Temporal and Spatial Evolution of Precipitation in the Central Inner Mongolia during 2016 to 2020 years

Yifan Liu

Water Conservancy and Civil Engineering College, Inner Mongolia Agricultural University, Hohhot, Inner Mongolia Autonomous Region, 010010, China

Abstract: *According to the precipitation data of the central region of Inner Mongolia, the trend of precipitation changes were firstly analyzed in temporal and spatial evolution, and the correlation relationship between precipitation and average temperature, relative humidity, altitude, effective sunshine hours,* ***,*** *green coverage area of built-up area were discussed then. The results showed that the precipitation decreased at first and then increased slightly in Ordos and Ulanqab while Baotou, Bayannur and Hohhot showed an irregular "W" in the inter-annual period, and the precipitation was mainly concentrated in July and August. In terms of space, the precipitation gradually decreased from the southeast to the northwest across the whole region, and it were greatly differences among cities. Through correlation analysis, we have identified the extremely association between the precipitation and average temperature, average relative humidity and effective sunshine hours in the study area.*

Keywords: *Inner Mongolia central region, precipitation, temporal and spatial Evolution, correlation analysis*

1. Introduction

Precipitation is an important part of hydrologic cycle, and its temporal and spatial variation is closely related to climate change, human production and life, and the evolution of ecological environment[1]. With the global warming, the non-uniformity of the spatial and temporal distribution of precipitation gradually increases, and the non-uniform distribution of precipitation events also increases in the region[2]. As the result, extreme precipitation events should be concerned in widely.

Inner Mongolia Autonomous Region is in the northernmost part of China, stretch across about 28 longitudes, from west to east across China's northwest, north, northeast three regions. The total area of 1.183 million km^2, accounting for about one-eighth of the total area of China. The average altitude is about 1000 m, which is mainly a plateau landform area. The average annual precipitation gradually decreases from 500 mm to about 50 mm from east to west, and the climate is temperate continental monsoon climate in general. The large spacing between the east and the west causes the small and uneven precipitation in the whole region, results the large difference natural environment also. As a typical eco-geographical transition zone from semi-arid region to arid region, the central region has complex and diverse terrain, fragile and single ecosystem, and precipitation directly determines the growth of vegetation, ultimately affects its ecosystem stability[3-6]. Li Hongyu et al.[7] revealed a good correlation between precipitation and temperature in Inner Mongolia. Ding Yong et al. [8] found that the spatial pattern of temperature and precipitation changes in Inner Mongolia was characterized by increased temperature and decreased precipitation, and vice versa. However, we find that these studies mainly focus on the regional distribution of precipitation and the influence of single factors, while there are relatively few analyses on the continuity of precipitation in time and space series. Therefore, this study selected five major cities in the central region of Inner Mongolia as the research object, by analyzing the characteristics of precipitation in spatial and temporal variation, and combining with meteorological and geographical factors, discussing the correlation relationship with precipitation, explored the evolution regularity of precipitation in spatial and temporal across the whole region, which aimed to provide more scientific value for the region sustainable development of water resources.

ISSN 2616-5872 Vol.4, Issue 8: 57-62, DOI: 10.25236/AJEE.2022.040811

2. Research area and research methods

2.1 Overview of the study area

The study area is in the central region of Inner Mongolia, including Hohhot, Baotou, Ordos, Bayannur and Ulanqab cities, with the area of about 251,000 km2, accounting for 21.77 % of the total area. The range of altitude the five cities is 756 m-2292 m, decreasing from the central to the north-south and east-west respectively, and there is large difference in altitude. The range of precipitation is 200 m- 400 mm in the study area. Due to the influence of East Asian summer monsoon and westerly circulation, there are obvious regional differences in precipitation, which presents more in southeast and less in northwest, and gradually transition from semi-arid to arid[5].The overview of the study area is shown in Figure 1.

2.2 Data sources and technical methods

The precipitation and meteorological data in this paper are derived from the Statistical Yearbook of the Statistical Bureau of the Inner Mongolia Autonomous Region (http://tj.nmg.gov.cn/tjyw/jpsj/) . Arc Map 10.2 and Excel were used for mapping. Statistical analysis was performed using SPSS 25.

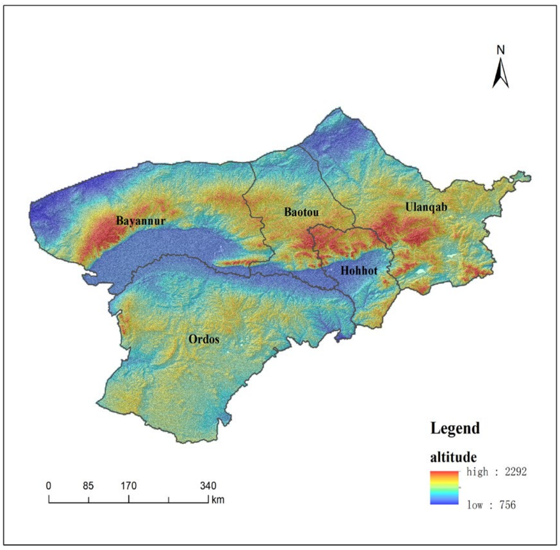

Figure 1: The general situation of study area

3. Results and analysis

3.1 Temporal Distribution Characteristics of Precipitation in Central Inner Mongolia during 2016 to 2020 years

Overall, the precipitation distribution in central Inner Mongolia was uneven and fluctuates greatly in different years. Among them, the precipitation trends in Ordos and Ulanqab was relatively consistent, with showing a decrease firstly and then a slow increasing. Baotou, Bayannur and Hohhot were more consistent, with the irregular “W” in rough. As the average annual precipitation, the five cities in the central region during 2016 to 2020 was shown as follows: Hohhot (444.6 mm) > Ordos (440.1 mm) > Ulanqab (403 mm) > Baotou (305.5 mm) > Bayannur (141.2 mm). The interannual variation of precipitation was significant, and the maximum difference among cities can reach 501.5 mm in the central region within 5 years. For example, the maximum annual precipitation of Hohhot and Baotou were in 2018, with 581.2 mm and 364.6 mm respectively. The maximum of Ordos was in 2016, which was 592.4 mm, and Bayannur was 193.3 mm in 2020 years, Ulanqab was 473.6 mm in 2016. The minimum annual precipitation of Hohhot, Baotou, Ordos and Ulanqab were 331.1mm, 208.2mm, 330.7mm and 337.9mm, respectively, which all in 2017 years. The minimum value of Bayannur was in 2019, with 90.9 mm. The annual distribution of precipitation in five cities in central Inner Mongolia from 2016 to 2020 is shown in Fig.2.

ISSN 2616-5872 Vol.4, Issue 8: 57-62, DOI: 10.25236/AJEE.2022.040811

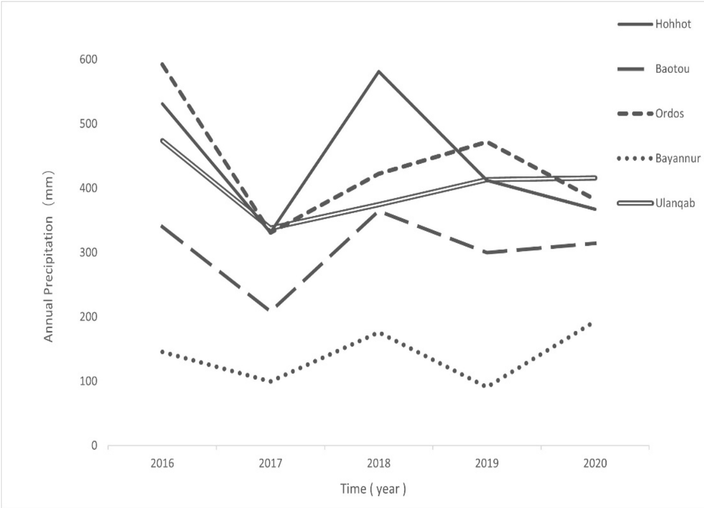

Figure 2: Temporal distribution of precipitation in central Inner Mongolia during 2016 to 2020 years

Table 1: Precipitation in central Inner Mongolia during 2016 to 2020 years

year	city	average monthly precipitation (mm)	min-monthly precipitation(mm) and min-value occurrence time (month)	max-monthly precipitation (mm) and max-value occurrence time (month)
2016	Hohhot	44.3	0.3 (1)	140.2 (7)
	Baotou	28.3	0 (1、11)	126.1 (8)
	Ordos	49.4	0.8 (11)	172.5 (8)
	Bayannur	12.2	0 (1、4、11、12)	52.1 (8)
	Ulanqab	39.5	0.7 (1)	142.0 (7)
	Central Region	34.7	0.36 (-)	126.6 (-)
2017	Hohhot	27.6	0 (11、12)	74.9 (6)
	Baotou	17.4	0 (11、12)	39.4 (6)
	Ordos	28.2	0 (11)	52.3 (10)
	Bayannur	27.6	0 (1、11、12)	21.1 (7)
	Ulanqab	8.3	0 (11、12)	86.8 (7)
	Central Region	21.8	0 (-)	54.9 (-)
2018	Hohhot	48.4	0 (2)	284.6 (7)
	Baotou	30.4	0 (2、12)	138 (7)
	Ordos	35.2	0.1 (12)	118.3 (7)
	Bayannur	14.7	0 (2)	58.3 (9)
	Ulanqab	31.2	0 (2)	182.3 (7)
	Central Region	32.0	0 .02 (-)	156.3 (-)
2019	Hohhot	34.3	0 (1)	102.3 (7)
	Baotou	25.0	0 (1)	91.6 (8)
	Ordos	39.3	0 (1)	104.5 (8)
	Bayannur	7.6	0 (1、2)	21.2 (7)
	Ulanqab	34.4	0 (1)	127.6 (7)
	Central Region	28.1	0 (-)	89.4 (-)
2020	Hohhot	30.6	0 (2、4)	148.9 (8)
	Baotou	26.2	0 (2、12)	98.5 (8)
	Ordos	31.9	0 (12)	118.3 (8)
	Bayannur	16.1	0 (3、10)	81.1 (8)
	Ulanqab	34.7	0 (2、12)	176.8 (7)
	Central Region	27.9	0 (-)	124.7 (-)

Note: the data in the table were respectively：the average monthly precipitation (mm), the maximum and minimum monthly average precipitation (mm) and the occurrence time of the extreme value in each year. The "-" indicated unclear time points.

ISSN 2616-5872 Vol.4, Issue 8: 57-62, DOI: 10.25236/AJEE.2022.040811

It can be seen from Table 1 that the monthly average precipitation ranged from 7.6 mm to 49.4 mm during the five years from 2016 to 2020 years in the central region of Inner Mongolia. The monthly average precipitation among the inter-annual overall in order was: 2016 (34.7 mm) > 2018 (32.0 mm) > 2019 (28.1 mm) > 2020 (27.9 mm) > 2017 (21.8 mm). The maximum and minimum monthly average precipitation were in Ordos (49.4 mm) in 2016 and Bayannur (7.6 mm) in 2019, respectively, with the difference was 41.8 mm. The monthly precipitation among five cities in central Inner Mongolia during 2016 to 2020 years was shown in Table 1. Monthly variation of precipitation showed high similarity in 5 cities, with more precipitation in July and August, and less in January to April, November and December. This mainly attributed to the rain and heat distribution synchronously. In general, the summer began in mid-to-late June and ended in early September in central Inner Mongolia, so the precipitation showed the highly concentrated trend[9]. It was worth noting that the time of max precipitation in Ordos was in October in 2017, which was relatively rare. We consulted and synthesized the local meteorological data found that mainly related to the humidity in 2017 was significantly higher than that in the same period over the years, and the ecological meteorological quality conditions were better than those in the same period over the years, also the autumn precipitation was more abundant than that in the same period over the years[10].

3.2 Spatial distribution characteristics of precipitation in central Inner Mongolia during 2016 to 2020 years

In general, the precipitation among the five cities in the central region of Inner Mongolia showed the decreasing trend from southeast to northwest and the difference was large. Precipitation was mainly concentrated in the southeastern Ulanqab, southeastern Hohhot and southeastern Ordos ; the precipitation in the north of Ulanqab and the northwest of Baotou decreased significantly. The precipitation in Bayannur was extremely poor, and the precipitation in the northwest and central parts were sometimes even less than 200 mm. The spatial distribution of precipitation in central Inner Mongolia during 2016 to 2020 was shown in figure 3. The change trend and distribution of the precipitation were basically consistent with the research results of Zhu Likai et al.[3]. Above that, we considered the change trend of precipitation was mainly related to the dual influence of East Asian monsoon and Yinshan Mountains topography. For example, Li Wenbao et al. also found that the average annual precipitation showed an increasing trend from the west to the middle and east in the central region of Inner Mongolia[7], which was highly consistent with the research in this paper.

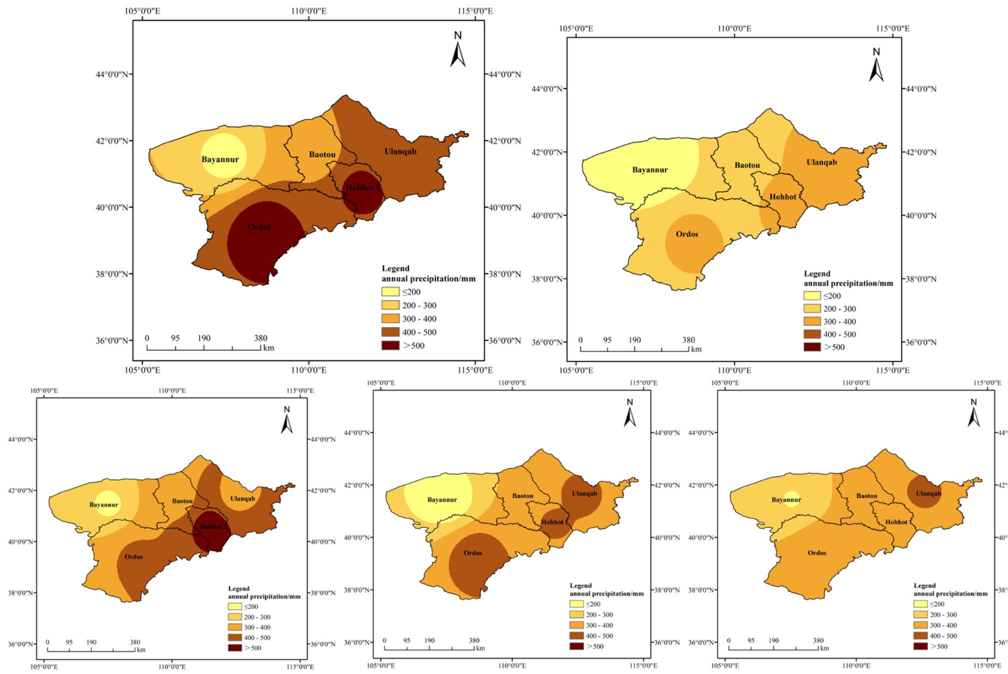

Figure 3: Spatial distribution of precipitation in central Inner Mongolia during 2016 to 2020 years

3.3 Correlation Analysis of Precipitation in Central Inner Mongolia during 2016 to 2020 years

The correlation analysis between precipitation and terrain, temperature, humidity and effective sunshine hoursin central Inner Mongolia and cities during 2016 to 2020 years was shown in Table 2. In general, the precipitation among five cities in the central region of Inner Mongolia was significantly correlated with the average temperature, average relative humidity and effective sunshine hours($p < 0.01$). It was significantly correlated with the green coverage area and altitude of the built-up area ($p < 0.05$). Li Hongyu et al.[7] analyzed the temperature and precipitation data of Inner Mongolia during 1951 to 2014 years and found that the high correlation between annual average temperature and annual precipitation in the central region, and passed the correlation test of confidence level, which was consistent with our conclusion. Ding Yong et al.[8] studied the changes of temperature and precipitation during 1969 to 2008 in Inner Mongolia and found that the area with a large increase in temperature had more precipitation, but it showed a decreasing trend, while the area with a small increase in temperature had an increasing trend in precipitation. There was a complex spatial and temporal relationship between the two changes, the results were similar to our paper. A large number of studies have shown that there was a close synergistic effect among humidity, temperature and precipitation[11,12], and the leading role of relative humidity in the interannual variation of surface water vapor pressure is particularly evident in low latitude land areas, which is consistent with the results of our study. In this study, the distribution of precipitation is mainly affected by the terrain of the Yinshan Mountains[13], the terrain trend of the Yinshan Mountains had serious impacts on the source of humidity in central Inner Mongolia[4], which affected the regional precipitation in further. Li Ying et al. analyzed the meteorological data of Tongliao City among long time and found that there was a significant negative correlation between sunshine hours and precipitation[14]. Shi Zhongjie et al.[15] studied the vegetation, temperature and precipitation during 1982 to 2006 years in Inner Mongolia and found that the variation trend of precipitation was highly correlated with different vegetation types. This result was also approximately similar to our study, indicated that precipitation had a strong correlation with effective sunshine hours and green coverage area.

In terms of each city, there was a significant correlation between precipitation and average temperature and average relative humidity in the five cities ($p < 0.01$), which correlation relationship was consistent with the overall the central region. The correlation with effective sunshine hours was only significant in Ulanqab ($p < 0.05$). The correlation with green coverage area of built-up area was not significant ($p > 0.05$). However, we didn't find the more detailed elevation data of Hohhot, Baotou, Ulanqab, Ordos and Bayannur in the study region, the correlation wasn't analyzed between precipitation and altitude among the five cities respectively here.

Table 2: Correlation analysis of precipitation in central Inner Mongolia during 2016 to 2020 years

precipitation (mm)	average temperatures (℃)	average relative humidity (%)	altitude (m)	effective sunshine hours(h)	Green coverage area of the built-up area (hm^2)
Hohhot	0.64**	0.55**	-	0.21	0.01
Baotou	0.66**	0.44**	-	0.11	0.04
Ulanqab	0.72**	0.56**	-	0.26*	-0.01
Ordos	0.71**	0.66**	-	0.22	-0.04
Bayannur	0.56**	0.46**	-	0.19	0.08
Central Region	0.60**	0.47**	0.13*	0.16**	0.13*

Note: * * Correlation difference is 0.01 level.   * Correlation difference is 0.05 level.

4. Conclusions and Prospects

Based on the monthly precipitation data of five cities in the central region of Inner Mongolia during 2016 to 2020 years, a series of methods were used to analyze the temporal and spatial aspects, and the following conclusions were drawn:

The annual precipitation was uneven distributed and large fluctuated in the central region of Inner Mongolia. Among the inter-annual period, Ordos and Ulanqab showed a decreasing trend firstly and then presented increasing slightly. While, Baotou, Bayannur and Hohhot showed an irregular "W". The ranges of monthly average precipitation among the five cities in the central region was 7.6 mm to 49.4 mm. The monthly precipitation was presented a high seasonality.

The annual precipitation showed a decreasing trend from southeast to northwest in the central region of Inner Mongolia spatial. The precipitation was mainly concentrated in southeastern Ulanqab,

ISSN 2616-5872 Vol.4, Issue 8: 57-62, DOI: 10.25236/AJEE.2022.040811

southeastern Hohhot and southeastern Ordos, and decreased obviously in the north of Ulanqab and the northwest of Baotou, Bayannur was extremely poor.

(3) according to the results of correlation analysis, the precipitation and average temperature, average relative humidity, effective sunshine hours, green coverage area of built-up area, and altitude were all strongly correlated in the central region of Inner Mongolia, the significant correlation between precipitation and average temperature, average relative humidity was still significant in severally city besides the green coverage area of built-up area.

It was suggested that the study region should strengthen the construction of infrastructure such as reservoirs and dams and make more complete project in flood and drought emergency measures. At the same time, the agricultural planting structure should be further optimized according to the precipitation situation and the selection of urban greening tree species should be adjusted, which aimed to improve the production and living benefits and maximize the utilization of water resources.

References

[1] Liu Yuexuan, Yu Hongbo, Zhang Qiaofeng, et al. Analysis on precipitation characteristics of Inner Mongolia at different time scales based on TRMM precipitation data [J]. Yangtze River, 2021, 52 (4): 107-115.

[2] Liu Linchun. Analysis of precipitation characteristics in central-eastern Inner Mongolia—1961-2016 [J]. Agriculture and Technology, 2019, 39 (19): 113-116.

[3] Zhu Likai, Meng Jijun. Spatiotemporal variation of precipitation in the central Inner Mongolia in recent 43 years [J]. Arid Zone Research, 2010, 27 (4): 536-544.

[4] Kou Yu. Analysis of precipitation characteristics around Hohhot in Inner Mongolia [J]. Inner Mongolia Science Technology & Economy, 2021, (3): 58-60.

[5] Li Wenbao, Li Changyou, Liu Zhijiao, et al. Distribution of precipitation and its effect factors analysis and western regions of Inner Mongolia during the last 60years [J]. Journal of Inner Mongolia Agricultural University (Natural Science Edition), 2015, 36(1): 85-94.

[6] Duan Xiaomei, Wang Ying. Analysis of Temporal and Spatial variation characteristics of precipitation in Inner Mongolia based on EOF [J]. Henan Science, 2020, 38(7): 1125-1130.

[7] Li Hongyu, Ma Long, Liu Tingxi, et al. Change and relationship of temperature and precipitation in Inner Mongolia during 1951 —2014 [J]. Journal of Glaciology and Geocryology, 2017, 39(5): 1098-1112.

[8] Ding Yong, Sa Rula, Liu Pengtao, et al. Spatial changes of temperature and precipitation in Inner Mongolia in the past 40 years [J]. Journal of Arid Land Resources and Environment, 2014, 28(4): 96-102.

[9] Li Wenbao, Li Changyou, Jia Debin, et al. Isotope changes in summer atmospheric precipitation in central Inner Mongolia [J]. Arid Zone Research, 2017, 34(6): 1214-1221.

[10] Inner Mongolia Meteorological Bureau. Comprehensive monitoring and evaluation report of eco-meteorology in Inner Mongolia in 2017 [Z]. Inner Mongolia, Inner Mongolia Ecological and Agricultural Meteorological Center, 2018.

[11] Hao Jiawei. The response of water vapor to temperature change and their synergies in precipitation variability [D]. Nanjing: Nanjing University of Information Science and Technology, 2022.

[12] Zhai Qingfei, Zhang Jinguang, Wang Binfei, et al. Correlation analysis of atmospheric temperature and humidity profiles retrieved from microwave radiometer with precipitation [J]. Journal of Meteorology and Environment, 2020, 36(6): 98-107.

[13] Fan Bin. Preliminary study on the influence of the Yinshan Mountains to the meteorological elements of the central region of the Inner Mongolia [J]. Meteorology Journal of Inner Mongolia, 2010, (1): 35-37.

[14] Li Ying. Variation characteristics of sunshine hours and its relationship with temperature, precipitation and wind speed in Tongliao city of Inner Mongolia in 60 Years [J]. Animal Husbandry and Feed Science, 2017, 38 (11): 48-50.

[15] Shi Zhongjie, Gao Jixi, Xu Lihong, et al. Effect of vegetation on changes of temperature and precipitation in Inner Mongolia [J]. Ecology and Environmental Sciences, 2011, 20(11): 1594-1601.