accountabilitylab PAKISTAN

POLICY BRIEF

Water Governance Challenges in Pakistan

/accountlabpk pakistan.accountabilitylab.org

Contents

Glossary

- **Per Capita Water Availability**: The amount of water available per person, used to assess water scarcity.
- **Flood Irrigation**: A traditional method where water is spread over fields, causing water loss through evaporation and runoff.
- **Water Use Efficiency**: The ratio of water effectively used by crops compared to the amount diverted for irrigation.
- **Non-Revenue Water (NRW)**: Water that is produced but not billed, often due to leakage or theft.
- **Groundwater Extraction**: The process of extracting water from underground sources, which can deplete aquifers.
- **Glacier Melt**: The melting of glaciers, which contributes to river flow, crucial for countries like Pakistan.
- **Volumetric Pricing**: Charging consumers based on the amount of water they use to promote conservation.
- **Drip Irrigation**: A water-efficient irrigation system that delivers water directly to plant roots.
- **Karez System**: An underground water channel system used to bring groundwater to the surface, common in arid regions.
- **Inter-Provincial Disputes**: Conflicts over water allocation between Pakistan's provinces.
- **Transboundary Water Dynamics**: The management of shared water resources between countries, such as the Indus River.
- **Water Footprint Calculator**: A tool that tracks individual or organizational water usage.
- **Precision Agriculture**: Farming that uses technology to optimize water use and increase crop yields.
- **Desalination Plants**: Facilities that convert seawater into fresh water, useful for coastal areas.
- **Wastewater Treatment**: The process of cleaning used water to make it reusable.
- **Public-Private Partnerships (PPP)**: Collaborations between government and private companies for developing water infrastructure.
- **Stakeholder Collaboration**: Joint efforts by different groups to address water management issues.
- **Water User Associations (WUAs)**: Community organizations that manage local water resources, often for irrigation.

Executive Summary

Pakistan is facing a severe and escalating water crisis, characterized by a dramatic decline in per capita water availability, from 5,000 cubic meters in 1950 to under 860 cubic meters today. This places the country well below the "water-stressed" threshold and dangerously close to "water-scarce" levels. The crisis is driven by a confluence of factors, including population growth, inefficient agricultural practices, climate change impacts, socio-economic inequities, institutional and policy mismanagement, interprovincial disputes, and transboundary water dynamics.

Agricultural Water Use: The agricultural sector is the largest consumer of water in Pakistan, accounting for around **95% of the total fresh water used annually across all sectors**. The inefficiency of this sector is a major concern, with traditional flood irrigation methods leading to 40-60% water loss through evaporation, seepage, and runoff. Canal water use efficiency is less than 40%, and modern irrigation technologies like drip irrigation are adopted on less than 5% of irrigated land, despite their potential to reduce water use by up to 60%.

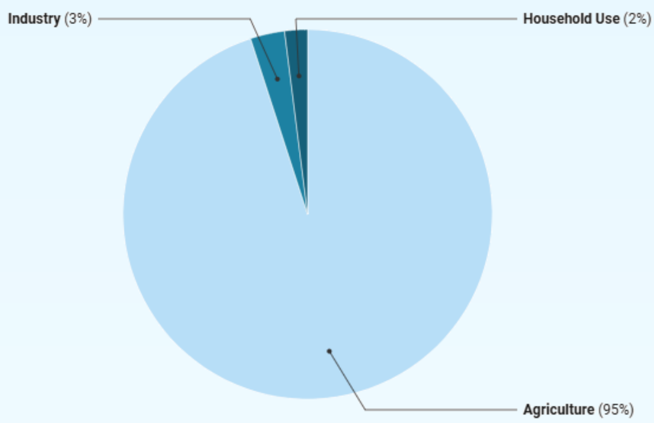

Figure 1: Inter-industry Fresh-water Use in Pakistan

Source: Government of Pakistan, Ministry of Water Resources, “National Water Policy," 2018

Urban Systems: It encompasses both water consumption by the population and industry. Non-revenue water (40-50% loss due to leakage and theft) in urban distribution systems, unregulated groundwater extraction depleting aquifers, and subsidized water tariffs disincentivize water conservation. Inadequate water supply in cities like Karachi, where demand far exceeds supply, and the reliance on expensive and often unregulated private water tankers, particularly in informal settlements.

Inefficiencies, Technological Adoptions, and Equitable Access:

- **Inefficiencies:** We identify significant inefficiencies across various aspects of water management. Canal water losses due to seepage and evaporation are estimated at 40-60%, largely attributed to unlined canals. Urban water systems suffer from high non-revenue water due to leaks and theft. Traditional flood irrigation in agriculture wastes substantial amounts of water. Groundwater extraction is largely unregulated, leading to aquifer depletion.

- **Technological Adoptions:** The adoption of water-efficient technologies remains low. Drip and sprinkler irrigation systems, which could significantly reduce agricultural water use, are used on less than 5% of cultivated land. Smart metering and precision agriculture technologies are also underutilized. Desalination and wastewater treatment, while promising, are not yet implemented at a scale sufficient to address the growing water scarcity.
- **Equitable Access:** Access to clean water is highly inequitable. Over 22 million people lack access to clean drinking water, with 84% residing in rural areas. Urban slums rely on expensive tanker water. Low-income households spend up to 10% of their income on water. Women and children, particularly in rural areas, bear the brunt of water collection, impacting their education and economic opportunities. The agricultural sector also exhibits inequities, with large landowners having better access to canal water compared to small farmers.

Pakistan's water crisis requires urgent and comprehensive reforms. Addressing the inefficiencies in the agricultural sector is paramount, given its massive water consumption. This involves promoting water-efficient irrigation technologies, lining canals to reduce seepage, and implementing volumetric water pricing to incentivize conservation.

Urban water management needs significant improvement through smart metering, reducing non-revenue water, regulating groundwater extraction, and revising water tariffs to reflect the true cost of water. Public awareness campaigns and educational programs are crucial to foster a culture of water conservation. Climate change adaptation measures, including investment in water storage infrastructure, drought-resistant crops, and flood management systems, are essential. Transboundary water issues necessitate diplomatic efforts to ensure equitable water sharing with neighboring countries.

Strengthening water governance through improved coordination among institutions, increased budgetary allocations for the water sector, and robust monitoring and evaluation mechanisms is vital. Policy solutions should prioritize equitable access to water, particularly for marginalized communities. Promoting stakeholder collaboration, involving communities, the private sector, and civil society organizations, can enhance the effectiveness and sustainability of water management initiatives. Leveraging emerging technologies, such as precision agriculture, smart irrigation, desalination, and wastewater treatment, can offer innovative solutions to address water scarcity. There is a need for a paradigm shift in Pakistan's approach to water management. Failure to address this crisis comprehensively and urgently will have severe consequences for the country's economy, food security, public health, and social stability. The recommendations provided offer a roadmap for achieving long-term water sustainability, but their success hinges on strong political will, effective implementation, and sustained commitment from all stakeholders.

Introduction

Pakistan is grappling with severe water scarcity, driven by declining per capita water availability and inefficiencies in its agricultural sector, where canal water losses are very high. On the other hand, climate change, regional disputes, particularly over water allocation and transboundary dynamics with neighboring India, coupled with socio-economic inequities in water access, further highlight the urgent need for comprehensive water management reforms.

Pakistan's annual per capita water availability has declined from approximately 5,000 cubic meters in 1950 to less than 860 cubic meters today, indicating a stark water scarcity issue. The agricultural sector's inefficiency exacerbates this crisis, with canal water losses estimated at 40-60% due to seepage and evaporation (Branch and Khan 2019). In Punjab, for instance, the irrigation efficiency remains below 35%, compared to global benchmarks of over 50%. Cities like Karachi, where daily water demand exceeds 1,200 million gallons, face shortages of nearly 600 million gallons. Groundwater extraction, which provides 70% of domestic and 50% of agricultural water needs, has led to a water table decline of 1-3 meters annually in urban centers like Lahore and Quetta, threatening long-term sustainability (The World Bank 2021). The water governance framework suffers from a lack of coordination among key institutions such as the Water and Power Development Authority (WAPDA), the Pakistan Council of Research in Water Resources (PCRWR), and provincial irrigation departments. A critical point of contention lies in the Indus River System Authority (IRSA), which is responsible for regulating and monitoring the distribution of water resources among the provinces based on the 1991 Water Apportionment Accord. However, IRSA's operations have been frequently criticized for a lack of transparency and perceived mismanagement in water distribution, leading to disputes and mistrust among the provinces.

For instance, in 2021, Sindh accused IRSA of unfair water distribution, claiming it received 37% less water than its allocated share during the Kharif cropping season. This claim was based on Sindh's measurements of water inflows at its barrages, which showed a significant shortfall compared to the allocations determined by IRSA. Sindh argued that IRSA's calculations were flawed and did not accurately reflect the actual water availability. They pointed to discrepancies in flow measurements and alleged that upstream provinces, particularly Punjab, were taking more than their allocated share. However, Punjab refuted these claims, maintaining that they were adhering to IRSA's directives and that the shortage in Sindh was due to factors like higher conveyance losses within the province.

IRSA, caught in the middle, attempted to mediate the dispute but faced challenges due to the lack of a robust, real-time monitoring system and differing interpretations of the Accord. This incident highlights the need for greater transparency in IRSA's operations, including publicly available, real-time data on water flows and allocations. Additionally, a more precise and mutually agreed-upon method for calculating water losses and distribution is needed to prevent such conflicts. An independent review mechanism could also be established to address grievances and ensure equitable distribution.

Furthermore, budgetary allocations to the water sector remain inadequate, averaging less than 0.5% of GDP over the past decade. Experts suggest that this figure needs to be increased to at least 2-3% of GDP to address the growing infrastructure needs and implement necessary reforms. This significant gap between the required and allocated budget limits the capacity for infrastructure development, maintenance, and the adoption of modern water management technologies.

Besides, only 36% of water users in urban areas have access to metered connections. While these meters measure the quantity of water supplied, they don't directly measure "efficient utilization." However, they are a crucial first step towards promoting responsible water use. By providing accurate data on consumption, meters enable the implementation of volumetric pricing and help identify leaks and wastage in the distribution system, indirectly contributing to more efficient water use.

Pakistan ranks among the top ten countries most affected by climate change, with economic losses estimated at $3.8 billion annually over the past two decades "Climate Crisis in Pakistan: Voices from the Ground - Pakistan | ReliefWeb" 2023). Glacial melt in the Hindu Kush Himalaya (HKH) region contributes to seasonal variations, with over 60% of the Indus River's flow originating from glacial sources. Extreme weather events such as the 2022 floods caused damages amounting to $30 billion, displacing over 33 million people. Rainfall variability, which has increased by 20% in the past 30 years, poses a significant risk to rain-fed agriculture in areas like Barani Punjab, which accounts for 10% of national crop production. The lack of adaptive infrastructure, such as flood retention basins, further amplifies these vulnerabilities.

Water allocation disputes between provinces under the 1991 Water Apportionment Accord are a persistent issue. Punjab, which uses over 49% of the Indus River's water, often faces accusations from Sindh for inequitable distribution (Mahmood, Khan, and Khan 2021). In 2020, Sindh's rice production dropped by 15% due to water shortages during critical growing periods. Projects like the Kalabagh Dam, projected to add 6,000 megawatts of hydroelectric capacity and store 6 million acre-feet of water, remain stalled due to opposition from Sindh and Khyber Pakhtunkhwa (From the Newspaper 2011). IRSA's operational data shows an average of 20% shortfall in meeting provincial water demands during dry years, highlighting the need for more transparent and equitable mechanisms. The Indus Waters Treaty (IWT), governing Pakistan's access to the Indus River System, is under strain due to India's construction of projects like the Kishanganga Dam, which diverts the river's flow. This diversion has reduced downstream availability in Pakistan's Neelum Valley by 16%, affecting both agriculture and hydropower generation. Pakistan's reliance on the Indus system for 90% of its freshwater resources makes it highly vulnerable to regional developments (Janjua et al. 2021).

Meanwhile, shared aquifers with Afghanistan, such as the Kabul River Basin Aquifer and the Quetta-Pishin Aquifer, remain underutilized. These aquifers hold substantial potential to supplement water supplies in Pakistan's western provinces of Khyber Pakhtunkhwa and Balochistan, but the absence of a formal water-sharing agreement with Afghanistan prevents their effective and equitable development and management. This underutilization further exacerbates water stress, particularly in these already water-scarce regions.

Over 22 million people in Pakistan lack access to clean drinking water, with rural areas accounting for 84% of this figure "Pakistan | WaterAid Global," n.d.). In Sindh, only 33% of the rural population has access to improved water sources, compared to the national average of 60% ("Rural Sindh and the Struggle for Clean Drinking Water" 2022). Urban slums in Karachi depend on tanker water, which costs up to Rs. 20 per liter, compared to Rs. 1-2 per liter for piped water. The economic burden of accessing water is particularly severe on low-income households, which spend up to 10% of their monthly income on water. Women in rural Tharparkar spend an average of three hours daily fetching water, a task that limits their participation in education and income-generating activities.

Traditional practices like flood irrigation waste up to 50% of water in agriculture, despite the availability of efficient methods such as drip irrigation, which uses 30-50% less water ("Background | on Farm Water Management" 2019). Adoption of such methods remains low, with less than 5% of cultivated land under modern irrigation systems. In urban households, average daily water usage exceeds 350 liters per person, compared to the recommended 100 liters by the United Nations (United Nations, n.d.). The slow adoption rate can be attributed to a combination of factors, including lack of awareness among farmers about the benefits of these technologies, limited access to financing and subsidies for purchasing the equipment, and insufficient technical support and training for installation and maintenance. Besides, awareness campaigns remain insufficient, indicating limited knowledge of water conservation practices (Rana et al. 2024). Investment in behavioral change programs could significantly enhance water use efficiency and reduce overall demand. Hence, addressing Pakistan's water crisis requires urgent reforms to ensure equitable access to water, improving agricultural efficiency, and fostering public awareness are crucial for securing the country's long-term water sustainability.

1. Water Scarcity and Inefficiency

The discourse on water in Pakistan must begin with its scarcity. The per capita water availability, a crucial metric, has plummeted from approximately 5,600 cubic meters in 1951 to below 1,000 cubic meters today (Davies et al. 2024). This places Pakistan far below the internationally recognized threshold of 1,700 cubic meters, defining it as a "water-stressed" country, and dangerously close to the "water-scarce" level. Population growth is a significant factor, with the population increasing from around 34 million in 1951 to over 240 million in 2024. This translates to a significantly high population growth while water availability has simultaneously declined.

The agricultural sector, responsible for about 20% of Pakistan's GDP, consumes over 90% of the nation's water resources (Raza et al. 2023). However, the efficiency of irrigation is alarmingly low. Traditional flood irrigation methods lead to an estimated 40-60% water loss due to evaporation, seepage, and runoff. On average, canal water use efficiency in areas like Multan and Faisalabad, known as the breadbasket of Pakistan, is less than 40% (Hussain et al. 2023). This means that for every 100 liters of water diverted from the canals, less than 40 liters actually reach the crops. This inefficiency is reflected in the low crop yields, with Pakistan's average wheat yield at around 3 tonnes per hectare compared to a global average of around 3.5 tonnes per hectare (Shahzad et al. 2022). Modern technologies like drip irrigation, which can reduce water use by up to 60% while increasing crop yields by 10-30%, are adopted in less than 5% of irrigated land.

The lack of storage capacity further compounds the issue. Existing dams, such as Tarbela and Mangla, have a combined storage capacity of approximately 15 MAF (million acre-feet), which is significantly less than the country's annual water demand (Khan, 1996). The proposed Diamer-Bhasha dam, planned to add 8.1 MAF of storage, has been plagued by delays with completion date pushed further away. In urban areas like Karachi and Lahore, non-revenue water (water lost due to leakage and theft) in urban distribution systems is estimated to be between 40-50%. Unregulated groundwater extraction through hundreds of thousands of tube wells depletes aquifers by 2-5 feet every year. The cost of groundwater extraction is also rising in Pakistan due to falling groundwater tables. In most of the populated areas, the water table has declined by over 200 feet in the past few years. Hence, the culture of subsidized water tariffs and underpricing (often regardless of their actual water consumption) disincentivizes conservation.

2. Climate Change Impacts

Climate change acts as a significant threat, with Pakistan ranked among the top 10 countries most vulnerable to its impacts ("Pakistan: Inter-Agency Monsoon Contingency Plan 2024 | OCHA" 2024). The country experiences an average annual temperature increase of 0.3 degrees Celsius per decade, and this warming trend is projected to accelerate. The mean temperature of Pakistan has increased by about 1°C over the last 50 years and might increase between 3-5°C by the end of this century (Ikramet al. 2016). This leads to an increased rate of glacier melt, with Himalayan glaciers losing an average of 0.3 meters in thickness per year. It has severe implications as the Indus River System's flow is heavily dependent on these glaciers. Analysis of long-term rainfall patterns indicates increased variability, with some areas facing extended droughts while others experience extreme floods. The floods of 2010, 2011, and most recently 2022, which caused damages worth billions of dollars and displaced millions, are evidence of this. The flood in 2022 affected over 33 million people (Nanditha et al. 2023).

Heat waves have increased in frequency and intensity historically, and the duration of heat waves is expected to increase more in the future (Amin et al. 2018). Higher temperatures contribute to increased evapotranspiration rates, exacerbating water stress, and creating water conflicts, especially in the agriculture sector. Drought indices indicate a significant increase in the frequency and intensity of droughts in regions like Thar, Baluchistan, and parts of southern Punjab. These areas have experienced below-average rainfall for several consecutive years, causing widespread crop failures and livestock losses.

3. Socioeconomic Inequities in Water Access

The effects of water scarcity are not distributed evenly in Pakistan, and rural households have significantly lower access to piped water compared to urban areas. These disparities in access are further amplified along economic lines. Households in the lowest income quintiles spend a large portion of their income on water purchased from expensive private water tankers, especially in cities like Karachi, where the official water supply covers only around 50% of the city (Ayub 2024). In cities, low-income neighborhoods are usually at the tail end of the distribution system and may only receive water once or twice a week for a few hours.

Waterborne diseases account for over 40% of all illnesses in Pakistan, disproportionately affecting the poor, children, and women (Ahmed et al. 2022). The burden of water collection disproportionately falls on women and children, with rural women walking an average of 1-3 hours daily for water. This greatly affects female literacy rates. In some areas, the percentage of women working is also low because water collection consumes so much time.

In the agricultural sector, large landowners, accounting for less than 10% of farmers, control majority of the irrigated land, often having better access to canal water, while small farmers and tenants are left with less reliable supply, leading to lower yields and lower economic gains (Saqib et al. 2024). The unequal access leads to food insecurity. Furthermore, most of the allocated irrigation water reaches the head end (close to the source of canal), while a limited amount reaches the tail end (Basharat, 2019).

4. Institutional and Policy Mismanagement

Canal water loss is mainly associated with conveyance losses where seepage accounts for the majority of the losses, while evaporation accounts for the remainder losses. This translates to a direct loss of approximately 24 MAF due to seepage, primarily from unlined canals (Baig 2023). The cost of lining these canals is estimated at billions of rupees, a capital expenditure often delayed due to budgetary constraints and political priorities.

Karachi's informal settlements (katchi abadis) are dependent on illegal water connections, and the unmaintained pipeline systems lead to further leaks. The average daily water supply in katchi abadis is estimated at around 50-70 liters per capita, far below the recommended standard of 150 liters per capita, leading to health issues (“Target 150” 2025). The economic burden placed on the residents of these areas to access water from private tankers further underscores the inequity.

The under-investment in water storage infrastructure is a critical problem, made worse by the alarming rate at which existing reservoirs are losing capacity due to sedimentation. It's not merely a case of not building enough dams; the capacity of the dams Pakistan already has is actively shrinking. A prime example is the Tarbela Dam, a cornerstone of the nation's water infrastructure. Studies estimate that around 200 million tons of sediment are deposited into the Tarbela reservoir each year (Hassan et al., 2022).

This relentless accumulation of sediment progressively reduces the volume of water the dam can hold, effectively diminishing its ability to regulate water flow, generate hydropower, and provide irrigation during dry periods. This means that the live storage capacity of major dams like Tarbela is decreasing rapidly, significantly increasing the country's vulnerability to water shortages, particularly during droughts.

The reduced storage capacity also hinders the effective management of peak flows during monsoon seasons, increasing the risk of flooding. The economic consequences of this declining storage capacity, coupled with the lack of sufficient new storage, are substantial, with estimated losses in agricultural productivity and hydropower generation amounting to several billion Rupees annually.

The rate of adoption for water-efficient irrigation systems, such as drip and sprinkler irrigation, is very slow. While the cost of these systems can be a deterrent, subsidies by federal and provincial governments have been limited, which is insufficient to drive large-scale adoption. It is estimated that shifting to drip irrigation could save up to 30-60% in water use, resulting in improved crop yields and economic benefits for farmers (Van der Kooij et al. 2013).

5. Interprovincial Disputes

Interprovincial disputes over water sharing, particularly between Sindh and Punjab, are a recurring problem with significant, quantifiable economic and agricultural impacts. These disputes are not merely anecdotal; they have real consequences that can be measured in terms of lost agricultural output and financial losses. During periods of water scarcity, Sindh, being the lower riparian province, often bears the brunt of the shortages. For example, studies have shown a 15-20% decline in crop yields in Sindh during water-scarce periods when irrigation supplies are inadequate ("Floods after Drought Devastate Sindh's Agriculture," n.d.).

This decline in yields is not uniform across all crops or regions within Sindh. For instance, cotton, a major cash crop for the province, is particularly vulnerable. In the tail-end areas of the irrigation system, which are the last to receive water and often face the most severe shortages, cotton yields can be drastically reduced during periods of water scarcity. Given prevailing market prices, the economic value of this cotton yield loss alone amounts to billions of Rupees each season, severely impacting the livelihoods of farmers and the provincial economy. Similarly, sugarcane, another significant crop for Sindh, also experiences substantial yield reductions due to water shortages, leading to significant financial losses for the sugar industry and impacting the livelihoods of those who are part of the industry.

Furthermore, the reduction in rice crop yields, particularly in the tail-end areas of Sindh during disputes and resultant water shortages, has long-term implications for the country's food security, as rice is a staple food for a large portion of the population. These recurring disputes and the resulting agricultural losses highlight the urgent need for a more transparent, equitable, and efficient water allocation mechanism between the provinces, as well as improved water management practices to mitigate the impacts of water scarcity.

The cost of disputes also comes in the form of delayed projects. The Kalabagh dam project, stalled due to political disagreements, had an estimated cost of 6.12 billion USD at the time it was initially proposed (Tribune 2017). The cost of delays is not just in terms of the lost storage capacity but also in terms of inflated project costs. Given the rising inflation, the estimated current cost has increased manifold. The Thal Canal, also a point of contention, has seen major delays and cost overruns due to political protests and legal battles between different provinces, and this has directly affected farmers in these regions (Khan and Majeed, 2020).

The allocation of water during the Kharif season (summer) is a crucial flashpoint. Sindh had a 15% water deficit against its allocated share, Punjab faced a 20% deficit, Khyber-Pakhtunkhwa 34%, and Balochistan 41% than their allocated shares in the Water Apportionment Accord (WAA) during the Kharif season (APP 2018). The economic losses to the farmers who rely on canal irrigation are immense, with many switching to crops that are less profitable, or abandoning farming due to water shortages. Farmers in the tail-end areas of Sindh have, on average, seen their income decrease relatively more compared to others due to insufficient irrigation water during Kharif seasons (Mangan et al. 2021). This has cascading effects on the entire local economy in these regions.

6. Regional and Transboundary Dynamics

The impact of transboundary water dynamics is not just about future risks, but also about existing challenges. There is a gradual decline in the average annual flow of the Indus River over the last 20 years. While the variability of annual flows makes precise measurements difficult, studies indicate a significant decrease in average annual flow as compared to the previous decades (Arfan et al. 2019). This decrease is attributable to various factors, including climate change, water diversion in upstream regions, and increased water usage in neighboring countries. The long-term impact of this decline is the reduction in the capacity of Pakistan to meet its growing water needs.

The melting of the Himalayan glaciers has a significant impact on river flow. It contributed roughly 50% of the Indus River's total flow in the summer (Mukhopadhyay and Khan, 2014). As the glaciers retreat, this contribution is projected to decrease by at least 20-30% in the next 50-100 years. This will not only affect the agricultural output, but also the hydro-power generation capacity in Pakistan, where almost 30% of power production is from hydro-power projects. This implies that Pakistan is not only looking at water stress for agriculture, but for its energy production as well.

The absence of water-sharing agreements with Afghanistan has severe consequences. The Kabul River, a crucial source of water for Peshawar Valley, contributes about 10% of the total

Indus system flows (Latif, 2021). The flow has decreased in the Kabul River by 15-20% in the last two decades, primarily due to increased water usage for agriculture and reduced snowmelt in the region. This is having a negative effect on the agricultural output of this region, where many rely on the river for irrigation.

7. Policy Solutions

This section discusses the potential for volumetric pricing to reduce agricultural water consumption. Let's consider the synergistic impact of coupling this with other policy changes. If volumetric pricing is introduced alongside targeted subsidies for the adoption of drip irrigation in Sindh and southern Punjab, the water savings could potentially increase to 25-30%, potentially saving up to 10-12 MAF annually. The subsidy program could be designed to cover up to 50% of the initial cost for smallholder farmers, creating an incentive for adoption, which is easily recouped through increased tax revenue generated due to increased crop yield and exports. A robust monitoring mechanism, using GIS technology to track progress, would be crucial for measuring impact.

In urban areas, the reduction of water wastage through smart metering could be further accelerated if combined with regulatory mechanisms for private water tankers. If municipalities impose stricter licensing and monitoring on the *tanker mafia*, there will be a significant reduction in water wastage. Moreover, this regulation would ensure that private suppliers are selling water at reasonable and regulated rates. The implementation costs of this are low, but it requires a political commitment from the government. Moreover, this could also ensure that the revenue generated goes directly to the municipality for infrastructure repair and upgrades.

Groundwater regulation needs a phased approach. A targeted program for groundwater recharge, combining rainwater harvesting and the restoration of *karez* systems in Balochistan, could lead to a notable annual recovery in groundwater tables over five years, and the cost of these programs is relatively low. Local communities can be actively involved in these activities, promoting ownership and sustainability. Furthermore, strict enforcement of existing laws can help to curb excessive water extraction.

Investing in the modernization of provincial irrigation departments is essential. A targeted investment focusing on training, technology upgrades, and data collection, could result in an efficiency increase of canal operations. Furthermore, there needs to be a focus on inter-departmental coordination and a more integrated approach to water management. The success of any policy is contingent on robust monitoring and evaluation mechanisms. Allocating a minimum of 2-3% of the total water sector budget for data collection and analysis would be a critical step to ensure evidence-based policymaking. This is currently lacking, and needs a robust framework, that is not politically motivated.

8. Public Awareness and Behavioral Challenges

The impact of public awareness campaigns can be amplified by tailoring the messages to specific segments of the population. A multi-pronged campaign, using a combination of traditional media, social media, and community outreach, can reach most households across the country in the first year. The cost of such campaigns is very small. Furthermore, creating localized campaigns, using local dialects and traditional messaging techniques, can increase effectiveness manifold. Furthermore, collaborating with religious leaders and community influencers is a more effective method than centralized media messaging.

Curriculum revisions that incorporate water conservation should be implemented gradually, starting with pilot programs in 100 schools in each province. The cost of these pilot programs is quite low but the knowledge gained from them can be used to scale up these programs throughout the education system. The measurable impact of these pilot programs would inform the national implementation. The target should be to train at least 10,000 teachers each year in effective methods of teaching water conservation.

If community-based awareness initiatives are linked with local level water management committees, the impact is far more pervasive. When awareness is not provided at the individual level, people rarely have the motivation to change their habits. It is also important to change people's habits by making it financially viable to change. Incentivizing local water conservation efforts, especially in water-stressed regions, can lead to measurable positive changes.

The adoption of water-saving habits can be accelerated by incorporating financial incentives and penalties. Subsidies for households that adopt water-saving measures and penalties for excessive water consumption, can serve as a tool to manage water consumption. Moreover, the implementation of a "water footprint calculator," and other similar techniques, can help citizens better understand their usage, and promote more efficient consumption.

9. Emerging Approaches and Technologies

The adoption of precision agriculture technologies holds significant promise for improving water use efficiency and agricultural productivity in Pakistan. This approach involves using a suite of technologies, including **GPS-based guidance systems, variable rate technology (VRT), remote sensing, and data analytics**, to optimize farming practices. To scale up its adoption to cover at least 10% of the total cultivated land within the next five years, a targeted subsidy program could be implemented. This program would require an initial investment to offset the costs of acquiring equipment and adopting new technologies. Precision agriculture can be unpacked and implemented in the following way:

1. **GPS-based Guidance and Variable Rate Technology (VRT):**
    - GPS guidance allows farmers to precisely map their fields and navigate machinery with greater accuracy, reducing overlap and minimizing input (water, fertilizer, pesticide) wastage.

- VRT enables farmers to apply inputs at varying rates across a field based on specific needs. For example, areas with lower soil moisture can receive more irrigation, while areas with sufficient moisture receive less. This targeted approach optimizes water use and reduces overall consumption.

2. **Remote Sensing and Soil Moisture Sensors:**
    - Remote sensing, using satellite or drone imagery, provides valuable data on crop health, soil conditions, and water stress. This information helps farmers make informed decisions about irrigation and other management practices.
    - Soil moisture sensors provide real-time data on moisture levels at different depths in the soil. This allows farmers to irrigate only when necessary and avoid over-irrigation, leading to significant water savings.
3. **Data Analytics and Decision Support Systems:**
    - Precision agriculture generates large amounts of data. Data analytics platforms can process this data and provide farmers with actionable insights, such as optimal irrigation schedules, fertilizer recommendations, and pest and disease alerts.
    - Decision support systems can further enhance these insights by integrating weather forecasts, market prices, and other relevant information to help farmers make optimal decisions.

To maximize the impact of this initiative, the program should also prioritize local manufacturing of precision agriculture equipment and promote technology transfer to Pakistani companies. This would not only reduce costs but also create local jobs and build domestic expertise in this emerging field. The economic return on investment from adopting precision agriculture is expected to be very high, driven by increased crop yields, reduced input costs (including water), and improved resource management. This approach can contribute significantly to making Pakistan's agricultural sector more resilient to water scarcity and climate change.

Smart irrigation technologies can be rolled out gradually, starting with pilot projects on selected canals by installing sensors and control systems. These technologies would enable irrigation departments to better manage the distribution of water, and would also make the system more responsive to changing water demands. The return on investment is very high due to the reduced water loss and better management capabilities.

Desalination plants for coastal regions can become financially viable if combined with renewable energy sources. The initial cost of setting up large-scale desalination plants is high, but these costs can be offset by the long-term security of water supply. A hybrid model, combining reverse osmosis (RO) technology with solar power, can reduce running costs by approximately 20-30% (Rahimi et al. 2021). Furthermore, the use of local materials for building the plants can bring down the overall cost. Furthermore, these desalinated water plants can also provide the much-needed drinking water in water-stressed regions.

A targeted investment in wastewater treatment plants, focusing on the most polluting industries and urban areas, could lead to the regular treatment of the wastewater produced, the benefits of such an investment would be immense, as this would provide a stable water source for industrial use and irrigation. Localized low-cost wastewater treatment technologies can also provide an affordable solution for rural areas.

10. Role of Stakeholders

The power of stakeholder collaboration is immense. Community-led initiatives for water management, when linked to effective government policies, have better chance of success (Kenia and Buisson, 2015). Local water committees and water user associations can be given the authority to collect tariffs and use these funds for maintenance of local water infrastructure. The financial autonomy of these committees leads to greater efficiency and lower corruption, due to enhanced community oversight.

If the private sector is involved in the process, there needs to be greater transparency and accountability. Private sector involvement in the provision of water infrastructure, if regulated, can increase the efficiency and reduce corruption. The cost of private sector involvement can also be significantly lower, if there is effective monitoring and evaluation of their services. Public-private partnerships can also accelerate the adoption of new technologies.

Civil society organizations need to be more involved in the process of governance. They can act as watchdogs and can bring accountability to government institutions. The cost-effectiveness of involving NGOs in local level awareness programs is very high and can bring about positive changes in the communities. They also bring technical expertise and access to local networks that the government lacks.

Conclusion

Pakistan faces a dire water governance crisis characterized by severe scarcity, inequities in access, and escalating environmental threats. With per capita water availability plummeting from 5,600 cubic meters in 1951 to under 1,000 cubic meters today, the nation is well below the water stress threshold. Rapid population growth, over 240 million people, has compounded this issue. The policy brief explores these challenges and potential solutions across key dimensions, emphasizing their interconnectedness.

Agriculture consumes over 90% of Pakistan's water resources but contributes just 20% to GDP, reflecting inefficient usage. Traditional flood irrigation methods lead to 40-60% water loss, and canal efficiencies in regions like Multan and Faisalabad remain below 40%. Although technologies such as drip irrigation could cut water use by 60% and boost yields, they are employed on less than 5% of irrigated land. Limited water storage further exacerbates the problem; reservoirs like Tarbela and Mangla store only 15 MAF against much higher demand.

Pakistan ranks among the ten most climate-vulnerable countries, facing significant challenges from rising temperatures and glacier melt. A 1°C temperature increase over the last 50 years and projected increases of 3-5°C by century's end accelerate the melting of glaciers feeding the Indus River System. Recent disasters, including the devastating 2022 floods, highlight the growing intensity of extreme weather events.

Water access is deeply inequitable. Rural populations have far less access to piped water compared to urban areas, and low-income households disproportionately rely on expensive private water tankers. Women and children in rural areas spend significant time collecting water, limiting educational and economic opportunities. In agriculture, large landowners monopolize access to water, leaving small farmers at a disadvantage.

Institutional inefficiencies further strain water management. Unlined canals contribute to the loss of approximately 24 MAF annually. Urban centers like Karachi face acute shortages, with informal settlements receiving only 50-70 liters per capita daily, far below the recommended 150 liters. Underinvestment in modern infrastructure and slow adoption of efficient irrigation systems compound these problems.

The Indus River's average annual flow has declined due to Himalayan glacier retreat, projected to reduce summer river flow by 20-30% in coming decades. The Kabul River, a crucial tributary, has already seen a 15-20% flow reduction, with significant impacts on agricultural productivity in areas like the Peshawar Valley.

Hence, we suggest several strategies to address these challenges. Volumetric pricing, paired with subsidies for drip irrigation, could save 10-12 MAF annually. Urban smart metering and regulation of private water tankers could curb waste and ensure equitable pricing. Rainwater harvesting and restoration of traditional systems like the karez could help recharge aquifers. Public awareness campaigns and school-based education programs are proposed to foster behavioral change.

Technological advancements, including precision agriculture and renewable-energy-powered desalination plants, hold promise for sustainable water management. Community-led initiatives and public-private partnerships are recommended to build resilient infrastructure. Effective coordination among stakeholders, transparency, and accountability are essential for the success of these interventions.

Pakistan's water crisis underscores the interplay between demographic pressures, climate change, and institutional inefficiencies. The challenges reveal the need for integrated policies that address social equity, technological adoption, and climate resilience. As similar crises loom globally, particularly in other developing nations, Pakistan's experience offers valuable lessons for sustainable water governance.

References

- Ahmed, Toqeer, Mohammad Zounemat-Kermani, and Miklas Scholz. "Climate change, water quality and water-related challenges: a review with focus on Pakistan." International Journal of Environmental Research and Public Health 17, no. 22 (2020): 8518.
- Amin, Asad, Wajid Nasim, Shah Fahad, Shaukat Ali, Shakeel Ahmad, Atta Rasool, Nadia Saleem, et al. "Evaluation and analysis of temperature for historical (1996–2015) and projected (2030–2060) climates in Pakistan using SimCLIM climate model: ensemble application." Atmospheric Research 213 (2018): 422-436.
- Arfan, Muhammad, Jewell Lund, Daniyal Hassan, Maaz Saleem, and Aftab Ahmad. "Assessment of spatial and temporal flow variability of the Indus River." Resources 8, no. 2 (2019): 103.
- Basharat, Muhammad. "Water management in the Indus Basin in Pakistan: challenges and opportunities." Indus River Basin (2019): 375-388.
- Davies, Stephen, Iqra Akram, Muhammad Tahir Ali, Mohsin Hafeez, and Claudia Ringler. The economywide impacts of increasing water security through policies on agricultural production: the case of rice and sugarcane in Pakistan. International Food Policy Research Institute, 2024.
- Hashmi, S. B., & Kausar, S. W. A. (2024). Effectiveness of Water Policy of Pakistan in Enabling Stakeholder Participation. Journal of Development and Social Sciences, 5(3), 376-388.
- Hassan, Shahzal, Nadeem Shaukat, Ammar Ahmad, Muhammad Abid, Abrar Hashmi, Muhammad Laiq Ur Rahman Shahid, Zohreh Rajabi, and Muhammad Atiq Ur Rehman Tariq. "Prediction of the amount of sediment deposition in Tarbela Reservoir using machine learning approaches." Water 14, no. 19 (2022): 3098.
- Hussain, Sajjad, Muhammad Mubeen, Wajid Nasim, Shah Fahad, Musaddiq Ali, Muhammad Azhar Ehsan, and Ali Raza. "Investigation of irrigation water requirement and evapotranspiration for water resource management in Southern Punjab, Pakistan." Sustainability 15, no. 3 (2023): 1768.
- Ikram, F., M. Afzaal, S. A. A. Bukhari, and B. Ahmed. "Past and future trends in frequency of heavy rainfall events over Pakistan." Pakistan Journal of Meteorology 12, no. 24 (2016).
- Kenia, Nandish, and Marie-Charlotte Buisson. "How successful are community-led organizations for water management? Evidence from an assessment of Water Management Organizations in Coastal Bangladesh." In Revitalizing the Ganges Coastal Zone: Turning Science into Policy and Practices Conference Proceedings. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food (CPWF), 2015.
- Khan, Asim Rauf. "A two-state deterministic dynamic programming model for optimising the joint operation of Mangla and Tarbela reservoirs in Pakistan." PhD diss., University of British Columbia, 1996.
- Khan, Tariq Anwar, and Gulshan Majeed. "Water management in Pakistan: roots of interprovincial conflicts." Journal of Politics and International Studies 6, no. 02 (2020): 103-113.
- Latif, Yasir, Yaoming Ma, and Weiqiang Ma. "Climatic trends variability and concerning flow regime of Upper Indus Basin, Jehlum, and Kabul River basins Pakistan." Theoretical and Applied Climatology 144 (2021): 447-468.
- Mangan, Tehmina, Ghulam Nabi Dahri, Muhammad Ashfaq, Richard Culas, Irfan Baig, Jehangir F. Punthakey, and Mustafa Nangraj. "Improving groundwater management to enhance agriculture and farming livelihoods: Socio-economic assessment for improving groundwater management in the Left Bank Command of the Sukkur Barrage, Sindh Pakistan." (2021).

- Mukhopadhyay, Biswajit, and Asif Khan. "A quantitative assessment of the genetic sources of the hydrologic flow regimes in Upper Indus Basin and its significance in a changing climate." Journal of Hydrology 509 (2014): 549-572.
- Nanditha, J. S., Anuj Prakash Kushwaha, Rajesh Singh, Iqura Malik, Hiren Solanki, Dipesh Singh Chuphal, Swarup Dangar, Shanti Shwarup Mahto, Urmin Vegad, and Vimal Mishra. "The Pakistan flood of August 2022: causes and implications." Earth's Future 11, no. 3 (2023): e2022EF003230.
- Rahimi, Bijan, Hamed Shirvani, Ali Asghar Alamolhoda, Fathollah Farhadi, and Mohammadreza Karimi. "A feasibility study of solar-powered reverse osmosis processes." Desalination 500 (2021): 114885.
- Rana, A. W., Gill, S., Meinzen-Dick, R. S., & ElDidi, H. (2024). Strengthening groundwater governance in Pakistan. Intl Food Policy Res Inst.
- Raza, Muhammad Yousaf, Rongxin Wu, and Boqiang Lin. "A decoupling process of Pakistan's agriculture sector: Insights from energy and economic perspectives." Energy 263 (2023): 125658.
- Saqib, Shahab E., Muhammad Yaseen, Shoukat Ali, and Supawan Visetnoi. "Agricultural Land Conversion and Challenges for Tenant Farmers: Empirical Evidence From Pakistan." Land Degradation & Development (2024).
- Shahzad, A., A. Hamid, A. Hussain, M. Rashid, M. Khan, and Z. Hussain. "Current situation and future prospects of wheat production in Pakistan." Journal of Life and Social Sciences 2022, no. 1 (2022): 5-5.
- Van der Kooij, Saskia, Margreet Zwarteveen, Harm Boesveld, and Marcel Kuper. "The efficiency of drip irrigation unpacked." Agricultural Water Management 123 (2013): 103-110.
- Branch, Malik, and Adnan Khan. 2019. “Evaluation of Water Losses in Unlined Canal: A Case Study Of.” https://thesis.cust.edu.pk/UploadedFiles/Adnan%20Ahmad%20Khan%20final%20.pdf.
- The World Bank. 2021. “Managing Groundwater Resources in Pakistan’s Indus Basin.” World Bank. March 25, 2021. https://www.worldbank.org/en/news/feature/2021/03/25/managing-groundwater-resources-in-pakistan-indus-basin.
- “Climate Crisis in Pakistan: Voices from the Ground - Pakistan | ReliefWeb.” 2023. Reliefweb.int. June 22, 2023. https://reliefweb.int/report/pakistan/climate-crisis-pakistan-voices-ground.
- Mahmood, Amjad, Ahmad Fraz Khan, and Mohammad Hussain Khan. 2021. “Water Politics Brings Punjab, Sindh Face to Face.” DAWN.COM. June 6, 2021. https://www.dawn.com/news/1627807.
- From the Newspaper. 2011. “Kalabagh Dam: Some Suggestions.” DAWN.COM. December 25, 2011. https://www.dawn.com/news/683195/kalabagh-dam-some-suggestions.
- Janjua, Shahmir, Ishtiaq Hassan, Shoaib Muhammad, Saira Ahmed, and Afzal Ahmed. 2021. “Water Management in Pakistan’s Indus Basin: Challenges and Opportunities.” Water Policy 23 (6). https://doi.org/10.2166/wp.2021.068.
- “Pakistan | WaterAid Global.” n.d. Www.wateraid.org. https://www.wateraid.org/where-we-work/pakistan.
- “Rural Sindh and the Struggle for Clean Drinking Water.” 2022. The Friday Times. March 21, 2022. https://thefridaytimes.com/21-Mar-2022/rural-sindh-and-the-struggle-for-clean-drinking-water.
- “Background | on Farm Water Management.” 2019. Agripunjab.gov.pk. 2019. https://ofwm.agripunjab.gov.pk/about_background.
- United Nations. n.d. “Water.” United Nations. https://www.un.org/en/global-issues/water.

- "Pakistan: Inter-Agency Monsoon Contingency Plan 2024 | OCHA." 2024. Www.unocha.org. June 28, 2024. https://www.unocha.org/publications/report/pakistan/pakistan-inter-agency-monsoon-contingency-plan-2024.
- Ayub, Imran. 2024. "Karachi Gets Only 50pc of Its Water Needs, Minister Tells PA." DAWN.COM. June 13, 2024. https://www.dawn.com/news/1839521.
- Baig, Zahid. 2023. "Pakistan Not Running out of Water: Report." Brecorder. April 2023. https://www.brecorder.com/news/40234921.
- "Target 150." 2025. Southeastwater.com.au. 2025. https://southeastwater.com.au/water-waste-and-environment/saving-water/target-150/.
- "Floods after Drought Devastate Sindh's Agriculture." n.d. Www.preventionweb.net. https://www.preventionweb.net/news/floods-after-drought-devastate-sindhs-agriculture.
- Tribune. 2017. "Kalabagh Dam Cost of Delays." The Express Tribune. December 28, 2017. https://tribune.com.pk/letter/1594426/kalabagh-dam-cost-delays.
- APP. 2018. "Water Shortfall Faced by Rabi Crops to Ease in Nov." The Express Tribune. October 10, 2018. https://tribune.com.pk/story/1822974/water-shortfall-faced-rabi-crops-ease-nov.