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Characteristics and risk analysis of hydrological disaster events from 1949 to 2015 in Urumqi, China

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Abstract

According to the statistics and collation of data on the main hydrological disasters that occurred in Urumqi from 1949 to 2015, the risk characteristics of the main hydrological disasters in the city are identified and analyzed to reveal the distribution of local hydrological hazard risk based on the comprehensive disaster risk assessment theory for historical disasters. The research findings are as follows: (1) the main hydrological disasters in Urumqi are caused by floods, snow, and droughts, among which floods have the greatest risk, while the risk of droughts is minimal. (2) There are various and complex types of flood disasters in Urumqi, which have frequent occurrences, a wide range of influence, and easily cause secondary disasters. Snow disasters are complex and diverse, with frequent occurrences. Moreover, there are varied and complex types of drought disasters in Urumqi, which have frequent occurrences. Drought disasters in Urumqi, which last for a long time, have enormous effects on agricultural and forestry crops, while the frequencies of frost and hail disasters in Urumqi are lower. (3) Historical hydrological disasters in Urumqi mainly occurred from May to August and November to March of the following year, which are high-frequency months for hydrological disasters. (4) Flood disasters in Urumqi occur every 1.59 years, on average, while snow disasters in Urumqi occur every 1.65 years, on average. Additionally, flood and snow disasters could easily occur in the next 15 years. (5) The hydrological disaster environment in Urumqi is mainly affected by local temperature, sunshine, elevation, topography, precipitation, plant resources, and the social economy.

1 Introduction

Risk refers to the probability that the value of someone or something will be adversely affected (Woodruff 2005). Risk analysis has received extensive attention from social and natural science researchers, and research results are widely developed in the fields of disaster prevention, finance and insurance, construction, transportation, and food safety. Urban hydrology disasters are one type of urban disaster that affect urban ecology, which restricts the ecological, economic, and social benefits of the city. In recent decades, the frequency and scale of urban disasters have increased rapidly under the background of global warming. Among them, the regional disasters of hydrological meteorology, including drought disasters, snowmelt floods, rainstorm floods, glacial lake floods, hail, frost, snow, and debris flows, are especially serious. To reduce disaster risk, it is necessary for global and local societies or communities to assess weather and climate events (Watanabe et al. 2017).

International research on disaster risk assessment began in the 1970s (Sun et al. 2008; Wang et al. 2012; Sun et al. 2013). These studies, therefore, provide reference for disaster risk researchers for additional studies. Disaster risk research has become one of the most important scientific frontier issues at this time and even in the future. In the 1980s, action-oriented research on disaster prevention and mitigation started at a global scale. The International Association of Risk was founded in 1981, and a growing number of people began research on disaster risk analysis, risk management, and policy (Gu 2009). By the 1990s, research on disaster prevention and mitigation became increasingly comprehensive. In 1994, the First World Conference on Natural Disaster Reduction adopted the Yokohama Strategy, which proposed that risk

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assessments are a necessary step in the formulation of successful disaster reduction policies and measures (Wilhite 2005). In the twenty-first century, the United Nations adopted the Kobe Declaration at the Second World Conference on Disaster Reduction, held in 2005, which pointed out that disaster risk reduction should be a priority. The Hyogo Framework for Action was also adopted by the General Assembly, which discerned disaster risk identification, assessment, observation, and early warning as key areas in the framework (Wu et al. 2001). Subsequently, at the Third United Nations World Conference on Disaster Risk Reduction held in 2015, the United Nations adopted the Sendai Framework for disaster risk reduction for 2015–2030, which proposed priority areas for action, including strengthening disaster risk governance and managing disaster risks. In addition, the United Nations International Strategy for Disaster Reduction convened the first global platform for a disaster risk reduction assembly in 2007. The follow-up assemblies were held in 2009, 2011, 2013, and 2017 (United Nations International Strategy for Disaster Reduction 2017). In conclusion, the attention given by international organizations and scholars to disaster risk assessments has not been attenuated.

At the 19th National Congress of the Communist Party of China (CPC) on Oct. 18, 2017, Xi Jinping proposed to speed up the reform of the ecological civilization system to build a more beautiful China and noted that man and nature are the foundation of life (Xinhua News Agency 2017). Ecological prosperity leads to the prosperity of civilization, and fundamentally reversing the deteriorative trend in the ecological environment in China is also the inevitable choice for building eco-civilized cities and adhering to green development (Wen 2017). Therefore, the scientific understanding of urban hydrological disasters and the use of scientific and technological methods to predict, evaluate, and control disasters are essential for communities. According to the institutional reform plan of the State Council of the People's Republic of China in 2018, the newly established Ministry of Emergency Management integrated the disaster prevention responsibilities of former ministries and departments of the State (Xinhua News Agency 2018), which also indicates that China's policy support for disaster prevention and emergency management has developed under the background of a new era. In recent years, the research results of hydrological hazard risk analysis have mainly focused on the fields of drought disaster (Gong et al. 2016; Zhang et al. 2017; Liu et al. 2018), flood disaster (Ye et al. 2016; Sun et al. 2016a, b; Liu and Zhang 2017; Zhao et al. 2018), hail disaster (Yin et al. 2013; Li et al. 2016), frost disaster (Lou et al. 2013; Yao et al. 2016; Yang et al. 2017), and snow disaster (Sun et al. 2016a, b; Han et al. 2017). However, studies on the comprehensive analysis of the above five types of disasters are relatively rare. Taking Urumqi as the research object and referring to the research methods for

historical disasters (Sun et al. 2012; Wan et al. 2017; Song et al. 2018), this paper identifies and analyzes the risk characteristics of the main hydrological disasters in Urumqi and reveals the distribution of the risk of hydrological disasters in Urumqi.

2 General situation of the study area

Urumqi, capital of the Xinjiang Uygur Autonomous Region of China, is located in the northern part of the middle Tianshan Mountains and along the southern edge of the Junggar Basin, which lies across the Xinjiang terrain comprising "two basins lying between three mountain ridges." The geographic coordinates of the city are 86° 37′ 33″–88° 58′ 24″ E, 42° 45′ 32″– 44° 08′ 00″ N, and the city extends along the rivers in a zonal pattern. As the capital of the Xinjiang Uygur Autonomous Region and the core area of the Silk Road Economic Belt, Urumqi belongs to a semiarid continental climate in the temperate zone. The climate presents characteristics such as a small amount of precipitation and large temperature differences between day and night. Due to the climate background, Urumqi is a typical inland city in an arid area. Therefore, water resources are precious to Urumqi. The main water resources of the city come from underground runoff and ground runoff formed by glacial meltwater, lakes, and precipitation. In 2015, the resident population of Urumqi was 355×10^4, the established area of the city reached 429.96 km², the green coverage of the urban area was 287 km², and the green area of the constructed area was 159 km². The green coverage rate was 40.3%, and the green space rate was 37%. The total amount of urban water supply was 2.98×10^8 m³, the rate of water usage was 99.98%, and there were 198 insurance institutions.[1]

As the water resources of Urumqi mainly come from the channels of glacial meltwater, lakes, and precipitation, and because the climate background is a semiarid continental climate in mid-temperate zones that presents a large temperature difference between day and night and a small amount of precipitation, to a large extent, the water resources in Urumqi mainly depend on glacial meltwater and lake water storage. However, there are limited and dispersed underground runoff resources in the Dabancheng-Chaiwapu depression, Urumqi valley, and northern sloping plain. Although there are 46 rivers, such as the Urumqi River, Toutun River, and Baiyang River, the water volume is small, and the main water supply comes from glacial meltwater. In addition, Urumqi, which is far from the coast, has a long, cold winter and an extremely uneven seasonal distribution. Once the glacier snowmelt is delayed, it is more likely to lead to drought, and the prolonged

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[1] According to *the Statistical Bulletin of the Urumqi National Economy and Social Development 2015*

duration of drought results in the loss of ecological, economic, and social benefits of Urumqi, which finally leads to drought disasters. As a result of climate warming and other factors leading to early glacier snowmelt, it is highly possible to produce snowmelt flood disasters due to the undulating terrain, wide mountainous area, main geological structure of the Gobi layer, and other factors. Urumqi is surrounded by mountains on three sides (excluding the north), and its topography is high in the southeast and low in the northwest. As a result, it is often invaded by cold air from northern polar regions and Siberia. The formation of hydrological disasters, such as hail disasters, frost disasters, and snow disasters, primarily depends on the special geographical environment of Urumqi. Historical hydrological disasters in Urumqi include droughts, floods, frost, hail, and snow. Moreover, these main hydrological disasters not only occur in a single form but are also accompanied by other hydrometeorology types. For example, in the history of Urumqi, heavy rain and hail, snowstorms, snowmelt, torrential rain floods, rainstorm floods, and other hydrological disasters have occurred in Urumqi. These hydrological disasters, in turn, induce secondary disasters, such as landslides, torrential rain, and debris flows.

3 Data sources and research methods

The data for this study come from the *Xinjiang Fascisule of China Meteorological Disaster Encyclopedia; Xinjiang Statistical Yearbook, Urumqi City Records; Urumqi County Records; 40 Years of Disaster Reduction in Xinjiang; Urumqi Disaster Reduction Research*, *Xinjiang Natural Disaster Research; Xinjiang Chorography: Water Conservancy Records*; the *Urumqi Meteorological Information Service Network*; the *Xinjiang Uygur Autonomous Region Highway Administration*; *Xinjiang Flood Control and Drought Relief Command*; and *People's Daily*. According to the above, the regional scope, intensity, frequency, and duration of the major hydrological disasters in Urumqi from 1949 to 2015 are statistically sorted out. Based on the comprehensive analysis of historical disaster data, the characteristics and risks of hydrological disasters in Urumqi are analyzed.

4 Results and analysis

Urumqi is mainly affected by five types of urban hydrological disasters: drought disaster, flood disaster, frost disaster, snow disaster, and hail disaster. The formation mechanisms of these hydrological disasters depend on the four combined effects of a hazard-prone environment, disaster-bearing body, hazard and disaster prevention, and mitigation

capabilities. Therefore, it is necessary to identify the influencing factors of drought, flood, frost, snow, and hail disasters in Urumqi.

4.1 Comprehensive characteristics of disasters

4.1.1 Characteristics of drought disasters in Urumqi

Drought disasters refer to disasters caused by harsh or abnormal droughts, which cause a series of problems, such as the loss of life and property, ecological degradation, and social unrest. These disasters are natural disasters with a wide range of spatial, duration, and long-term impacts on the social economy and environment (Mishra and Singh 2010). Through the statistical analysis of historical drought disasters in Urumqi, the comprehensive characteristics of drought disasters in Urumqi can be found as follows:

(1) Drought disasters have a wide range of influence. These disasters in Urumqi affect not only the planting area; yields of the crop, forest and fruit industries; and yield of animal husbandry but also the quality and order of human life. In particular, drought that caused crop and fruit damage in 1991 indirectly led to difficulties for 1486 people living through the winter.

(2) Drought disasters last a long time. The duration of a drought disaster in Urumqi in 1961 was 100 days; it was 200 days in 1974, 60 days in 1981, 120 days in 1990, 100 days in 1991, 80 days in 1994, 30 days in 1995, and 80 days in 1997.

(3) Drought disasters have a deep impact on agricultural and forestry crops. Especially in 1961, 1962, 1967, 1968, 1981, and 1991, drought disasters in Urumqi caused crop failure. In 1985, a drought disaster in Urumqi led to a crop damage area of 12.01 km^2, which affected a forest area of 0.05 km^2 that resulted in an overwintering reserve reduction of 750×10^4 kg. In 1991, a drought disaster in Urumqi resulted in a reduction in grain production by 50×10^4 kg. The disaster area in the Dabancheng District was 2.67 km^2, with a grain reduction of 20×10^4 kg, and that in the Dongshan District was 1.83 km^2. In addition, the drought disaster risk in Urumqi is influenced and restricted by factors such as the geographical characteristics of its location in the mainland far away from the coast, the climate characteristics of aridity in the temperate zone, the lack of water resources, and the reliance on the supply of water mainly from melted glaciers and snow.

4.1.2 Characteristics of flood disasters in Urumqi

Flood disasters refer to losses and disasters caused by floods that affect normal human life and production activities

(Randeniya 2018). Based on the statistical analysis of historical floods in Urumqi, the comprehensive characteristics of flood disasters in Urumqi can be found as follows:

(1) Complex and varied types. The types of flood disasters in Urumqi are complex and varied and are usually accompanied by other meteorological events, such as floods caused by rainstorms, melted glaciers, and snow or floods from glacial lake outbursts.

(2) Frequent occurrence. According to the statistical data, 105 flood disasters have occurred during 1949–2015, with an average interval of 1.59 years.

(3) Wide range of influence. Flood disasters have affected the Urumqi River Basin, Toutun River, Ala Creek, Daban District, Nanshan, Houxia, and Urumqi urban area.

(4) Likelihood of causing secondary disasters. Flood disasters in Urumqi easily cause secondary disasters, such as debris flow, torrential rain debris flow, and landslides. In addition to precipitation factors, the risk of flood disasters in Urumqi is also affected and restricted by Urumqi's topography, vegetation cover, and distribution of water systems.

4.1.3 Characteristics of frost disasters in Urumqi

Frost disasters are one type of extreme event characterized by a short duration of freezing air, which is destructive for crop growth and production (Crimp et al. 2016; Frederiks et al. 2015). According to the analysis of statistical data, the frequency of historical frost disasters in Urumqi is lower, but these frost disasters that have occurred are not minor in terms of duration and disaster area. In particular, a frost disaster lasted for 4 days in 1991, resulting in a disaster area of 5.34 km^2. In 1993, the duration of a frost disaster reached 3 days, resulting in a disaster area of 10.61 km^2 and a crop-failure area of 1.11 km^2; another frost disaster lasted for 1 day in 1996.

In addition, the risk of frost disasters in Urumqi is affected by cold currents and air humidity and restricted by the topography to the north, which lacks huge mountain peaks.

4.1.4 Characteristics of hail disasters in Urumqi

Hail is produced in deep convective storms, which are characterized by strong updrafts, large supercooled liquid water contents, high cloud tops, and sufficient lifetimes. Hail often causes large losses to industries, transportation, and even the lives and property of people in local areas, which leads to a hail disaster (Punge and Kunz 2016). According to the analysis of statistical data, the frequency of historical hail disasters in Urumqi is lower, but the hail disasters that have occurred

are not minor in terms of duration and disaster area. Hail disasters in Urumqi occur mainly in Xiaoquzi, the Urumqi River, Toutun River, Ala Creek, Nanshan, Houxia, Daban District of Urumqi, Urumqi County proper, and the urban area of Urumqi mainly in the form of hail and rainstorm hail. A hail disaster in Urumqi in 1959 caused damage to crops (0.85 km^2) and light damage to vegetables. In 1960, a hail disaster in Xiaoquzi caused the winter wheat disaster area to reach 0.13 km^2. In 2008, a hail storm in Urumqi, which lasted 10 min, caused severe crop failure.

In addition, the risk of hail disaster in Urumqi is affected and restricted by water content, wind direction, and air flow.

4.1.5 Characteristics of snow disasters in Urumqi

Snow disasters refer to all types of losses and accidents related to snow due to snow accumulation caused by long-term, large-scale snowfall. For example, avalanche and snow cover cause major power failure and poor visibility; moreover, snow cover can also cause traffic jams and house collapses (Nakai et al. 2012). According to the statistical analysis, snow disasters in Urumqi mainly occurred in the Daban District, the Urumqi County, and the urban area of Urumqi and had the following characteristics:

(1) Complex and varied types. The types of snow disasters in Urumqi are complex and diverse and mainly occur in the form of snow disasters and blizzard disasters.

(2) Frequent occurrence. During 1949–2015, 40 snowstorms occurred in Urumqi, with an average interval of 1.65 years. It should be noted that 28 snowstorms occurred in Urumqi during the period of 2000–2015. In terms of time interval and frequency, Urumqi has been prone to snow disasters during the last 15 years.

In addition, the risk of snow disasters in Urumqi is affected and restricted by the abnormal global climate, the accelerated melting of glacial snow, and the terrain.

4.2 Hierarchical characteristics of disasters

Referring to the methods for classifying historical hydrological disasters and considering the actual situation in Urumqi, flood disasters are classified into three grades: severe, moderate, and general. (1) Severe disasters: more than 1000 people die, and the property damage exceeds 10 million yuan. (2) Moderate disasters: population mortality is from 100 to 1000 people, and property loss is from 1 to 10 million yuan. (3) General disasters: less than 100 deaths occur, and there is less than 1 million yuan in property damage (Ye and Chen 1996).

The hierarchical characteristics of historical hydrological disasters in Urumqi are obtained from statistics. Before the mid-1990s, the flood disaster grade in Urumqi was general,

and the flood disaster grade in Urumqi was severe after the mid-1990s (Yang and Chen 1999; Chen and Yang 1999; Wang et al. 2008). The grade of snow disasters in Urumqi was severe (Xu et al. 2014), and the grade of drought disasters in the city of Urumqi was moderate (Wu et al. 2016), while the grade of hail disasters in Urumqi was general (Shi et al. 2015; Shi et al. 2017). There are few studies on frost disasters in Urumqi, which may be related to the low frequency of frost disasters in Urumqi.

4.3 Interdecadal characteristics of disasters

Since the founding of the People's Republic of China in 1949, according to the statistical data of historical drought disasters, flood disasters, frost disasters, hail disasters, and snow disasters in Urumqi, the frequency changes and fitted curves of hydrological disasters in the history of Urumqi are plotted in Fig. 1, which shows the following:

(1) The frequency of flood disasters in Urumqi was high in the 1950s, 1960s, 1970s, 1990s, and 2010–2015 (Fig. 1a).
(2) The frequency of snow disasters in Urumqi was high in the 1980s, 1990s, 2000–2009, and 2010–2015 (Fig. 1b).
(3) The frequency of drought disasters in Urumqi was high in the 1960s, 1990s, and 2000–2009 (Fig. 1c).

(4) The frequency of hail disasters in Urumqi was 1 in the 1950s, 1960s, 1980s, and 2000–2009 (Fig. 1d).
(5) The frequency of frost disasters in Urumqi was high in the 1990s (Fig. 1e).

Figure 2 shows that the type of hydrological disaster with the most tremendous influence in the history of Urumqi is the flood disaster, and the disaster with the second-most influence is the snow disaster, followed by drought disasters; hail disasters and frost disasters have much lower frequencies than the other kinds of hydrological disasters. Therefore, in the process of making and implementing policies on disaster prevention and mitigation in the future, it is necessary to pay close attention to floods, snow, and droughts in Urumqi.

4.4 Monthly variation characteristics of disasters

According to the statistics on the cumulative frequency of historical hydrological disasters in Urumqi since 1949, it can be seen that the concentrated outbreak period of hydrological disasters in Urumqi is from May to August. As shown in Fig. 3, Urumqi suffers from a high degree of hydrological hazard risk in every month of the year except September and October.
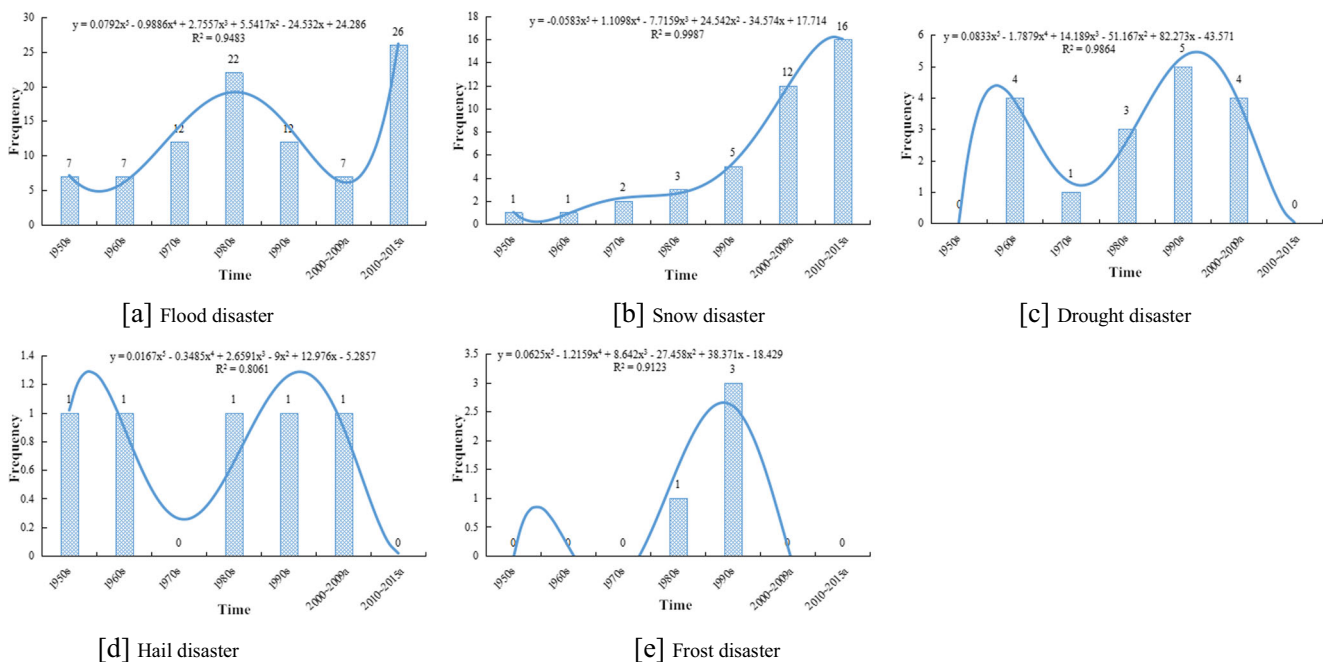

Fig. 1 Variation in frequency and the fitted curve of hydrological disasters in Urumqi during 1949–2015. Data sources: According to *Xinjiang Chorography Civil Records*, *Xinjiang Chorography Water Conservancy Records*, *Urumqi City Disaster Reduction Research*, *Urumqi City Records*, *Urumqi County Records*, *40 Years of Disaster Reduction in Xinjiang*, *Urumqi Meteorological Information Service Network*, *Xinjiang Uygur Autonomous Region Highway Administration*, *Xinjiang Flood Control and Drought Relief Headquarters*. Note: Because debris flow, torrential rain debris flow, and mountain collapse are secondary disasters caused by flood disaster, they are counted together. **a** Flood disaster. **b** Snow disaster. **c** Drought disaster. **d** Hail disaster. **e** Frost disaster
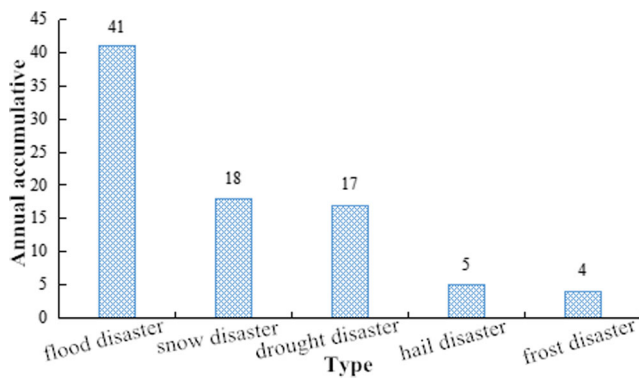
Fig. 2 Cumulative annual statistics of hydrological disasters in Urumqi during 1949–2015. Data sources: According to *Xinjiang Chorography Civil Records*, *Xinjiang Chorography Water Conservancy Records*, *Urumqi City disaster reduction Research*, *Urumqi City Records*, *Urumqi County Records*, *40 Years of Disaster Reduction in Xinjiang*, *Urumqi Meteorological Information Service Network*, *Xinjiang Uygur Autonomous region Highway Administration Bureau*, *Xinjiang Flood Control and drought Relief headquarters*

According to the monthly statistics on hydrological disasters in Urumqi from the 1950s to 2015, there are 137 hydrological disasters in total. The results show that the risk of historical hydrological disasters in Urumqi occurs in every month of the year, especially during the high frequency months from May to August and November to March of the following year.

4.5 Characteristics of periodic changes in disasters

To intuitively analyze the periodic changes in the main hydrological disasters in Urumqi, hydrological disasters that occurred in Urumqi from the 1950s to 2015 were counted annually. The average intervals between flood and snow disasters are 1.59 years and 1.65 years, respectively. Therefore, Urumqi will be prone to flooding and snow during the next 15 years.
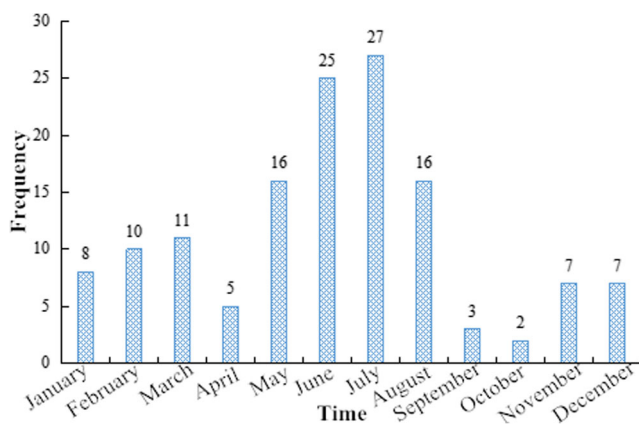

Fig. 3 Monthly variation on hydrological disasters in Urumqi

5 Hazard-prone environment affecting disaster events

A hydrological disaster environment refers to the environmental state of a hydrological disaster, which includes both a natural environment and a social environment. An environmental sensitivity analysis is also an indispensable factor for the risk assessment of hydrological disasters in Urumqi. In the first section, an analysis of the natural situation and socioeconomic profile of Urumqi is conducted, which is also the environment for hydrological disasters in Urumqi. For the environmental sensitivity assessment on hydrological disasters in Urumqi, it is necessary to comprehensively consider influencing factors, such as climate, landforms, precipitation, plant resources, and the social environment.

5.1 Climate

Urumqi has a continental semiarid climate in the middle temperate zone, and the temperature variation is very uneven, which reflects the characteristics of large diurnal temperature and annual temperature differences. Three types of hydrological disasters, i.e., flood disasters, drought disasters and snow disasters, which mainly affect Urumqi, are selected. By considering climatic factors, such as temperature, precipitation, and sunshine, the correlation analysis was carried out with the SPSS 19.0 software, and the results are shown in Table 1.

According to Table 1, there is a very significant positive correlation between the flood disaster year and average annual precipitation amount. The drought disaster year has an extremely significant negative correlation with the annual average precipitation amount, while it has a significant positive correlation with the annual average temperature and sunshine hours. Snow disasters are significantly and negatively correlated with the annual average temperature, while they have a significantly positive correlation with the annual average precipitation.

Table 1 Environmental correlation of hydrological disasters in Urumqi

Correlation coefficient	Temperature	Precipitation	Hours of sunshine
Drought disaster	0.819*	− 0.956**	0.806*
Flood disaster	0.087	0.927**	− 0.521
Snow disaster	− 0.929**	0.847*	0.418

** and * denote that the correlation is significant at the 0.01 level and 0.05 level, respectively (2-tailed). The data on the historical disasters of hail disasters and frost disasters in Urumqi are very small; therefore, they are not analyzed

5.1.1 Temperature

Through the data processing of the average temperature each year in Urumqi, information within the study period can be obtained by statistics, which are shown in Table 2. According to the data in Table 2, Urumqi is within the subzero temperature environment for 5 months (from November to March of the following year). During this period, it is easy to form the temperature environment for hydrological disasters (e.g., snow and frost). From 1949 to 2015, the frequency of snow disasters in Urumqi in September and October was 4 and 1, respectively, which was related to abnormal climate change.

5.1.2 Sunshine

The data processing results of the average sunshine hours each year in Urumqi are shown in Table 3, which reveals that the average monthly sunshine hours from May to August in Urumqi are more than 300 h, forming a drought-prone environment. Therefore, there is a greater risk of drought disaster between May and August. Taking the historical disaster data of drought disasters in Urumqi from 2000 to 2009 as an example, there were four drought disasters, which occurred in 2001, 2004, 2006, and 2008.

5.1.3 Precipitation

The water resources in Urumqi mainly rely on glacial melting, lakes and precipitation recharge. Precipitation is shown in Fig. 4. Through the data processing of the average monthly precipitation and annual monthly precipitation in Urumqi, the average monthly precipitation in Urumqi can be obtained, which is shown in Table 4.

As shown in Fig. 4 and Table 4, the precipitation in Urumqi for 5 months (from April to August) is greater than 30 mm. During this period, the mean monthly temperature of Urumqi

Table 2 Monthly mean temperature and annual average temperature in Urumqi (°C)

Time	Temperature	Time	Temperature
January	−12.2	July	24.2
February	−12.2	August	23.0
March	0.6	September	17.2
April	11.2	October	9.4
May	17.5	November	−0.3
June	22.5	December	−9.8
Mean	7.8		

Data source: the *Statistical Yearbook of Urumqi*; data processing of basic meteorological data via the product sharing service platform of the Xinjiang Uygur Autonomous Region

The statistical time is from 1970 to 2015

Table 3 Average sunshine hours per year in Urumqi (h)

Time	Hours	Time	Hours
January	108.4	July	315.0
February	128.3	August	307.6
March	220.4	September	281.7
April	273.9	October	238.2
May	313.6	November	138.8
June	312.7	December	95.2
Total	2733.9		

Data source: the *Statistical Yearbook of Urumqi*; data processing of the basic meteorological data via the product sharing service platform of the Xinjiang Uygur Autonomous Region

The statistical time is from 1999 to 2015

is between 11.2 and 23.0 °C, and the monthly average sunshine time is between 273.9 and 307.6 h, which is also conducive to the formation of glacial melting and snowmelt flooding. Urumqi is also located along a river; therefore, the formation of a flood-prone environment exists during this period. Taking the historical disaster data of the flood disasters in Urumqi from 2000 to 2009 as an example, the monthly average precipitation in Urumqi from April to August is up to 120 mm, and the precipitation and temperature during this period are higher than those in any other month. Therefore, there is a greater risk of flood disasters between May and August.

5.2 Topography and geomorphology

Urumqi is located in the northern part of the middle Tianshan Mountains and along the southern edge of the Junggar Basin. According to the analysis of elevation, terrain, geographical location, topography, and geomorphology, Urumqi is a typical arid region far away from the coast and is surrounded by mountains on three sides (excluding the north); the south has a high elevation, while the north has a low elevation and extends along the rivers in a zonal pattern. The unique topographic and geomorphological environment is favorable for hydrological disasters in Urumqi.

5.3 Plant resources

Urumqi is rich in plant resources. Taking the year 2014 as an example, the total afforestation area of the shelterbelt in Urumqi was 31.32 km², and the planting area of fruit trees reached 9.29 km². Among them, the planting area of apples was 2.41 km², with a yield of 858 t; the grape area was 2.47 km², with a yield of 3094 t; the peach area was 0.22 km², with a yield of 390 t; the apricot area was 3.42 km², with a yield of 458 t; the planting area of red jujubes was 0.17 km², with a yield of 306 t,
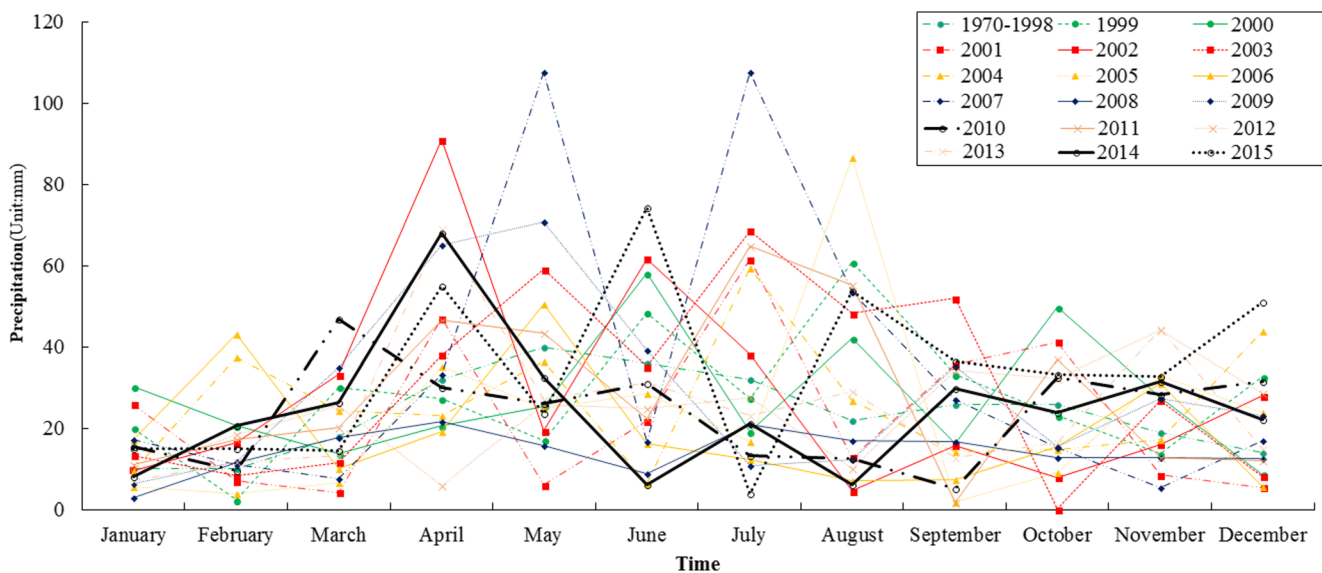
Fig. 4 Annual average monthly precipitation and annual monthly precipitation in Urumqi. Source: *Urumqi Statistical Yearbook*, Xinjiang Uygur Autonomous Region basic meteorological data and product sharing service platform. Note: The statistical time is from 1970 to 2015

and the remaining planting area was 0.6 km^2, with a yield of 1524 t. At the end of the year, the area for seedling cultivation was 9.21 km^2, and the timber cutting capacity of the village was 2412 m^3.

Forest vegetation has ecological benefits, such as preventing wind and sand erosion, conserving water sources, and conserving soil and water. However, when forest vegetation is destroyed, it aggravates the formation and occurrence of disasters. For example, the destruction of forest vegetation by human activities can lead to the gradual loss in the ecological benefits of the original vegetation. The destruction of forest vegetation also increases the occurrence of hydrological disasters under the influence of other hazard-prone environments, such as temperature, sunshine, precipitation, and topography.

Table 4 Average monthly precipitation and annual precipitation in Urumqi (mm)

Time	Precipitation	Time	Precipitation
January	13.0	July	34.9
February	15.3	August	31.3
March	20.0	September	22.3
April	40.5	October	22.6
May	36.2	November	24.1
June	31.6	December	21.4
Total	312.9		

Data source: the *Statistical Yearbook of Urumqi*; data processing of basic meteorological data via the product sharing service platform of the Xinjiang Uygur Autonomous Region

The statistical time is from 1999 to 2015

5.4 Social environment

The analysis of the social environment in Urumqi has been made in section 2, which shows that Urumqi has a large population, but the scale of educational institutions is smaller than that of any other provincial capital in China, which directly affects the percentage of the population that can receive education and, thus, indirectly affects the number of people that can receive an education on disaster prevention and mitigation. In other words, the scale of educational institutions in Urumqi restricts the ability of the local population to prevent and reduce disasters. Therefore, the social environment is also one of the forming factors for hydrological disasters.

6 Discussion

Existing research shows that there is a positive correlation between the annual flood frequency, disaster area and regional precipitation in Xinjiang. After the 1980s, the precipitation scales and frequency in most areas of Xinjiang obviously increased (Jiang et al. 2004; Liu 2009). The results of our study are consistent with this observation. Under the trends of global warming and increasing precipitation, Urumqi has a great risk for flooding in the future. Our research shows that snowfall and snowfall days in Urumqi are increasing each year. This city is one of the cities with a high probability of snowfall in Xinjiang and is a frequent area of snowstorms (Li. 2013). The results of this study are also consistent with this finding that Urumqi is in danger of snow disasters. Based on the analysis of hydrological disasters in Xinjiang from the perspective of social vulnerability, the main hydrological disaster in Xinjiang is flooding, followed by drought (Zhu 2011). The results of this study are consistent

with this observation and show that the risk of flooding in Urumqi is higher than that of drought. Existing research shows that the harm caused by hail in northern Xinjiang has gradually decreased since the 1960s (Xiang et al. 2007). The risk of hail disasters in Urumqi is far less than that of flood disasters, snow disasters, and drought disasters. Since the 1960s, frost weather in Urumqi has shown the trend that the final frost date is ahead of schedule, and the first frost date is postponed; thus, the frost-free period is prolonged, and the overall benefit of agricultural production is favorable (Zheng et al. 2015), as frost has the least disastrous effect on Urumqi.

7 Conclusion

According to the processing of statistical data, this paper has identified the main hydrological hazard risks in Urumqi and analyzed hydrological disasters in Urumqi from three aspects: the magnitude of the disaster risk, the characteristics of periodic change, and the hazard-prone environment.

First, hydrological disasters, which are more prone to occur in Urumqi, include flood disasters, snow disasters, and drought disasters. Among them, the risk of flood disaster is the highest, the risk of snow disaster is the second highest, and the risk of drought disaster is the lowest.

Second, through the statistical analysis of historical hydrological disasters in Urumqi, the following characteristics can be found: flood disasters in Urumqi are complex and diverse, with frequent occurrences. Moreover, this disaster has a wide range of impacts and easily causes secondary disasters. Snow disasters are complex, vary, and occur frequently. Drought disasters have a wide range of effects and long durations, which has a deep impact on agricultural and forestry crops. Frost disasters and hail disasters occur less frequently.

Third, according to the monthly statistics on the hydrological disasters in Urumqi from the 1950s to 2015, 137 hydrological disasters occurred during this period. The risk of historical hydrological disasters in Urumqi occurred every month of the year, especially in the high frequency months from May to August and November to March of the following year.

Fourth, the average interval of flood disasters in Urumqi is 1.59 years, and that of snow disasters in Urumqi is 1.65 years. Therefore, Urumqi will be prone to flooding and snow in the next 15 years.

Fifth, the environment for hydrological disasters in Urumqi is mainly affected by local temperature, sunshine, elevation, topography, precipitation, plant resources, and the social economy.

Compliance with ethical standards

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