and wife are professional having time constraint and professional commitments. In contrast, in rural areas, women have a poor opportunity cost of time. They consider it a part and parcel of their lives. It generates a negative externality with an external cost burden to households to avoid a water deficit level with the substitute water goods. The growth of external costs at the household level depends on the level of water deficit-induced water stress. Therefore, a water deficit results in visible and invisible water stress in small cities and households.

Of course, a water deficit results in water stress. It is a query whether water deficit is the only determinant. Of course, it depends on the adaptation capacity of the household. Let's check it. If adaptation capacity is higher, water stress will be lower than expected. In reverse cases, where adaptation capacity is lower, water stress will be higher. In the adaptation capacity, there are variables: literacy, awareness, training, membership, age, poverty, employment, and income, along with locations. Therefore, the adaptation capacity of a household is also a determinant. In the literature, the water deficit is directly related to the ratio between water use and water availability in a society as well as in a household. If water use grows at the same water availability, the water deficit will increase. If water use is constant but water availability decreases, a water deficit follows again. In the function, the water deficit is $W_{D,}$ water use is $W_{U,}$ and water availability is W_A. Mathematically,

$$W_D = W_U / W_A \qquad (1)$$

3. RESULTS

This section presents the results of the study to measure water deficit and water stress levels in the small cities of the Marshangyadi River Basin in Nepal. Further, it also discusses its economic implications and solutions.

3.1. Water Deficit and Water Stress Level of Small Cities

Water Deficit-induced stress *is* an emerging big challenge in developing countries, Nepal, particularly in small, emerging and big cities. Raising a query about how urban people maintain their water demand for personal drinking, sanitation, cleanliness, cooking, bathing, washing and cleaning, Bista (2016, 2021) mentions it in Kathmandu Valley with irregular water supply and water leakages. It is a water deficit-induced stress scenario of Metropolitan city particularly at squatter and indigenous settlements (Phuyal et al., 2013). Manandhar (2024) reveals an extreme water deficit that is 120 million liters from the sum of 360 million liters per day water demand and 90-140 million liters per day water supply. Thus, water deficit and stress are prevalent in small and big cities.

The national budget of Nepal has given top priority to water supply projects under the vision of clean, reliable, hygienic and sustainable drinking water to all in the Fifteen National Plan (Bista, 2021 and NPC, 2022). As policies, the plan emphasized water services, climate resilience, disaster friendly and water conservation. In 2002, there was effective to the 20 years long-term perspective plan to ensure water quality, quantity, access, supply, time and reliability (Bista, 2016). However, water deficit-induced water stress seems to be a prominent issue.

This issue is diagnosed in the context of these cities. In these cities, this complex issue is a by-product of composite variables including people-oriented unplanned and haphazard urbanization, people-oriented housing and infrastructure, poor urban development plans and ineffective rule and regulation (Pandey, 2021, and Mishra *et al.* 2021). People's construction behavior and focus is only unilaterally allocating investment resources to construct a big and beautiful concrete house with the assumption that constructing a house can resolve all issues. In general, it begins with issues such as roads, clean drinking water, electricity, health facilities, education, and so on, with the assumption that the concrete big houses are safe, secure, and potentially rent-seeking.

3.2. Water Deficit and Stress Level of Small Cities

Its effects can be found haphazardly in the extraction of water resources, land resources, and other resources. Its negative externality of water scarcity and deficit led to external cost and water stress. This study identifies and quantifies water stress levels in small cities in Nepal through a survey. Table 1 presents the water deficit and water stress levels of small cities.

Table 1: Water Deficit and Water Stress

Ecological zones	Cities	Water Deficit	Range	Water Stress Level
Himal	Nasong	-0.3	<0	Extremely Stress
	Nishyang	-0.1	<0	Extremely Stress
	Chame	-0.2	<0	Extremely Stress
	Norphu	-0.3	<0	Extremely Stress
Hill	Bandipur	0.7	0.5-1	Moderate Stress
	Bhanu	1.4	>1	No stress
	Dordi	1.9	>1	No stress
	Devighat	2.0	>1	No stress
	Abhukharini	1.6	>1	No stress
	Beshishar	3.0	>1	No stress
	Marshangdi	0.9	0.5-1	Moderate Stress
Terai	Chitwan	-0.1	<0	Extremely Stress
	Mean	0.9	0.5-1	Moderate Stress

Source: Field Survey, 2021

Table 1 presents the water deficit and water stress levels of 12 small cities in the watershed areas of the Marshangdi River across three ecological zones (Himal, Hill, and Terai). By nature, these watershed areas are rich in water resources. This richness is not reflected in these ecological zones and cities where the different income groups of people live. In the table, Himal has a greater water deficit than Hill and Terai because the water availability of Himal is below average 0.9, whereas Hill and Terai have a better situation. This deficit is categorized as stress. The people of Himal and Terai have extremely high stress but the people of Hills is comfortable without stress, except in Bandipur. In Himal, low temperature stresses the water availability in winter but are comfortable in summer, and flooding pollutes water quality in summer and dries in winter in Terai, according to Micro-Workshop and KII (2020). However, the Hill has a geographical barrier, but natural water sources have contributed significantly to increasing water availability in summer.

3.3. Water Deficit and Stress (Min and Max)

Water deficit is measured using water per capita per day as a reference line. WHO (2021) mentions 20 liters of water per capita per day as the minimum for basic water requirement for personal drinking and sanitation but 50 liters of water per capita per day as the maximum for basic water requirements for personal drinking and sanitation. Let's suppose two points to this water per capita per day: minimum of 20 litres and maximum of 50 liters. Table 2 shows the water deficit and water stress between 20 liters(min) and 50 liters(max).

Basic Water Requirement between 20 liters(min) and 50 liters(max).

Table 2: Water Deficit and Water Stress

Ecological Belt	Cities	Water Deficit (min)	water deficit (max)	Range (min)	Water Stress Level (min)	Range (max)	Water Stress Level (max)
Himal	Nasong	-0.3	-0.7	<0	Extremely Stress	<0	Extremely Stress
	Nishyang	-0.1	-0.6	<0	Extremely Stress	<0	Extremely Stress
	Chame	-0.2	-0.7	<0	Extremely Stress	<0	Extremely Stress
	Norphu	-0.3	-0.7	<0	Extremely Stress	<0	Extremely Stress
Hill	Bandipur	0.7	-0.31	0.5-1	Moderate Stress	<0	Extremely Stress
	Bhanu	1.4	-0.05	>1	No stress	<0	Moderate stress
	Dordi	1.9	0.14	>1	No stress	<1	Moderate stress
	Devighat	2.0	0.2	>1	No stress	<1	Moderate stress
	Abhukharini	1.6	0.0	>1	No stress	<1	Moderate stress
	Beshishar	3.0	0.6	>1	No stress	<1	Moderate stress
	Marshangdi	0.9	-0.2	0.5-1	Moderate Stress	<0	Extremely Stress
Terai	Chitwan	-0.1	-0.6	<0	Extremely Stress	<0	Extremely Stress
	Mean	0.9	-0.3	0.5-1	Moderate Stress	<0	Extremely Stress

Source: Field Survey, 2021

Table 2 presents water deficit and water stress levels in the range between 20 liters(min) and 50 liters(max) across 12 small cities across three ecological zones (Himal, Hill, and Terai) to meet the basic requirement of water for personal drinking and sanitation. The minim range (20 litres) per capita per day of water is itself critical in that on average, of 12 small cities lie between 0.5 between 1. It is nothing more than moderate stress. Five small cities in Himal and Terai are extremely stressed, meanwhile, 7 small cities in the Hill are not stressed, with except two cities, Bandipur and Marshangdi. These two cities have moderate stress. Relatively, In the minimum range, the Hill is free from water deficits more than Himal and Terai.

Similarly, the maximum range (50 liters per capita per day) of water is itself comfortable in that an average of 12 small cities lies in the range of less than zero. It is extremely stressful. This stress, five small cities in the Himal and Terai are extremely stressed in two more small cities in the Hills are also extremely stressed in addition, five small towns of Hill are experiencing moderate stress. The Hill's water stress is lower than that of the Himalayan and Terai.

It is not sufficient if a person uses water for drinking, personal sanitation, washing clothes, food preparation, and household hygiene to improve their standard of living. Therefore, WHO (2021) notes water per capita per day requires between 50 liters and 100 liters. Let's suppose two points to this water per capita per day: minimum of 50 liters and maximum of 100 liters. Table 3 shows the water deficit and water stress between 50 liters(minimum) and 100 liters(maximum).

Basic Water Household Requirement between 50 liters (minimum) and 100 liters(maximum).

Table 3: Water Deficit, Water Threshold & Water Stress

Ecological Belt	Cities	Water Deficit (min)	Range (min)	Water Stress Level (min)	water deficit (max)	Range (max)	Water Stress Level (max)
Himal	Nasong	-0.7	<0	Extremely Stress	-0.9	<0	Extremely Stress
	Nishyang	-0.6	<0	Extremely Stress	-0.8	<0	Extremely Stress
	Chame	-0.7	<0	Extremely Stress	-0.8	<0	Extremely Stress
	Norphu	-0.7	<0	Extremely Stress	-0.9	<0	Extremely Stress

Hill	Bandipur	-0.31	<0	Moderate Stress	-0.7	<0	Extremely Stress
	Bhanu	-0.05	<0	Extremely Stress	-0.5	<0	Extremely Stress
	Dordi	0.14	<1	Moderate stress	-0.5	<0	Extremely Stress
	Devighat	0.2	<1	Moderate stress	-0.4	<0	Extremely Stress
	Abhukharini	0.0	<1	Moderate stress	-0.5	<0	Extremely Stress
	Beshishar	0.6	<1	Moderate stress	-0.2	<0	Extremely Stress
	Marshangdi	-0.2	<0	Extremely Stress	-0.6	<0	Extremely Stress
Terai	Chitwan	-0.6	<0	Extremely Stress	-0.8	<0	Extremely Stress
	Mean	-0.24	<0	Extremely Stress	-0.63	<0	Extremely Stress

Source: Field Survey, 2021

Table 3 presents water deficit and water stress levels in the range between 50 liters (minimum) and 100 liters (maximum) across 12 small cities across three ecological zones (Himal, Hill, and Terai) to meet the basic requirements of water for personal drinking and sanitation plus washing clothes, food preparation, and household hygiene. The minimum (50 liters) water per capita per day is sufficient for personal drinking and sanitation but it is critical for washing clothes, food preparation, and household hygiene. The water deficit of 12 small cities across three ecological zones (Himal, Hill and Terai) is less than zero (<0) which is on average -0.24. It is so critical that it generates extreme water stress levels but not intense. Except for four small cities in the Hill regions, Dordi, Devighat, Abhukirni, and Marshangdi, all remaining small cities in Himal, Hill, and Terai have extreme water deficit and extreme water stress for meeting personal drinking and sanitation needs washing clothes, food preparation, and household hygiene.

Similarly, the maximum range (100 liters) per capita per day of water is itself critical that, on average, 12 small cities lie in a range of less than zero. It is extremely stressful. Water stress levels are different across 12 small cities across three ecological zones (Himal, Hill, and Terai) but the people have extremely high levels of discomfort. This scenario is an interesting reflection of water poverty-induced poor living standards, and barriers to productive activities of the people because water resources are available in the Marshangadi River and other rivers, and rivulets but extraction and distribution of water resources are major issues. Let's imagine the cleanliness and living standards of the people living in these 12 small cities of Nepal.

4. DISCUSSIONS

This section discusses the result of the study covering water deficit and water stress levels in the 12 cities of the Marshyangdi River Basin, Nepal. Both issues are independent and unidirectional interrelated each other. It means that water deficit induces water stress but there is not vice versa. The study has three scenarios based on water utility: a) water for personal drinking, b) water for personal drinking and sanitation and c) drinking, personal sanitation, washing clothes, food preparation, and household hygiene to improve their standard of living. In another word, water is used only for survival, survival and hygiene, and standard of living. In the first scenario, the small cities have a water deficit with moderate stress on average. Ecologically, the cities of Himal and Terai have extreme water deficit and water stress whereas the cities of Hill have no water deficit and stress. In other words, the cities of Hill are comfortable for only drinking water more than Himal and Terai for just their survival. In the second scenario, there are two ranges: 20 liters per day per capita (minimum) and 50 liters per day per capita (maximum). In the minimum range, the results of the small cities are similar with the first scenario. But, in the maximum range, the results of small cities are dissimilar. It means all cities have water deficits and stress. The cities of Hill have moderate deficit and stress, whereas Himal and Terai have extreme points. Lastly, in the third scenario, there are two ranges: 50 liters per day per capita (minimum) and 100 liters per day per capita (maximum) providing a standard of living. It is the WHO's standard. By these ranges, all cities of Himal, Hill and Terai have extreme water deficit led to extreme water stress levels. Thus, almost all households of the small cities in the Marshayangadi River Basin have extremely stressful lives due to extreme water deficits by international standards. Therefore, the living standards of the people living in such water deficit and stress are critically poor. This is a big challenge to achieve the targets of SDG and higher living standards. The result is validated by WHO (2023) with 73 percent water stress in South Asia. It is further validated by UNICEF (2023) and the World Resource Institute (2023). Concernusa(2022) has listed Nepal as a water stress country. Further, it is validated by Pandey (2021), Mishra et al. (2021), Maskey *et al.* (2020), Dahal *et al.* (2019), Dahal *et al.* (2020) Saraswat et al. (2017) , McManus (2021), Ojha, *et al*. (2019), Pradhan (2012), Rai, *et al.* (2019).

This result contradicts the assumption of water availability due to the Marshayangadi River Basin. It is quiet surprising indicating the poor governance of water management systems, institutions and policies to use water availability for reducing water deficit and stress in the small cities of the water basin. It also indicates that the powerful local government that is the municipality has not accounted for such a situation to provide the planned alternative to address the people's water deficit and stress issues, like as the provincial and federal governments. It may be a big driver to migrate somewhere other cities where water deficit and stress are zero not only for the living standards but also for agricultural and industrial activities for improving output, income and welfare.

5. CONCLUSIONS

The impending global water deficit crisis, expected to impact two-thirds of the world's population by 2025, is a critical issue that requires immediate attention. Nepal's cities are facing water stress despite the country's abundance of water resources, affecting agriculture, industry, and households. This study examines the impact of water deficit-induced stress in 12 small cities located in the Marshyangadi River Basin. It provides valuable insights and policy recommendations for sustainable water management in the face of climate change and development goals. This research investigates the Milankovitch Theory to understand how Earth-Sun relationships impact long-term climate changes, influencing temperature, rainfall, and societal strategies for climate stability. The Water Deficit Model assesses the effects of water scarcity on communities by identifying stress indicators such as discomfort, inconvenience, and increased expenses. The study evaluates the ability to adapt, which is influenced by multiple factors, in order to measure the level of water stress in 12 cities in Nepal's Gandaki Province. The study has three scenarios based on water utility: a) water for personal drinking, b) water for personal drinking and sanitation and c) drinking, personal sanitation, washing clothes, food preparation, and household hygiene to improve their standard of living.

The results of the study indicate the seriousness of water scarcity-induced stress in both small and large cities in Nepal, characterized by inconsistent supply and leakages despite a focus on urbanization in policies. In the standard of living, all cities of Himal, Hill and Terai have extreme water deficit led to extreme water stress levels. Different stress levels are seen in the chosen cities, with the Himalayas experiencing severe stress, while the Hill and Terai regions encounter moderate stress due to geographical and seasonal factors. It indicates that water deficit-induced stress has made vulnerable to almost all households in these small cities. Therefore, the living standards of the people are critically poor. Hence, water deficit poses a significant challenge to Sustainable Development Goal (SDG) targets and federalism in Nepal, impacting survival, hygiene, and overall quality of life; addressing this urgent issue requires prompt action, accountability, budget allocation, and a comprehensive strategy for reducing water poverty in the face of poor governance and inadequate policies in the Marshyangadi River Basin.

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