Assessment of Water Resources Development and Exploitation within the Framework of the Human Right to Water

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ABSTRACT

Recent years have seen an alarming global water problem brought on by population increase, climate change, and the corresponding rise in water demands. The global water situation has become difficult as a result. Water supplies in many countries are insufficient to meet even the most basic human needs. Although the State has historically dominated discussions of international water policy, new human rights instruments have changed the dynamic. One of the most important advancements in international environmental and human rights legislation is the recognition of the right to water as human rights. Despite the fact that water is necessary for life, health, and dignity, millions of people around the world still struggle with its scarcity, contamination, and unequal access. The theoretical underpinnings, legal acknowledgement, and practical difficulties of achieving the right to water are all examined in this essay. Building on agreements like the International Covenant on Economic, Social, and Cultural Rights (ICESCR) and the United Nations General Assembly Resolution 64/292 (2010), it examines how states have a duty to guarantee that water is available, affordable, accessible, and of high quality for everyone. Conflicts over privatization, transboundary water governance, and climate-induced shortages are among the issues raised by the abstract, which also emphasizes the difficulties between water as an ecological resource, economic commodity, and public good. Through an analysis of case law, constitutional provisions, and policy frameworks from various jurisdictions, this paper makes the point that integrating legal guarantees with equitable practices, participatory governance, and sustainable resource management is necessary for the effective implementation of the right to water. Thus, the right to water is not just a legal right but also a fundamental component of environmental justice, sustainable development, and international human rights defense.

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1. INTRODUCTION

The acceleration of progress and the rise in living conditions in many parts of the world over the past few decades may give the impression that we will finally be able to overcome our dread of poverty. This study, however, obstinately adopts a pessimistic stance and decides to focus on the persistent poverty and hardship. In order to create the best policies for tackling water poverty, our ultimate goal is to accurately define poverty. The UN created the Sustainable Development Goals, a collection of 17 objectives meant to achieve sustainable development globally1, in order to track progress toward ending poverty. Indicator 1.2.2, which calculates the percentage of the population living in a multidimensional state of poverty based on national norms, is a crucial tool for tracking progress towards SDG 1 [1]. This indicator considers a number of elements that lead to poverty, such as living conditions, income, and access to essential services like healthcare and education. However, employing efficient monitoring techniques is necessary to gauge progress towards SDG 1.2.2. The Multidimensional Poverty Index and the composite indicator At Risk of Poverty or Social Exclusion are two of the most well-known and successful approaches in this area.

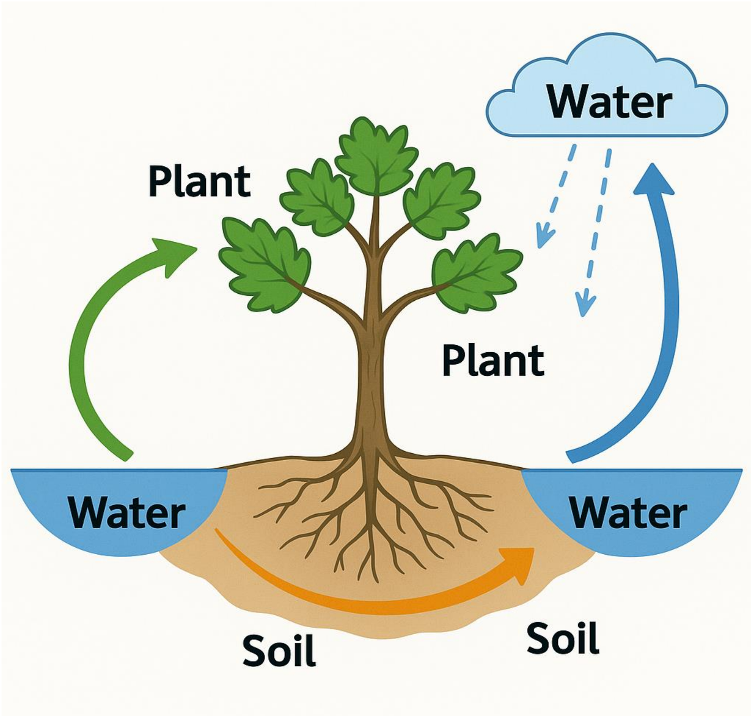

Figure 1. Interaction of Water, Soil, and Plants

As part of the larger hydrological cycle, the customized graphic illustrates the dynamic interactions between soil, plants, and water [2], providing insights into water management from an ecological and legal standpoint. The soil-plant-water continuum is at the heart of this cycle, supporting agricultural productivity and ensuring ecological sustainability.

Water Entry and Storage: The main natural source of water entering this system is precipitation. Rainwater seeps into the ground, recharging subterranean aquifers and surface water bodies. As a natural reservoir, the soil controls how water is distributed and stored. Texture, structure, and organic matter all affect its capacity to retain and release water. Thus, good soil management practices have a direct impact on groundwater recharge and plant water availability.

Plant Absorption and Utilization [3]: Through capillary action, plant roots draw water from the soil, supplying the vital moisture required for metabolic processes, nutrient transfer, and photosynthesis. This stage emphasizes how important vegetation is to preserving soil health, stopping erosion, and promoting sustainable land-water usage. Since excessive extraction or ineffective irrigation upsets the soil-water balance, legislation controlling irrigation methods in agriculture are strongly related to this part of the cycle.

Transpiration and Atmospheric Recycling: Transpiration from plant leaves releases a sizable amount of absorbed water into the atmosphere. This process, in conjunction with soil evaporation, adds moisture to the atmosphere, which eventually condenses to produce precipitation and clouds. The interdependence of atmospheric and ground systems is shown by this cyclical interchange. This knowledge is frequently used to support watershed conservation programs and the legal recognition of ecological flows, which guarantee that ecosystems have enough water to support these natural processes.

Soil-Water-Ecosystem Balance: The figure highlights that soil is an important regulator of water distribution rather than just a passive medium. Healthy soils maintain plants, control runoff, and aid in groundwater recharge. On the other hand, damaged soils can result in biodiversity loss, decreased agricultural production, and flooding. As a result, regulations pertaining to natural resources and water increasingly acknowledge soil and water conservation as a combined state responsibility under the intergenerational fairness principle.

Relevance to Research and Policy: This cycle offers a scientific basis for Integrated Water Resources Management (IWRM), which encourages the fair and sustainable distribution of water among rival industries, families, and farmers. Legally speaking, the diagram supports the idea that water is a human right and a resource of public trust and those governments must protect ecosystems while guaranteeing access. The duty of states to protect water quality and availability as part of the right to life and dignity is reaffirmed by case law from countries such as South Africa and India.

2. RELATED WORKS

Monitoring and reporting the effects of water policy on resource management and water shortage has been claimed to be essential. Monitoring policy implementation practices to evaluate policy impacts is thought to be best accomplished through results-oriented policy monitoring [4]. It is maintained that the strategy shifts the attention from inputs and outputs to the results and effects of policy activity. Numerous studies have been conducted in this area to evaluate the effect of policies on the sustainable use of water resources. For example, changes in free drinking water availability in California public schools following the introduction of the 2010 Federal and State school water policy were examined in the United States of America (USA).

For smart cities to have efficient water distribution, measuring the quality of the water is essential. One of the most important things to do is to find the contaminants in the water source. Wastewater is treated using a variety of AI-based techniques [5]. AI methods related to the process of treating wastewater. The authors also covered the cost and logistics of the entire process, as well as the uses of AI in wastewater management. The two main successful AI techniques applied in the wastewater treatment process, according to the authors, were federated learning (FL) and artificial neural networks (ANN).

Excessive water loss is caused by antiquated irrigation methods and inefficient farming practices. Traditional methods don't sufficiently encourage the adoption of new technologies or encourage water saving practices. Water resources are usually managed separately by a number of sectors, including towns, industry, and agriculture [6]. This disjointed strategy may impede overall sustainability and result in disputes over resource distribution. Furthermore, many water distribution and supply systems are antiquated and unable to satisfy modern demands. Traditional management budgets may be strained by the significant costs required to maintain and upgrade this infrastructure. The involvement of multiple stakeholders, including local communities, governments, businesses, and environmental organizations, is necessary for effective water management. It's likely that inclusive decision-making procedures are not given priority by traditional approaches.

In essence, supervised learning is the intended effect of an instructor's or programmer's efforts. Through an iterative learning process, it may create predictive and classification models using properly coded inputs with labeled data connected to corresponding outputs [7]. This method can be applied to a number of social domains, such as demographic features and evolution, as well as predictive indicators like water management and health. To elaborate on the previous statement, supervised learning necessitates a dataset representing the issue area that contains labeled samples. Supervised learning algorithms efficiently capture the correlations between input characteristics and output labels by iteratively adjusting their internal parameters to minimize the difference between anticipated and actual labels.

For the purpose of delivering spatially detailed data on a variety of ecosystems, including surface water resources [8], remote sensing has proven to be an economical and successful technique. In addition to monitoring semi-arid tropical areas, earth observation tools like contemporary UAVs, balloons, multispectral, and hyper-spectral sensors may be able to solve issues like pollution, water scarcity, and water quality preservation. Policymaking, freshwater protection, future LULC development considerations, and efficient watershed management all depend on an understanding of the connection between LULC and water resources. Insights into the causes of water quality issues, water quality evaluation indices, strategies for finding appropriate explanatory variables, and processing techniques required to capture spatial impacts are also provided by the study.

China, the world's most populous nation with the fastest-growing economy, has water resources per capita that are barely 25% of the global average. In the meantime, this nation's grain production and water resources are extremely unequally divided geographically. China's food security and water sustainability may be at jeopardy due to the unpredictability of water supply in the northern agricultural region. Furthermore, non-point source pollution, which is hard to eradicate due to fertilizer inefficiency, poses a covert threat to the ecosystem and water resources' sustainability [9]. To aid in the development of conservation measures for water resources, it is imperative to disclose the effects of agricultural production and consumption.

Surface water, groundwater, and rainfall were the primary local water supplies prior to the 1950s. As cities increased in size and urban areas got more crowded, surface waters became contaminated and deadly diseases like cholera and typhoid fever sprang out due to the concentration of human and animal waste in metropolitan areas [10]. The two primary ways to address these harmful conditions were to provide a sewage network to remove human waste and to provide a piped water supply. After local water sources, such as rainwater, were gradually abandoned and shown to be scientifically justifiable, efforts are now being made to pipe distant waters for a centralized water supply in dispersed tiny towns. Decentralization of telecommunications and energy supply (including gas, electricity, and oil) is a recent worldwide trend that has a significant impact on water management. Technology transfer from developed to underdeveloped countries is expected to play a significant role in this effort. One could argue that the fragmentation of telecommunications has already been finished with regard to mobile phones and decentralized banking.

3. METHODS AND MATERIALS

3.1 Water resources management

The management of water resources is a complex legal and institutional matter in addition to being a technical and environmental one. Fundamentally, it entails managing water resources in a way that strikes a balance between ecological sustainability, economic growth, and human needs. Legally speaking, water management frameworks specify who is entitled to use water, how much they can use it, and under what circumstances. Water is regarded as a public trust resource in many countries, which means that the state manages it for the good of all residents [11]. Governments are required by this legal concept to guarantee fair distribution, stop overexploitation, and safeguard water quality against pollution from household, agricultural, and industrial sources**.**

Modern Integrated Water Resources Management (IWRM) models emphasize the necessity for a comprehensive legal strategy that connects water rights to community involvement, land use, and environmental sustainability [12]. Many nations now have laws governing groundwater extraction, imposing accountability for pollution, and requiring environmental impact studies (EIAs) for projects that harm water. At the global level, legal frameworks like the Helsinki Rules (1966) and the UN Watercourses Convention (1997) set standards for managing shared rivers and aquifers [13], placing a strong emphasis on fair and reasonable use as well as the obligation to avoid serious harm across national boundaries. These tools highlight the universal understanding that water management requires cooperative governance among governments and cannot be limited inside political borders.

The UN General Assembly Resolution 64/292 (2010) affirms the right to water as a human right, which is a crucial component of legal water governance [14]. States are now required by law to ensure that water is available, affordable, accessible, and of high quality for everyone, especially underserved populations. This idea has been further supported by numerous national constitutions and court decisions, which hold governments responsible for their inability to provide clean drinking water. The right to water, for instance, has been construed by South African and Indian courts as an expansion of the fundamental right to life and dignity. As a result [15], human rights norms are being included into water management legal frameworks in addition to environmental and regulatory safeguards.

However, legal disputes over water resources are common, particularly where there is privatization or scarcity. Water as a commercial commodity and water as a public good are still hotly debated topics. Despite occasionally increasing efficiency [16], privatization strategies have frequently resulted in unequal access, which has prompted legal action and policy changes. Similar to this, disputes involving upstream and downstream users in shared river basins often end up before courts or arbitration panels, requiring just and sustainable legal resolutions. Water resources management law aims to balance conflicting interests and ensure long-term sustainability by resolving these issues through legislation, judicial interpretation, and international treaties in Figure 2 [17].

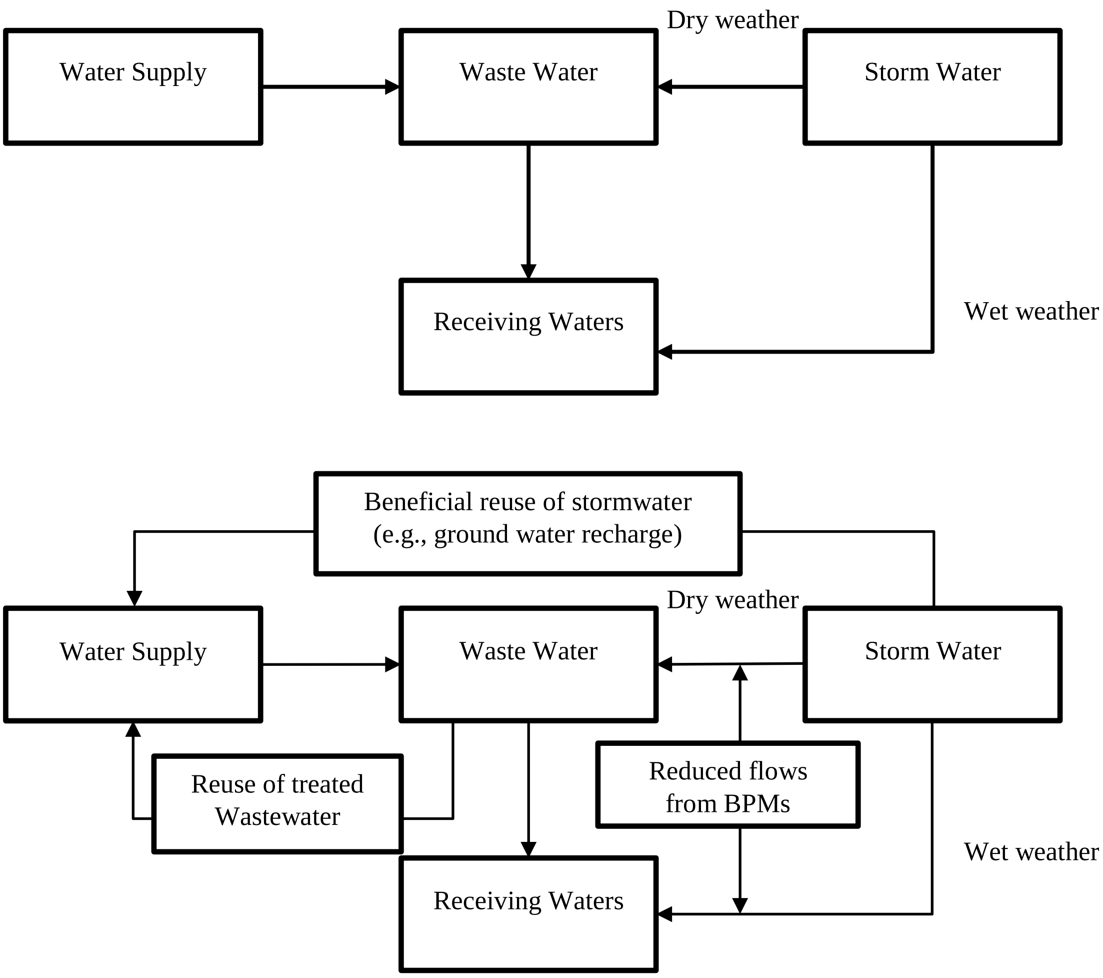

Figure 2. Water management for municipal separate storm sewer systems: traditional versus comprehensive

3.2 Challenges in managing supply and demand

Finding a balance between supply and demand management within institutional and legal frameworks is one of the main issues in the control of water resources. Despite being a limited resource, demand for water is always increasing as a result of urbanization [18], population increase, industrialization, and intensifying agriculture. Nearly 70% of freshwater withdrawals worldwide are attributed to agriculture alone, with the remaining portion being shared by families and enterprises. By changing rainfall patterns, decreasing groundwater recharge, and escalating droughts and floods, climate change makes these stresses worse. Given this, legal frameworks are being asked to control the amount of water that can be taken out, by whom, and under what circumstances, all the while maintaining ecosystem flows.

Historically, supply management has concentrated on expanding the amount of water available through infrastructure projects including groundwater extraction, dams, canals, and reservoirs. Community displacement, interstate conflicts, and ecological deterioration are only a few of the legal and ecological issues that these projects frequently entail [19]. Water diversion projects have triggered lawsuits in numerous nations over indigenous rights, environmental preservation [20], and the constitutional right to livelihood. Transboundary rivers also give rise to complicated supply management problems involving the unilateral regulation of water flows by upstream governments, which can lead to disputes with downstream states. International accords, like the 1960 Indus Waters Treaty between India and Pakistan, demonstrate how supply management issues need for legally binding agreements to avoid conflict and foster collaboration.

Demand management, on the other hand, aims to reallocate water among competing users, improve efficiency, and lower usage. Demand is controlled by use of legal tools like permit systems, allocation quotas, and water pricing. However, when price systems restrict access for underprivileged and marginalized people, these technologies raise questions about equality. For instance, lawsuits have surfaced to challenge government policies that privatize urban water supplies or implement cost-recovery methods as infringement of the right to water. Therefore, the issue for legislation and policy is to strike a balance between social justice and economic efficiency, making sure that demand management does not compromise the idea of universal access to reasonably priced and safe water.

The division of legal authority in water governance is another major challenge. Surface water, groundwater, irrigation, drinking water, and sanitation are regulated by various bodies in many jurisdictions, which results in overlapping duties and enforcement gaps. Demand and supply management are made more difficult by this fragmentation, especially when users take advantage of weaknesses or when there is a lack of institutional coordination. In a number of nations, courts have intervened to make clear the hierarchy of rights, give drinking water precedence over industrial use, and require governments to implement integrated methods to water resource management.

3.3 Legal Views on the Idea of Integrated Water Resources Management (IWRM)

The goal of integrated water resources management (IWRM), a comprehensive strategy, is to promote social and economic well-being while maintaining ecological sustainability by coordinating the development and oversight of water, land, and other resources. Unlike traditional water governance, which often focused on supply augmentation through dams, canals, and diversions, IWRM emphasizes efficiency, equity, and ecological balance. Legally, this concept requires water management frameworks that cut across sectors, balance competing demands, and integrate principles of human rights, environmental law, and sustainable development.

The principle of IWRM has been endorsed globally in documents such as the Dublin Statement on Water and Sustainable Development (1992) and Agenda 21, which stress that water should be treated as an economic good while safeguarding access as a basic human right. Many countries have incorporated IWRM into their national water laws, requiring integrated planning, stakeholder participation, and consideration of environmental flows. However, implementation has faced obstacles due to fragmented legal frameworks, institutional overlaps, and conflicts between economic development and ecological protection.

Judicial interventions have played a key role in shaping the IWRM framework. In Subhash Kumar v. State of Bihar (1991), the Indian Supreme Court recognized the right to clean water as part of the constitutional right to life under Article 21, placing an obligation on the state to prevent water pollution. Similarly, in Mazibuko v. City of Johannesburg (2009), the Constitutional Court of South Africa held that while the state must progressively realize the right to sufficient water, allocation must balance resource availability with broader public policy goals. Both cases reflect the challenge of operationalizing IWRM within legal systems — courts seek to uphold the right to water while recognizing the need for equitable distribution and sustainable use.

At the international level, transboundary water disputes also highlight the role of IWRM in legal frameworks. The Gabcíkovo-Nagymaros Project case (Hungary/Slovakia, ICJ 1997) underscored the importance of sustainable use and environmental protection in managing shared watercourses.

The International Court of Justice emphasized that development projects must be balanced with ecological considerations, echoing the core principles of IWRM. Similarly, the UN Convention on the Law of the Non-Navigational Uses of International Watercourses (1997) incorporates the doctrine of “equitable and reasonable use” and the duty to prevent significant harm — both central to IWRM.

3.4 Can Water Scarcity Issues Be Solved by Rainwater Harvesting?

Rainwater harvesting is not only an environmental and technological solution but also a matter deeply rooted in legal and policy frameworks. The recognition of the human right to water under international law, particularly in General Comment No. 15 of the UN Committee on Economic, Social and Cultural Rights, obligates States to ensure availability, accessibility, and sustainability of water resources. Within this framework, rainwater harvesting emerges as a legally relevant strategy to meet States’ duty to progressively realize this right. By encouraging decentralized water collection systems, rainwater harvesting can directly advance equitable access, particularly for marginalized rural and urban populations often excluded from centralized water supply systems.

National legal systems have also begun to institutionalize rainwater harvesting through statutory provisions, municipal by-laws, and policy directives. For instance, certain countries mandate the inclusion of rainwater harvesting structures in new residential and commercial buildings, framing the practice not merely as an optional environmental measure but as a legal obligation. This reflects a shift in the perception of water governance, where States recognize that addressing scarcity requires proactive regulation rather than reactive crisis management. Embedding rainwater harvesting in legal frameworks also provides a mechanism for accountability, ensuring that both public and private actors contribute to sustainable water resource management.

However, the legal integration of rainwater harvesting faces challenges, particularly in balancing private property rights with communal water needs. Questions often arise regarding ownership of harvested rainwater, distribution rights, and potential conflicts with existing water laws that prioritize groundwater and surface water regimes. Without harmonization, rainwater harvesting laws may create fragmentation in water governance. Therefore, a comprehensive legal approach is needed—one that aligns rainwater harvesting regulations with broader water rights regimes, environmental laws, and urban planning policies. This would not only strengthen water security but also affirm States’ compliance with international obligations under the human right to water.

4. IMPLEMENTATION AND EXPERIMENTAL RESULTS

4.1 Water in Soil: Legal and Environmental Dimensions

One of the most important yet sometimes disregarded aspects of managing natural resources is the water content of the soil. In addition to supporting agriculture and plant growth, soil water is essential for groundwater recharge, ecological balance, and hydrological cycle regulation. Soil water management is connected to both property rights and public trust obligations in the legal and policy framework. The availability and distribution of soil moisture are influenced by land-use patterns, irrigation rights, and groundwater extraction, all of which are governed by legal frameworks. Widespread soil degradation brought on by excessive groundwater extraction, carelessly managed irrigation, and industrial contamination has prompted legal and legislative actions. Since damaged soils jeopardize food security and the environment, Indian courts, for example, have construed the constitutional right to life under Article 21 to include access to clean water and healthy soil. The importance of sustainable soil and water management in stopping land degradation and ensuring equity for future generations is also emphasized by international accords such as the United Nations Convention to Combat Desertification (UNCCD). As a result, soil water is both a legal and an agronomic issue, requiring comprehensive regulatory frameworks to reconcile private land-use rights with public interests in sustainability, ecological preservation, and the realization of the human right to water.

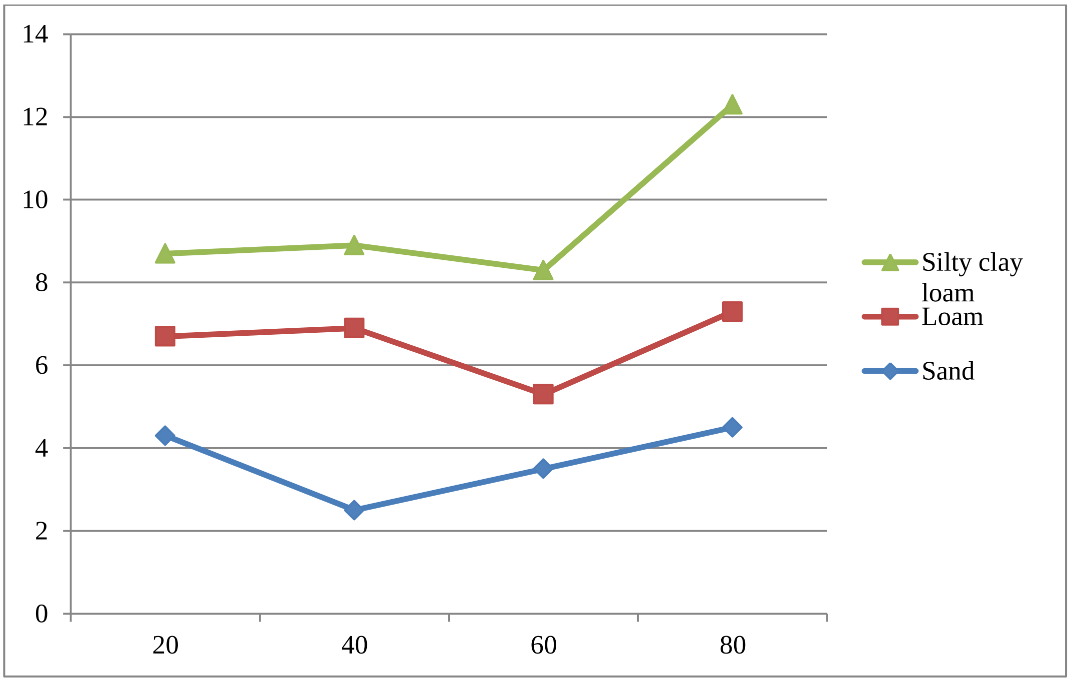

Figure 3. The average amount of water in three different types of soil

Soil plays a critical role in determining the availability and distribution of water resources, directly influencing agriculture, groundwater recharge, and the realization of the human right to water. The average water content in different soils depends on their texture, structure, and porosity. Sandy soils have large particles and wide pore spaces, which allow water to drain quickly. As a result in figure 3, their average water-holding capacity is relatively low, often retaining only about 5–10% of their volume as water. This makes sandy soil less suitable for crops that require consistent moisture, and it often necessitates supplementary irrigation.

In contrast, clay soils have very fine particles and small pore spaces, leading to high water retention but poor drainage. On average, clay soils can hold 40–50% of their volume as water. While this may seem advantageous, the tightly bound water in clay is not always available to plants, which can cause waterlogging and reduced soil aeration. Legally, this type of soil poses challenges for land use and agricultural planning, requiring regulations to manage irrigation and drainage to avoid environmental degradation.

Loamy soils, a balanced mixture of sand, silt, and clay, exhibit the most favorable characteristics. They hold an average of 20–30% water by volume, providing both sufficient retention and adequate drainage. This makes loam highly productive for agriculture and a preferred soil type in land and water management policies. In the context of water rights and natural resource law, loamy soils represent the ideal model for sustainable development because they support food security while conserving water resources. Thus, understanding the average water content in different soils is not only a scientific concern but also a legal and policy matter, guiding irrigation practices, land use regulations, and integrated water resource management strategies.

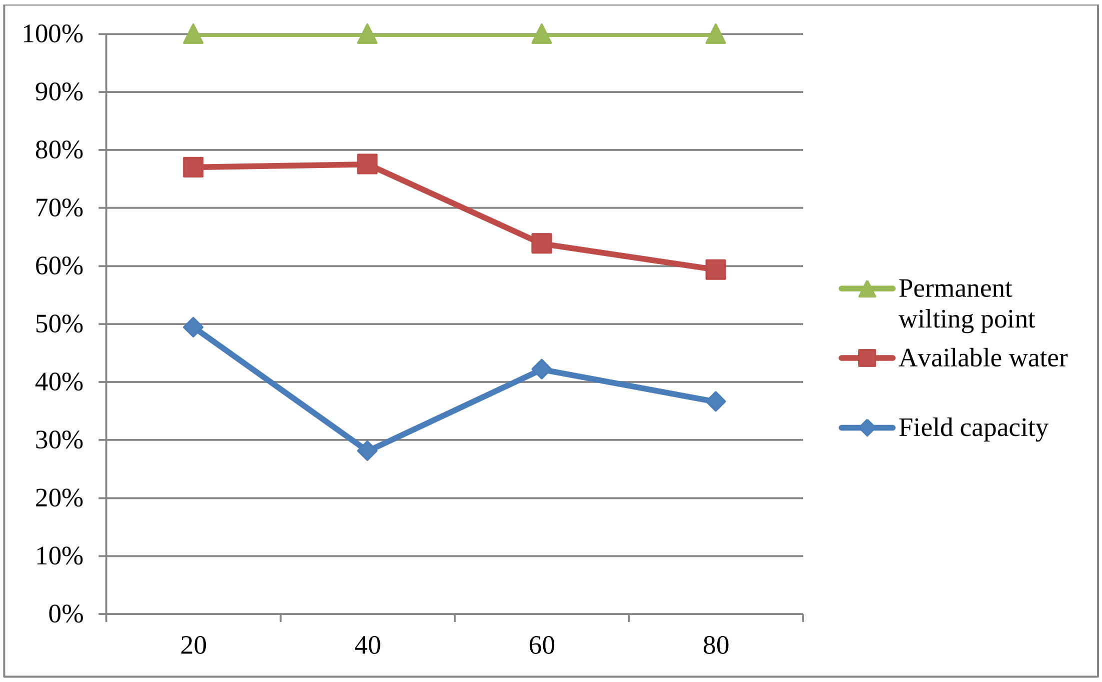

Figure 4. The connection between soil texture, permanent withering point, field capacity, soil concentration, and soil water availability

The level of soil moisture at which plants can no longer draw enough water, resulting in permanent wilting, is known as the permanent wilting point (PWP). This threshold varies depending on the texture of the soil: clay soils retain water but much of it is unavailable because of strong molecular adhesion, whereas sandy soils hit PWP quickly because they lose water quickly. The maximum quantity of water that soil can retain against gravity after surplus water has been drained away is known as the field capacity (FC). The available water capacity (AWC), a crucial indicator of the amount of water available for plant growth, is defined as the difference between field capacity and the permanent wilting threshold. Because they balance availability and retention, loamy soils usually have the highest AWC (Figure 4).

Soil concentration, particularly the presence of dissolved salts and minerals, also plays a crucial role in soil-water relationships. High soil salinity reduces the osmotic potential of water, making it more difficult for plants to absorb moisture even when the soil appears sufficiently wet. This condition, often regulated under environmental and agricultural laws, emphasizes the need for soil and water quality standards to ensure sustainable land use.

5. CONCLUSION

Numerous studies have unequivocally demonstrated that water is one of the most crucial elements influencing plant growth and development. Additionally, the productivity of various agricultural crops is significantly reduced as a result of soil water loss. Environmental influences that alter the physiological pathways of plant metabolism can have an impact on these products.

Soil properties can affect several plant functions, including nutrient uptake and utilization, water uptake and the relationship between water and plants, and physiological processes. Soil problems usually occur in areas with little or no rainfall or where evapotranspiration surpasses soil water uptake. Poor management of water resources can deteriorate soil quality, which impacts plant growth and yield.

The assessment of water resources development and exploitation within the framework of the human right to water reveals the urgent need to balance human needs, ecological sustainability, and equitable distribution. While technological advances and infrastructure development have expanded access to water, unsustainable exploitation of rivers, groundwater, and other natural sources often undermines long-term availability and violates the principle of intergenerational equity. The recognition of water as a fundamental human right by international law imposes binding obligations on States to regulate water use, prevent over-extraction, and ensure that marginalized communities are not excluded from access. Effective legal frameworks must therefore promote integrated water resources management, encourage sustainable practices such as rainwater harvesting and wastewater reuse, and establish mechanisms of accountability for both public and private actors. Ultimately, securing the human right to water requires not only adequate resource development but also careful governance that prioritizes equity, sustainability, and justice in water allocation and use.

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