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The Looming Crisis: Global Groundwater Depletion and its Unseen Impacts, Climate Change

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Abstract:

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The Looming Crisis: Global Groundwater Depletion and its Unseen Impacts, Climate Change

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Abstract

Groundwater depletion is a growing threat to global sustainability, impacting ecosystems, agriculture, and human populations. This viewpoint explores the causes and consequences of unsustainable groundwater extraction, highlighting its far-reaching effects on local and global climates. The paper examines specific examples from various regions worldwide, showcasing the widespread nature of this crisis. It also delves into the challenges associated with accurately measuring global temperature rise due to changes in weather station environments and data collection methods. Finally, the paper emphasizes the urgency to address groundwater depletion and its relation to local and global climate changes.

Keyword: Groundwater; Aquifer; Climate Change; Temperature Rise; Weather Station

Introduction

Groundwater aquifer depletion is becoming one of the most critical environmental and socio-economic challenges of the 21st century [1]. As the world's population grows, the demand for freshwater is surging, placing immense pressure on groundwater resources. These subterranean reservoirs, which supply about 30% of the world's freshwater, are being extracted at unsustainable rates in many regions, leading to severe consequences for ecosystems, agriculture, and human populations [1]. This is a looming crisis that threatens the very sustainability of this resource: global groundwater depletion.

The phenomenon of groundwater depletion occurs when water is withdrawn from aquifers faster than it can be naturally replenished. This imbalance is driven by various factors, including agricultural irrigation, industrial use, and domestic consumption. Agriculture alone accounts for approximately 70% of global freshwater withdrawals, heavily relying on groundwater in arid and semi-arid regions. Declining water tables can render wells dry, jeopardizing drinking water supplies for communities and hindering agricultural productivity in regions heavily reliant on irrigation [2] Furthermore, excessive groundwater extraction can cause land subsidence, the sinking of the earth's surface, leading to infrastructure damage and altering natural drainage patterns [3]. Saltwater intrusion, the movement of saltwater into freshwater aquifers, is another critical consequence, particularly in coastal regions, rendering freshwater unusable [4].

The issue of groundwater depletion is not a distant threat; it's a pressing reality for many regions worldwide. Studies by Wada et al. (2010) [5] indicate a doubling of global groundwater extraction between 1960 and 2000, with hotspots emerging in arid and semi-arid areas with high population densities and limited surface water resources. Regions like Northwest India, Northeast Pakistan, the Central US, and parts of China and Iran are experiencing significant depletion, raising concerns about long-term water security [6]. California's Central Valley and the Ogallala Aquifer in the Great Plains in

US already showed alarming levels of groundwater depletion due to extensive irrigation practices. In Mexico City, over-pumping for municipal water supply has led to notable subsidence and dwindling groundwater levels.

The Middle East, particularly Iran, Saudi Arabia, and Yemen, grapples with severe groundwater depletion as these countries extract water for both agricultural and urban uses beyond sustainable limits. Lebanon, a country known for its rich history and stunning Mediterranean coastline, faces a significant groundwater depletion and saltwater intrusion. The Beqaa Valley, Lebanon's breadbasket, is a region particularly vulnerable to groundwater depletion. Studies using satellite data and well monitoring have shown significant declines in water levels in this area [8]

North Africa's arid regions, such as Libya and Egypt, face similar issues where limited renewable water resources combined with agricultural use have led to substantial declines in groundwater levels [9]. The Sahel is a semi-arid region that depends on groundwater for agriculture and domestic use, and it is threatened by depletion. Western Australia's Perth Basin also suffers from significant depletion driven by agricultural and mining activities [9].

The largely spoken impact of groundwater depletion is reduced water availability that threatens food security and can lead to conflicts over water resources. Land subsidence, a common consequence of excessive groundwater extraction, damages infrastructure and alters landscapes. Reduced groundwater discharge into streams and rivers can affect aquatic life and wetland habitats. Additionally, the lowering of water tables can degrade water quality, concentrating pollutants and making water unsafe for consumption and irrigation [9]. As water tables drop, wells run dry, jeopardizing drinking water supplies for communities and hindering irrigation for agriculture. This can lead to water scarcity, impacting everything from household needs to food security. Reduced agricultural productivity due to irrigation limitations can lead to food shortages and price hikes.

Groundwater depletion is a growing concern, not just in well-studied regions, but also in many areas where crucial data is lacking. These regions, often heavily reliant on groundwater for daily needs, face the specter of irreversible aquifer depletion [9]. Extreme drought events further exacerbate this global problem. Studies claim that climate change worsened the groundwater depletion situation, at least through decrease of precipitation and increase in temperature.

Climate change is exacerbating groundwater depletion, or it is the other way around. Water plays a vital role in distributing and exchanging heat around the Earth through several key mechanisms [7]. Water is integral to Earth's heat exchange through its ability to absorb, store, and transport heat. Ocean currents, phase changes, and interactions with the atmosphere are key processes that regulate climate and weather, illustrating the dynamic and complex role of water in the Earth's heat budget [7]. Understanding the role of water in global heat exchange process is essential for studying climate variability or what is called climate change.

This article delves into the effect of water heat exchange on Earth and investigates how might groundwater depletion affect local or global climates. The relation of water to global or local climate is largely known in atmospheric and physical sciences. Further investigation is required to understand the link of water to climate over local or global climate.

Materials and Methods

World large and small aquifers

Groundwater aquifers, which are vast underground reservoirs of water, are distributed across all continents. These aquifers play a crucial role in supplying water for agricultural, industrial, and domestic use. Earth's 37 largest aquifers were spotted using GRACE data [9,10 and 11]. It described the depletion and replenishment in millimeters of water per year. Among the 37 aquifers, twenty-one aquifers have demonstrated irreversible depletion situation, and 13 of these are located in regions of short water availability (Figure 1).

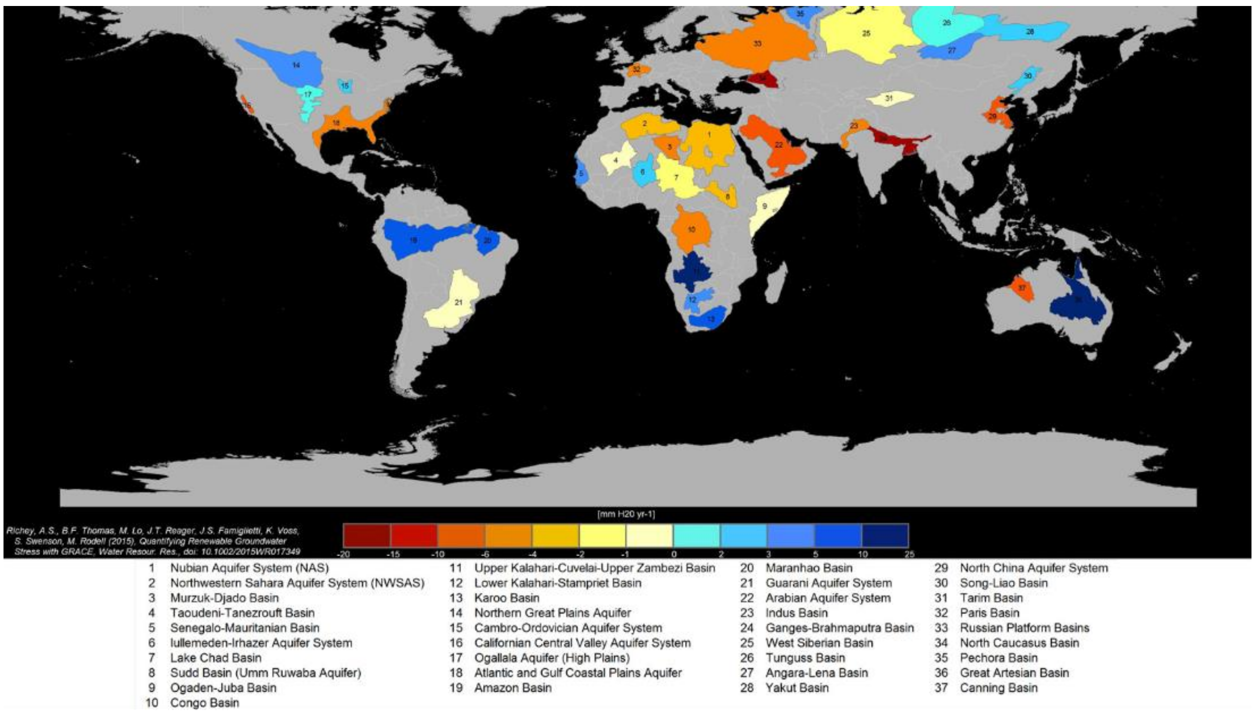

Figure 1. Earth's 37 largest aquifers (NASA/JPL-Caltech).

The global earth land area is about 148 million sqm. The main groundwater aquifers extend over an area of about 8 million sqm that makes about 5.5% [12]. However, all Earth's lands have underneath them water aquifers of various groundwater depths. In other words, there is no land without a groundwater aquifer that lies underneath it. The depth of the aquifers or underground water differ greatly from area to another [12].

Various large aquifers over the world are listed below by continent [13 and 14]:

- Africa

- Nubian Sandstone Aquifer System: Covers around 2 million square kilometers.
- Northern Sahara Aquifer System: Approximately 1 million square kilometers.

- Asia

- Indus Basin Aquifer: About 1.1 million square kilometers.
- North China Plain Aquifer: Roughly 0.3 million square kilometers.

- Europe

- Cretaceous Aquifers (Various): Combined, these aquifers cover several hundred thousand square kilometers across multiple countries.

- North America

- Ogallala Aquifer: Around 450,000 square kilometers.
- Floridan Aquifer: Approximately 260,000 square kilometers.

- South America

- Guarani Aquifer: Covers around 1.2 million square kilometers.
- Amazon Basin Aquifers: These are part of the larger Amazon Basin, which spans about 7 million square kilometers, but the aquifers themselves are smaller and distributed within this area.

- Australia

- Great Artesian Basin: About 1.7 million square kilometers.

- Antarctica

- Subglacial Aquifers: The exact surface area extends over the entire Antarctica.

- Middle East

- West Bank Aquifer, Palestine: Small, localized aquifers providing water in a water-scarce region.
- Al-Azraq Aquifer, Jordan: A critical source of water for local communities in an arid region.
- Bekaa Valley Aquifers, Lebanon: Small aquifers providing water to agriculture and local communities in the valley.

While major aquifers are well-documented, small aquifers exist globally and play crucial roles in local water supplies. Almost all small or large aquifers worldwide are overexploited. However, small aquifers are more often vulnerable to overextraction, leading to depletion [14]. Hence, identifying aquifers of less or no overexploitation can be challenging, as many aquifers worldwide face varying degrees of stress due to population growth, and agricultural demands. Only some aquifers are relatively less exploited, often due to their remote locations, lower population densities, or effective management practices.

Depletion of aquifers might reach up to about 50 m of groundwater deference in depth (Table 1). The original water depths and the depletion of a few aquifers show various degrees of pressure and pumping [11, 13 and 14].

Table 1. Original and depleted groundwater depts in aquifers around the world.

Aquifer	Location	Original Water Depth (meters)	Depletion (meters)
Ogallala Aquifer	USA	30 - 90	Up to 46
Central Valley Aquifer	California, USA	15 - 60	Up to 30
Santiago Basin Aquifer	Chile	15 - 30	Up to 9
Po Valley Aquifer	Italy	6 - 18	Up to 10
Ebro Basin Aquifer	Spain	9 - 24	Up to 15
North China Plain Aquifer	China	9 - 30	Up to 30
Ganges-Brahmaputra Basin Aquifer	India and Bangladesh	3 - 15	Up to 12
Nubian Sandstone Aquifer System	North Africa	60 - 450	Up to 15
Limpopo Basin Aquifer	Southern Africa	3 - 9	Up to 8
Great Artesian Basin	Australia	30 - 300	Up to 6
Arabian Aquifer System	Middle East	30 - 150	Up to 20
Edwards-Trinity Plateau Aquifer	Texas, USA	30 - 90	Up to 30
Coastal Plain Aquifers	Eastern USA	15 - 45	Up to 15
Santa Cruz River Valley Aquifer	Arizona, USA	20 - 60	Up to 10
Valle de Uco Aquifer	Argentina	10 - 30	Up to 10
Caribbean Coastal Aquifers	Colombia	10 - 40	Up to 15
Meghalaya Aquifers	India	5 - 20	Up to 5
Western Ghats Aquifers	India	10 - 30	Up to 10
Jeju Island Aquifer	South Korea	20 - 50	Up to 10
Chalk Aquifer	England	10 - 40	Up to 10
Karst Aquifers	Balkans	5 - 25	Up to 5
Tuscany Aquifers	Italy	5 - 20	Up to 5
Basque Country Aquifers	Spain	5 - 20	Up to 5
Bavarian Forest Aquifers	Germany	10 - 30	Up to 10
Napa Valley Aquifers	California, USA	15 - 45	Up to 15
San Juan Basin Aquifers	New Mexico, USA	20 - 60	Up to 20
Mackenzie River Basin Aquifers	Canada	10 - 40	Up to 10
Patagonia Aquifers	Argentina	10 - 30	Up to 10
Amazon Basin Tributary Aquifers	Brazil	10 - 50	Up to 5
Tasmanian Aquifers	Australia	10 - 40	Up to 5
Kimberley Region Aquifers	Western Australia	20 - 60	Up to 10
Bekaa Valley Aquifers	Lebanon	10 - 30	Up to 50
Salalah Plain Aquifers	Oman	20 - 60	Up to 10

Groundwater overexploitation significantly impacts surface water resources through a process known as streamflow depletion. When groundwater is excessively extracted, the natural equilibrium between groundwater and surface water bodies, such as rivers, lakes, and wetlands, is disrupted. This imbalance reduces the base flow that groundwater normally contributes to these surface water systems, leading to lower water levels and diminished flow in rivers and streams. Additionally, overextraction can cause surface water bodies to dry up or become disconnected from their groundwater sources, exacerbating water scarcity, harming aquatic ecosystems, and reducing water quality [14]. The resultant decline in surface water availability can have far-reaching consequences for drinking water supplies, agriculture, industry, and the environment. Many of these aquifers have seen significant impacts on surface water bodies, including reduced river flows, drying of springs and wetlands, and increased salinity in estuaries (Table 2).

Table 2. Depleted world aquifers and affected surface water.

Aquifer	Surface Water Affected	Impact on Surface Water
Ogallala Aquifer (USA)	Arkansas River, Platte River, Canadian River	Decreased baseflows, drying of streams
Central Valley Aquifer (California, USA)	Sacramento-San Joaquin River Delta	Reduced river flows, drying of wetlands, increased salinity
Santiago Basin Aquifer (Chile)	Maipo River	Lower stream flows, reduced water availability for agriculture and urban use
Po Valley Aquifer (Italy)	Po River	Lower river flows, impact on agriculture, industry, and hydropower
Ebro Basin Aquifer (Spain)	Ebro River	Reduced river flows, impact on irrigation and ecosystem health
North China Plain Aquifer (China)	Hai River system	Shrinking or disappearing rivers and lakes, decreased water availability
Ganges-Brahmaputra Basin Aquifer (India and Bangladesh)	Ganges River, Brahmaputra River	Lower baseflows, exacerbated water scarcity during dry seasons
Nubian Sandstone Aquifer System (North Africa)	Oases in Libya and Egypt	Reduced flows to oases, desertification, loss of agricultural land
Limpopo Basin Aquifer (Southern Africa)	Limpopo River	Decreased baseflows, impact on agriculture, domestic use, and ecosystems
Great Artesian Basin (Australia)	Natural springs	Reduced spring pressure, drying of springs, impact on ecosystems
Arabian Aquifer System (Middle East)	Wadis, springs	Drying up of wadis and springs, impact on agriculture and local water supplies
Edwards-Trinity Plateau Aquifer (Texas, USA)	San Antonio River, Guadalupe River	Reduced spring flows, impact on aquatic habitats

Aquifer	Surface Water Affected	Impact on Surface Water
Coastal Plain Aquifers (Eastern USA)	Coastal estuaries	Reduced freshwater inflows, increased salinity, impact on fish and shellfish populations
Santa Cruz River Valley Aquifer (Arizona, USA)	Santa Cruz River	Lower baseflows, impact on riparian habitats and groundwater-dependent ecosystems
Valle de Uco Aquifer (Argentina)	Local rivers	Reduced river flows, impact on wine production and local agriculture
Caribbean Coastal Aquifers (Colombia)	Local rivers and streams	Reduced flows, impact on agriculture and ecosystems
Meghalaya Aquifers (India)	Local rivers and streams	Reduced baseflows, impact on local water availability
Western Ghats Aquifers (India)	Local rivers and streams	Reduced flows, impact on agriculture and ecosystems
Jeju Island Aquifer (South Korea)	Local rivers and streams	Reduced baseflows, impact on local water availability
Chalk Aquifer (England)	Local rivers and streams	Reduced flows, impact on ecosystems and water availability
Karst Aquifers (Balkans)	Local rivers and springs	Reduced flows, impact on ecosystems and water availability
Tuscany Aquifers (Italy)	Local rivers and streams	Reduced flows, impact on local water availability
Basque Country Aquifers (Spain)	Local rivers and streams	Reduced flows, impact on ecosystems and water availability
Bavarian Forest Aquifers (Germany)	Local rivers and streams	Reduced flows, impact on ecosystems and water availability
Napa Valley Aquifers (California, USA)	Local rivers and streams	Reduced flows, impact on agriculture and ecosystems
San Juan Basin Aquifers (New Mexico, USA)	Local rivers and streams	Reduced baseflows, impact on ecosystems and local water availability
Mackenzie River Basin Aquifers (Canada)	Mackenzie River	Reduced flows, impact on ecosystems and water availability
Patagonia Aquifers (Argentina)	Local rivers and streams	Reduced flows, impact on local water availability
Amazon Basin Tributary Aquifers (Brazil)	Tributaries of Amazon River	Lower baseflows, impact on biodiversity and indigenous communities
Tasmanian Aquifers (Australia)	Local rivers and streams	Reduced flows, impact on ecosystems and local water availability
Kimberley Region Aquifers (Western Australia)	Local rivers and streams	Reduced flows, impact on ecosystems and local water availability
Bekaa Valley Aquifers (Lebanon)	Local rivers and streams	Reduced flows, impact on local water availability

Aquifer	Surface Water Affected	Impact on Surface Water
Salalah Plain Aquifers (Oman)	Local rivers and streams	Reduced flows, impact on agriculture and local water availability

Surface water evaporation and evapotranspiration

When water evaporates, it absorbs energy from its surroundings to break free from the liquid phase and enter the gaseous phase. This absorption of energy is essentially heating transfer from the surroundings to the water [15]. The energy required for evaporation is known as the latent heat of vaporization. The rate of evaporation depends on several factors, including the temperature of the water, the surface area exposed to the air, the humidity of the surrounding air, and the rate of airflow over the water surface [16]. If from soils, it should not be neglected the soil color and types of landcover [17].

The rate of heat transfer during evaporation (Q) can be described by the following equation:

$$Q = \dot{m} \cdot \Delta H_{\mathrm{vap}}$$

Where:

- Q is the rate of heat transfer (in watts or joules per second),
- $\dot{m}$ is the mass flow rate of water evaporating (in kilograms per second), and
- $\Delta Hvap$ is the latent heat of vaporization (in joules per kilogram).

During evaporation, water absorbs heat from its surroundings, causing it to evaporate and enter the gaseous phase. The rate of heat transfer during evaporation is governed by the mass flow rate of water evaporating and the latent heat of vaporization.

Surface water and local climates

Large water bodies, such as oceans and large lakes, play a significant role in influencing weather patterns due to their ability to absorb, store, and release heat energy. Water has a higher specific heat capacity compared to land, meaning it can absorb and retain more heat [18]. Consequently, coastal areas often experience milder temperatures compared to inland regions. This moderating effect is most noticeable in regions with maritime climates, where summers are cooler, and winters are warmer than locations further inland [19].

Water bodies are a primary source of moisture for the atmosphere through evaporation. The process of evaporation involves the conversion of liquid water into water vapor, which then becomes part of the atmosphere. This moisture is essential for the formation of clouds and precipitation, influencing local and regional weather patterns. Evaporation from large water bodies like oceans, lakes, and rivers helps regulate temperatures by absorbing excess heat during the day and releasing it at night [20].

When warm, moist air from the ocean moves over cooler land areas, it can lead to the formation of fog. This coastal fog can have significant impacts on visibility and local weather conditions, particularly in areas with strong temperature gradients between land and sea [21].

Water bodies also influence wind patterns. During the day, the land heats up more quickly than the water, causing air to rise over the land and creating lower pressure. This draws cooler air from the water toward the land, resulting in a sea breeze. At night, the process reverses, with warmer air over the water leading to a land breeze [22].

In shallow groundwater and aquifers, when water is closer to the soil surface, it can evaporate into the air. This process absorbs heat energy from the surrounding environment, including the soil and the air, leading to a cooling effect. Soil moisture plays a role in regulating local climate conditions. Areas with higher soil moisture levels tend to have more evaporation, which can contribute to cooler temperatures compared to areas with dry or arid soil conditions [23].

Changes in soil moisture can influence the local climate over time. For example, during periods of drought, when soil moisture levels are low, there is less evaporation, which can contribute to higher air temperatures [24]. Conversely, during wet periods, higher soil moisture levels can enhance evaporation and contribute to cooler temperatures.

Soil moisture also affects the transfer of heat between the soil and the atmosphere. Moist soil can absorb more heat during the day and release it more slowly at night, moderating temperature fluctuations [24]. In contrast, dry soil heats up and cools down more rapidly, leading to more extreme temperature variations.

Overall, water evaporation is a fundamental process that influences both local and global climate patterns by regulating temperature and contributing to the formation of precipitation. Nonetheless, soil moisture influences air temperature through its role in evaporation, local climate regulation, and heat transfer processes. Changes in soil moisture levels can have significant impacts on the local microclimate and broader weather patterns.

Forest areas and local climates

Forests contribute to the water cycle through evapotranspiration, the combined process of water evaporation from soil and plant surfaces and transpiration from plants. This process releases moisture into the atmosphere, which can contribute to cloud formation and subsequent precipitation [25]. Tropical forests are known for high rates of evapotranspiration.

The rough surface of forest canopies disrupts air flow, enhancing the upward movement of air. This turbulence can lead to more cloud formation and precipitation as the moist air rises and cools [26]. Forests help regulate local temperatures by providing shade and releasing moisture. This regulation can affect local humidity levels and influence rainfall patterns. Forested areas tend to have more stable and moderate microclimates compared to deforested regions.

Forests play a crucial role in the hydrological cycle by intercepting rainfall and facilitating groundwater recharge. This stored water can then be released slowly, affecting local water availability and precipitation patterns over time [27].

Groundwater Extracted Volume and rainwater recharge

The volume of groundwater pumped worldwide is substantial. Current estimates indicate that about 982 km^3 of groundwater are extracted annually. This makes groundwater the most extracted raw material globally [28].

Expansion of urban areas with impermeable surfaces (like roads and buildings) reduces the amount of water that can infiltrate into the ground. Instead, water is directed into storm drains and rivers, bypassing natural recharge processes [29].

Agricultural practices and urban development can lead to soil compaction and erosion, which reduces the soil's ability to absorb water, thereby limiting groundwater recharge [30].

Global Temperature Rising

The IPCC's findings underpin global temperature goals set by international agreements, such as the Paris Agreement. This landmark accord aims to limit global warming to well below 2°C above pre-industrial levels, with efforts to limit the increase to 1.5°C. The IPCC's Special Report on Global Warming of 1.5°C was crucial in highlighting the differences in impacts between 1.5°C and 2°C of warming, influencing the adoption of these targets.

Worldwide, temperature records are gathered from large networks of weather stations and satellites. These record temperature measurements at land and sea surfaces, in relation to IPCC reports. The exact condition of this network of weather stations needs to be investigated and analyzed from several perspectives. The point location of a weather station is crucial for data accuracy and for standardizing purposes.

Until late nineteen century, weather stations around the world uses Stevenson screen, also known as a meteorological screen or instrument shelter. A Stevenson screen is a standardized structure designed to house manual meteorological instruments such as thermometers, hygrometers, and barometers. It protects these instruments from precipitation and direct solar radiation, while allowing air to circulate freely around them.

Location of a Stevenson screen significantly affects data measurements. Proper placement is essential to ensure the accuracy and reliability of the recorded meteorological data. Factors impacting climate parameters data measurements are numerous, among them:

- Proximity to Buildings and Structures: Heat Sources: Buildings, paved surfaces, and other structures can emit heat, especially if they are made of materials like concrete or asphalt, which absorb and re-radiate solar energy. This can cause higher temperature readings.
- Shade: Structures can cast shadows that may lead to cooler temperature readings during certain times of the day.
- Obstruction: Trees and shrubs can obstruct airflow and sunlight, affecting temperature and humidity measurements.
- Soil covers: Vegetation can create localized microclimates. The ground surface should be natural, such as grass or soil, to avoid the influence of heat retention and reflection that comes from artificial surfaces like concrete or asphalt. For example, grassy areas are generally cooler than bare soil or paved areas.

- Above Ground Level: The standard height for placing a Stevenson screen is 1.25 to 2 meters above ground. Deviating from this height can result in measurements that are not comparable to standard meteorological data.
- Topography: Placing the screen in a valley, on a slope, or at a higher elevation can affect the readings due to variations in air flow, temperature, and humidity related to the terrain.
- Wind Flow: An open area ensures that the screen is exposed to natural wind flow, which is important for accurate temperature and humidity readings.

The rapid urbanization and land cover changes have significantly impacted existing weather stations. The conditions surrounding many weather stations worldwide have altered considerably since their initial installation. For example, weather stations in Beirut, Lebanon, began recording climate data in the 1880s when the population was between 15,000 and 25,000. Today, in 2024, Beirut's population is estimated to be around 2.5 million. This growth, along with increased pavement and urban development, has transformed the natural environment around these weather stations, which have been recording climate data for centuries. Similar changes have affected weather stations globally.

The location of the weather station did not only change through its landcover, but other hidden aspects were also altered. Groundwater depletion, drying of nearby surface water and seawater intrusion are among the various aspects that need to be considered once studying temperature records. Unfortunately, worldwide weather stations did not describe its location carefully. The physical characteristics of the weather station location need to be described over large surrounding area. Soil moisture content should be measured over the whole year, in wet and dry seasons. The yearly average temperature is a result of soil moisture changes over the seasons. Soil moisture and groundwater depth are the factors that change the ambience over weather stations.

Surface water affects relative humidity of the area and causes water seepage to the surrounding soils. Humidity of the ambient air alters temperature recording as well. Soil moisture and evaporation play a major role in ambient temperature changes. A thermometer records temperature over moist soil reads differently once compared to another located on bare soils. Soil color, soil organic matter, and rock outcrop affect temperature recording. Thus, the ambience where a thermometer is located must be well investigated and thoroughly described. Most weather stations worldwide did not describe its ambience at all. Nevertheless, there is no further studies on changes that happened with time during the recording period of climate parameters. Adding, thermometers are no longer placed in Stevenson screen.

The advancement of technology has eliminated the Stevenson screen and replace it by radiation shield of a white plastic cap. Automated Weather Stations has become sitting in the field recording climate data on various conditions because of its simple plug and play manufacturing forms. These white plastic shields change their insulation shortly with time. The white color does not remain all bright because of the solar radiation effect. Nonetheless, outdoor environment always has dust that accumulates inside the thermometer and on the radiation shield, no matter how clear/clean is the ambient. Dust accumulation and color change of the radiation shield will elevate temperature recording to various level, following heat accumulation conditions. Nonetheless, the radiation shield is hooked to the main Automated Weather Station body skeleton that also accumulates heat and transferred by physical contact.

Temperature measured using automated weather stations through radiation shields is likely to record higher values. Radiation shields accumulate heat when they change color to off-white and collect dust. Consequently, the average daily temperature will reflect higher values, elevating the yearly average records. Moreover, the humidity and temperature thermocouple sensor within the radiation shield is enclosed within a steel mesh with very narrow openings. This steel mesh accumulates dust, which slows the direct exposure of the thermocouple sensor to the ambient conditions of the weather station, thereby affecting its accuracy. Nevertheless, automated sensors require continuous monitoring to ensure their accuracy, as they might record outliers and peaks unrelated to the actual environment. In many scenarios, it is impossible to accurately verify these anomalies. Consequently, the recorded data often goes unverified in terms of its accuracy.

Automated weather stations and their advanced technologies offered significant improvements in data collection, ensuring the accuracy of recorded climate data remains a complex challenge. The reliability of temperature measurements is influenced by various factors, including the placement, maintenance of sensors, changes of ambient conditions, groundwater depth and soil moisture, the condition of radiation shields, and changes in the surrounding environment over time. As urbanization and environmental conditions evolve, continuous monitoring and verification of weather station data are crucial. To maintain the integrity of climate records, it is essential to address the potential discrepancies and anomalies that can arise, thereby ensuring that the data used to inform global temperature goals and climate policies are as accurate and reliable as possible. The investigation of global temperature rise should encompass all the aspects mentioned above, especially soil moisture levels and groundwater conditions.

Discussion

Groundwater depletion is an urgent environmental and socio-economic challenge exacerbated by growing global populations and increasing demand for freshwater resources. The consequences of this crisis are multifaceted, affecting ecosystems, agriculture, infrastructure, and human populations. The unsustainable rate of groundwater extraction, particularly for agricultural irrigation, has led to a decline in water tables, rendering wells dry and jeopardizing drinking water supplies. This depletion is evident in regions like Northwest India, the Central US, and parts of China, Iran, and in many other places in the world highlighting the widespread nature of the problem.

The data from various aquifers worldwide show significant declines in groundwater levels, with some areas experiencing depletion of up to 50 meters. This overextraction not only impacts groundwater availability but also affects surface water systems through streamflow depletion. The reduction in baseflows has detrimental effects on rivers, lakes, and wetlands, which in turn harm aquatic ecosystems, reduce water quality, and limit water availability for agriculture and domestic use. For example, the Ogallala Aquifer's overextraction has led to decreased flows in the Arkansas and Platte Rivers, impacting agricultural productivity and local water supplies.

The interaction between groundwater depletion and climate change adds another layer of complexity to this issue. Groundwater plays a vital role in the Earth's heat exchange processes, influencing local and global climates. Evaporation from soil moisture and surface water bodies regulates temperature and contributes to precipitation patterns. However, groundwater depletion can alter these processes, potentially exacerbating micro-level climate change effects by reducing soil moisture and affecting local microclimates.

The impact of groundwater depletion on temperature recordings from weather stations is also significant. As urbanization and land cover changes have altered the conditions around many weather stations, the accuracy of climate data has been compromised. Factors such as soil moisture, groundwater depth, and local surface water availability influence ambient temperatures and humidity, which in turn affect temperature measurements. The historical data from weather stations, such as those in Beirut, Lebanon, may not accurately reflect current climate conditions due to these environmental changes.

Conclusion

Groundwater depletion is a critical issue with far-reaching consequences for environmental sustainability and human livelihoods. The overextraction of groundwater, primarily driven by agricultural needs, has led to significant declines in water tables, impacting ecosystems, agricultural productivity, and drinking water supplies. The interplay between groundwater and climate change further complicates this issue, as changes in soil moisture and surface water availability influence local and global climates.

Addressing groundwater depletion requires comprehensive management strategies that balance water extraction with natural replenishment rates. Sustainable agricultural practices, effective water management policies, and investment in technologies for efficient water use are essential to mitigate this crisis. Additionally, a thorough understanding of the relationship between groundwater and climate processes is crucial for developing adaptive strategies to cope with the impacts of climate change.

Future research should focus on improving the accuracy of climate data by considering the environmental changes around weather stations. Detailed descriptions of the physical characteristics and changes in the surroundings of weather stations are necessary to ensure reliable climate data. This approach will help in better understanding the complex interactions between groundwater depletion, surface water systems, and climate change, ultimately contributing to more comprehensive situation understanding what really causing local and global climate change.

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