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## Water Resources and Development and Utilization in Belt and Road Countries: Postprint

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**Date:** 2020-06-01T00:00:00+00:00

### Abstract

Based on data regarding per capita water resources, transboundary water resources, and water utilization from the Food and Agriculture Organization of the United Nations (FAO) and the World Bank, and employing ArcGIS mapping and graphical analysis methods, this study examines the status of water resources and their development and utilization in countries along the Belt and Road Initiative in recent years. The results demonstrate that: Southeast Asia exhibits the highest per capita renewable water resources, while West Asia and North Africa show the lowest, manifesting pronounced regional heterogeneity; West Asia experiences the most significant decline in per capita renewable water resources, whereas Central and Eastern Europe along with certain other countries display a modest increasing trend. The disparity in water resources development and utilization is most pronounced between Southeast Asia and West Asia, with the latter achieving the highest water utilization rate and the former the lowest. The majority of countries feature transboundary water resources, with Central and Eastern Europe maintaining a relatively high proportion; however, in some nations, the incoming water component within renewable water resources equals zero. Agricultural water use constitutes a high proportion across Asian regions, while industrial and urban domestic water use account for relatively larger shares in Central and Eastern Europe.

### Full Text

#### Analysis on Water Resources and Their Utilization in Countries Along the “Belt and Road” Initiative

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**Abstract:** Utilizing statistical data on per capita water resources, cross-border water resources, and water utilization from the Food and Agriculture Organization of the United Nations and the World Bank, this study employs ArcGIS mapping and chart analysis methods to examine the status of water resources and their development and utilization in countries along the “Belt and Road” initiative in recent years. The results reveal significant regional disparities: Southeast Asia possesses the highest per capita renewable water resources, while West Asia and North Africa have the lowest. The most pronounced reduction in per capita renewable water resources occurs in West Asia, whereas Central and Eastern Europe and some other countries exhibit slight growth trends. Water resource development and utilization patterns show stark contrasts between regions, with West Asia demonstrating the highest utilization rate and Southeast Asia the lowest. Most countries have cross-border water resources, with Central and Eastern Europe showing relatively high proportions of external water. In some nations, the inbound water component of renewable water resources is zero. Agricultural water use accounts for a large proportion throughout Asia, while industrial and urban domestic water use constitute larger shares in Central and Eastern Europe.

**Keywords:** “Belt and Road” initiative; water resources; data statistics; exploitation and utilization

Water resources constitute an indispensable and irreplaceable natural resource for human social development, directly constraining population distribution and economic growth [1]. Since the proposal of the “Belt and Road” initiative, connectivity among participating countries and regions has intensified, with each nation seizing this opportunity to develop its economy and related industries on the international stage. Spanning vast distances and extensive territories, the “Belt and Road” initiative faces water security as a global challenge during its implementation [2], attracting considerable scholarly attention. Understanding the basic conditions of water resource development and utilization in these countries not only clarifies the current water situation and helps position the initiative accurately regarding water resources, but also provides valuable references for relevant foreign investment policies while laying a foundation for water security research. Moreover, as a fundamental national resource, water resources often reflect a country’s basic economic development model, helping identify factors that constrain economic growth and thereby promoting economic construction in “Belt and Road” countries and regions.

## 1 Data Sources and Methods

All water resource data for countries along the “Belt and Road” initiative were obtained from the Food and Agriculture Organization database (<http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en>) and the World Bank database ([https://data.worldbank.org.cn/indicator/ER.H2O.FWIN.ZS?end=2016&most\\_rece](https://data.worldbank.org.cn/indicator/ER.H2O.FWIN.ZS?end=2016&most_rece)). The list of “Belt and Road” countries and the administrative boundary base map (National Development and Reform Commission version) were provided

by the “Pan-Third Pole Environment” project of the Chinese Academy of Sciences. ArcGIS mapping technology was employed to integrate data with maps for analysis. Although some data were missing in certain analyses, their impact on overall regional results was minimal.

## 2 Basic Overview of the “Belt and Road” Initiative

The “Belt and Road” initiative, short for the “Silk Road Economic Belt” and the “21st Century Maritime Silk Road” [3], has attracted many countries to join and establish cooperation agreements with China since its proposal in 2013, fostering mutual development on this international platform. As of October 2018, 65 countries and regions participated in the initiative. Chinese scholar Li Zhifei divided the “Belt and Road” region into four parts: Central Asia and the Commonwealth of Independent States, East Asia, South Asia, and West Asia [4]; Zuo Qiting et al. classified it into 11 primary water resource zones based on physical geography and water resource differences [5]. Considering that Japan, North Korea, and South Korea in East Asia are beyond the scope of discussion, and to better analyze the spatial distribution characteristics of water resources, this paper adopts a geographical classification, dividing the “Belt and Road” region into six major areas: Central Asia, China-Mongolia-Russia, Southeast Asia, South Asia, Central and Eastern Europe, and West Asia/North Africa (Table 1).

**Table 1** List of countries along the “Belt and Road” initiative

*Central Asia:* Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan, Turkmenistan

*China-Mongolia-Russia:* China, Mongolia, Russia

*Southeast Asia:* Vietnam, Laos, Cambodia, Thailand, Malaysia, Singapore, Indonesia, Brunei, Philippines, Myanmar, Timor-Leste

*South Asia:* India, Pakistan, Bangladesh, Afghanistan, Nepal, Bhutan, Sri Lanka, Maldives

*Central and Eastern Europe:* Poland, Czech Republic, Slovakia, Hungary, Slovenia, Croatia, Romania, Bulgaria, Serbia, Montenegro, Macedonia, Bosnia and Herzegovina, Albania, Estonia, Lithuania, Latvia, Ukraine, Belarus, Moldova

*West Asia/North Africa:* Turkey, Iran, Syria, Iraq, United Arab Emirates, Saudi Arabia, Qatar, Bahrain, Kuwait, Lebanon, Oman, Yemen, Jordan, Israel, Palestine, Armenia, Georgia, Azerbaijan, Egypt

[Figure 1: see original paper] Geographical distribution of countries along the “Belt and Road” initiative

Most “Belt and Road” countries and regions are located in the Northern Hemisphere, primarily in Asia, with some Central and Eastern European countries and Egypt in North Africa. Among the six regions: (1) Central Asia comprises five landlocked countries characterized by temperate desert and continental climates. High mountains block moisture from the Indian and Pacific Oceans in the southeast, resulting in scarce rainfall and arid conditions. (2) The China-Mongolia-Russia region spans vast territories, particularly Russia’s

enormous east-west extent. Mongolia is landlocked, and both countries have predominantly continental climates. China, with its broad territory, features subtropical monsoon, temperate monsoon, and continental climates, with significant regional variations in rainfall. (3) Except for Laos, all Southeast Asian countries are coastal, bordering the Pacific Ocean to the east, the Indian Ocean to the west, facing Oceania across the sea to the south, and distributed along the South China Sea to the north. Located near the equator, the region has tropical rainforest and monsoon climates with abundant rainfall. (4) In South Asia, Afghanistan, Nepal, and Bhutan are landlocked, while Pakistan, India, and Bangladesh border the Indian Ocean to the south, and Maldives and Sri Lanka are island nations. Most areas have tropical monsoon climates with year-round high temperatures and significant precipitation variations. (5) Central and Eastern Europe borders Asia to the east and the Mediterranean Sea to the south, predominantly featuring Mediterranean and temperate continental climates with cold winters, hot summers, large annual temperature ranges, and concentrated but limited annual rainfall. (6) West Asia occupies a unique position as a hub connecting Asia, Africa, and Europe, bordering the Mediterranean Sea to the northwest, the Indian Ocean to the southeast, and adjacent to Asia and Africa in the northeast and southwest respectively. The region has tropical desert and temperate continental climates with arid conditions, scarce rainfall, and extensive grasslands and deserts.

### 3 Analysis of Water Resources Distribution in “Belt and Road” Countries

#### 3.1 Status of Per Capita Freshwater Resources

Among various natural resources, freshwater is the most heavily utilized [6]. Countries’ freshwater resources exhibit obvious regional differences in total volume due to geographical location, climate, and other conditions. When assessing a nation’s water resource status and scarcity, population factors must be considered—a large total water volume does not necessarily indicate abundance. For instance, in 2014, China’s internal renewable water resources totaled 2 813 km<sup>3</sup>, while per capita renewable water resources were only 1 999 m<sup>3</sup>, indicating severe water scarcity despite seemingly abundant resources.

[Figure 2: see original paper] Internal renewable freshwater resources per capita in countries along the “Belt and Road” initiative (2014)

In contrast to China, Laos in Southeast Asia presents the opposite scenario. In 2014, Laos’ internal renewable water resources amounted to 190.4 km<sup>3</sup>, less than one-tenth of China’s total, yet its per capita renewable water resources reached 2 8952 m<sup>3</sup>—over ten times China’s per capita availability. Laos’ abundant water resources benefit from its favorable climatic conditions of tropical and subtropical monsoon climates, with a five-month rainy season bringing 1 834 mm of precipitation annually [7], making it one of the most water-abundant countries in Southeast Asia. Beyond Laos, Southeast Asia has become one of

the world's most water-rich regions due to its unique geographical location and monsoon-induced rainfall. However, Singapore within this region faces extreme water scarcity despite abundant annual precipitation, due to its small land area, surrounding seas, lack of major rivers and lakes, rapid surface runoff to the ocean caused by topography, limited water storage capacity, high population density, and high urbanization levels with substantial water demand.

In stark contrast, West Asia suffers from arid, hot climates with minimal and uneven rainfall across most tropical and subtropical regions [8]. While oil reserves are extremely abundant, water resources are critically scarce. Except for Georgia (with 15 832 m<sup>3</sup> per capita renewable water resources), most countries face severe water shortages: Saudi Arabia has only 76 m<sup>3</sup> per capita renewable water resources, Qatar merely 26 m<sup>3</sup>, and countries including Israel, Yemen, Oman, and Kuwait all confront serious water scarcity. In West Asia, “water is more expensive than oil” has become a common perception.

Central and South Asia exhibit uneven water resource distribution. All five Central Asian countries (Kazakhstan, Kyrgyzstan, Uzbekistan, Tajikistan, and Turkmenistan) are landlocked with hot, arid climates. Statistical data show Uzbekistan and Turkmenistan have the lowest per capita water resources, followed by Kazakhstan, while Kyrgyzstan and Tajikistan are relatively abundant. Influenced by topography and river distribution, the region's two major rivers—the Amu Darya and Syr Darya—originate in Kyrgyzstan and Tajikistan, giving these upstream countries richer water resources [9]. In South Asia, Afghanistan, Nepal, and Bhutan are landlocked, while the other five countries border the Indian Ocean. Most areas have tropical monsoon climates influenced by southwest monsoons, with more precipitation in the northeast and less in the northwest [8]. In 2014, India's internal renewable water resources reached 1 446 km<sup>3</sup>, with 1 103 m<sup>3</sup> per capita, while Bangladesh, Nepal, and Bhutan have relatively high per capita renewable water resources. Bhutan's internal renewable water resources total 78 km<sup>3</sup>, with per capita availability reaching 10.0×10<sup>3</sup> m<sup>3</sup>.

Central and Eastern Europe's per capita renewable water resources rank second after Southeast Asia. Croatia leads with 24 882 m<sup>3</sup>, followed by Serbia and Latvia, while the Czech Republic has the least at 1 427 m<sup>3</sup>, followed by Poland at 1 567 m<sup>3</sup>. The China-Mongolia-Russia region shows large disparities: internal renewable water resources are 2 813 km<sup>3</sup>, 34.8 km<sup>3</sup>, and 4 312 km<sup>3</sup> respectively, with per capita values of 1 999 m<sup>3</sup>, 11 761 m<sup>3</sup>, and 30 058 m<sup>3</sup>, influenced by geography, climate, land area, and population.

### 3.2 Spatiotemporal Variation of Per Capita Freshwater Resources

Water scarcity poses a severe challenge to most countries, particularly water-deficient nations, with increasingly prominent socio-economic problems. Approximately 1.50×10<sup>9</sup> people worldwide lack adequate drinking water resources [10]. Global per capita renewable water resources are gradually decreasing. Based on the latest FAO statistics and using 2014 as the cutoff year, this analy-

sis examines changes in per capita renewable water resources between 2007 and 2014 in “Belt and Road” countries.

*Note: Negative values indicate increased water resources*

[Figure 3: see original paper] Per capita freshwater resources reduction rate along the “Belt and Road” initiative from 2007 to 2014

The figure clearly shows that most countries experienced reduced per capita freshwater resources in 2014 compared to 2007, with reduction rates showing regional patterns. Central Asia, South Asia, and most Southeast Asian countries had similar reduction rates of 6%-11%. West Asia showed the highest overall reduction rates; except for Syria and Georgia, which saw increases, most countries experienced substantial declines. Qatar and Oman exhibited the most dramatic changes, with per capita renewable water resources dropping from 49 m<sup>3</sup> and 540 m<sup>3</sup> in 2007 to 26 m<sup>3</sup> and 311 m<sup>3</sup> in 2014, respectively—reduction rates of 47% and 42% that demand serious attention. Research indicates Qatar’s early water policies were extremely lax, with citizens even receiving free water, leading to weak cost awareness and severe waste [11]. Between 2007 and 2014, most Central and Eastern European countries maintained stable or even increasing per capita renewable water resources. The region’s numerous rivers and mild, humid climate contribute to this trend. Romania, with 4 864 rivers totaling 78 900 km in length and almost its entire land area within the Danube River basin [12], achieved an 8% growth rate in per capita renewable water resources due to its temperate continental climate and abundant precipitation. Lithuania, leveraging its geographical advantages with numerous lakes and rivers, achieved the highest growth rate of 13% among all “Belt and Road” countries.

### 3.3 Internal and Cross-Border Water Resources

Renewable water resources comprise internal (domestic) and cross-border (external) components. Globally, 286 international rivers involve 151 countries [13], with cross-border water issues increasingly affecting 90% of the world’s population and 60% of available freshwater resources [14]. Most “Belt and Road” countries have cross-border rivers. According to FAO statistics, while most countries rely primarily on internal water, many have substantial external water components. The proportion of inbound water reflects a country’s dependence on external water resources and serves as a crucial indicator in cross-border river assessments [15].

[Figure 4: see original paper] The proportion of internal and external water in countries along the “Belt and Road” initiative (2014)

The figure shows that most countries have high proportions of internal water resources, including China and Russia; Myanmar in Southeast Asia; Iran and Georgia in West Asia; and Poland and Bulgaria in Central and Eastern Europe. Some countries have entirely internal renewable water resources with zero inbound water, including Mongolia; Malaysia, Singapore, Indonesia, Philippines,

and Timor-Leste in Southeast Asia; Bhutan, Sri Lanka, and Maldives in South Asia; the United Arab Emirates, Saudi Arabia, Yemen, and Oman in West Asia; and the Czech Republic in Central and Eastern Europe.

However, countries with high inbound water proportions are concentrated in Central and Eastern Europe, West Asia, and parts of Central, South, and Southeast Asia. High inbound water proportions reflect either relative scarcity of internal water, as in Kuwait, Egypt, and Pakistan, or topographical and river distribution factors. Kuwait's renewable water resources are entirely inbound water (0.02 km<sup>3</sup>) with zero internal production; the country once planned to import water from Iran via pipeline [16] and now relies primarily on expensive desalinated seawater, making it the world's most expensive water user. Conversely, the Danube River basin, with its numerous tributaries across multiple countries, makes inbound water the primary source for most Central and Eastern European nations.

**Table 2** Water resources status of some countries with high proportion of external water (2014)

Some countries experience “outbound” internal water, such as Kyrgyzstan and Tajikistan in Central Asia. The region has numerous transboundary rivers, most importantly the Amu Darya and Syr Darya, which originate in Tajikistan and Kyrgyzstan respectively, flow through multiple countries, and ultimately drain into the Aral Sea [17]. Besides these two Central Asian countries with substantial “outbound water,” Turkey and Lebanon in West Asia also have considerable water outflows due to topography and transboundary rivers.

**Table 3** Basic situation of “outbound” water resources in some countries along the “Belt and Road” initiative (2014)

## 4 Analysis of Water Resources Development and Utilization in “Belt and Road” Countries

### 4.1 Status of Water Resources Development and Utilization

The greatest value of water resources lies in their usability. For water-scarce countries, improving utilization efficiency to maximize limited water availability presents a major challenge. Water withdrawal measures a nation's economic development and basic domestic water consumption. In water-rich regions, withdrawal is far below internal renewable resources, whereas in arid, water-scarce regions, withdrawal approaches or even exceeds internal renewable resources, with some countries' total renewable resources insufficient for national development needs. Table 4 lists typical countries with significant differences in water resource development and utilization rates.

**Table 4** Status of water resources development and utilization in some countries along the “Belt and Road” initiative

*Note: Due to partial data missing, some countries in Table 4 and Figure 5 [Figure 5: see original paper] are from non-synchronous years*

[Figure 5: see original paper] The relationship between water withdrawal and total water resources in some countries along the “Belt and Road” initiative in 2012 (km<sup>3</sup>)

The data reveal substantial inter-country differences in water resources development and utilization, with clear regional patterns. West Asia and Southeast Asia present the most striking contrast: most West Asian countries have withdrawal volumes exceeding total renewable water resources, indicating extreme withdrawal pressure and the highest utilization rates along the “Belt and Road.” In contrast, Southeast Asian countries show lower withdrawal pressure, with most withdrawal volumes significantly below total renewable resources and consequently lower utilization rates. Due to geographical location, climate, and water resource conditions, South Asia, Central Asia, the China-Mongolia-Russia region, and Central and Eastern Europe show considerable variation in utilization rates without clear regional patterns.

## 4.2 Categorized Water Utilization

Water resources serve three fundamental purposes: industrial, agricultural, and urban (domestic) use, with proportions varying according to national development conditions. Recent World Bank statistics reveal significant regional differences in water use composition along the “Belt and Road” initiative.

**Table 5** Countries with a large proportion of agricultural water use

**Table 6** Countries with a large proportion of industrial water use

**Table 7** Countries with a large proportion of urban domestic water use

[Figure 6: see original paper] Basic situation of water resources utilization in the countries along the “Belt and Road” initiative

The data demonstrate that agricultural water use proportions are generally high across Asian regions. India, for instance, uses 90.41% of its water for agriculture and only 2.23% for industry. South Asia shows the most prominent agricultural water use, where extensive plains and seasonal monsoon rains make agriculture the primary water consumer, with high proportions also in Pakistan, Bangladesh, and Bhutan. High agricultural water use also characterizes the China-Mongolia-Russia region, Central Asia, Southeast Asia, and West Asia. In Central and Eastern Europe, recent statistics show larger industrial and urban water use proportions: Montenegro’s urban water use reached 59.91% in 2010, with industrial use at 39.03%; Bulgaria’s industrial water use accounted for 69.3% in 2015, with urban and agricultural uses at 15.98% and 14.72% respectively. This indicates that Central and Eastern Europe consumes most water resources through industrial and urban uses rather than agriculture. Figure 6 roughly reflects different regional economic development models, notably

South Asia's agriculture-centered economy versus Central and Eastern Europe's urban and industry-centered economy. Due to non-uniform data years from the World Bank, Figure 6 only provides a general overview of recent water use conditions.

## 5 Problems and Reflections

Water resource imbalance has become a prominent issue among “Belt and Road” countries, with varying degrees of disparity in water resource allocation across regions and even within the same region. The contrast between water-scarce West Asia and water-rich Southeast Asia is most pronounced, with West Asia characterized by arid conditions and sparse rivers, while Southeast Asia is humid with numerous rivers. Within the same region, such as Central Asia, Kyrgyzstan and Turkmenistan show dramatic differences: per capita internal renewable water resources are 8 237 m<sup>3</sup> and 261 m<sup>3</sup> respectively, though cross-border rivers adjust their total per capita renewable water resources to 3 976 m<sup>3</sup> and 4 609 m<sup>3</sup>. Beyond natural factors, how social and cultural elements such as national water policies and public water use habits affect water resource allocation remains to be investigated. Meanwhile, human impacts on water resources are increasingly prominent, with unsustainable activities occurring across many countries and regions, causing varying degrees of impact from resource reduction to complete depletion. This phenomenon is particularly evident in water-scarce regions like Central Asia, West Asia, and North Africa. Additionally, the Qinghai-Tibet Plateau, known as the “Roof of the World” and “Asia's Water Tower,” is the source of China's Yangtze and Yellow Rivers, Southeast Asia's Lancang River, and South Asia's Ganges and Indus Rivers. Research indicates that climate change on the plateau affects surrounding regions and even the globe, raising questions about whether water resource changes in the Asian portion of the “Belt and Road” are influenced by plateau climate change that warrant further investigation.

Cross-border water issues require serious attention. Most “Belt and Road” countries have cross-border water, with the majority including inbound water in their renewable water resources. International conflicts and disputes over cross-border water exist, particularly in Central Asia, where dense and complex transboundary rivers create shared water systems among multiple countries. Issues such as water allocation and balancing upstream-downstream relationships with agricultural irrigation have intensified inter-country contradictions [18]. Under the “Belt and Road” framework, properly addressing and peacefully resolving these issues through enhanced cooperation is key to achieving common development on the international stage.

Water resources development and utilization present common challenges. The relationships between total renewable water resources, internal water resources, and water withdrawal vary significantly across regions and countries. Water withdrawal reflects basic national water use conditions, and comparison with total renewable resources reveals withdrawal pressure. In water-rich Southeast

Asia, most countries' withdrawal volumes are far below internal renewable resources, indicating low withdrawal pressure, sufficient self-sufficiency, and low utilization rates. In water-scarce West Asia, Israel's internal renewable resources total  $0.75 \text{ km}^3$ , total renewable resources  $1.78 \text{ km}^3$ , yet withdrawal reaches  $1.594 \text{ km}^3$ —insufficient for national needs, requiring “borrowing” from neighboring countries. Other severely water-scarce countries like Iran, Kuwait, and Saudi Arabia also maximize water resource development, but overexploitation impacts ecological environments. Thus, resolving water scarcity while balancing ecological considerations is an unavoidable issue for most “Belt and Road” countries, especially the most water-scarce ones.

The problems in water resources status and development along the “Belt and Road” include both geographically induced imbalances and human-caused resource depletion. Identifying problem nature and seeking solutions is crucial. At the national level, countries must first recognize realities, assess water resource status and existing problems, then implement relevant policies. Water-rich countries can leverage their advantages to develop water-related industries, while water-scarce countries must address their shortcomings to prevent economic constraints. At the inter-country level, nations should enhance cooperation on water resources within the “Belt and Road” platform, especially neighboring countries, to resolve cross-border water issues rationally. Fundamentally, as a basic resource for human survival, water resources must be rationally allocated in all aspects of extraction, transfer, control, and conservation to eliminate waste.

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*Note: Figure translations are in progress. See original paper for figures.*

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