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Internal Challenges in the Management of Pakistan's Water Resources: A Semi-Systematic Literature Review

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Research Assistant

Working Paper

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Abstract

The present study identifies major internal challenges in the way of effective water resource management in Pakistan at micro, meso, and macro levels through a semi-systematic literature review (SSLR) method. The review found 24 major internal challenges to the management of Pakistan's water resources that were synthesised into eight categories: economic and financial; information; policy, legal and regulatory; institutional; technical; awareness; social, cultural, and behavioural; and mega trends. The results show that challenges related to mega trends, including the interconnected problems of rapid population growth and urbanisation were discussed the most in selected publications. The second most discussed challenges were institutional ones, including coordination and capacity issues. Technical and policy, legal, and regulatory challenges also had a prominent representation in selected publications, compared to other challenges, except institutional and those related to mega trends. Social, cultural, and behavioural challenges were the least discussed in the reviewed literature. The study notes that there is a need to recognise and take required measures to manage population growth and urbanisation rates, implement institutional reforms in the water sector, and pursue a collaborative approach involving multiple stakeholders if Pakistan is to tackle its worsening water scarcity threat decisively.

Keywords: Water Scarcity, Water Mismanagement, Population Growth, Water Quantity, Water Quality.

1. Introduction

Water scarcity is recognised as one of the most significant threats facing humanity today. Acknowledging this, the United Nations (UN) Sustainable Development Goal (SDG) 6.4 calls for minimising the number of people experiencing scarcity of water by the year 2030. The UN broadly describes water scarcity as the 'unavailability of water due to physical shortage, or its inaccessibility due to the institutional failure to ensure a regular supply of water or the lack of adequate infrastructure.' Today, the stress on this finite resource is rapidly surging, attributable to the ever-augmenting climatic changes, continuously increasing water demand, and over-exploitation of water resources by human beings. Over the course of almost two centuries, the annual mean global temperature has significantly risen. The mean global temperature in 2022 was found to be equivalent to 1.15°C above the average of 1850-1900,[1] due to accelerated melting of glaciers and frequent extreme weather events, including droughts and heatwaves, which are directly linked to water stress. Pollution by agricultural, human, and industrial waste is further burdening this meagre resource by contaminating major water resources. Current water resources support a global population of 8.1 billion[2] and with increase in population to 9.7 billion in 2050 would indeed fall short as this would increase demand by about 40%.[3]

In Pakistan, the challenge of water scarcity is even more pronounced due to its greater vulnerability to global climate change and water mismanagement, putting an immense burden on this resource. Presently, Pakistan has storage capacity in the Indus Basin of approximately 9% of the average annual inflow, compared to estimated global average of 40%,[4] leading to water wastage. Productivity and efficiency of water are also exceedingly low in Pakistan,[5] and in terms of water usage rate, Pakistan is ranked

1 World Meteorological Organisation, "Global Temperatures Set to Reach New Records in Next Five Years," press release, May 17, 2023, https://public-old.wmo.int/en/media/press-release/global-temperatures-set-reach-new-records-next-five-years.
2 Worldometer, "Current World Population," Accessed November 27, 2023, https://www.worldometers.info/world-population/.
3 World Bank, "Water in Agriculture," October 5, 2022, https://www.worldbank.org/en/topic/water-in-agriculture.
4 Muhammad Aslam Rasheed and Daud Ahmed, "Storage and Hydropower," in *Water Policy in Pakistan: Issues and Options*, ed. Mahmood Ahmad (Cham: Springer, 2023), 200, https://doi.org/10.1007/978-3-031-36131-9.
5 Shahid Ahmad, "Water Sector of Pakistan: A Situational Analysis," *Development Advocate Pakistan*, December, 2016, sec. A., 7.

fourth in the world.[6] Besides water quantity, mismanagement of water quality adds to the challenge, as inadequate safety measures for agriculture, industrial and domestic wastage disposal continue to pollute surface and groundwater resources.[7] Therefore, only 36% of the population has access to safe water.[8]

Consequently, Pakistan's per capita water availability has declined to less than a thousand cubic metres (m³) from 5,650 m³ in 1951.[9] Experts suggest that the per capita availability of surface water will reduce to 860 m³ by 2025,[10] and Pakistan may reach a state of absolute water scarcity by 2040. Based on an agro-economy, the country derives 23% of its GDP from agriculture, which directly or indirectly absorbs a labour force of 37.4% and accounts for 70% of its exports.[11] Moreover, over 70% of people in rural areas predominantly rely on natural resources for survival, and every three in four poor people depend on natural resources and farms for their livelihood.[12] Thus, effect of water scarcity on the nation's economy and human security of the masses is and will continue to be devastating. For reference, poor water management is projected to cost Pakistan around USD 12 billion per year, or 4% of the GDP.[13] Another estimate suggests that the total GDP losses might reach up to 11.07% by the year 2040 under various water shortage scenarios.[14] Additionally, Pakistan's welfare

6 Shahzaib Ahmad, Jaudat Zahra, Mohsan Ali, Sibgha Ali, Sana Iqbal, Sidra Kamal, Maliha Tahir and Abdullah Tundi Aborode, "Impact of Water Insecurity Amidst Endemic and Pandemic in Pakistan: Two Tales Unsolved," *Annals of Medicine and Surgery* 81, (2022), https://doi.org/10.1016%2Fj.amsu.2022.104350.

7 Ahmad, "Water Sector of Pakistan: A Situational Analysis," 7.

8 Global Waters, "Pakistan," Accessed November 28, 2023, https://www.globalwaters.org/wherewework/asia/pakistan.

9 "Water Availability Down to Alarming Levels: WAPDA," *Express Tribune*, November 29, 2023, https://tribune.com.pk/story/2388645/water-availability-down-to-alarming-levels-wapda.

10 Muhammad Ibrahim Shafi, "Environment: Every Drop Cunts!" *Dawn*, April 29, 2023, https://www.dawn.com/news/1749843.

11 Food and Agricultural Organisation of the United Nations, "Pakistan at a Glance," Accessed November 27, 2023, www.fao.org/pakistan/our-office/pakistan-at-a-glance.

12 Dianxi Zhang, Muhammad Safdar Sial, Naveed Ahmad, António José Filipe, Phung Anh Tu, Malik Zia-Ud-Din and António Bente Caleiro, "Water Scarcity and Sustainability in an Emerging Economy: A Management Perspective for Future," *Sustainability* 13, no. 1 (2021): 144, https://doi.org/10.3390/su13010144.

13 World Bank, "Pakistan's Scarce Water Can Bring More Value to People and Economy," press release, February 4, 2019, https://www.worldbank.org/en/news/press-release/2019/02/04/pakistans-scarce-water-can-bring-more-value-to-people-and-economy.

14 Muhammad Zeeshan and Muhammad Shakeel, "Water Crisis in Pakistan: A Dynamic CGE-Water Mode," *Research Square*, May 3, 2021, https://assets.researchsquare.com/files/rs-337680/v1_covered.pdf.

loss due to water scarcity is expected to range between USD 3.6 and 10.9 billion by 2030.[15]

Thus, addressing current challenges that are directly or indirectly responsible for mismanagement of water resources remains imperative. In view of this, this study aims to highlight major internal factors that are constraining effective management of the country's water resources. The purpose is to call attention to issues that must be urgently addressed to ensure Pakistan's short- and long-term water security. To this end, a Semi-Systematic Literature Review (SSLR) was undertaken to gather, synthesise, and evaluate existing evidence regarding the subject under consideration. The paper has been split into five sections. Following the introduction, the second section presents the methodology employed to conduct the review. Section three details the results. Section four discusses the results, while section five provides a conclusion and highlights policy implications.

2. Methodology

The present study was undertaken using the Semi-Systematic Literature Review (SSLR) method, which is particularly useful for investigating a broad topic. This method involves developing a strategy for literature search on a specific topic, selecting relevant studies/publications for review that meet a pre-determined criteria, systematically analysing identified literature, and synthesising research results to determine key themes. While the SSLR method involves a systematic literature analysis, similar to a Systematic Literature Review (SLR), it provides some flexibility in the search and selection process, such as by allowing for a relatively less exhaustive search process.

The literature search for the review was carried out in November 2023 on the Scopus Electronic Database, i.e., the largest database of peer-reviewed literature.[16] The search terms for identifying relevant literature included (water) AND (scarcity) AND (Pakistan); (water) AND (management) AND (challenges) AND (Pakistan); (water)

15 Zeeshan and Shakeel, "Water Crisis in Pakistan," 1.

16 Amila Omazic and Bernd Markus Zunk, "Semi-Systematic Literature Review on Sustainability and Sustainable Development in Higher Education Institutions," *Sustainability* 13, no. 14 (2021): 7683, https://doi.org/10.3390/su13147683.

AND (mismanagement) AND (Pakistan); and (water) AND (insecurity) AND (Pakistan). The terms were to be searched within the publications' titles, abstracts, and keywords.

Inclusion criteria in the search were as follows: all English-language publications, including research articles, conference papers, book chapters, books, review papers, conference reviews, and reports published between 2013 and 2023. According to the general rule of thumb, a ten-year window is recommended for a literature search for studies aiming to capture contemporary insights.[17] In other words, a ten-year time frame is appropriate if the review objectives aim to gather contemporary challenges or trends.[18] In such a context, relatively older findings are considered utilisable if their continued validity is supported by research findings from the past ten years.[19] The present study was undertaken not to trace the historical roots of Pakistan's water scarcity problem but to identify current challenges that constrain effective management of its water resources; hence, a ten-year time frame for literature search was deemed appropriate.

Exclusion criteria in the search were as follows: notes, letters, short surveys, editorials, erratum, retracted papers, data papers, abstract reports, and business articles, all publications before 2013, and publications in languages other than English. Filters in Scopus were applied following these criteria.

The initial literature search, incorporating the above-mentioned criteria, yielded 563 records filtered to 509 after removing duplicates by title. Another 366 records were excluded after reviewing the abstracts and titles in the screening process, and a further 94 were excluded after reviewing the complete text, leaving 49 publications. The exclusion and inclusion criteria in the process of screening and determining eligibility of the publications was to incorporate all publications, including case studies, that highlighted or discussed the internal challenges for water resource management in Pakistan and exclude publications irrelevant to addressing the research objective. Six

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17 Patricia Cronin, Frances Ryan and Michael Coughlan, "Undertaking A Literature Review: A Step-By-Step Approach," *British Journal of Nursing* 17, no. 1 (2008): 38-43, https://doi.org/10.12968/bjon.2008.17.1.28059; Nina Machin, "CHS 211 Literature Review," *University Writing & Speaking Center*, Accessed November 27, 2023, https://www.unr.edu/writing-speaking-center/writing-speaking-resources/chs-211-literature-review.

18 Timothy Meline, "Selecting Studies for Systematic Review: Inclusion and Exclusion Criteria," *Contemporary Issues in Communication Science and Disorders* 33, (2006): 21-27, 1092-5171/06/3301-0021.

19 Law Insider, "Contemporary Research Definition," Accessed July 12, 2024, https://www.lawinsider.com/dictionary/contemporary-research.

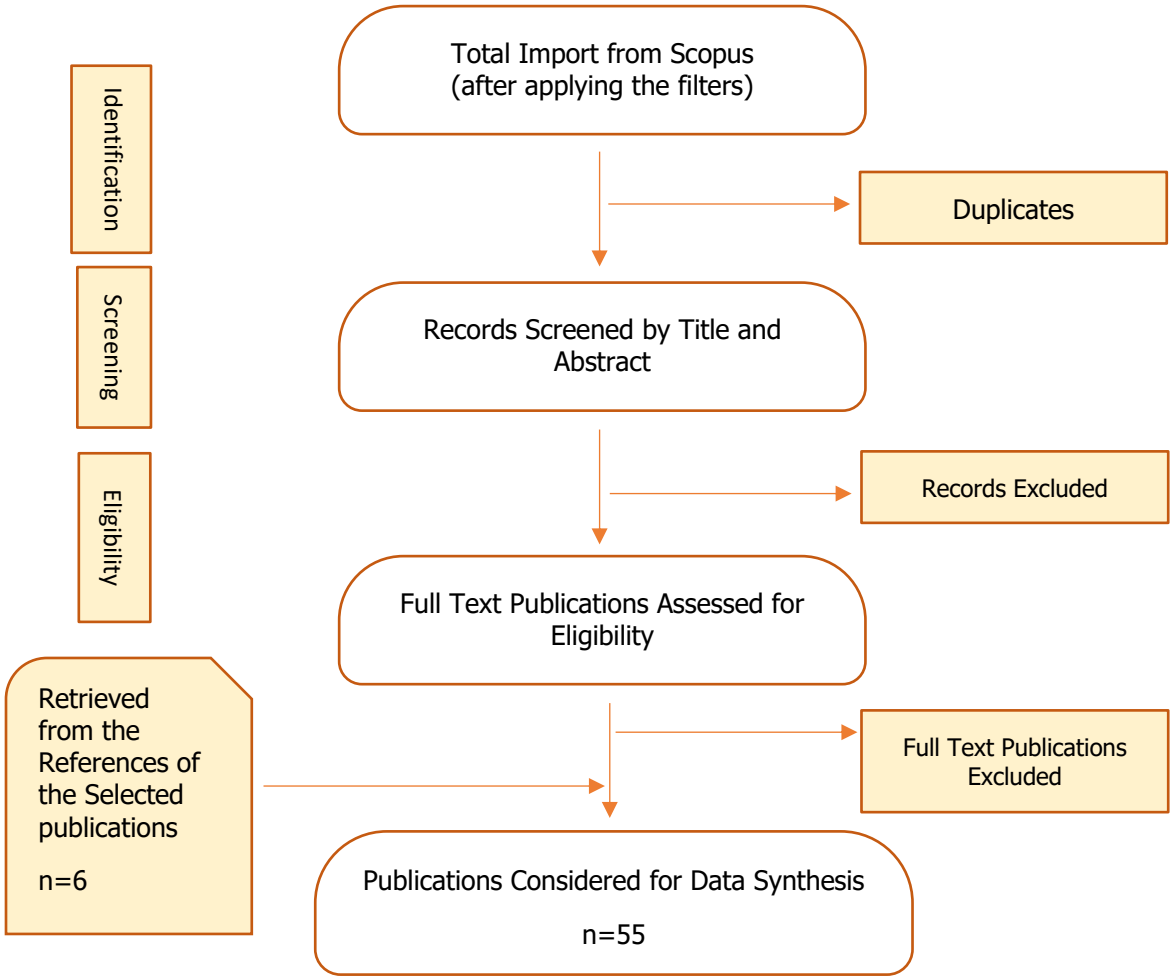
other relevant studies were retrieved from references of selected publications and considered for data synthesis and analysis. The PRISMA flow diagram in Figure 1 illustrates and summarises the literature search and selection process.

The final synthesis stage combined and evaluated the data from selected publications to determine review outcomes. The 'Best Fit Framework Synthesis' (BFFS) approach was employed for data synthesis considered a flexible approach for integrating primary and secondary data.[20] It provides a framework against which findings from different components of the literature assessment can be synthesised and organised. BFFS allows a researcher to select a framework that aligns with the research objective/questions and offers flexibility to expand the framework by adding additional aspects to incorporate data that may not fit within the concepts or categories of the selected framework.[21] A framework based on several categories employed for barrier analysis in the field of climate change was identified from the literature (*refer to section 3*). It was found to be the 'best-fit' pre-existing framework to help bring together and organise the findings for the present review study. The framework was also expanded to incorporate data that may not fit within the pre-determined categories of the selected framework (*see section 3*). Figure 1 visually illustrates the search and selection process as explained in detail above. Briefly, 563 studies were imported from Scopus electronic database; 54 duplicates were excluded; remaining 509 records were screened by title and abstract; 366 of the 509 records found to be irrelevant were excluded; the remaining 143 full-text publications were assessed for eligibility; 94 publications were excluded after reviewing the complete text; and six relevant studies were retrieved from references of selected publications. In the end, findings from 55 studies were reviewed and synthesised.

[20] Andrew Booth and Christopher Carroll, "How to Build Up the Actionable Knowledge Base: The Role of 'Best Fit' Framework Synthesis for Studies of Improvement in Healthcare," *BMJ Quality and Safety* 24, (2015): 700-708, doi:10.1136/bmjqs-2014-003642.

[21] National Centre for Biotechnology Information, "Three Approaches to Analysis in Systematic Reviews of Qualitative Studies," Accessed November 27, 2023, https://www.ncbi.nlm.nih.gov/books/NBK569586/box/ch4.box12/?report=objectonly.

Figure 1: PRISMA Flow Diagram: Search and Selection Process



Source: *Author's own.*

3. Results

The following section identifies and integrates the internal challenges for effective water resource management in Pakistan in terms of quantity and quality at micro, meso, and macro levels, as presented in the selected publications. Challenges discussed in at least two publications were considered. The framework based on six categories, including 'information', 'awareness', 'economic and financial', 'social, cultural, and behavioural', 'policy, legislative, and regulatory', and 'technical', was selected to categorise the challenges. These categories have earlier been employed for barrier analysis in the field of climate change.[22] An additional category of

[22] Qamar uz Zaman Chaudhry, Muhammed Irfan Tariq and Expert Working Group on Adaptation, Ministry of Climate Change, *Technology Needs Assessment for Climate Change Adaptation: Barrier Analysis and Enabling Framework*, report (Ministry of Climate Change, Government of Pakistan, 2016),

'institutional' was added, and a category of 'mega trends' was included to incorporate the mega trends at the national level that pose a challenge for water resource management in Pakistan. Mega trends refer to large-scale, long-term global or national changes that significantly shape policies, economies, and societal priorities. In water resource management, these can include trends like rapid urbanisation, climate change, population growth, technological advancements, and shifts in economic or agricultural practices. For Pakistan, addressing water challenges requires understanding how these overarching forces drive demand, affect supply, and influence governance structures.

3.1. Economic and Financial

3.1.1. High initial investment and operational costs of high-efficiency irrigation methods and farmers' monetary constraints

Pakistan is a water-intensive economy, with 95% of its water used in agriculture, primarily for irrigation.[23] Flood irrigation, which involves covering entire fields with water, remains the most commonly used irrigation method in Pakistan, despite being highly inefficient. Non-traditional methods, such as drip irrigation (delivering water directly to root zones), sprinkler irrigation (simulating controlled rainfall), and laser land leveling (smoothing land for uniform water distribution), have shown significant potential for improving water-use efficiency and productivity. However, in Pakistan, adoption of these high-efficiency irrigation methods remains limited due to their high initial investment and operational costs,[24] making their adoption costly for a significant proportion of the country's farmers.[25] For reference, in Punjab, over 80% of farmers

https://mocc.gov.pk/SiteImage/Misc/files/PAK%20TNA%20BAEF%20FINAL%20DEC%202016%20(29-3-17).pdf.

23 Shahid Ahmad and Ghufran Ahmad, "Water Supply and Demand: National and Regional Trends," in *Water Policy in Pakistan: Issues and Options*, ed. Mahmood Ahmad (Cham: Springer, 2023), 100, https://doi.org/10.1007/978-3-031-36131-9.

24 Mobin-ud-Din Ahmad, Ilyas Masih and Mark Giordano, "Constraints and Opportunities for Water Savings and Increasing Productivity through Resource Conservation Technologies in Pakistan," *Agriculture, Ecosystems, and Environment* 187, (2014): 106-115, https://doi.org/10.1016/j.agee.2013.07.003; Muhammad Abid, Mohsin Hafeez and Muhammad Arif Watto, "Sustainability Analysis of Irrigation Water Management in Punjab, Pakistan," in *Water Resources of Pakistan: Issues and Impacts*, ed. Muhammad Arif Watto, Michael Mitchell and Safdar Bashir (Cham: Springer, 2021), 139, https://doi.org/10.1007/978-3-030-65679-9; Muhammad Naveed Anjum, Muhammad Jehanzeb, Masud Cheema, Fiaz Hussain and Ray-Shyan Wu, "Precision Irrigation: Challenges and Opportunities," in *Precision Agriculture: Evolution, Insights, and Emerging Trends*, ed. Qamar Zaman (Cambridge: Academic Press, 2023), 139, https://doi.org/10.1016/C2022-0-01117-X.

25 Syed Muhammad Khair, Shahbaz Mushtaq, Kate Reardon-Smith and Jenny Ostini, "Diverse Drivers of Unsustainable Groundwater Extraction Behaviour Operate in an Unregulated Water

have small landholdings of less than two hectares and lack the capital to adopt high-efficiency irrigation methods.[26] Financial assistance in the form of soft loans should be provided to users of high-efficiency irrigation technologies, while adequate efforts should be made to mobilise funding from international and national funding sources for their free-of-cost diffusion among small farmers.

3.1.2. Cost considerations for installation of household water conservation systems

Household water conservation systems, like rainwater harvesting (RWHS), can significantly improve urban water management, as domestic use constitutes a major share of city water demand. Recently, cities like Lahore have incorporated RWHS installation into building regulations for new residential constructions.[27] However, uptake remains slow, with the perceived high installation cost being a key barrier to widespread adoption of RWHS at the household level.[28] In addition to RWHS, other water conservation systems, such as sprinkler systems for garden irrigation, face limited adoption due to their perceived high costs and maintenance challenges.[29] Community programmes should promote awareness of the long-term benefits of water conservation systems and highlight cost-effective installation methods, such as incorporating them during property construction.

3.1.3. High establishment, operational, and maintenance costs of wastewater treatment facilities

Despite worsening water quality, water treatment remains inadequate across Pakistan, from small and mid-tier cities to large metropolitans.[30] In Lahore, much of the untreated wastewater is discharged into River Ravi, which supplies water to

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Scarce Region," *Journal of Environmental Management* 236, (2019): 340-350, https://doi.org/10.1016/j.jenvman.2018.12.077; Abid, Hafeez and Watto, "Sustainability Analysis of Irrigation Water Management in Punjab, Pakistan," 139; M. Awais Ali Khan, Khalid Mahmood Ch, Ijaz Ashraf, Muhammad Tahir Siddique and Jerry W. Knox, "Evaluating Socio-economic and Environmental Factors influencing Farm-level Water Scarcity in Punjab, Pakistan," *Irrigation and Drainage* 70, no. 4 (2021): 797-808, https://doi.org/10.1002/ird.2552.

26 Abid, Hafeez and Watto, "Sustainability Analysis of Irrigation Water Management in Punjab, Pakistan," 139.

27 Muhammad Shafaat Nawaz, "An Assessment of Rainwater Harvesting System in Residential Buildings in Lahore, Pakistan," *Urban Water Journal* 18, no. 3 (2021): 163-172, https://doi.org/10.1080/1573062X.2020.1860239.

28 Ibid., 167.

29 Toqeer Ahmed, Sardar Muhammad Zahir and Anwar Ahmad, "Consumer Perception and Behaviour Toward Water Supply, Demand, Water Tariff, Water Quality, and Willingness-To-Pay: A Cross-Sectional Study," *Water Resource Management* 36, (2022): 1339-1354, https://doi.org/10.1007/s11269-022-03085-5.

30 Erum Sattar, "The Political Economy of Water," in *Water Policy in Pakistan: Issues and Options*, ed. Mahmood Ahmad (Cham: Springer, 2023), 49, https://doi.org/10.1007/978-3-031-36131-9.

downstream communities. Similarly, in Karachi, over 80% of sewage is dumped into the Arabian Sea without treatment.[31] Financing new wastewater treatment plants is a major challenge,[32] while existing facilities in cities like Islamabad, Faisalabad, and Karachi struggle with inadequate functionality due to financial constraints in maintenance and operations.[33] Many plants, such as those in Faisalabad, were established with donor assistance, but their long-term operations have been hindered by the exhaustion of donor funds.[34] Redirecting adequate budgetary resources from the water sector allocation is essential to expand, upgrade, and sustain water treatment facilities nationwide.

3.1.4. Budgetary constraints faced by relevant authorities

Water resource management authorities frequently face financial constraints, as highlighted in the literature. For example, each province's Environmental Protection Agency (EPA), tasked with controlling pollution - including water pollution - operates under its respective Environmental Protection Act but often struggles with limited funding to fulfill its mandate effectively.[35] However, EPAs face budgetary constraints that hinder their ability to fulfill their responsibilities, such as assessing industries' compliance with environmental standards.[36] Similarly, the Indus River System Authority (IRSA), a federal body tasked with water allocation, faces challenges in ensuring provincial compliance with withdrawal limits. Its ability to conduct objective

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31 Imran S. Khalid and Ahmed Awais Khaver, "Political Economy of Water Pollution: An Overview," (paper, Sustainable Development Policy Institute, Islamabad, 2019), https://sdpi.org/sdpiweb/publications/files/Political-economy-of-water-pollution-in-pakistan-an-overview(W-170).pdf.

32 Muhammad Ashraf, Saiqa Imran and Abdul Majeed, "Water Quality and Salinity," in *Water Policy in Pakistan: Issues and Options*, ed. Mahmood Ahmad (Cham: Springer, 2023), 139, https://doi.org/10.1007/978-3-031-36131-9.

33 Zeshan Ali, Riffat Naseem Malik, Alvina Gul and A. Mujeeb Kazi, "Taming Food Security through Wastewater Irrigation Practices," in *Plants, Pollutants, and Remediation*, ed. Münir Öztürk, Muhammad Ashraf, Ahmet Aksoy, M. S. A. Ahmad and Khalid Rehman Hakeem (Cham: Springer, 2015), 125, https://doi.org/10.1007/978-94-017-7194-8.

34 Fozia Parveen and Sher Jamal Khan, "Wastewater Treatment in Pakistan: Issues, Challenges, and Solutions," in *Water Policy in Pakistan: Issues and Options*, ed. Mahmood Ahmad (Cham: Springer, 2023), 330-334, https://doi.org/10.1007/978-3-031-36131-9.

35 Ayesha Kiran, Ghulam Murtiza, Amna Yousaf, Muzzamal Hussain and Entessar Al Jbawi, "A Critical Analysis of Legal Responses to Water Pollution in Pakistan," *Cogent Social Sciences* 9, 2254944 (2023), DOI: 10.1080/23311886.2023.2254944.

36 Amy Syvrud, Huw Pohlner, Jehangir F. Punthakey, Melita Grant and Trudy Green, "Advancing Urban Water Security in the Indus Basin, Pakistan-Priority Actions for Karachi and Lahore," *Cogent Social Sciences* 9, 2254944 (2021), DOI: 10.1080/23311886.2023.2254944; Ibid., 10-13.

water audits is hampered by provincial resistance and funding gaps.[37] Water service delivery companies often face financial constraints, limiting their ability to expand service networks and improve water supply and sanitation (WSS) operations.[38] Insufficient revenue collection typically fails to cover their operation and maintenance (O&M) costs.[39] Budgetary allocations for the water sector, from both federal and provincial budgets, should be managed efficiently to ensure equitable and consistent financial support for all competent water management authorities. Furthermore, the existing water governance structure should be reviewed, with inefficient departments closed and agencies with overlapping responsibilities merged to enhance efficiency and coordination.

3.2. Information

3.2.1. Lack of a systematic and wider groundwater monitoring

Groundwater levels and quality in Pakistan have significantly deteriorated over the years. From 2008 to 2018, Punjab saw a 15% increase in areas with groundwater tables below 600 cm, while areas with groundwater tables between 0-150 cm decreased by 35%. In Balochistan, groundwater levels are declining by 2-3 metres annually. A 2020 study warned that smallholder farmers in 20% of Balochistan and 15% of Punjab could lose access to groundwater by 2025 without effective management measures. The situation is relatively better in Khyber Pakhtunkhwa (KPK) due to less reliance on groundwater and surplus canal water and in Sindh, where poor water quality restricts extensive groundwater use.[40] In terms of quality, about 80% of rural groundwater resources and 70% of urban groundwater resources have been declared unsafe for consumption.[41]

Effective groundwater management and governance require systematic monitoring to provide consistent and timely data on groundwater dynamics, levels, quality, and

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37 Madison Condon, Don Kriens, Anjali Lohani and Erum Sattar, "Challenge and Response in the Indus Basin," *Water Policy* 16, (2014): 58-86, DOI: 10.2166/wp.2014.004.

38 Rachel Cooper, *Water Management/Governance Systems in Pakistan*, report (London: Department for International Department, 2018), https://assets.publishing.service.gov.uk/media/5c6c293140f0b647b35c4393/503_Water_Governance_Systems_Pakistan.pdf.

39 Ibid., 6.

40 Asad Sarwar Qureshi, "Groundwater Governance in Pakistan: From Colossal Development to Neglected Management," *Water* 12, (2020): 3017, http://dx.doi.org/10.3390/w12113017.

41 Hifza Rasheed, Naveed Iqbal, Muhammad Ashraf and Faizan ul Hasan, "Groundwater Quality and Availability Assessment: A Case Study of District Jhelum in the Upper Indus, Pakistan," *Environmental Advances* 7, (2022): 100148, https://doi.org/10.1016/j.envadv.2021.100148.

discharge and recharge patterns.[42] Monitoring groundwater discharge (upward outflow from an aquifer) and recharge (downward influx into an aquifer) is crucial, particularly in dry regions where discharge often exceeds recharge, exacerbating water scarcity.[43] Groundwater monitoring in Pakistan requires significant improvement and expansion. In Punjab, 50% of the area, including the Cholistan Desert, Thal region, and the Potohar region (districts of Attock, Jhelum, Chakwal, and Rawalpindi), lacks coverage by a groundwater monitoring network.[44] Balochistan, Sindh, and KPK also lack systematic groundwater monitoring, with limited programmes operated by Water and Sanitation Agencies (WASA) in some municipalities, which fail to effectively cover agricultural and rural areas.[45] Deficiencies in groundwater monitoring tend to stem from several factors, including outdated monitoring technologies,[46] lack of capacity to undertake monitoring,[47] or a general lack of a culture of measurement.[48] Programmes for systematic and widespread groundwater monitoring should be developed and implemented, while dedicated facilities should coordinate the data assessment activities and make the information readily available to relevant stakeholders.

3.2.2. Lack of standard and regular monitoring of water supply and sanitation

Monitoring water supply and sanitation (WSS) is crucial for sustainable water management, as it provides essential data on water availability, usage, demand-supply gaps, and quality.[49] To support this, UNICEF facilitated the launch of a water information management system in KPK, aimed at improving operations and maintenance (O&M) and consolidating data on related schemes across the province.[50]

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42 Naveed Iqbal, Faisal Hossain, Hyongki Lee and Gulraiz Akhter, "Integrated Groundwater Resource Management in Indus Basin using Satellite Gravimetry and Physical Modelling Tools," *Environmental Monitoring and Assessment Journal* 189, (2017): 128, DOI 10.1007/s10661-017-5846-1; Ibid.

43 Qureshi, "Groundwater Governance," 12.

44 Ghulam Zakir-Hassan, Catherine Allan, Jehangir F. Punthakey, Lee Baumgartner and Mahmood Ahmad, "Groundwater Governance in Pakistan: An Emerging Challenge," in *Water Policy in Pakistan: Issues and Options*, ed. Mahmood Ahmad (Cham: Springer, 2023), 170, https://doi.org/10.1007/978-3-031-36131-9.

45 Muhammad Tousif Bhatti, Arif A. Anwar and Muhammad Aslam, "Groundwater Monitoring and Management: Status and Options in Pakistan," *Computer and Electronics in Agriculture* 135, (2017): 143-153, https://doi.org/10.1016/j.compag.2016.12.016.

46 Zakir-Hassan, Allan, Punthakey, Baumgartner and Ahmad, "Groundwater Governance," 170.

47 Ibid.

48 Qureshi, "Groundwater Governance," 12.

49 Syvrud, Pohlner, Punthakey, Grant and Green, "Advancing Urban Water Security in the Indus Basin," 9.

50 Cooper, *Water Management/Governance Systems*, 6.

However, standard, regular, and reliable data collection on WSS on a broad scale throughout the country is lacking.[51] An overarching strategy for collecting and managing data on water supply and sanitation should be developed for WASAs.

3.3. Policy, Legal and Regulatory

3.3.1. Absence of a comprehensive groundwater management policy/regulatory framework

In 2018, the federal government introduced the National Water Policy of Pakistan (NWPP) to address water resource management, including groundwater. The policy proposed establishing a 'Groundwater Authority' to set and enforce standards for the development and utilization of groundwater resources.[52] While the NWPP marked a positive step, Pakistan still lacks an effective, comprehensive, and dedicated groundwater management policy or regulatory framework to address the challenge of unsustainable groundwater extraction. Provinces also need a clear framework within which to develop their own groundwater management policies.[53] The NWPP only briefly addresses groundwater resources and fails to recognise the open-access nature of groundwater, which has been a key factor in its unsustainable use.[54] Additionally, the stated goals (Appendix A) with regard to groundwater management are not supported by substantive policy measures and actions. As a case in point, the NWPP states that 'the abstraction from the aquifer shall be managed to a sustainable level that balances recharge and boundary flows' but does not delineate concrete actions and policy measures that can help achieve this.[55] A groundwater development policy

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51 Ibid., 5; Syvrud, Pohlner, Punthakey, Grant and Green, "Advancing Urban Water Security in the Indus Basin," 8; Mohsin Hafeez and Usman Khalid Awan, "Water Resource Potential: Status and Overview," in *Water Policy in Pakistan: Issues and Options*, ed. Mahmood Ahmad (Cham: Springer, 2023), 87, https://doi.org/10.1007/978-3-031-36131-9.

52 AbuBakr Muhammad and James L. Wescoat Jr., "Developing Knowledge Capacity and Wisdom for Water Resource Management and Service Delivery: New Conceptual Models and Tools," in *Water Policy in Pakistan: Issues and Options*, ed. Mahmood Ahmad (Cham: Springer, 2023), 409, https://doi.org/10.1007/978-3-031-36131-9.

53 Zofeen T. Ebrahim, "Is Pakistan Running Dry?" in *Water Issues in Himalayan South Asia*, ed. Amit Ranjan (Singapore: Springer, 2020), 172, https://doi.org/10.1007/978-981-32-9614-5; James L. Wescoat Jr., Waqas Ahmed, Steven Burian, Jehangir F. Punthakey and Ayesha Shahid, "Examining Irrigated Agriculture in Pakistan with a Water-Energy-Food Nexus Approach," in *Water Resources of Pakistan: Issues and Impacts*, ed. Muhammad Arif Watto, Michael Mitchell and Safdar Bashir (Cham: Springer, 2021), 139, https://doi.org/10.1007/978-3-030-65679-9; Sanval Nasim, "Managing Pakistan's Groundwater," in *Water Policy in Pakistan: Issues and Options*, ed. Mahmood Ahmad (Cham: Springer, 2023), 257, https://doi.org/10.1007/978-3-031-36131-9.

54 Nasim, "Managing Pakistan's Groundwater," 259.

55 Ibid., 258-259.

and regulatory framework based on a comprehensive assessment of the groundwater resources should be formulated, adopted, and regularly updated.

3.3.2. Absence of a national policy on wastewater treatment and reclamation

At the national level, key wastewater regulations include the NWPP, the National Environmental Quality Standards, and the National Sanitation Policy.[56] However, there is no dedicated national policy on wastewater treatment and reclamation.[57] Formulating and adopting a comprehensive national policy is essential to provide clear directives for wastewater management and reclamation efforts.

3.3.3. Negligible pricing of water

Water pricing in Pakistan is minimal, failing to cover O&M costs or the marginal cost of resource allocation.[58] This has contributed to low productivity and efficiency of water use for domestic, agricultural, and industrial purposes. This has resulted in low water use productivity and efficiency across domestic, agricultural, and industrial sectors. For example, as of 2021, canal irrigation water was provided to farmers at PKR 135 per acre, roughly equivalent to the market price of 4 kg of wheat grain.[59] This near-free pricing encourages overuse and wastage, leaving farmers with little incentive to adopt high-efficiency irrigation systems.[60]

Similarly, at the household level, negligible pricing of water makes it easily affordable, offering little incentive for households to invest in water conservation systems, such as rainwater harvesting systems (RWHS).[61] A study in Hyderabad revealed that while major water sources included groundwater and tap water, households lacking adequate access to these sources often relied on purchasing water from tanker services. These households were found to be more cautious in optimising their water

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56 Parveen and Khan, "Wastewater Treatment in Pakistan: Issues, Challenges, and Solutions," 335.

57 Cooper, *Water Management/Governance Systems*, 5; Toqeer Ahmed, 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, (2020): 8518, doi:10.3390/ijerph17228518; Ibid., 340.

58 Mahmood Ahmad, "A Transformative Framework for the Water Sector," in *Water Policy in Pakistan: Issues and Options*, ed. Mahmood Ahmad (Cham: Springer, 2023), 453, https://doi.org/10.1007/978-3-031-36131-9.

59 Muhammad Umar Munir, Anwar Ahmad, Jan W. Hopmans, Azaiez Ouled Belgacem and Mirza Barjees Baig, "Water Scarcity Threats to National Food Security of Pakistan," in *Emerging Challenges to Food Production and Security in Asia, Middle East, and Africa*, ed. Mohamed Behnassi, Mirza Barjees Baig, Mahjoub El Haiba and Michael R. Reed (Cham: Springer, 2021), 256, https://doi.org/10.1007/978-3-030-72987-5.

60 Ahmad, "A Transformative Framework for the Water Sector," 453.

61 Nawaz, "An Assessment of Rainwater Harvesting System," 169.

usage compared to those with access to tap water.[62] A pricing mechanism should be introduced to charge for water usage exceeding basic needs, complemented by non-pricing measures such as awareness campaigns to promote efficient water use, particularly in rapidly growing urban areas.

3.3.4. Policy promoting over-extraction of groundwater

The policy of electricity subsidies has significantly contributed to the over-extraction of groundwater in Pakistan. In water-scarce regions like the semi-arid highlands of Balochistan, farming families frequently rely on groundwater pumping, a practice further encouraged by government-subsidised electricity.[63] Farmers in Balochistan widely perceive that energy subsidies have been a major driver of excessive tube well development, leading to significant groundwater depletion in the province.[64] Similarly, in South Punjab, electricity subsidies were introduced to support agro-economic and socioeconomic growth. However, research indicates that prolonged provision of these subsidies has encouraged unsustainable and excessive water extraction in the region.[65] While efforts are underway to support farmers in transitioning to solar-powered tube wells and reduce subsidy allocations for tube well users. However, strict regulation of water extraction remains essential to ensure that it does not exceed natural recharge rates, preventing further groundwater depletion.

3.3.5. Rigidity of the Warabandi system

The *Warabandi* system is a traditional canal water distribution method used in rural areas, where water is supplied to farms periodically at fixed intervals. Each farmer is allocated a specific day to irrigate their fields.[66]The system is supply-based, disregarding the spatial and temporal water demands at the farm level. This often results in water wastage, [67] such as applying water when crop water requirements are

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62 Hafiz Usama Imad, Muhammad Akram Akhund, Muhammad Ali, Ashfaque Ahmed Pathan and Aftab Ahmed, "Non-Volumetric Pricing is a Threat to Water to Water Reserves," *Civil Engineering Journal* 5, no. 2 (2019): 422-428, doi.org/10.28991/cej-2019-03091256.

63 Khair, Mushtaq, Reardon-Smith and Ostini, "Diverse Drivers of Unsustainable Groundwater," 347.

64 Syed Mohammad Khair, Shahbaz Mushtaq and Kathryn Reardon-Smith, "Groundwater Governance in a Water-Starved Country: Public Policy, Farmers' Perceptions, and Drivers of Tubewell Adoption in Balochistan, Pakistan," *Groundwater* 53, no. 4 (2014): 626-37, doi: 10.1111/gwat.12250.

65 Taimoor Akhtar, Hassaan F. Khan and Daanish Mustafa, "Water Security in Pakistan: Availability, Accessibility, and Utilisation," in *Water Resources of Pakistan: Issues and Impacts*, ed. Muhammad Arif Watto, Michael Mitchell and Safdar Bashir (Cham: Springer, 2021), 67, https://doi.org/10.1007/978-3-030-65679-9.

66 Munir, Ahmad, Hopmans, Belgacem and Baig, "Water Scarcity Threats to National Food Security of Pakistan," 249.

67 Abid, Hafeez and Watto, "Sustainability Analysis of Irrigation Water Management," 138.

low.[68] Insufficient water supply during critical crop growth stages drives farmers to over-extract groundwater for irrigation.[69] To allow for some flexibility, the practice of exchanging and trading water turns among water users based on their *Warabandi* water rights should be encouraged and promoted.

3.4. Institutional

3.4.1. Challenges of vertical coordination

Pakistan's water sector governance involves multiple authorities at federal and provincial levels. Following the 18th Amendment to the Constitution, responsibilities for environment, water supply and sanitation, and agriculture were devolved to the provinces, making water management a shared responsibility between provincial and federal governments.[70] At the same time, there is considerable overlap in roles and responsibilities between provincial and local bodies, particularly in groundwater governance. At the federal level, the Planning Commission and the Ministry of Water Resources handle planning and policymaking, while the Water and Power Development Authority (WAPDA) develops water resources with provincial consent. Provincially, irrigation departments oversee groundwater pollution, usage, and overexploitation. Meanwhile, under the Local Government Ordinance 2001, local governments in municipal and rural areas are tasked with managing tube wells and private water sources for drinking water, creating further duplication of authority.[71]

These overlapping responsibilities require effective coordination, but the current communication linkages among federal, provincial, and local entities remain insufficient to ensure cohesive water governance.[72] Provincial departments such as

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68 Riaz Hussain Qureshi and Muhammad Ashraf, *Water Security Issues of Agriculture in Pakistan*, report (Islamabad: Pakistan Academy of Sciences, 2019), https://www.paspk.org/wp-content/uploads/2019/06/PAS-Water-Security-Issues.pdf.

69 Fazilda Nabeel, "Groundwater Crisis: A Crisis of Governance?" in *Water Resources of Pakistan: Issues and Impacts*, ed. Muhammad Arif Watto, Michael Mitchell and Safdar Bashir (Cham: Springer, 2021), 202, https://doi.org/10.1007/978-3-030-65679-9.

70 Hafeez and Awan, "Water Resource Potential: Status and Overview," 85.

71 Nabeel, "Groundwater Crisis: A Crisis of Governance?" 7.

72 Saima Mian, "Pakistan's Flood Challenges: An Assessment through the Lens of Learning and Adaptive Governance," *Environmental Policy and Governance*, (2014), DOI: 10.1002/eet; M. A. Kamran, A. Aijaz and G. Shivakoti, "Institutions for Governance of Transboundary Water Commons: The Case of the Indus Basin," in *Redefining Diversity and Dynamics of Natural Resource Management in Asia,* Vol. 1, ed. Ganesh P. Shivakoti, Ujjwal Pradhan and Helmi (Amsterdam: Elsevier, 2017), 213, https://doi.org/10.1016/C2015-0-04333-7; Syvrud, Pohlner, Punthakey, Grant and Green, "Advancing Urban Water Security in the Indus Basin."; Waseem Ishaque, Mudassir Mukhtar and Rida Tanvir, "Pakistan's Water Resource Management: Ensuring

irrigation, agriculture, and public health lack adequate coordination with their federal counterparts, including the Ministries of Climate Change, Food Security and Research, and Science and Technology. Similarly, coordination is weak with district-level entities like the WASA, On-Farm Water Management (OFWM), Provincial Irrigation and Drainage Authorities (PIDAs), and public health departments.[73] This fragmentation has hindered the effective implementation of the NWPP, as assembling multiple stakeholders on a unified platform remains a significant challenge.[74]

3.4.2. Challenges of horizontal coordination

A lack of inter-provincial, inter-ministerial, and inter-organisational coordination poses a significant challenge to effective water resource management in Pakistan. At the national level, key organisations like the Federal Flood Commission, IRSA, and WAPDA operate under the Federal Ministry of Water Resources but lack the necessary coordination to align their activities and functions effectively.[75] Inter-provincial coordination is crucial, as actions in one province can have significant externalities on others within the Indus Basin, where the hydrologic system transcends political boundaries.[76] Strengthening inter-provincial coordination is essential for effective water sector planning and management in Pakistan.

Enhanced coordination is also needed among water storage, management, and distribution agencies, as well as water-related research and development departments and among organisations managing groundwater and surface water resources in Pakistan. This is crucial because, despite advancements in water management technologies, these innovations often fail to reach the relevant stakeholders effectively.[77]

Enhancing both vertical and horizontal coordination necessitates not just operationalising spaces for active engagement among stakeholders and orientating

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Water Security for Sustainable Development," *Frontiers in Environmental Science*, (2023), https://doi.org/10.3389/fenvs.2023.1096747.

73 Kamran, Aijaz and Shivakoti, "Institutions for Governance of Transboundary Water Commons: The Case of the Indus Basin" 213.

74 Ahmed, Zounemat-Kermani and Scholz, "Climate Change, Water Quality, and Water-Related Challenges," 13.

75 Ishaque, Mukhtar and Tanvir, "Pakistan's Water Resource Management," 10.

76 Condon, Kriens, Lohani and Sattar, "Challenge and Response in the Indus Basin," 82.

77 Munir, Ahmad, Hopmans, Belgacem and Baig, "Water Scarcity Threats to National Food Security," 256-257; Shazia Perveen and Amar-Ul-Haque, "Drinking Water Quality Monitoring, Assessment and Management in Pakistan: A Review," *Heliyon* 9, (2023): e13872, https://doi.org/10.1016/j.heliyon.2023.e13872; Qureshi, "Groundwater Governance," 12

them on their respective responsibilities but also creating forums and an environment for comprehensive dialogue and negotiation.

3.4.3. Challenges of institutional capacity

Effective management of water resources is also hindered as competent authorities lack the desired levels of capacities to implement their respective mandates, including enforcing laws, policies, and regulations.[78] The reviewed literature has highlighted some cases in point. For example, provincial EPAs responsible for enforcing environmental regulations and laws, besides being underfinanced (*refer to section 3.1.4.*), lack required levels of techno-legal and managerial competencies to ensure effective compliance with the Environmental Protection Acts by the relevant entities, such as the industries. Sufficient investment is not made in the professional cadres, including environmental specialists, attorneys, and managers.[79]

As another case in point, Tehsil Municipal Authorities (TMAs) and WASAs in charge of water supply and sanitation operations in the urban areas lack necessary levels of capacity, including human resource and managerial capacities, to effectively undertake their activities and manage water resources in cities and municipalities.[80] Similarly, inadequate infrastructure, limited resources, and inadequate experience of the human resource make it challenging for WASA to enforce water quality regulations.[81] In urban areas, poor institutional and administrative frameworks also hinder effective enforcement of policies by municipal bodies for establishing water conservation systems, such as the RWHs, at household and organisational levels.[82]

Another example of coordination challenges is the Provincial Irrigation and Drainage Authorities (PIDAs), established in 1997. The PIDA Act defined groundwater extraction rights, tasked Water User Associations (WUAs) with monitoring groundwater extraction in canal command areas, and advocated for demarcating critical groundwater zones and issuing licenses for tubewell installation in these zones.

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78 Syvrud, Pohlner, Punthakey, Grant and Green, "Advancing Urban Water Security," 8.

79 Khalid and Khaver, "Political Economy of Water Pollution: An Overview," 8; Kiran, Murtiza, Yousaf, Hussain and Al Jbawi, "A Critical Analysis of Legal Responses to Water Pollution in Pakistan," 10.

80 Cooper, *Water Management/Governance Systems*; Ishaque, Mukhtar and Tanvir, "Pakistan's Water Resource Management," 11.

81 Perveen and Haque, "Drinking Water Quality Monitoring, Assessment and Management," 14, 24.

82 Attaullah Shah, Rehmat Karim and Karamat Ali, "Review of Impacts of Climate Changes on the Urban Water Security of Islamabad, Pakistan," *Journal of Water and Land Development* VII-IX, no. 54 (2022): 109-115, DOI: 10.24425/jwld.2022.141561.

However, its implementation has been limited due to capacity-related challenges faced by PIDAs.[83] To address the capacity-related challenges faced by PIDAs, comprehensive training programmes and formally accredited courses should be developed and implemented to build the capacity of PIDA staff and associated stakeholders, ensuring effective implementation of the PIDA Act.

3.5. Technical

3.5.1. Siltation of the surface water storage reservoirs

Pakistan currently has an insufficient water storage capacity, limited to a maximum 30-day supply, to store excess water for periods of low supply. This challenge is exacerbated by ongoing loss of reservoir capacity due to siltation.[84] Mangla and Tarbela reservoirs, built as replacement works under the Indus Waters Treaty, have seen significant reductions in storage capacity - Mangla by 11.8%, Tarbela by 38%, and Chashma by a staggering 62.3%.[85] With heavy siltation loads from rivers, storage capacity of these reservoirs is expected to decline further, posing a serious threat to water resource management.[86] Frequent desilting operations must be undertaken to prevent accumulation of sediments over time.

3.5.2. Conveyance losses

Conveyance losses refer to water lost from canals or streams due to leakage, evaporation, seepage, or evapotranspiration. In Pakistan, poor maintenance of irrigation infrastructure significantly exacerbates these losses, reducing efficiency of water delivery systems,[87] with one estimate suggesting that conveyance losses account for one-third of water loss.[88] Approximately 18.3 million acre-feet (MAF) of irrigation water is lost annually through seepage from canals and watercourses. This amount of water, if conserved, has the potential to irrigate an additional 3.0 million

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83 Qureshi, "Groundwater Governance," 11.

84 Ibid., 67; Salim Khoso, Farhan Hussain Wagan, Abdul Hanan Tunio and Abdul Aziz Ansari, "An Overview on Emerging Water Scarcity in Pakistan, Its Causes, Impacts, and Remedial Measures," *Journal of Applied Engineering Science* 13, no. 1 (2015): 35-44, doi:10.5937/jaes13-6445; Naeem Shahzad, "Averting a Water War through Surface Water Management in Pakistan," *Proceedings of the Pakistan Academy of Sciences* 53, no. 3 (2016): 139-148; Shahmir Janjua, Ishtiaq Hassan, Shoaib Muhammad, Saira Ahmed and Afzal Ahmed, "Water Management in Pakistan's Indus Basin: Challenges and Opportunities," *Water Policy* 23, no. 6 (2021): 1329, doi: 10.2166/wp.2021.068.

85 Rasheed and Ahmed, "Storage and Hydropower," 194.

86 Condon, Kriens, Lohani and Sattar, "Challenge and Response in the Indus Basin," 77.

87 Ibid., 81; Abid, Hafeez and Watto, "Sustainability Analysis of Irrigation Water Management," 136.

88 Khan, Ch, Ashraf, Siddique and Knox, "Evaluating Socio-economic and Environmental Factors."

acres of land each year, highlighting the need for improved irrigation infrastructure and management.[89]

Conveyance losses in Pakistan have grown significantly, with only about 30% of the water flowing through the Indus River system reaching farmers.[90] In Punjab alone, an estimated 21 MAF of the apportioned 56 MAF is lost during distribution and conveyance from rivers to canals and from canals to watercourses and distributaries before reaching farms.[91] To mitigate these losses, efficient methods such as compacted earth lining - using compacted earthen material to line canal beds and sides - should be explored and implemented.

3.5.3. Waterlogging and salinity

Waterlogging and salinity are widespread challenges in Pakistan, especially in Sindh. Key causes include outdated surface irrigation allocations, which provide excessive water during the Kharif (summer) season but insufficient supply in winter, and the lack of field drainage systems to evacuate water from agricultural lands.[92] Infrastructure development, such as roads, has blocked many natural drains, while existing drainage facilities often remain non-functional due to poor maintenance.[93] To address these issues, efficient practices such as improved soil drainage, crop rotation, and the use of salt-tolerant plants should be encouraged and widely promoted.

3.5.4. Parallel water supply and sewage pipelines

In many cities, water supply and sewage discharge pipelines often run parallel, leading to frequent contamination of the limited water supply. Poor maintenance of sewage pipelines results in occasional leakages, causing sewage to mix with the water supply

89 Khoso, Wagan, Tunio and Ansari, "An Overview on Emerging Water Scarcity in Pakistan," 311.

90 Mahmood Ahmad, "Water Pricing, Demand Management, and Allocative Efficiency," in *Water Policy in Pakistan: Issues and Options*, ed. Mahmood Ahmad (Cham: Springer, 2023), 296, https://doi.org/10.1007/978-3-031-36131-9.

91 Abid, Hafeez and Watto, "Sustainability Analysis of Irrigation Water Management," 136.

92 Condon, Kriens, Lohani and Sattar, "Challenge and Response in the Indus Basin," 70; Frank van Steenberg, Muhammad Basharat and Bakhshal Khan Lashari, "Key Challenges and Opportunities for Conjunctive Management of Surface and Groundwater in Mega-Irrigation Systems: Lower Indus, Pakistan," *Resources* 4, (2015): 831-856, doi:10.3390/resources4040831; Muhammad Basharat, "Developing Groundwater Hotspots: An Emerging Challenge for Integrated Water Resources Management in the Indus Basin," in *Indus River System: Water Security and Sustainability*, ed. Sadiq I. Khan and Thomas E. Adams, III (Amsterdam: Elsevier, 2019), 417-425, https://doi.org/10.1016/C2016-0-04119-0," 421.

93 van Steenberg, Basharat and Lashari, "Key Challenges and Opportunities for Conjunctive Management," 842-843.

and posing significant health risks.[94] The installation of parallel supply and sewage discharge pipelines should be strictly regulated. Physical barriers can also be implemented between existing parallel pipeline infrastructures to prevent the mixing of sewage with the water supply and ensure safe water delivery.

3.6. Awareness

3.6.1. Lack of awareness about water conservation strategies among urban dwellers

Urban dwellers lack sufficient awareness of water conservation strategies, which has contributed to the slow uptake of RWHs in cities like Lahore and Islamabad, alongside cost considerations.[95] Moreover, the importance of wastewater recycling is not widely recognised.[96] To address this, extensive awareness and informational materials on water conservation strategies should be developed and disseminated through door-to-door campaigns, training sessions, workshops, and media campaigns.

3.6.2. Lack of farmers' awareness of high-efficiency irrigation methods

In recent years, adoption of high-efficiency irrigation methods, such as drip irrigation, sprinkler irrigation, and laser land leveling, has grown in Pakistan. However, their rapid and large-scale adoption is hindered not only by cost but also by a lack of understanding, knowledge, and information about their benefits and operational aspects, particularly among small-scale farmers.[97] To address this, comprehensive awareness and informational materials should be developed and disseminated through training sessions, workshops, and media campaigns targeted at farmers.

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94 Toqeer Ahmed, Miklas Scholz, Furat Al-Faraj and Wajeeha Niazi, "Water-Related Impacts of Climate Change on Agriculture and Subsequently on Public Health: A Review for Generalists with Particular Reference to Pakistan," *International Journal of Environmental Research and Public Health* 13, (2016): 1051, doi:10.3390/ijerph13111051; Syvrud, Pohlner, Punthakey, Grant and Green, "Advancing Urban Water Security in the Indus Basin," 6; Perveen and Haque, "Drinking Water Quality Monitoring, Assessment and Management," 2; Prince Kumar, Fatima Arshad, Sean Kaisser Shaheen, Arsalan Nadeem, Zarmina Islam and Mohammad Yasir Essar, "Water Sanitation in Karachi and its Impact on Health," *Annals of Medicine and Surgery* 77, (2022): 103688, https://doi.org/10.1016/j.amsu.2022.103688.

95 Nawaz, "An Assessment of Rainwater Harvesting System," 166; Ahmed, Zahir and Ahmad, "Consumer Perception and Behaviour toward Water Supply," 1339.

96 Ishaque, Mukhtar and Tanvir, "Pakistan's Water Resource Management," 11.

97 Ahmad, Masih and Giordano, "Constraints and Opportunities for Water Savings," 112; Khan, Ch, Ashraf, Siddiqui and Knox, "Evaluating Socio-economic and Environmental Factors."; Abid, Hafeez and Watto, "Sustainability Analysis of Irrigation Water Management," 139; Ibid., 281-284.

3.6.3. *Insufficient awareness among masses about the challenge of declining water quality*

Public understanding of water pollution and declining water quality as major contributors to freshwater scarcity in Pakistan is inadequate. There is limited awareness among the masses about the various causes of water pollution. [98] Targeted awareness campaigns should be launched to educate the public about causes and impacts of water pollution on freshwater scarcity

3.7. Social, Cultural and Behavioural

3.7.1. *Unnecessary water wastage*

Extravagant water consumption and wastage contribute significantly to water mismanagement. In urban areas, common practices like turning off water supply only after tanks overflow exemplify everyday wastage.[99] At the farm level, excess water is often allowed to flow downstream during winters and monsoon rains instead of being stored in farm-scale ponds for future use.[100] Similarly, excessive clean water usage during car washes at service stations is a frequent issue. Active awareness and information campaigns should be conducted to promote water conservation at all levels.

3.8. Mega Trends

3.8.1. *Looming population numbers*

Pakistan's burgeoning population poses an immense challenge for effectively managing the country's water resources.[101] Rapid population growth contributes not

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98 Ahmed, Zounemat-Kermani and Scholz, "Climate Change, Water Quality, and Water-Related Challenges," 6; Kiran, Murtiza, Yousaf, Hussain and Al Jbawi, "A Critical Analysis of Legal Responses to Water Pollution in Pakistan," 10.

99 Shah, Karim and Ali, "Review of Impacts of Climate Changes," 113; Ahmed, Zahir and Ahmad, "Consumer Perception and Behaviour toward Water Supply," 1348.

100 Munir, Ahmad, Hopmans, Belgacem and Baig, "Water Scarcity Threats to National Food Security," 255.

101 Condon, Kriens, Lohani and Sattar, "Challenge and Response in the Indus Basin," 64; Khoso, Wagan, Tunio and Ansari, "An Overview on Emerging Water Scarcity in Pakistan," 35; Ahmed, Scholz, Al-Faraj and Niazi, "Water-Related Impacts of Climate Change," 9; Shahzad, "Averting a Water War through Surface Water Management in Pakistan," 145; Cooper, *Water Management/Governance Systems*, 6; Marium Sara Minhas Bandeali, "Water Governance and Management in Indus Basin-Challenges and Threats," *Studies of Applied Economic* 38, no. 3 (2020): DOI: http://dx.doi.org/10.25115/eea.v38i3.3601; Basharat, "Developing Groundwater Hotspots"; Ebrahim, "Is Pakistan Running Dry?" 156; Zhang, Sial, Ahmad, Filipe, Tu, Zia-Ud-Din and Caleiro, "Water Scarcity and Sustainability in an Emerging Economy," 4-5; Munir, Ahmad, Hopmans, Belgacem and Baig, "Water Scarcity Threats to National Food Security," 244; Syvrud, Pohlner, Punthakey, Grant and Green, "Advancing Urban Water Security," 5; Shah, Karim and Ali, "Review of Impacts of Climate Changes," 113; Kumar, Arshad, Shaheen, Nadeem, Islam and

just to increasing water demand in the municipal sector but also to expanding industrial activities and need for agricultural irrigation.[102] On the one hand, this has squeezed existing water resources. In particular, groundwater resources are being tremendously burdened due to increased groundwater withdrawal rates with increased population density.[103] Population growth has also affected water quality and increased wastewater volumes.[104] Pakistan's present population growth rate is 2.8%, and the country's total population is projected to be 250 million by 2025. The proportion of people living in cities is likely to surge from 35% in 2017 to 52% in 2025, which will place further pressure on water resources.[105] For reference, water demand in Pakistan for commercial, residential, and purposes other than agriculture alone is expected to increase 8% by 2025.[106] Effective population management necessitates robust collaboration between the health sector, government, and civil society, as well as determined efforts to reduce income inequalities and inequalities to basic services, including education and health.

3.8.2. Rapid urbanisation

As cities in Pakistan expand to meet the needs of a growing population, urbanisation has intensified challenges such as increased storm runoff, erosion, sewage disposal, and excessive abstraction of surface and groundwater, placing significant pressure on urban water resources and deteriorating water quality. Despite these challenges, investments in wastewater treatment, water supply, and sanitation infrastructure have lagged behind the rapid pace of urbanization. To alleviate these pressures, developing rural economies and smaller towns will be crucial in reducing migration-driven urban growth. Figure 2 illustrates the frequency of these challenges as discussed in the selected publications.

Essar, "Water Sanitation in Karachi," 2; Kiran, Murtiza, Yousaf, Hussain and Al Jbawi, "A Critical Analysis of Legal Responses," 13; Mahmood Ahmad, ed., *Water Policy in Pakistan: Issues and Options* (Cham: Springer, 2023), https://doi.org/10.1007/978-3-031-36131-9.

102 Sajjad Hussain, 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, (2023): 1768, https://doi.org/10.3390/su15031768.

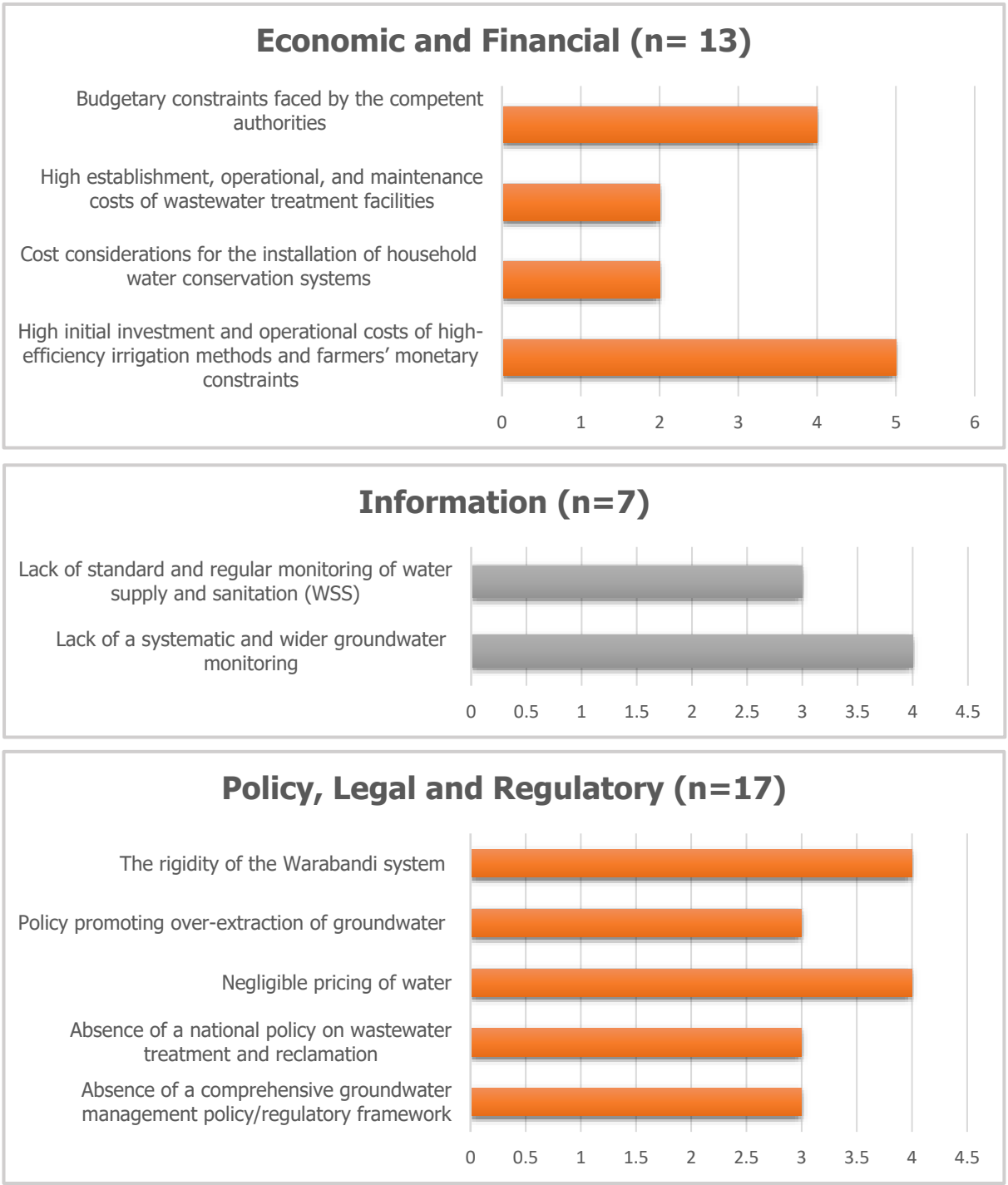
103 Khalil Ur Rahman, Anwar Hussain, Nauman Ejaz, Muhammad Shahid, Zheng Duan, Babak Mohammadi et al., "Evaluating the Impact of the Environment on Depleting Groundwater Resources: A Case Study from a Semi-arid and Arid Climatic Region," *Hydrological Sciences Journal*, (2022), DOI: 10.1080/02626667.2022.2044483.

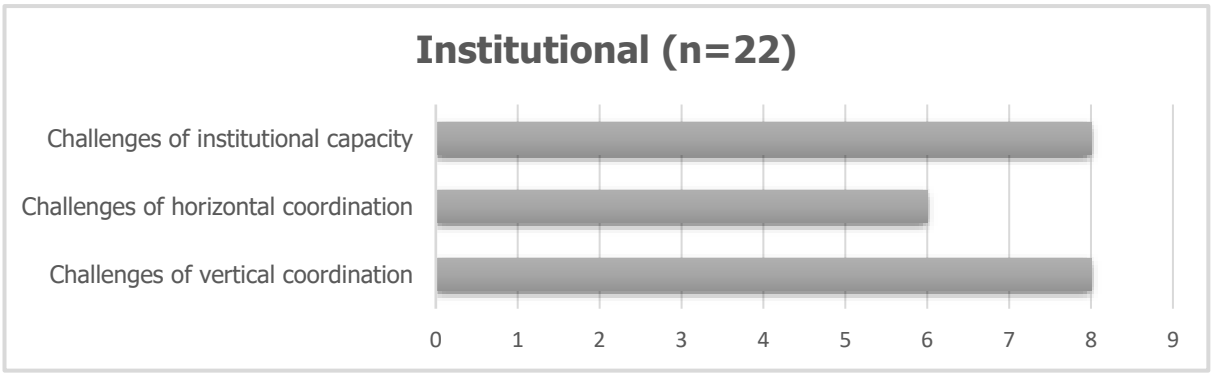
104 Ali, Malik, Gul and Kazi, "Taming Food Security through Wastewater," 113.

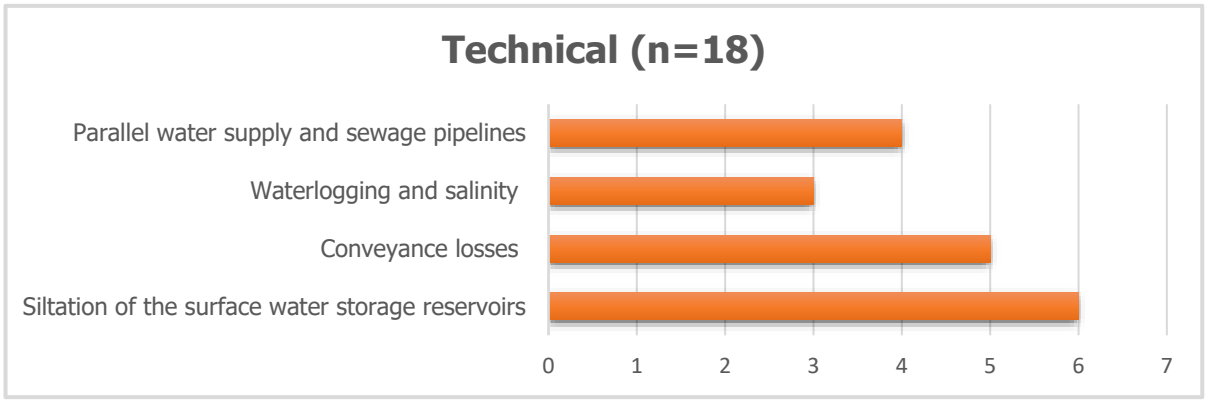
105 Janjua, Hassan, Muhammad, Ahmed and Ahmed, "Water Management," 1332

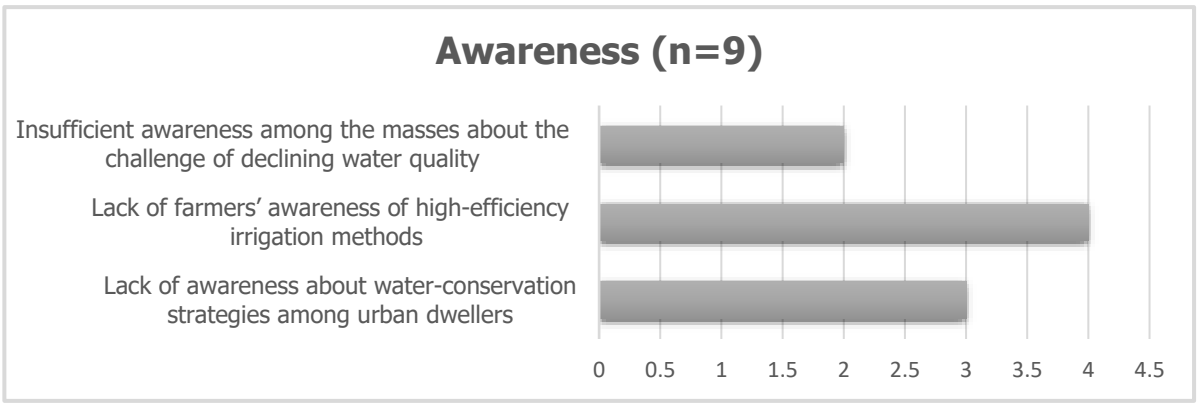
106 Hafeez and Awan, "Water Resource Potential: Status and Overview," 77.

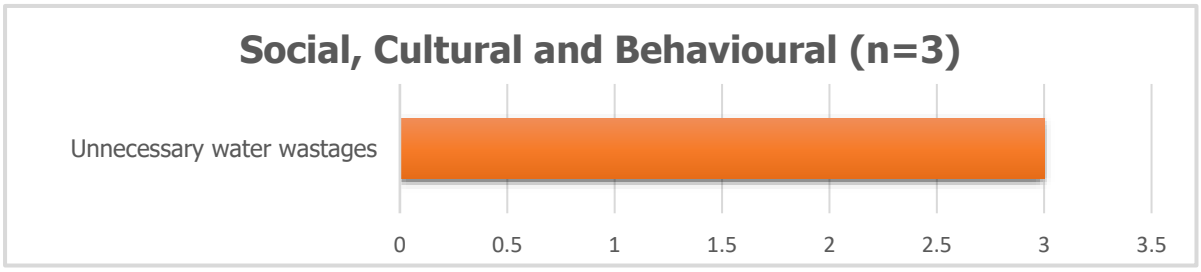
Figure 2: Frequency of Discussions on Key Challenges in Selected Publications

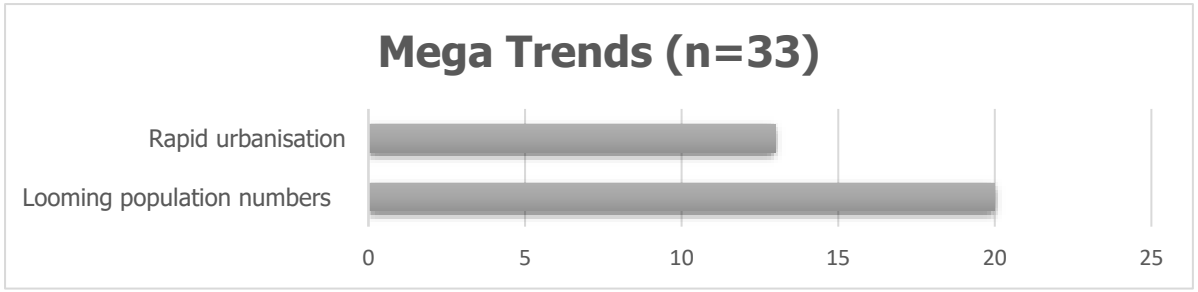












Source: Author's own.

4. Discussion

The review found 24 major internal challenges (outlined in section 3) for management of Pakistan's water resources that were synthesised into eight categories: economic and financial; information; policy, legal and regulatory; institutional; technical; awareness; social, cultural, and behavioural; and mega trends. The results show that the challenges related to mega trends, including interconnected problems of rapid population growth and urbanisation were discussed the most in selected publications (Figure 2). This finding is hardly surprising as, according to a recent assessment, population growth alone will lead to a widespread and unprecedented drop in water availability per capita in the world.[107] Experts also suggest that Pakistan may not be able to address water scarcity without effectively controlling population growth, even if new water reservoirs are constructed.[108] However, despite this, the urgency of controlling rapid population growth and urbanisation is not accorded a fair share of attention in the policy debates on water management. The NWPP is a case in point. The 41-page policy document acknowledges the challenge of looming population numbers within different sections but does not propose policy measures for managing urbanisation and population growth to address the country's water scarcity challenge.[109]

The second most discussed challenges were the institutional ones, including coordination and capacity-related challenges (Figure 2). This is a persuasive finding, as robust institutional framework is critical to implementing policies to address challenges in majority of the other domains. For instance, attracting investments and formulating resource mobilisation strategies to address economic and financial impediments requires vertical and horizontal coordination among institutions and a specialist institutional cadre of professionals. Regular and systematic monitoring of water resources can be effectively undertaken if institutional capacity is strengthened. Establishing and implementing policies and regulations to address policy and regulatory challenges is contingent on institutional coordination and robust

107 ReliefWeb, "Opinion: Water Scarcity: Coming Soon," July 29, 2021, https://reliefweb.int/report/world/opinion-water-scarcity-coming-soon.

108 Sehrish Wasif, "Water supply, Demand Gap to Reach 31% by Year 2025," *Express Tribune*, March 16, 2018, https://tribune.com.pk/story/1661330/water-supply-demand-gap-reach-31-year-2025.

109 Ministry of Water Resources, *National Water Policy* (Government of Pakistan, 2016), https://mowr.gov.pk/SiteImage/Misc/files/National%20Water%20Policy.pdf.

institutional capacities. Over the recent years, efforts have been reflective of the government's commitment towards combating water scarcity, and introduction of a water policy in 2018 was particularly illustrative of this. However, the policy implementation lingers on seven years later, proof of pervasive institutional challenges.[110] The National Climate Change Policy has also faced an almost similar fate.

Technical and policy, legal, and regulatory challenges also had a prominent representation in the selected publications, compared to other challenges, except institutional challenges and challenges related to mega trends (Figure 2). Interestingly, social, cultural, and behavioural challenges were the least discussed in the reviewed literature. This is an encouraging finding as even studies that focused, for instance, on the barriers to adopting water conservation techniques and technologies did not find social and cultural resistance to be a significant barrier to their adoption, as might be believed otherwise.

However, it must be noted that if Pakistan is to tackle its water scarcity threat, addressing each challenge will be imperative. According to an emerging expert consensus, any reductionist approach to address Pakistan's water management problems, such as rehabilitating more canals alone, implementing water pricing alone, or reforming institutions alone, will not bring about the desired results vis-a-vis addressing water scarcity due to the multifaceted and interconnected nature of the problems.[111] The challenges are mutually supportive; failure to address one can have adverse spillover effects and undermine other efforts.

5. Conclusion and Policy Implications

The paper presents the findings of an SSLR on major internal challenges for water resource management in Pakistan. High initial investment and operational costs of high-efficiency irrigation methods, cost considerations for installing household water conservation systems, high establishment, operational, and maintenance costs of

110 Shafqat Kakakhel, "Why Hasn't Pakistan's National Water Policy been Implemented," *Geo News*, June 27, 2022, https://www.geo.tv/latest/424722-why-hasnt-pakistans-national-water-policy-been-implemented; Abdur Rehman Cheema, "Pakistan is Facing a Looming Water Crisis," *DandC*, October 11, 2023, https://www.dandc.eu/en/article/government-islamabad-has-launched-several-initiatives-address-countrys-water-problems.

111 Ebrahim, "Is Pakistan Running Dry?" 154.

wastewater treatment facilities, and budgetary constraints faced by competent authorities were found to be major economic and financial challenges. A lack of systematic and wider groundwater monitoring and standard and regular monitoring of water supply and sanitation (WSS) were found to be major information-related challenges. Absence of a comprehensive groundwater management policy/regulatory framework, a national policy on wastewater treatment and reclamation, negligible water pricing, a policy promoting over-extraction of groundwater, and rigidity of the *Warabandi* system were found to be major policy, legal, and regulatory challenges. Major technical challenges were found to be sedimentation of surface water storage reservoirs, conveyance losses, waterlogging and salinity, and parallel installation of water supply and sewage pipelines. A lack of awareness about water conservation strategies among urban dwellers, lack of farmers' awareness of high-efficiency irrigation methods, and insufficient awareness among masses about declining water quality were found to be major awareness-related challenges. The practice of unnecessary water wastage was found to be a major behavioural challenge. Looming population numbers and rapid urbanisation were major challenges related to mega trends.

The following policy implications can be derived from the study. First and foremost, managing population growth and urbanisation rates is of utmost importance if Pakistan is to decisively tackle the water scarcity challenge and manage the country's water resources effectively. This is particularly important for cities experiencing the greatest water scarcity burden. Developing rural economies and smaller towns and cities is imperative to reducing migratory outflows to larger metropolitan areas. Moreover, effective population management necessitates robust collaboration between the health sector, government, and civil society, as well as dedicated efforts to reduce income inequalities and inequalities in basic services, including education and health. Second, a serious reform in the water sector can only be attained through institutional reforms. This should include reforms to narrow vertical and horizontal coordination gaps among relevant entities at federal, provincial, and local levels; enhancing institutional accountability by establishing appropriate feedback mechanisms and performance indicators; and building capacity of relevant authorities through rigorous capacity building measures. A misalignment persists in translating policies and plans into implementation, given lack of harmonisation among multiple institutions at different levels; duplication of responsibilities; and insufficient capacities

of relevant institutions. Third and closely connected, challenges in effectively managing Pakistan's water resources are multifaceted and interconnected, and any reductionist approach to address Pakistan's water management problems may not produce the desired results. Collaborative governance, involving multiple and diverse stakeholders, from national and provincial ministries down to local water associations, local communities, and farmers, ought to be the practical way forward to pursue the shared goal of addressing the country's water scarcity threat.

Appendix A

Goals for Groundwater Management in the National Water Policy of Pakistan

1. The Indus aquifer, underlying the vast Indus plains, and other aquifers in valleys and in the hard rock formation are recognised as important national resources and deserve protection from pollution and unsustainable abstractions.
2. Monitoring efforts shall be strengthened to determine sustainable groundwater potential and prepare groundwater budgets for sub-basins and canal commands. All measures to prevent lateral/vertical movement of saline water interface shall be introduced. Provincial governments shall be persuaded to enforce legislation and take regulatory measures.
3. Various technologies used for sustainable extraction and skimming of fresh groundwater layers overlying saline water shall be evaluated and development of improved techniques initiated.
4. The transition of SCARP tube wells in the public sector to the private sector shall be expedited leaving development of fresh groundwater entirely to the private sector, as a local resource.
5. All sources of recharge/discharge and their interaction on groundwater reservoir shall be evaluated. Groundwater recharge including artificial recharge shall be promoted wherever technically and economically feasible. Abstractions from the aquifer shall be managed to the sustainable level that balances the recharge and boundary flows.
6. The Provinces shall be encouraged to prepare a Groundwater Atlas for each Canal Command and sub-basin delineating:
    - Groundwater development potential;
    - Water quality zones;
    - Water table depth zones;
    - Recommendations for installation of different types of tube wells.
7. Investment in groundwater recharge schemes shall be given due priority.
8. Secondary salinisation due to indiscriminate groundwater abstraction shall be avoided by controlling or restricting pumping through enforcement of a strict regulatory framework.

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