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Review

# An Engineering Perspective of Water Sharing Issues in Pakistan

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**Abstract:** Water sharing within the states/provinces of a country and cross-border is unavoidable. Conflicts between the sharing entities might turn more severe due to additional dependency on water, growing population, and reduced availability as a result of climate change at many locations. Pakistan, being an agricultural country, is severely water stressed and heading toward a worsening situation in the near future. Pakistan is heading toward water scarcity as water availability in the Indus basin is becoming critical. Being a downstream riparian of India and Afghanistan in the Indus basin, water availability depends on the releases of water from both countries. The Indus Water Treaty is governing the water distribution rights between India and Pakistan. However, there exists no proper agreement between Pakistan and Afghanistan and the construction of new dams on the Kabul River is another threat to water availability to Pakistan. Correct implementation of the Indus Water Treaty with India is required, together with an effective agreement with Afghanistan about the water sharing. In addition to water shortage, poor management of water resources, inequitable sharing of water, lack of a systematic approach, old-fashioned irrigation practices, and growing agricultural products with large water footprints are all exacerbating the problem. The water shortage is now increasingly countered by the use of groundwater. This sudden high extraction of groundwater is causing depletion of the groundwater table and groundwater quality issues. This water shortage is exacerbating the provincial conflicts over water, such as those between Punjab and Sindh provinces. At one end, a uniform nationwide water allocation policy is required. At the same time, modern irrigation techniques and low-water-footprint agricultural products should be promoted. A fair water-pricing mechanism of surface water and groundwater could be an effective measure, whereas a strict policy on groundwater usage is equally important. Political will and determination to address the water issues are required. The solutions must be based on transparency and equity, by using engineering approaches, combined with comprehensive social support. To develop a comprehensive water strategy, a dedicated technopolitical institute to strengthen the capabilities of nationwide expertise and address the issues on a regular basis is required to overcome the complex and multidimensional water-related problems of the country.

**Keywords:** Pakistan water resources; water sharing; surface water and groundwater

## 1. Water-Resource Sharing

Sharing water resources regionally or across borders is a common issue in water-resource management. It is natural and inevitable to have some conflicts or problems over the sharing of resources. Water disputes, sometimes associated with violence, are an internal, as well as international, problem, often with a long history. The intensity of conflicts over water have become more severe due to the increasing population, climatic changes, and more dependency on water resources [1,2]. There are about 310 international river basins in the world, and the total surface that they cover is little more than 47% of the world's land surface [3,4]. According to Majidyar [5], "Studies show that there is a 75–95% probability of water wars in the next 50–100 years as the effects of climate change spur intense competition for increasingly scarce resources".

Well-known international water disputes are found around Lake Turkana, Nile, Ogooue, Sanaga, Brahmaputra, Helmand River, Indus, Jordan, Mekong, and a few more places. Every conflict is different regarding the details of the sharing problem. For example, the Silala is claimed with exclusive rights by Bolivia, which Chile contests through the International Court of Justice. Another interesting example is sharing the electricity generated by Itaipu Dam, owned jointly by Paraguay and Brazil on the Parana. The water-sharing issue between US and Mexico concerning the Tijuana mainly focuses on water quality. Bosnia and Herzegovina and Croatia are in conflict about hydropower generation on the Neretva. In many parts of Europe, flooding and flood management infrastructures are causes of disputes. Water issues are not only found at the international level but also within countries. In India, for example, the water conflict between upstream Karnataka State demanded an increase in its water share for the purpose of irrigation, at the cost of the existing water share of downstream Tamil Nadu. This dispute resulted in violence and many deaths [6]. Yemen's capital, Sana'a, also experienced a serious shortage of water in September 2011, which led to violence. Residents had to buy water from wells at a very high price. The Murray in Australia runs through New South Wales, Victoria, and South Australia. These states have conflicts regarding management of the river amid calls by activists for government intervention.

### 1.1. Water Resources of Pakistan

Pakistan relies on Indus River system for its water needs. It would be interesting to analyze the water-sharing paradigm across the border and within the country, under severe water stresses. Pakistan has become a water-stressed country over the last decade [7,8]. According to an estimate of the United Nations (UN), Pakistan has an annual per capita water availability of 1090 m<sup>3</sup>. The pressure on the national water resources is measured by the UN's Food and Agriculture Organization (FAO) by calculating the total water withdrawal as a percentage of Total Renewable Water Resources (TRWR) [9]. The stresses are considered to be high if the TRWR value is above 25%. Its neighboring country India has a pressure of 34%, and Afghanistan has a pressure of 31%, but the pressure in Pakistan is 74%, which is extremely high [7]. The seriousness of the water crisis in Pakistan can be concluded from the fact that Pakistan will become a water-scare country by 2025 [10–12], whereas the water scarcity is a shortage in the availability of renewable freshwater relative to demand [13]. Due to an increase in the population, the demand–supply gap is growing, resulting in conflict between the provinces [14]. According to a recent report by the International Monetary Fund (IMF), Pakistan ranks third in the world among countries facing acute water shortage [11]. Therefore, the water-sharing issues of Pakistan need urgent attention. According to the United Nations, the demand of water in Pakistan is increasing at the rate of 10% per year [15]. According to this estimate, the water availability by 2025 will be 809 m<sup>3</sup> per capita per annum [16]. The total deficit of about 100 km<sup>3</sup>/year is expected, which is almost two-thirds of the entire Indus River system's current annual average flow [17].

### 1.2. Assessment Approach

The water-sharing issues vary in nature from one place to the next. Understanding of issues and identification of possible solutions need a thorough understanding of water resources’ availability, their temporal and spatial distribution, and water demands, as well as demographic and climatic characteristics. Water–energy–food nexus, family planning, population growth, and women empowerment could be very effective measures. The importance of these factors has been well recognized by Ripple, Wolf et al. [18] and Bongaarts [19]. However, social measures to reduce the demands of water supply are beyond the scope of this manuscript.

As this manuscript intends to elaborate the water-sharing issues in Pakistan with engineering perspective only, a systematic approach (slightly customized) was developed to assess the water-sharing arena with supply–demand and management efficiencies (refer to Figure 1). The assessment mechanism analyzes the cross-border water sharing at the first instance. The cross-border water issues will determine the availability of water to be shared among the provinces/states at the national level. One of the reasons behind the water conflicts is the increasing gap in demand and supply of water [20]. The water sharing is a subject of water availability. Water demands, management efficiencies, water footprint efficiencies, and the availability of additional water resources are the factors that play the major role in water sharing. The same are investigated for Pakistan’s case.

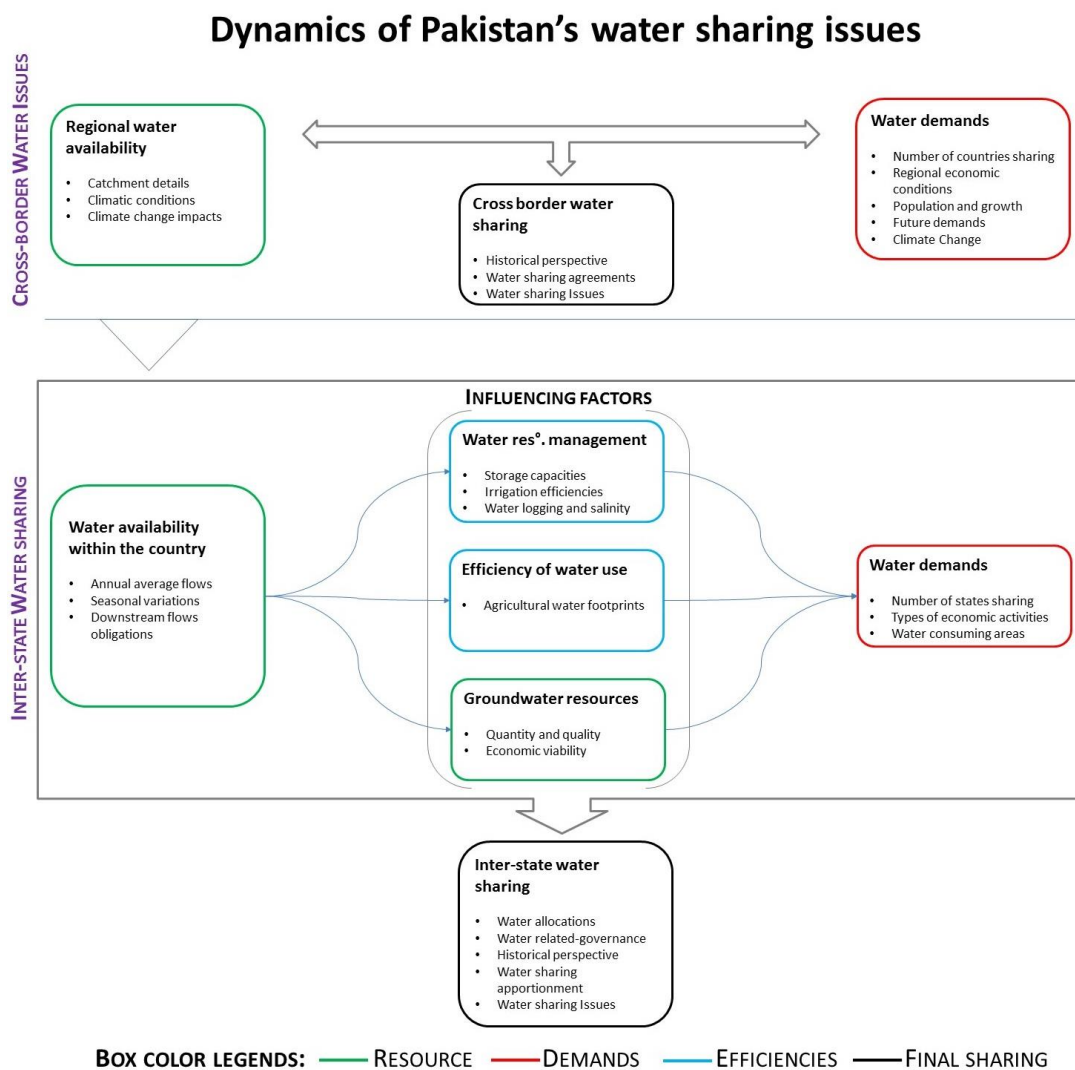


Figure 1. Schematic approach for assessment of Pakistan’s water-sharing issues.

## 2. Cross-Border Water Issues

Being one of the most arid countries of the world, yet having the world's fourth highest rate of water use, Pakistan's supply of water comes mostly from a single source, which is the Indus River system [21]. The Sutlej, Jhelum, Chenab, Ravi, Beas, and the Indus itself are the six major tributaries of this system (Figure 2). These rivers are fed by rainfall, glacier melt, and snowmelt. Summer monsoons are the main source of rainfall, which averages around 494 mm per year. Precipitation varies greatly between seasons and is unevenly distributed over space. Approximately 240–258 km<sup>3</sup> is the Indus Basin's long-term surface-water availability, of which 175–190 km<sup>3</sup> is extracted in Pakistan. Out of the total average renewable-water availability of about 190 km<sup>3</sup>, 50–55 km<sup>3</sup> comes from groundwater [22]. Out of the total surface water available, 74% is extracted, while 83% of the annual groundwater recharge is extracted, which is extremely high [8,22].

The Indus Basin provides water to roughly 300 million people [23]. Pakistan, Afghanistan, and India also depend on food supply for their massive populations. In this water-stressed region, the Indus River Basin has become an area of severe rivalry and conflict over water between India, Afghanistan, and Pakistan [24]. Pakistan being the lower riparian has to manage the continuous water supplies from the upper-riparian Afghanistan, and from India.



### 2.1. Water Sharing with India

Pakistan is sharing its main water resources with India. Seven months after Pakistan came into existence, India stopped water in the Sutlej from flowing across the border into West Punjab, threatening Pakistan's agriculture [23]. A standstill agreement between India and Pakistan on water had expired on 31 March 1948. On 4 May 1948, India and Pakistan agreed to the Inter-Dominion Agreement to allow the continuation of water supplies for irrigation purposes, until the Pakistani side managed to develop alternative water resources. In 1951, former chairman of the Tennessee Valley Authority David Lilienthal also visited the region and suggested an engineering solution that later formed the basis of conflict resolution. In 1960, through the World Bank's mediation, a treaty (the Indus Basin Water Treaty (IBWT)) was signed between India and Pakistan, to solve the water disputes between the two countries [25]. The treaty gave the exclusive rights of three Eastern Rivers (the Ravi, the Beas, and the Sutlej) to India, while the other three Western Rivers (the Chenab, the Jhelum, and the Indus) were given to Pakistan. India was additionally given some specified non-consumptive use rights on the Western Rivers. Until now, the treaty has held up, even while Pakistan and India have fought three wars with each other [25]. The canal system of Southern Punjab, which previously was receiving water from the three Eastern Rivers, is the most affected region due to the Indus Water Treaty. The treaty reduced the international dispute but became a source of inter-provincial conflicts between the provinces of Sindh and Punjab and between Sindh and Baluchistan [23].

India has constructed mega hydropower projects on Western Rivers, which control water flow through these rivers, which are the only sources of water to Pakistan. Baglihar Dam, Ratle Hydroelectric Plant, Kishanganga Hydroelectric Plant, and Salal Hydroelectric Power Station are the main hydropower projects which are considered controversial and caused strain between the two countries. The technical support from the office of Indus Water Commissioner was limited due to its limited expertise. Pakistan can engage with India within the context of the IWT more positively than defensively, by improving technical expertise [26,27]. Many experts are also calling for revisiting some of the clauses of the treaty to include provisions for climate change and flood management [26].

### 2.2. Water Sharing with Afghanistan

Afghanistan has abundant water resources. Because of being a land-locked country, virtually all of Afghanistan's major rivers drain into neighboring countries, like Tajikistan, Turkmenistan, Uzbekistan, Iran, and Pakistan [28]. It produces 80 billion m<sup>3</sup> of water per year, draining 60 billion m<sup>3</sup>/year to the neighbors, particularly Pakistan. The Kabul River supplies 26% of the annual flow of water into Pakistan. Afghanistan and Pakistan share at least nine rivers but have never signed any agreement on joint management of the shared watercourses, which is really required at present [29].

The Kabul River, with its tributaries Kunar, Alishing, Alingar, Logar, Panjshir, Shutol, Ghorbund, Laghman, and Maidan, rises in the Hindu Kush and drains into the Indus River, near the city of Attock in Pakistan, after flowing along the borders of 11 provinces [5,30,31]. The Kunar River originates in Pakistan [32]. The Kabul River is one of the most important rivers and a potential source of hydropower for both countries. More than 7 million people in Afghanistan, equivalent to 23% of the Afghan population, live in the Kabul River Basin (KRB). In Pakistan, the river is a source for irrigation in KPK province and contributes to the irrigation network of Pakistan.

The Kabul River travels 560 km inside Afghanistan before entering Pakistan [32,33]. The Kunar River is one of the main tributaries of KRB that flows into the eastern part of Afghanistan and the northwestern part of Pakistan. The total length of this river, which ends in the Indus River in Pakistan, is 700 km. Importantly, in the KRB, Afghanistan and Pakistan are both upstream and downstream of each other. There is now a growing awareness in Afghanistan that peace in the country requires effective management of water resources [33,34]. India is supporting water-storage development in KRB, which results in further pressure on water resources in Pakistan [35–37].

### 3. Inter-State Water Sharing

Pakistan's international water disputes with India and Afghanistan are important, but inter-provincial water disputes are threatening political, domestic, and environmental security under the prevailing fragile political conditions. In Pakistan, disputes over the distribution of water between provinces did occur from time to time, particularly between Punjab and Sindh, but they have not led to serious conflict, as they remained peaceful and were limited to the political arena [7,35].

#### 3.1. Water-Resources Management

Poor management of water resources is another cause of increased water scarcity, and the outcomes of management failures are evident, both politically and technically, at the national and international level. If the water of the Indus River is managed equitably and efficiently, it is enough to provide for the livelihood of the people of all provinces [26].

In Pakistan, river flows are highly uneven through the year. As a result, agriculture depends on suitable storage capacity [26]. However, Pakistan has a storage capacity for only 30 days of average water consumption. This can be considered to be extremely low in comparison with other countries, such as Egypt (700 days), United States of America (900 days), and India (120 to 220 days) [38]. Currently, Pakistan has a water-storage capacity of 144 m<sup>3</sup> per capita. Ethiopia, a country with considerably less water resources than Pakistan has almost the same water storage capacity as Pakistan [39–41]. Due to this inadequate storage and high variation of freshwater availability, floods and droughts are extensive, affecting a large part of the country and causing significant adverse socioeconomic impacts. [39]. There are about 150 dams with a height of over 15 m or above in Pakistan. In contrast, neighboring India has constructed 3200 dams and reservoirs to save water for future needs [42]. The two major Pakistani dams are Mangla and Tarbela, with a maximum reservoir capacity of 7.2 and 13.7 km<sup>3</sup>, respectively [12]. The storage capacity of the two major dams is decreasing, and no new dam of the same level of capacity is being built. About 30% of the total storage capacity of Tarbela Dam has already been lost due to silting [43].

Development of new water-storage reservoirs is critical in Pakistan, but construction of dams has been delayed due to provincial conflicts [26,27,44,45]. The KBD project is the most controversial multipurpose project in Pakistan. Except for Punjab, all provinces are opposing its construction and commissioning. In March 2011, three provincial assemblies, Sindh, Khyber Pakhtunkhwa (KPK), and Baluchistan, passed resolutions against its commissioning, although Baluchistan is not directly impacted by the project [46]. The 7.52 km<sup>3</sup> of water stored at Kalabagh is planned to be distributed as KPK 1.36 km<sup>3</sup>, Punjab 2.59 km<sup>3</sup>, Sindh 2.59 km<sup>3</sup>, and Baluchistan 0.86 km<sup>3</sup>. A total of 971,245 hectares of additional land will be irrigated, with the smaller provinces getting far more than their proportionate share of water [47]. The project of the Diamer-Basha dam is in early stages of implementation, but the construction has not started yet.

Multiple organizations, divisions, directorates, public-sector consultancies, excellence centers, academies, and institutes are working in the water sector, covering different aspects of water management [21,43]. The current situation shows that the development of new storage facilities does not just have the technical aspects, but development of institutional capacity is missing to address the issues in accordance with cultural values and social circumstances [21].

#### 3.2. Water Demands

Most water is consumed by the agricultural sector. According to Blomquist and Ingram [48], out of the total available freshwater resources, 94% (196.79 km<sup>3</sup>) is used by the agricultural sector, 5% (4.71 km<sup>3</sup>) by municipalities, and only 1% (1.36 km<sup>3</sup>) is withdrawn by the industry [49,50]. This requirement of 202.85 km<sup>3</sup> is likely to increase to 217.78 km<sup>3</sup> by 2025. The economy of Pakistan depends heavily on agriculture. Of Pakistan's labor force, 44% is employed in agriculture, which contributes 21% to the GDP. Agriculture and agro-based products account for 75% of the country's total export



earnings [49]. Two-thirds of the entire Pakistani population lives in rural areas, and agriculture is the main livelihood for them [10]. During the last 72 years, the total cultivated area of Pakistan has increased by about 50%, while the population has increased almost five times. The urban areas have expanded over seven times, and this has put pressure on cultivated land [51].

Due to water consumption by the agricultural sector, this article will focus on water extraction for agriculture. The existing population densities and agricultural productivity could not have been possible in Pakistan without the present irrigation system. The delivery efficiency of the irrigation system is low, ranging between 35% and 40% from canal head to the crop root zone, due to age and poor maintenance [49,52]. Pakistan has a financially unsustainable irrigation system due to poor water pricing, which results in wastage of water by farmers [52]. As far as irrigation practices are concerned, flood irrigation is the most widely used irrigation technique in Pakistan. Current irrigation techniques are outdated and inefficient. The government is encouraging modern and efficient irrigation techniques. A \$1.3 billion drip irrigation program, which was subsidized by the Government of Pakistan, was launched in August 2007. The Japanese government assisted Pakistan with the aim to double irrigation efficiency, from 45% to 90% [53]. Along with the conservation of water, drip irrigation also increases the yield for the farmers, especially in the semi-arid regions. In comparison to conventional flood irrigation, drip irrigation has several advantages, such as less soil erosion, increased crop productivity, water savings, and reduced labor [40]. Increase in the yield ranges from 20% to 100% and water savings reach 40% to 70%.

### 3.3. Large-Water-Footprint Crops

The main agricultural exports of Pakistan are cotton, rice, and sugarcane. All of these three cash crops are water intensive. Among these three, sugarcane is the most water-intensive crop [54]. It consumes 1.6 times more water than rice, 2.7 times more water than cotton, and almost 6.8 times more water than wheat. Sugarcane is the second largest cash crop of Pakistan, after cotton. Pakistan is the tenth largest producer of sugarcane in the world, producing about five million tons of sugar per year. It is being cultivated on 966 thousand hectares, contributing around 3.6% of GDP. Sugarcane currently accounts for 4.8% of cropped area and 11% of value added of all crops. The productivity of sugarcane is reduced by almost 50% under heavy saline conditions [55]. Average yield of sugarcane in Pakistan is 47.5 tons/hectare, which is low in comparison to other sugarcane growing countries. Average yield of sugarcane in the world is 62.5 tons/hectare, and many countries have a sugarcane yield of almost twice that of Pakistan. The yield of sugar from sugarcane is also very low in Pakistan. The sucrose recovery from sugarcane in many countries averages 12%–14%, while, in Pakistan, the sucrose recovery is only 9% [56]. Therefore, Pakistan is among the world's highest-cost sugar producers in the world [57].

### 3.4. Emerging Role of Groundwater

Designed essentially as a supply-based system, the irrigation systems cannot adequately accommodate changing water demands during the crop season [58,59]. Therefore, in most parts of the Indus Basin, semi-arid to arid conditions prevail, and the surface water is not sufficient to meet the evapotranspiration demand of crops and high-intensity cropping [8,60,61]. Groundwater has become an important resource in Pakistan due to increasing demands in industrial, domestic, and agriculture sectors. Popularity of groundwater to supplement the shortfall of surface water is due to many reasons. For example, its availability on demand, high productivity, less initial investment, accessibility, and reliability.

Due to the increase in cultivated area and intensified irrigation practices by farmers over time, canal water availability per unit of irrigated land has become limited [61], and this has led to overexploitation of groundwater. Almost 800 thousand water pumps are operating in Pakistan. The farmers with access to groundwater are able to cultivate 90% of their total area as compared to only 63% for those who are fully dependent on canal water [62]. Income of farmers who have access to both

groundwater and surface-water resources is five times larger than that of farmers who depend fully on canal water [59].

Pakistan's groundwater potential is 68 km<sup>3</sup>/year, about 75% of which is being used, with 82% being used in Punjab, 8% in Sindh, 5% in KPK, and 1% in Baluchistan [63]. In Punjab, 50%–70% of agricultural water requirements are met by groundwater [59,64–66]. Groundwater withdrawal rates in Pakistan are unsustainable in most areas. Many parts of the Indus Basin have observed a continuous decline in groundwater tables, which results from the imbalance between recharge and abstraction. There are possibilities that the use of groundwater will be reduced due to increasing salinity and water logging in Pakistan [61].

### 3.5. Inter-State Water Sharing

Since the construction of the massive canal system by the British, the problem of water allocation and, consequently, conflicts between provinces occurred from time to time [67]. The water distribution between Bahawalpur state, Sindh, and Punjab have gone through Sutlej Valley Project Inquiry Committee (1932), Anderson Committee (1935), and Rao Commission (1945) [68]. According to the determined allocations, 94% of the water from the five eastern tributaries of the Indus was given to Punjab, and the remaining 6% was allocated to Sindh [69]. After the partition of the subcontinent in 1947, the Indus Water Treaty between Pakistan and India was signed. Link canals and storages from the western half of the Indus Basin to the eastern half were constructed to compensate for the water loss to India. The compensatory water and the storage on the Indus and the Jhelum Rivers was widely perceived by the Sindh to be compensation to the Punjab Province instead of Sindh [70].

Water is supplied to groups of 20–200 farmers through each outlet, and they share it through the “Warabandi System” (sharing by weekly roster of water turns), with one farmer only using the flow supplied by the watercourse during that time [71]. According to the 2010 Agricultural Census, almost 90% (17.24 million hectares) of total farm area is cultivated area [72]. Punjab accounts for about 63% of the total cultivated area of Pakistan, Sindh 18%, KPK 9.5%, and Baluchistan 8%. Punjab also has the highest cropping intensity in Pakistan. The total irrigated area in Punjab is about 8.62 million ha, and the harvested area is 14 million hectares, which indicates the highest cropping intensity [73], which is 76.38% of the total cropped area in Pakistan. The rural workforce, employed in agriculture, in Punjab, is about 63% [74]. Punjab, being the most intensive cultivated area is getting a supply of 69 km<sup>3</sup>/year (47.6%), whereas Sindh is getting a supply of 60.19 km<sup>3</sup>/year (41.4%). Baluchistan has received plenty of water and is never able to fully utilize its allocated water.

#### 3.5.1. Water Apportionment Accord 1991

The Interprovincial Water Accord was signed between the provinces of Pakistan in 1991, and the prolonged conflict of water between the provinces reached a settlement. At that time, for the first time in the history of Pakistan, all provincial governments belonged to the same political party. The accord was based on the assumed average flow of 141 km<sup>3</sup>/year in the Indus system (3.70 km<sup>3</sup>/year above the Rim stations). According to this accord, the allocations were for Punjab 69.03 km<sup>3</sup>/year, Sindh 60.17 km<sup>3</sup>/year, KPK 7.13 km<sup>3</sup>/year, and Baluchistan 4.78 km<sup>3</sup>/year. Future storage and flood water were to be distributed to Punjab and Sindh each 37%, KPK 14%, and Baluchistan 12%, as shown in Table 1 [40,43].

In order to balance river supplies to Punjab and Sindh, the Indus River System Authority (IRSA) was established on 10 December 1992 [75,76]. Problems arose when Sindh accused Punjab for not releasing its agreed quantity of water. The Baluchistan government also accused Sindh for not releasing water to Baluchistan [40]. The reservoir operations of the Mangla and Tarbela dams were the main causes of dispute among the provincial governments.

**Table 1.** Water allocation among the provinces.

Province	Total Allocation (km <sup>3</sup> )	Kharif Allocation (km <sup>3</sup> )	Rabi Allocation (km <sup>3</sup> )	Balance Supply Shares * (%)
Punjab	69.03	45.76	23.30	37
Sindh **	60.17	42.00	18.29	37
Baluchistan	4.78	3.51	1.25	12
KPK	7.13	4.29	2.83	14
Ungauged Canals ***	3.7	2.22	1.48	
Total	144.87	95.4	45.70	100

(Source: Indus Water Apportionment Accord 1991). \* Including future storages and flood flows; \*\* Including already sanctioned urban and industrial uses for Karachi; \*\*\* Ungauged Civil Canals above Rim Stations (A Rim Station, in the Indus Basin, is defined as the control structure (reservoir, barrage, etc.) on the river, just when it enters into the Pakistani territory or upstream of the canal-irrigated Indus plain of the Punjab and Sindh Provinces. The Rim Stations for the main Indus, Jhelum and Chenab Rivers are the Kalabagh Barrage, Mangla Reservoir, and Marala Barrage, respectively.) in KPK.

The Water Apportionment Accord of 1991 has no allocations of water for the special areas, which included Federally Administered Tribal Areas (FATA), Azad Jammu and Kashmir, Gilgit-Baltistan, and the capital, Islamabad, and does not provide a formula for new provinces or areas. Data from 1937 to 2007 show that the flows of the western rivers vary from 112.5 to 231.6 km<sup>3</sup>/year. At 50% probability, the mean annual river flows came out to be 168 km<sup>3</sup>/year. When the river flows are less than 141.11 km<sup>3</sup>/year, which happens with a 17% probability of exceedance, there is less water than stipulated in the Accord, which creates disputes amongst the provinces [77].

### 3.5.2. Viewpoints of Provinces

Lack of trust among the provinces of Pakistan, especially between Sindh and Punjab and between Sindh and Baluchistan, is the main cause of water disputes. Sindh always objects, as a lower riparian, about the withdrawal of the water from the upper canals by Punjab and objects that Punjab is using its water share. The groundwater salinity and the degradation of land in Sindh is more serious than in Punjab. Sindh claims more surface water to overcome the problem of salinity and sea water intrusion. Punjab, on the other hand, considers surpluses of 37–43 km<sup>3</sup>/year, which pass downstream Kotri as wastage and argues that it should be stored and put to use [78].

According to Punjab, the water distribution should have been based on irrigated area, which is not the case. Punjab had 75.5% of the entire irrigated area of Pakistan in 1990, and it got only 47.67% of the total water allocation. At the time of this Accord, Sindh had only 15.5% of total irrigated area, but it was allocated 41.55% of total water from the Indus River system. In Punjab, the agricultural sector was using 97% of total water available. For every cropped hectare, Sindh received 1.16 m<sup>3</sup> of canal water against 0.66 m<sup>3</sup> for Punjab. When compared to Sindh, Punjab has more than twice the cropped area, but the canal supplies are only slightly higher. As per unit of canal water, Punjab has a much higher productivity than Sindh.

Punjab's main objection is in regard to the excessive water release below the Kotri Barrage. From the Punjab point of view, up to September 2010, which is over the past 35 years, 1352 km<sup>3</sup> of water was wasted into the sea, which was equal to 10 years of canal withdrawals. A minimum amount of water is required below Kotri, for the protection of the ecosystem. The rest is a direct economic loss. If the 370 km<sup>3</sup> of the water required for environmental protection is deducted, the worth of remaining water comes out to be almost \$149 billion [76].

Of the water allocated to Baluchistan by IRSA, which is 4.77 km<sup>3</sup>/year, it only utilizes 1.01 km<sup>3</sup>/year. Baluchistan is not able to fully utilize its water share until its crop cultivation is expanded by developing the Kirthar and Pat feeder command area and beyond. Baluchistan accuses Sindh of utilizing its water share which they are not able to utilize. The Kalabagh dam project has no direct impact on Baluchistan; however, the provincial government is supporting the smaller provinces [16]. Water shortage is not an

urgent problem for KPK due to its location. The only problem KPK has is with the construction of Kalabagh's dam [44].

#### 4. Conclusions and Recommendations

Water sharing is a worldwide issue, but the problem exacerbates as the gap between the water supply and demand increases. The problem is further influenced by water-management practices, water-footprint efficiencies, and availability of additional water resources. Pakistan is facing severe water shortage at present, and the problem will become more severe due to climate change, growing population, and poor management of water resources. The country is situated in a water-stressed region, where other water-sharing countries are keen to get more and more water. The present water sharing with India and Afghanistan needs technical and political capabilities, to better negotiate the sharing issues. The main water conflict takes place between the downstream province of Sindh and the upstream province of Punjab and between Sindh and Baluchistan. Different water allocations nationwide, and a lack of trust between the provinces of Pakistan, worsened by inadequate technical policies, political defiant, and absence of latest technologies, is the main cause of water issues and inter-state disputes in Pakistan.

The scarcity of water is not just an issue of natural scarcity. It is socially generated scarcity as well. All the aforementioned problems have effective engineering solutions. However, the bottleneck is the political trust in such solutions. A sound technical and political strategy is essential to secure the due share of water resources. The water policy must aim at efficient utilization of water resources and small-water-footprint products, while developing a sense of equality and fairness. Water pricing can be introduced gradually, to encourage the efficient uses of water resources. The allocation formula must be based on some systematic engineering approach to accommodate Islamabad, newly added federally administered tribal areas into KPK, Gilgit-Baltistan, and any new province that may be created in the future. A proper water-sharing mechanism for groundwater, like that for surface water, should be made and properly implemented, to prevent over-extraction of groundwater. In order to ensure the accountability and transparency, efforts should be made to ensure suitable checks and balances of reported water data and of decisions made by the irrigation officials and water managers.

The water-resource issues of Pakistan are complex and multidimensional. The present technical capability of Pakistan proved its negotiation power in the region and incapability of handling the provincial sharing issues. This demands a well-thought-out water-issues understanding, reinforced and supported by a dedicated socio-engineering institute, to address the broad range of water-sharing issues. Such a new or restructured existing institute should interconnect all existing institutes/organizations by aiming the integration of multiple disciplines, capacity building, and dedicated research for the indigenous issues of Pakistan's water.

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