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Spatial Variability of Water Resources State of Regions around the "Belt and Road"

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Abstract: Water resource has become a key constraint for implementing the "Belt and Road" initiative which was raised by the Chinese government. Besides the study of spatial and temporal variability of precipitation, this study created a water hazard risk map along the "Belt and Road" zone through combined flood and drought data from 1985. Our results showed that South-Eastern Asia, southern China and eastern Southern Asia are areas with the most abundant precipitations, while floods in these areas are also the most serious. Northwest China, Western Asia, Northern Africa and Southern Asia are areas highly vulnerable to drought. Furthermore, the potential influence of flood and drought were also analyzed by associating with population distribution and corridor map. It reveals that China, South-Eastern Asia, Southern Asia, Western Asia and Northern Africa have the largest population number facing potential high water hazard risk. China–India–Burma Corridor and China–Indo-China Peninsula Corridor have the largest areas facing potential high water hazard risk.

Keywords: water security; precipitation; drought; flood; transport planning

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1. Introduction

In 2013, China proposed the "Silk Road Economic Belt" and the "21st-Century Maritime Silk Road" initiatives, which are collectively referred to as the "Belt and Road" [1]. The "Vision and Action for Promoting the Construction of the Silk Road Economic Belt and the 21st Century Maritime Silk Road" ("Vision and Action") was issued subsequently in 2015, which marks the formal implementation of the "Belt and Road" [2]. "Vision and Action" proposes that infrastructure interconnection is a priority mission for the "Belt and Road", due to improving the accessibility of roads not only facilitating the lives of local individuals but also promoting the sustainable development of the local economy and society [3]. Strengthening the ecological cooperation of the countries and regions along the corridor to avoid potential ecological risks and establish a green silk road is another important recommendation of the "Vision and Action" [2]. It is foreseeable that the implementation of the "Belt and Road" will have a significant impact on the transportation, urbanization and water resources in the countries and regions along the corridor. However, water scarce, flood and drought have posed a huge potential threat to the implement of the "Belt and Road" and sustainable development of society, especially in arid and semi-arid areas [4–7]. Therefore, understanding the temporal and spatial variability of water resources and water-caused natural hazards along the corridor can not only ensure the smooth construction of transportation infrastructure but also promote the sustainable development of countries and regions along the "Belt and Road" zone [8].

The "Belt and Road" zone traverses Eurasia and spans subtropical, temperate, cold temperate and frigid zones, with complex terrain and geological conditions. It is a high-risk zone for natural hazards such as flood, drought and extreme precipitation [9]. In Central and Western Asia, the construction of transportation, oil and gas pipelines is threatened by high temperatures, droughts and extreme precipitation. Frequent floods in Southern and South-Eastern Asia have also brought tremendous security risks to the operation of transportation facilities. According to the EM-DAT hazard database, there were more than 7200 natural hazards that happened in the world from 1990 to 2010 and more than 3003 times in the "Belt and Road" area, including 1131 floods and 94 droughts respectively which caused serious casualties and property damage [10]. At the same time, most countries and regions along the "Belt and Road" corridor are economically underdeveloped and agricultural dependent with relatively weak ability to withstand water stress [11]. Impacted by global warming, the risks of encounter extreme precipitation, drought and flooding are increasing [12–15], which brings tremendous potential risk to local human life, property, agriculture, economy and society along the "Belt and Road" corridor [16–19]. The fifth assessment report of Intergovernmental Panel on Climate Change (IPCC) indicated that the Lancang-Mekong River Basin has an increased precipitation during the monsoons of the past 30–50 years, while the precipitation during the dry season has dropped sharply, and with the accelerated thaw of the Himalayan glaciers and the Pamirs glaciers, the supply of glaciers to the rivers will be significantly decreased, and in a few years the billions of people living in South and Central Asia may confront the risk of losing fresh water [20]. Xia et al. found that there will probably be an increase in extreme floods and droughts in the Eastern Monsoon of China and irrigation water in the North China Plain will increase by 4% with the impact of global warming [21]. Reza et al. analyzed the data observed by more than 400 river monitoring stations distributed throughout Iran and discovered that floods caused by extreme precipitation in most parts of Iran have an obvious growth [22]. Other studies have shown that Belt and Road countries or regions, such as the Philippines, and Vietnam, Pakistan, the North-South Road Corridor and East-West Road Corridor of Myanmar, South Asia and South-Eastern Asia, also faced serious risk of floods and droughts [23–25]. However, spatial variability of water resources' condition and its related risk at a macro scale is more significant to the sustainability of Belt and Road Initiative.

Since water resources is a major constraint to the execution of "Belt and Road" initiative, it is necessary to figure out the spatio-temporal pattern of water resources on a macro scale. In this paper, we first analyzed the spatial distribution of mean precipitation in more than 60 countries of the "Belt and Road" zone. Then we used the flood data and drought data in the same period to make the water hazard risk map and graded the map with five levels based on potential water-caused risk. In addition, based on the flood and drought frequency map, we assessed the potential impact population, the corridor along the "Belt and Road" zone. We hope this paper will provide some support of water resources' state for the Belt and Road initiative to some extent.

2. Materials and Methods

2.1. Study Area

The "Belt and Road" zone stretches across the continent of Asia, Europe and Africa from the Pacific in the East to the Atlantic Ocean in the west and from Indonesia in the South to the Arctic Ocean in the north (Figure 1). Over 60% of areas of the "Belt and Road" zone is arid and semi-arid grassland, desert and high-altitude ecologically fragile areas with dry climate and low precipitation caused by effect of the Himalayas and global weather patterns [4]. Central Asia, Western Asia and Northern Africa are the driest areas in the world where serious water shortage and severe land desertification pose serious threats to social and economic sustainable development. South-Eastern Asia and Southern Asia are strongly affected by monsoon, with frequent natural disasters including droughts, torrential rains and floods [26]. "Belt and Road" countries have a population amounting to more than 70% of the world's population. However, the amount of water resources is only 36% that of the global total. It poses higher pressure in water security compared with the world average level [27]. In the initial vision for "Belt and Road Initiative" in 2015, there are 6 land economic and transportation corridors, which are a global economic connectivity program led by China. The 6 land corridors are China–Mongolia–Russia Corridor, New Eurasian Continental Bridge, China-Central Asia-West Asia Corridor, China–Pakistan Corridor, Bangladesh–China–India–Burma Corridor and China-Indochina Peninsula Corridor (Figure 1). Herewith, we zoned the study area of "Belt and Road" to 6 major zones of the Mongolia-Russia and Central Asia zone (MRCA), the South-Eastern Asia zone, the Southern Asia zone, the Western Asia and Northern Africa zone (WANA), the Central and Eastern Europe zone (CE Europe) and China [28] according to the 6 corridors.

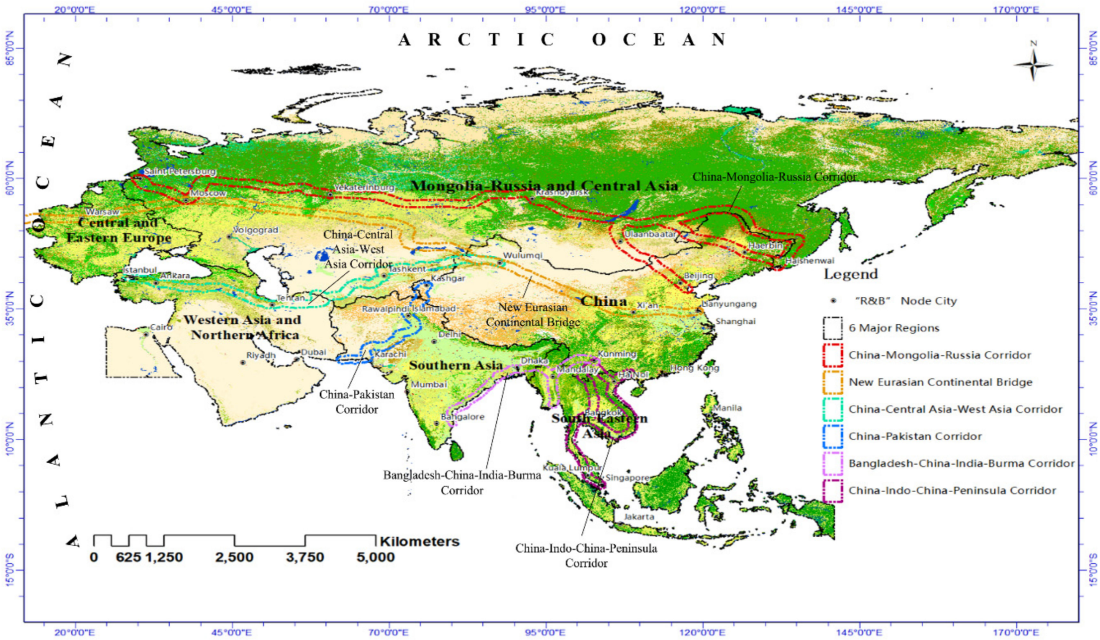

Figure 1. "Belt and Road" monitoring area and corridor map.

2.2. Data Source

The data used in this paper mainly include precipitation, drought, flood, population, cropland, highway and railway. The specific data sources and formats are shown in the following table (Table 1).

Table 1. Data specification.

Item	Spatial Resolution	Temporal Resolution	Format	Time	Source
Precipitation	0.5° × 0.5°	1 day	tif	1985–2016	National Oceanic and Atmospheric Administration
Drought	0.5° × 0.5°	1 month	tif	1985–2016	National Oceanic and Atmospheric Administration
Flood	0.5° × 0.5°	1 year	tif	1985–2016	Dartmouth Flood Observatory, University of Colorado
Population	30″ × 30″	/	tif	2015	Socioeconomic Data and Applications Center, NASA
Cropland	30 m × 30 m	/	tif	2015	U.S. Geological Survey
Railway	/	/	shp	2016	Resource and Environment Data Cloud Platform
Highway	/	/	shp	2016	Environment Data Cloud Platform

(1) Precipitation

Global daily precipitation data of 1985-2016 is derived from the NOAA Climate Prediction Center (CPC) Unified Precipitation Products dataset. It is created on a 0.5° lat/lon over the global land by interpolating gauge observations from 30,000 stations by considering orographic effects in precipitation.

(2) Drought

The Global SPEI (Standardized Precipitation Evapotranspiration Index) drought dataset of 1985–2016 is made available by Consejo Superior de Investigaciones Científicas (CSIC), with a 0.5 degrees spatial resolution and a monthly time resolution. SPEI is one of the most widely used drought indices in monitoring and quantifying droughts, which is developed by Vicente-Serrano et al. [29] based on the standardized precipitation index (SPI). The specific procedures for calculating SPEI can be found in the studies of Mahmoudi et al. [30] and Pei et al. [31] Positive values of SPEI indicate wet conditions, while negative values indicate dry conditions. SPEI classification rules are as follows: SPEI > -0.5 no drought; $-1.0 <$ SPEI ≤ -0.5 light drought; $-1.5 <$ SPEI ≤ -1.0 moderate drought; $-2.0 <$ SPEI ≤ -1.5 severe drought; SPEI ≤ -2.0 especially severe drought. In this paper, the droughts severity of no drought, light drought, moderate drought, severe drought and especially severe drought is assigned to values of 0, 1, 2, 3, and 4, respectively. Then, the drought frequency was classified into 5 classes of approximately equal number of grid cells based on the accumulated 32 years of datasets of drought severity from 1985 to 2016.

(3) Flood

The flood dataset of 1985–2016 is derived from Dartmouth Flood Observatory, University of Colorado, with a 0.5 degrees spatial resolution and a yearly time resolution, which is mainly retrieved based on official reports and remote sensing sources (http://floodobservatory.colorado.edu/index.html, accessed on 30 July 2021). The original data of floods is divided into three classes of severity based on 1–2 scale. Class 1 (large flood events): significant damage to structures or agriculture; fatalities; and/or 1–2 decades-long reported interval since the last similar event. Class 2 (very large events): with a greater than 2 decades but less than 100 year estimated recurrence interval and/or a local recurrence interval of at 1–2 decades and affecting a large geographic region (> 5000 km^2). Class 3 (Extreme events): with an estimated recurrence interval greater than 100 years. In this paper, we assigned the Class 1, Class 2 and Class 3 to values of 1, 2 and 3, respectively, and generated the 5-classes flood frequency map similar to drought frequency map mentioned above.

(4) Population

The population data of 2015 is obtained from Socioeconomic Data and Applications Center of NASA with spatial resolution is $30'' \times 30''$. Population input data are collected at the most detailed spatial resolution available from the results of the 2010 round of Population and Housing Censuses, which occurred between 2005 and 2015. The raster datasets are constructed from national or subnational input administrative units to which the estimates have been matched.

(5) Cropland

The Global Food Security-support Analysis Data 30 meter (GFSAD30) Cropland Extent data product provides cropland extent data across the globe, divided and distributed into 7 separate regional datasets, for nominal year 2015 at 30 meter resolution which was released by Department of the Interior, U.S. Geological Survey. Additionally, the validation dataset used to conduct an independent accuracy assessment of global cropland extent is available.

(6) Railway and Highway

The railway and highway data of 2016 was downloaded from the Environment Data Cloud Platform of Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences. The data format is ARCGIS shapefile.

3. Analysis of Spatio-Temporal Heterogeneity of Water Security

3.1. Precipitation

Changes in precipitation is the primary driving forces of flash floods [32,33]. Similar to previous studies of precipitation in the regions of the Belt and Road [34–37], our analysis of mean precipitation along the "Belt and Road" zone from 1985 to 2016 shows that the spatial distribution of precipitation is extremely uneven. The Western Asia and Northern Africa zone has the least annual precipitation of 142 mm among all regions; the areas with the most abundant precipitation are mainly concentrated in South-Eastern Asia, eastern Southern Asia and southern China. In particular, South-Eastern Asia has the highest average precipitation of 1867 mm, much higher than the average level of "Belt and Road" zone (Figure 2, Table 2). Spatial distribution of precipitation within China is also extremely uneven. While there is abundant precipitation in the southeast coast, precipitation in Northwest China is scarce. Southern Asia and South-Eastern Asia are faced with similar situations as China. Precipitation in the Mongolia-Russia and Central Asia and the Central and Eastern Europe are both at moderate level along the "Belt and Road" zone. Areas starting from Northwest China to Western Asia and Northern Africa are faced with severe water shortages, which is consistent with the fact that this area has extensive deserts with rare precipitation and intensive evaporation. This area has the most fragile ecological systems, which means special attention should be paid to local water resources' condition and ecological environment before carrying out urban and transport planning in this area.

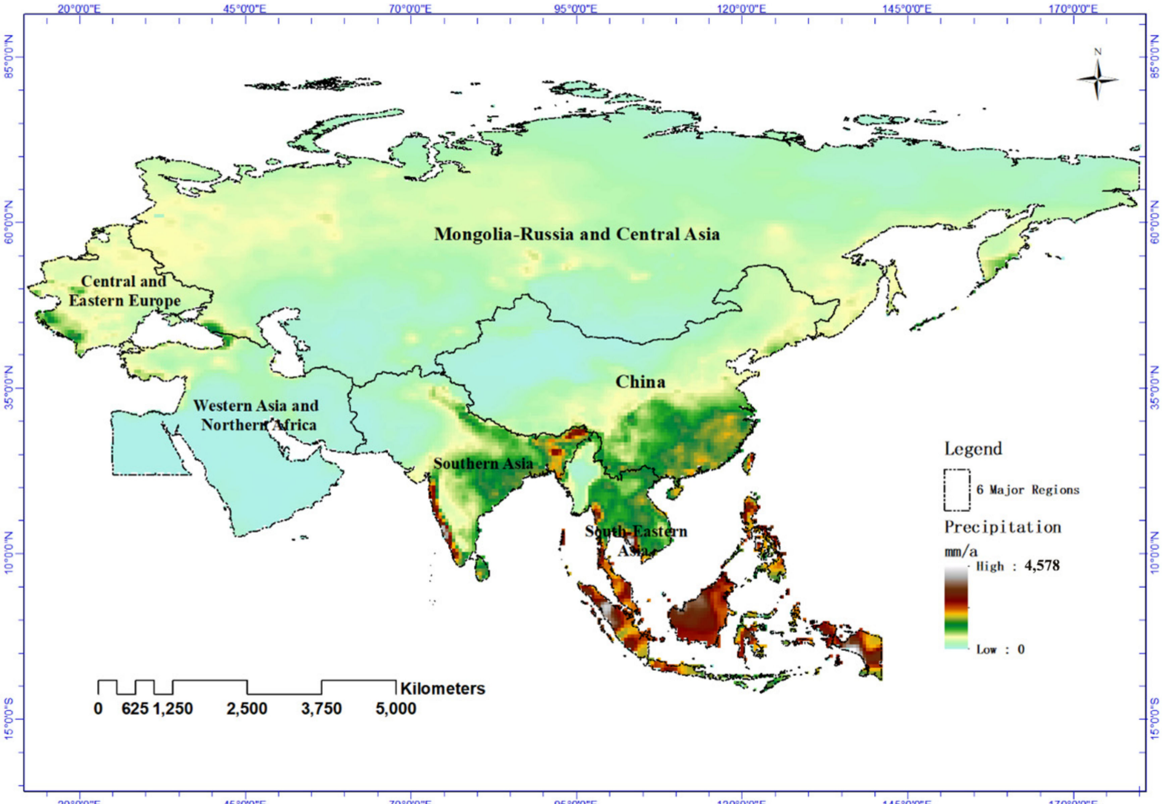

Figure 2. The spatial distribution of mean precipitation along the "Belt and Road" zone from 1985 to 2016.

Table 2. "Belt and Road" regional precipitation statistics table.

Zone	Minimum (mm)	Maximum (mm)	Mean (mm)	Std. Dev.
China	0	2573	549	466
South-Eastern Asia	0	4578	1867	900
MRCA	0	1396	351	156
Southern Asia	0	4059	778	618
WANA	0	1552	142	190
CE Europe	0	1448	603	146
Belt and Road	0	4578	497	531

Furthermore, we also analyzed the inter-annual variation trend of precipitation during 24 h with at least 50 mm according to the Chinese national standard of "grade of precipitation (GB/T 28592-2012)". Figure 3 shows an increasing trend with extreme precipitation in most areas of South-Eastern Asia, South-Eastern China and eastern Southern Asia, while the change trend in other areas is not obvious.

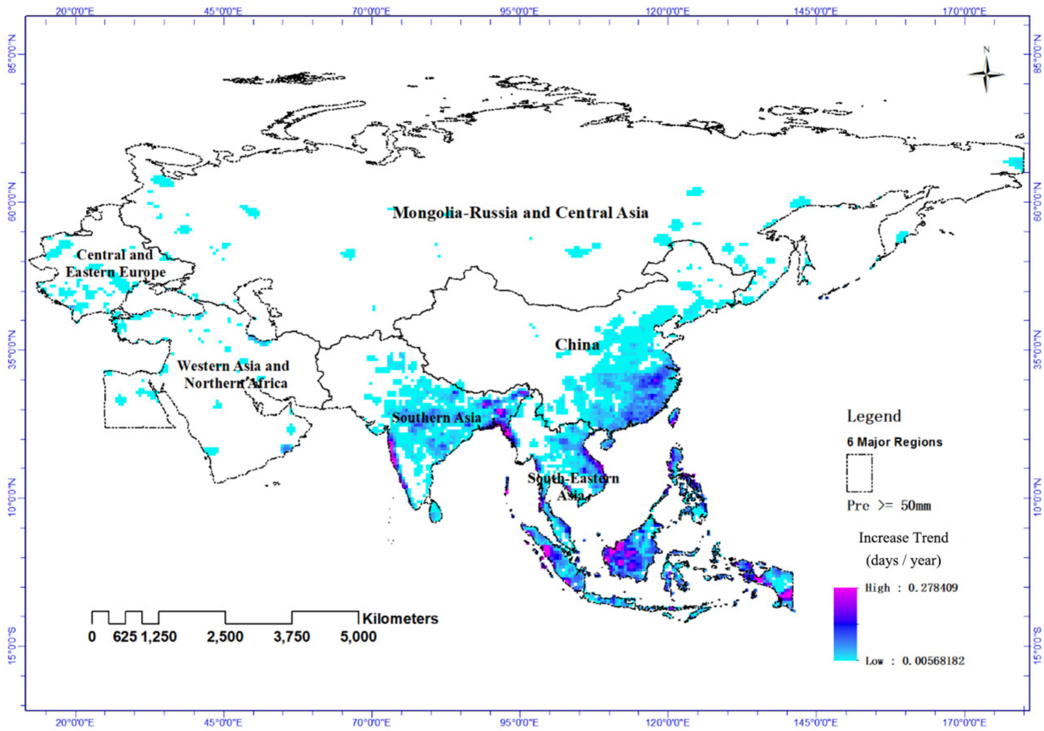

Figure 3. Inter-annual variation trend of precipitation during 24 h with at least 50 mm from 1985 to 2016.

3.2. Droughts

Drought is a natural disaster that has high occurrence frequency, long duration and a wide range of impacts. Drought can be regarded as regional and time-series water deficit processes, resulting in diminished water resource availability and ecosystem carrying capacity [38,39]. As shown in Figure 4a, Central Asia, Southern Asia, Western Asia and Northern Africa along the "Belt and Road" zone are all threatened by desertification and drought to varying degrees [40]. As can be seen, the drought in most areas of Western Asia and Northern Africa and Northwestern China are the most severe and the impact of drought in Mongolia-Russia and Central Asia is the most moderate. The severity of drought in eastern China, Southern Asia, South-Eastern Asia and Central and Eastern Europe is the slightest.

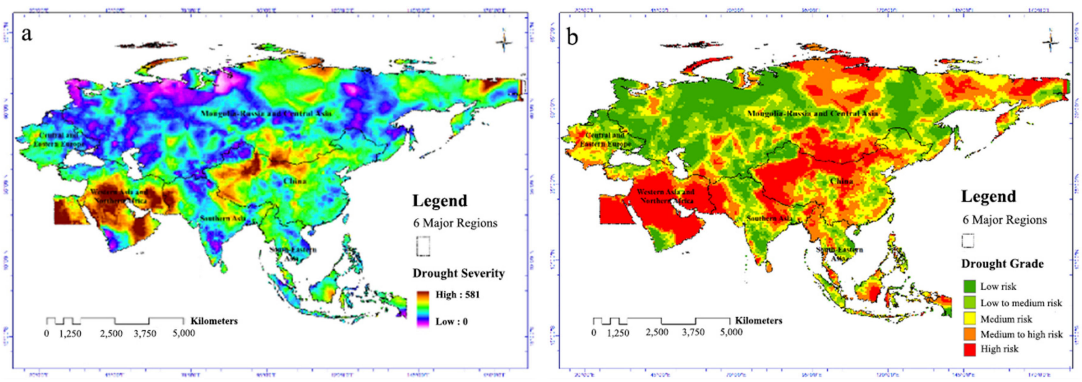

Figure 4. (**a**) drought frequency map along the "Belt and Road" zone; (**b**) drought frequency hierarchical map.

Then the drought frequency map was classified into five classes of approximately equal number of grid cells (Figure 4b). The greater the grid cell value in the final dataset, the higher the relative frequency of drought occurrence. The five drought frequency grades are low drought risk, low to medium drought risk, medium drought risk, medium to high drought risk and high drought risk respectively.

As shown in the table (Table 3), droughts in Western Asia and Northern Africa are the most serious, with high drought risk area covering 67% of the region, far exceeding the average level of "Belt and Road" zone. Droughts in China and Southern Asia are slightly better than Western Asia and Northern Africa but still not optimistic. The shares of the areas that suffer with medium drought risk and medium to high drought risk in South-Eastern Asia are both higher than the average level of "Belt and Road" zone. Central and Eastern Europe and Mongolia-Russia and Central Asia are the least affected areas by drought along the "Belt and Road" zone.

Table 3. "Belt and Road" drought impact area and proportion statistics table.

Zone	Low Drought Risk		Low to Medium Drought Risk		Medium Drought Risk		Medium to High Drought Risk		High Drought Risk	
	Area (10^4 km^2)	Percentage	Area (10^4 km^2)	Percentage	Area (10^4 km^2)	Percentage	Area (10^4 km^2)	Percentage	Area (10^4 km^2)	Percentage
China	50	5%	130	13%	248	26%	257	27%	276	29%
South-Eastern Asia	35	8%	98	22%	137	30%	140	31%	38	9%
Southern Asia	70	14%	111	22%	111	22%	103	21%	105	21%
MRCA	662	29%	522	23%	414	19%	412	18%	246	11%
WANA	30	4%	55	7%	66	9%	98	13%	509	67%
CE Europe	39	18%	68	31%	65	30%	41	18%	6	3%
Belt and Road	886	17%	984	19%	1041	20%	1051	20%	1180	23%

3.3. Flood

Flood is the most common natural hazard in the world which causes tremendous losses to human life and property every year [41–43]. Based on the analysis of the distribution of floods that happened along the "Belt and Road" zone from 1985 to 2016, the flood frequency map was obtained (Figure 5a); it revealed that southern China, South-Eastern Asia and the north of Southern Asia are the regions with the most serious floods, while floods in Mongolia-Russia and Central Asia, Central and Eastern Europe and Western Asia and Northern Africa are relatively rare.

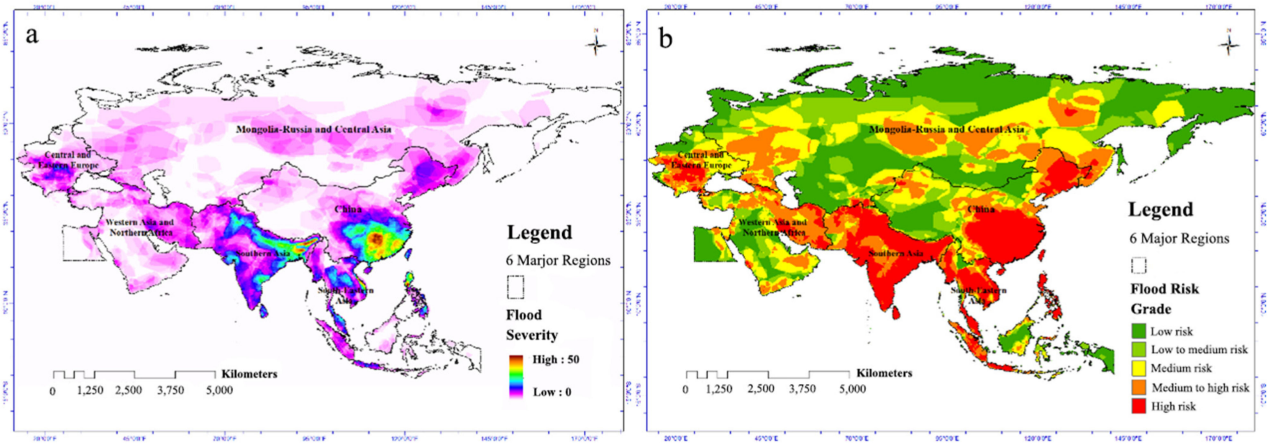

Figure 5. (**a**) flood frequency map along the "Belt and Road" zone; (**b**) flood frequency hierarchical map.

Then the flood frequency map was classified into five classes of approximately equal number of grid cells (Figure 5b). The greater the grid cell value in the final dataset, the higher the relative frequency of flood occurrence. The five flood frequency grades are low flood risk, low to medium flood risk, medium flood risk, medium to high flood risk and high flood risk respectively.

As shown in the table (Table 4), floods in Southern Asia are the most serious, with high flood risk area covering 67% of the region, far exceeding the average level of the "Belt and Road" zone. Floods in China and South-Eastern Asia are slightly better than Southern Asia but it is still not optimistic. The shares of the areas that suffer with medium flood risk and medium to high flood risk in Western Asia and Northern Africa and Central and Eastern Europe are both higher than the average level of "Belt and Road" zone. Mongolia-Russia and Central Asia is the least affected area by flood along the "Belt and Road" zone. There are especially few floods in Central Asia.

Table 4. "Belt and Road" flood impact area and proportion statistics table.

Zone	Low Flood Risk		Low to Medium Flood Risk		Medium Flood Risk		Medium to High Flood Risk		High Flood Risk	
	Area (10^4 km^2)	Percentage	Area (10^4 km^2)	Percentage	Area (10^4 km^2)	Percentage	Area (10^4 km^2)	Percentage	Area (10^4 km^2)	Percentage
China	138	14%	133	14%	182	19%	188	20%	319	33%
South-Eastern Asia	106	24%	31	7%	52	12%	87	19%	171	38%
Southern Asia	5	1%	5	1%	22	5%	131	26%	336	67%
MRCA	977	43%	417	18%	515	23%	336	15%	11	1%
WANA	179	24%	124	16%	182	24%	218	29%	56	7%
CE Europe	30	14%	23	11%	71	32%	59	27%	34	16%
Belt and Road	1435	28%	733	14%	1024	20%	1019	20%	927	18%

In addition, the distribution of flood in 2016 and potential affected cropland, railway and highway was analyzed. The most serious floods occurred in South-Eastern China. Southern Asia was affected by floods the most extensively. Total area affected by flood is the largest in Mongolia-Russia and Central Asia, while no floods occurred in Central Asia. Floods and disasters not only cause fatal blows to infrastructure of cities and industries, they also have serious consequences on agriculture and transportation [44]. Statistics on regions along the "Belt and Road" zone affected by floods are made based on spatial distribution of cropland, highways and railways. The results are shown below (Figure 6, Table 5).

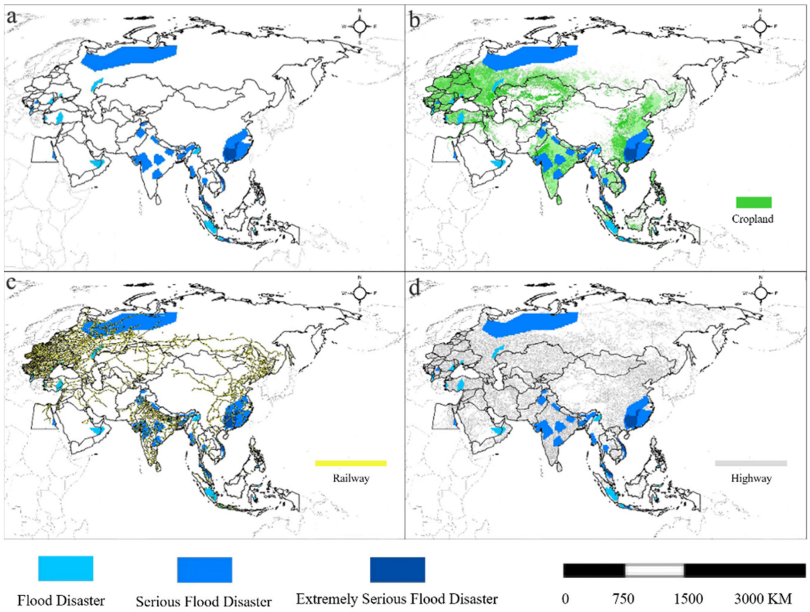

Figure 6. (**a**) spatial distribution of floods in 2016 along the "Belt and Road" zone; (**b**) potential affected cropland by floods in 2016 along the "Belt and Road" zone; (**c**) potential affected railway by floods in 2016 along the "Belt and Road" zone; (**d**) potential affected highway by floods in 2016 along the "Belt and Road" zone.

Table 5. Potential affected cropland/railway/highway by floods in 2016 along the "Belt and Road" zone.

Zone	Flood Area (10^4 km^2)	Cropland (10^4 km^2)	Highway (10^4 km)	Railway (10^3 km)
China	105	92	7	10
South-Eastern Asia	76	46	3	8
Southern Asia	117	93	9	22
MRCA	195	21	7	30
WANA	28	7	2	2
CE Europe	10	9	1	4
Belt and Road	531	268	29	76

In 2016, Mongolia-Russia and Central Asia had the largest area affected by flood disasters, reaching as high as 2 million km^2. However, since flood areas are mainly located in sparsely populated old-growth forest areas, the area of cropland affected is not large. China and Southern Asia have the largest areas of cropland affected by floods, both exceeding 1 million km^2. With respect to highways and railways, China, Southern Asia and the Mongolia-Russia Central Asia are the most heavily affected areas. Central and Eastern Europe and Western Asia and Northern Africa are the least affected areas in cropland, highways and railways (Figure 7a,b).

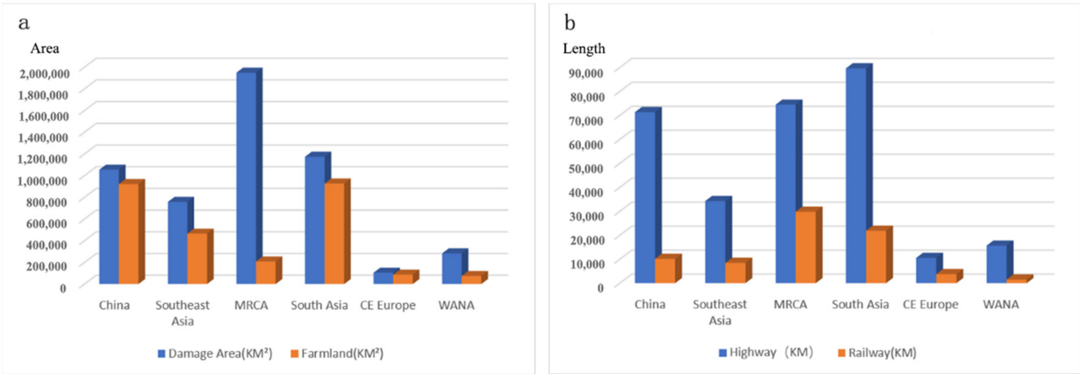

Figure 7. (**a**) Statistic of floods potential affected land and cropland along the "Belt and Road" zone in 2016; (**b**) Statistic of floods potential affected railway and highway along the "Belt and Road" zone in 2016.

4. Hydrological Disaster Impact Analysis

4.1. Water Hazard Risk Analysis

Water security is a key element to national and social development and regional stability, and many scholars have studied the vulnerability framework which combines natural and human-related risks [45–48]. In this paper we drew the water hazard risk map by combining flood data (Figure 5b) and drought data (Figure 4b) during 1985–2016 by accumulating the assigned values of drought severity and flood severity (Figure 8). Then the severity of the water hazard risk map was classified into five classes of approximately equal number of grid cells: low risk, low to medium risk, medium risk, medium to high risk and high risk respectively.

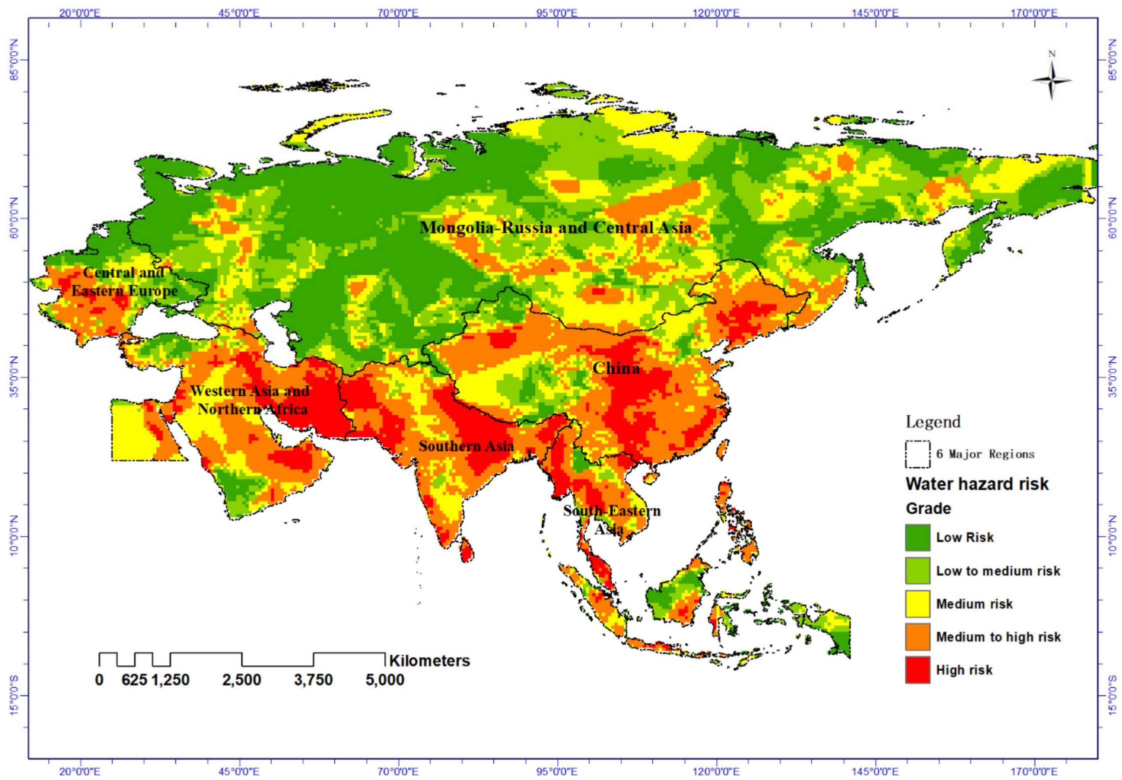

Figure 8. Water hazard risk map.

According to the statistics data from water hazard risk map (Table 6), 80% of the lands in Southern Asia are threatened by high and medium to high water hazard risk, which is much higher than the average level of the "Belt and Road" zone. The areas face high and medium to high water hazard risk in China, Western Asia and Northern Africa and South-Eastern Asia have also reached 65%, 62% and 56% respectively; the security of water resource is also not optimistic. The best areas with respect to water resources condition along the "Belt and Road" zone is Mongolia-Russia and Central Asia, where the areas facing high hazard risk in water resources are basically zero. The water security condition in Central and Eastern Europe is at a moderate level.

Table 6. "Belt and Road" regional water hazard risk statistics table.

Region	Low Risk		Low to Medium Risk		Medium Risk		Medium to High Risk		High Risk	
	Area (10^4 km^2)	Percentage	Area (10^4 km^2)	Percentage	Area (10^4 km^2)	Percentage	Area (10^4 km^2)	Percentage	Area (10^4 km^2)	Percentage
China	57	6%	94	10%	185	19%	445	46%	178	19%
South-Eastern Asia	63	14%	62	14%	71	16%	175	39%	77	17%
Southern Asia	5	1%	12	2%	86	17%	228	46%	168	34%
MRCA	927	41%	652	30%	486	21%	190	8%	2	0%
WANA	42	6%	48	6%	198	26%	303	40%	167	22%
CE Europe	60	27%	41	19%	37	17%	66	30%	15	7%
Belt and Road	1154	22%	909	17%	1063	20%	1407	27%	607	12%

As shown in the Figure 9, Southern Asia faces much higher water risk than other regions, followed by China and South-Eastern Asia, Mongolia-Russia and Central Asia; Central and Eastern Europe have the best water security condition.

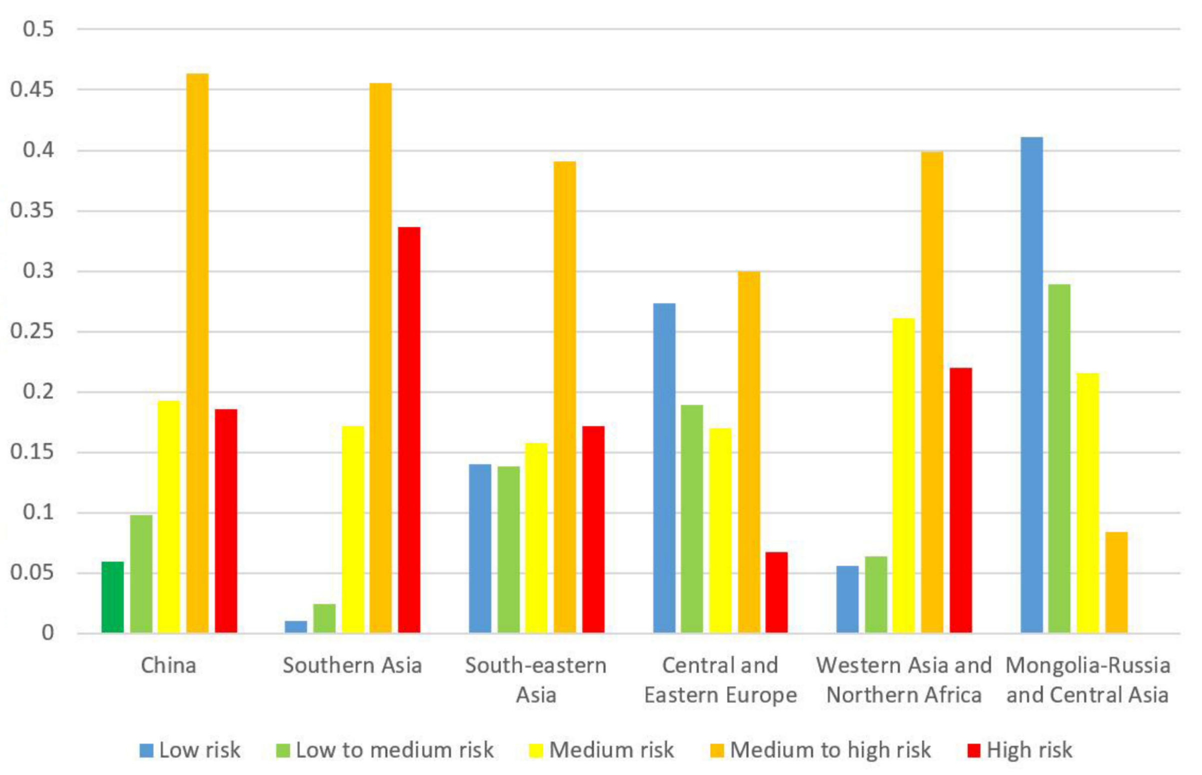

Figure 9. "Belt and Road" regional water hazard risk histogram.

4.2. Potential Impact Population Analysis

The "Belt and Road" zone passes through three continents—Asia, Europe and Africa, covering a wide range of areas, with complex and diverse natural environments and highly fluctuating population density (Figure 10). Spatial distribution of population has been recognized as a fundamental indicator of various studies including ecosystem assessment [49].

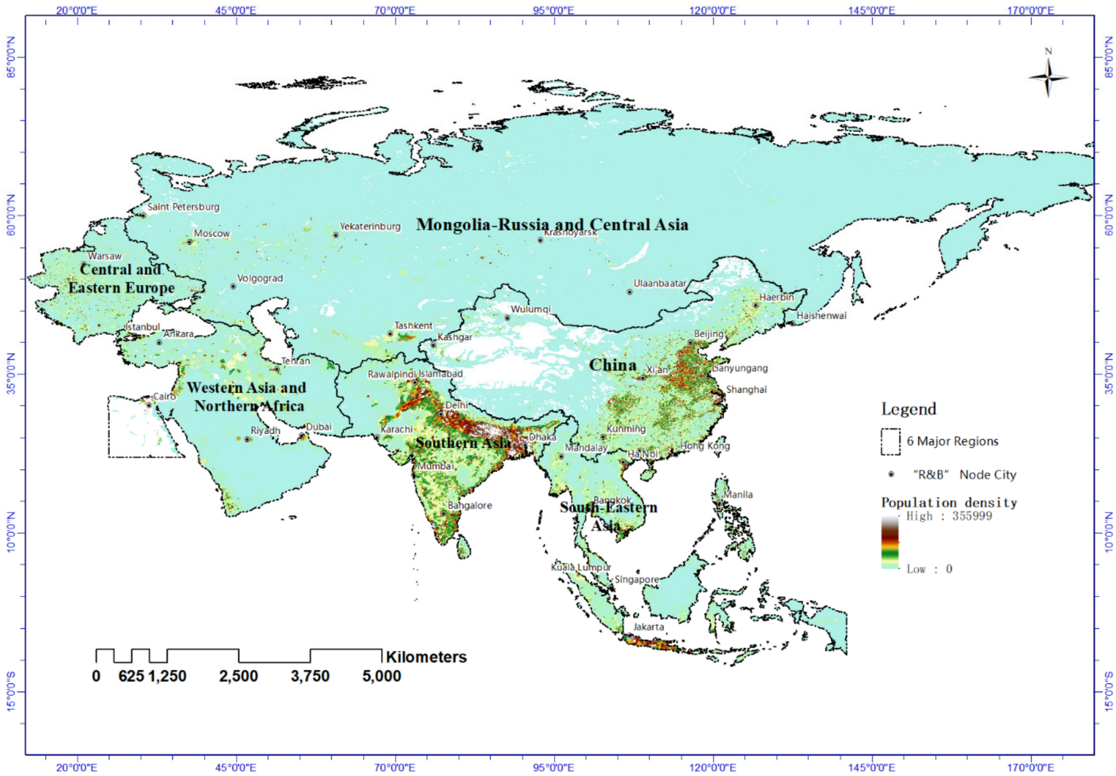

Figure 10. "Belt and Road" zone population density map.

By integrating the population density map of areas along the "Belt and Road" zone with the map of water hazard risk (Figure 8), the results are shown as the following table (Table 7). This means that 84%, 82%, 79% and 77% of the population of China, South-Eastern Asia, Southern Asia, Western Asia and Northern Africa are facing potential high water hazard risk, which is the most severe along the "Belt and Road" zone. The population facing potential water hazard risk in Mongolia-Russia and Central Asia is the least, followed by Central and Eastern Europe.

Table 7. Potential impact population along the "Belt and Road" zone by water hazard.

Region	Low Risk		Low to Medium Risk		Medium Risk		Medium to High Risk		High Risk	
	Popu (million)	Percentage	Popu (million)	Percentage	Popu (million)	Percentage	Popu (million)	Percentage	Popu (million)	Percentage
China	29	2%	47	3%	152	11%	838	59%	361	25%
South-Eastern Asia	22	4%	35	6%	66	11%	327	56%	132	23%
Southern Asia	0	0%	17	1%	278	17%	742	45%	609	37%
MRCA	80	43%	63	34%	26	14%	14	8%	1	1%
WANA	22	4%	32	6%	64	13%	245	50%	135	27%
CE Europe	38	21%	34	18%	27	15%	70	38%	15	8%
Belt and Road	191	4%	228	5%	613	14%	2236	50%	1253	28%

4.3. Potential Impact Corridor Analysis

The key areas of "Belt and Road" initiative mainly include six corridors, which are China–Mongolia–Russia Corridor (CMRC), New Eurasian Continental Bridge (NECB), China-Central Asia-West Asia Corridor (CCAWAC), China–Pakistan Corridor (CPC), Bangladesh–China–India–Burma Corridor (BCIBC) and China–Indo-China Peninsula Corridor (CICPC). Take NECB as an example, it runs through China and Central Asia with possible plans for expansion into South and West Asia. The Eurasian Land Bridge system is important as an overland rail link between China and Europe, with transit between the two via Central Asia and Russia. By integrating the corridors map (Figure 1) along the "Belt and Road" zone with the map of water hazard risk (Figure 8), the results are shown as the following table (Table 8). This means that 85%, 72% and 57% of the area of the China–India–Burma Corridor, China–Indo-China Peninsula Corridor and China–Pakistan Corridor are facing potential high water hazard risk, which are the most severe along the "Belt and Road" zone. China–Mongolia–Russia Corridor and New Eurasian Continental Bridge have the least area facing potential water hazard risk, followed by China-Central Asia-West Asia Corridor.

Table 8. Potential impact corridor area along the "Belt and Road" zone by water hazard.

Corridor	Low Risk		Low to Medium Risk		Medium Risk		Medium to High Risk		High Risk	
	Area (10^4 km^2)	Percentage	Area (10^4 km^2)	Percentage	Area (10^4 km^2)	Percentage	Area (10^4 km^2)	Percentage	Area (10^4 km^2)	Percentage
CMRC	66	27%	53	21%	72	30%	48	20%	6	2%
NECB	61	35%	37	21%	28	16%	35	20%	15	8%
CCAWAC	27	28%	26	27%	11	11%	23	24%	10	10%
CPC	5	12%	2	5%	10	26%	14	34%	9	23%
BCIBC	1	1%	1	1%	7	13%	31	60%	13	25%
CICPC	1	1%	5	7%	16	20%	36	46%	20	26%

5. Discussion

Water hazard risk of regions around the "Belt and Road" have increased in response to continued global warming and rapid urbanization. Understanding the spatial variability of water resources state of regions is necessary to the "Belt and Road" initiative. In nations of Western Asia and Northern Africa (WANA), the major water problem is the high drought risk (67% in Table 3), which leads to a decrease in food production, forest ecosystems degradation, expansion of desert and so on. Herewith, to WANA, the steps of afforestation, forest care and management, tree species improvement, domestic water saving, water use and irrigation efficiency improvement, utilization of sewage and rainwater, industrial water recycling and sewage treatment should be included in the "Belt and Road" initiative. Whereas, in Southern Asia, South-Eastern Asia and China, the main threat of water is the high risk of flood (Table 4), which also leads to vast economic loss and damage. Herewith, various methods such as enhancing flood prevention research, strengthening hydrologic infrastructure, emphasizing the role of flood early-warning systems, raising the standard of flood control and utilizing the resources of flood water, will be helpful to these regions in the "Belt and Road" initiative.

According to the experience of China, drought can be solved by the thought of harmony between human and water, construction of water-saving society, management of water resources and strategy of connecting river and lake systems. To the flood outside the city, a large number of water projects are necessary. While loosening waterlogging in the city needs cooperation from several departments of government, including water resources, municipal administration, transportation, land and so on. Of course, many countries around the "Belt and Road" are very concerned about water problems. However, under the conditions of frequent extreme climate, lack of water resources, fragile ecological environment and complex transboundary water resources issues, water resources security and its corresponding ecological security are significant to the "Belt and Road" initiative.

In this paper, we focused on floods and droughts to represent water security, which is mainly retrieved from surface water. Whereas groundwater is important to floods and droughts for providing nearly half of the water used for irrigated agriculture and it supplies drinking water for billions of people. Groundwater levels declining will exacerbate the risk of droughts in countries around the “Belt and Road”. Furthermore, the hydrological interaction between ground water and surface water will loosen the risk of floods. So, when considering the water security around the “Belt and Road”, groundwater resources and their availability for exploitation should be taken into account in the future. Furthermore, apart from the quantitative aspect, water quality both of surface and ground water is also a significant issue to water security. It is the same for droughts and floods; water quality deterioration has been classified as an important water hazard. Although water quality data is scarce around the “Belt and Road”, the utility value of surface and groundwater should also be analyzed in terms of its quality in future study.

6. Conclusions

Analysis of water security along the “Belt and Road” zone from 1985 to 2016 shows that, (1) The areas with the most precipitation are mainly distributed in the southeast, including South-Eastern Asia, southern China and eastern Southern Asia. Precipitation is scarce from Northwestern China to Western Asia and Northern Africa, with annual precipitation being less than 100 mm in most areas. (2) To the impact of floods, Southern Asia is most serious impacted, followed by China and South-Eastern Asia; Mongolia-Russia and Central Asia are the least affected area by flood along the “Belt and Road” zone. (3) To the impact of droughts, Western Asia and Northern Africa are the most serious, followed by China and Southern Asia. Central and Eastern Europe and Mongolia-Russia and Central Asia are the least affected areas by drought along the “Belt and Road” zone. (4) To the potential water hazard risk, China, South-Eastern Asia, Southern Asia, Western Asia and Northern Africa have the largest population number facing potential high water hazard risk. China–India–Burma Corridor and China–Indo-China Peninsula Corridor have the largest areas facing potential high water hazard risk.

Water security has become a key constraint to the sustainable economic and social development of countries along the “Belt and Road” zone. Rapid urbanization has exacerbated the contradiction between water shortage and water demand and has also caused the increasingly serious floods and droughts in urban areas. Therefore, bearing capacity of water resources and the environment should be carefully considered before formulating urban and transport planning. All these considerations will contribute to the smooth implementation of the “Belt and Road” Initiative. Of course, there are still many shortcomings in this study. For example, all the countries along the “Belt and Road” zone are not included in the analysis. Only the precipitation, drought and flood in the region are analyzed. The data such as groundwater and soil moisture are not taken into consideration. The utility value of surface and groundwater should also be analyzed in terms of its quality. All of the above shortcomings will be the emphasis in our future research.

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