Relationship between Oases Development and Climate Change in Xinjiang, China in Recent Years

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Abstract

The cultivation area in Xinjiang, China has increased greatly in the recent 45 years, in some regions it has even increased 7 times since 1950 due to the oases development. We are trying to clarify the relationship between oases development and climate change in the oases during recent years. By analyzing the meteorological data obtained in some stations inside the oases in the recent 43 years, it was found that air temperature was increasing in winter, but decreasing in the summer and precipitation was increasing in summer. In some places, precipitation has increased about 100 percent in the summer. By examining the effects of the oases on the climate improvement and detailing changes of the oases, the present study provides some detailed discussion on the oasis agricultural activities and environment changes and their effects on the climate change in Xinjiang, China.

Key words: climate change, oases climate, oases development, Xinjiang, China

1. Introduction

Air temperature is increasing in the world according to many observation data analyses, especially since 1977 (Jones and Briffa, 1992). Some simulation models demonstrate that there will be an increase in precipitation in the middle latitude (Folland *et al.*, 1990). However, almost all the research work on the climate change in the arid land of China has pointed out that the climate is becoming drier and drier (Geng, 1986; Zhu *et al.*, 1989; Zhang *et al.*, 1992; Ye and Chen, 1992; Zhu and Chen, 1994). Xinjiang is located in the northwestern part of the arid land of China. There is a long history of oases development in Xinjiang and great change has been experienced in recent years. Human beings will have to use some arid area due to population increases in the future. It is found that many people from the eastern part of China have been moving to the Taklimakan Desert and North Xinjiang for farm work in the recent years. Studies on the relationship between climate change and oases development in this area are of great importance. Du (1993, 1996) and Du *et al.* (1996) conducted some data analysis on air temperature and precipitation in arid China in recent years and studied climate changes and agricultural activities in the Taklimakan Desert and suggested that recent climate change was due to both the global change effects and the local environmental change, such as the expansion of the area of oases. The present study gives some detailed discussion on the relationship between oases development and climate change in Xinjiang, China in recent years.

2. Climate Change in Xinjiang

The western part of arid China is characterized as a basin type which is distributed mainly in four basins, Jungar Basin, Tarim Basin, Turpan Basin and Chaidam Basin. The high peaks (over 5,500m a.s.l.) of the surrounding mountains are covered by permanent snow, ice or glaciers. The geographical sketch map of the region is shown in Fig. 1. The climate there is characterized by a great annual thermal range with severe low temperature in winter, scarce precipitation but occasional heavy rainfall, and frequent severe sand and dust storms.

Monthly mean surface air temperature and monthly precipitation of thirteen meteorological stations from 1951 to 1993 were used. The thirteen meteorological stations are shown in Fig. 1 (as ■). All stations are located inside big oases in the basins. Concerning oases development and meteorological data collected, Xinjiang was divided into three parts: Taklimakan Desert include Kuqa, Kashi, Hotan, Qiemo and Ruqiang; northern part of Xinjiang include Altay, Tacheng, Yining, Wushu and Urumqi and eastern part of Xinjiang include Hami, Turpan and Dunhuang (although Dunhuang is not a part of Xinjiang). Regional means of inter-annual variations of precipitation and surface air temperature for summer (June, July and August) and winter (December, January and February) in the recent 43 years (1951-1993) were calculated and are shown in Fig. 1. Air temperature was increasing obviously in all stations in winter. It can be calculated that mean surface air temperature in the Taklimakan Desert has increased about 3.0°C with a range from 2.0 to 9.0°C since 1951. The increasing rate reaches to 0.05 - 0.21°C / year in winter. However, mean surface air temperature in summer in all stations has decreased. It decreased about 1.0°C in the Taklimakan Desert and 2.0°C in the eastern part of Xinjiang. Although there were many fluctuations, indicating no general trends in precipitation in winter, precipitation in summer seems to be increasing at most stations, according to the five years' running means. Increasing summer precipitation was most distinguished in Taklimakan Desert. Precipitation in northern part of Xinjiang had decreased during 1954 to 1980 and this phenomenon had been considered as evidence that the climate has become drier. However, summer precipitation has increased since 1980 in northern part of Xinjiang. The mean precipitation in summer at the 5 stations in the Taklimakan Desert has increased about 50% in the recent 43 years as shown in Fig. 1. Compared to the mean of 1975-1979, the mean precipitation in the summer of 1989-1993 has increased about 5% (at Ruqiang) to 100% (at Hotan). Monthly mean precipitation at the 5 stations in the Taklimakan Desert in May and in August has increased more than 100%. Monthly mean precipitation of 13 stations has also increased about 100% in the western part of arid China in July. This increasing precipitation, especially large amounts of rain in 1993, has great influence on the plant growth there. We observed that the "Gobi" parts in Qira near Hotan were covered by small grasses in the summer of 1993, where there used to be no vegetation cover. Although it was said that this kind of scene occurs about once ten years, they existed in some parts until the summer of 1994.

Fig. 1. Sketch map of study region and names of observation stations and oases with inter-annual variations of precipitation (P) and air temperature (T) for summer (s, sum or mean of Jun., Jul. and Aug.) and winter (w, sum or mean of Dec., Jan. and Feb.) in recent 43 years (1951-1993) (A.: 5 years running mean).

Taklimakan Desert: Kuqa, Kashi, Hotan, Qiemu and Ruoqiang; Northern part of Xinjiang: Altay, Tacheng, Yining, Wushu and Urumqi; Eastern part of Xinjiang: Hami, Turpan and Dunhuang

3. Comparison of Climate between oases and desert

It is well known that all the factors in the heat budget change with surface condition and that climate changes with different surface conditions. Fig. 2 gives a comparison of some factors of radiation and heat budget between desert area and rain forest area in summer time. It shows that 1) about 90% of solar radiation where reaches the earth surface in the desert area is mainly due to less water vapor in the air, while that in a rain forest area is only 70%, 2) Compared to solar radiation at the earth's surface, there is less net radiation in the desert area than in the rain forest area, 3) Almost all net radiation energy is used for heat transfer between earth and air in the desert area, however, net radiation energy is used for evaporation in the rain forest area. Therefore, diurnal and annual temperature variation is much greater in the desert area than in the rain forest area. Using the same theory, radiation and heat budget will change and oases climate will be formed when oases are built within desert areas.

Fig. 2 A comparison of some factors of radiation and heat budget between desert area and rain forest area in the summer time. (So: Solar radiation at the top of atmosphere. St: Solar radiation at earth surface. Rn: Net radiation. H: Heat flux between surface and air and between surface and deeper layer of the earth. LE: Latent heat flux by evaporation.)

Fig. 3 Comparison of monthly mean air temperature between an oasis (o) and desert (d) in Hotan, China from November 1991 to October 1992.

According to Sun (1990), Ling (1990), Du and Maki (1994), the climate in an oasis is characterized by a comparatively lower wind speed; smaller temperature variation, higher air humidity and evapotranspiration and more precipitation than in the desert area due to increase in irrigation of water and vegetation growth. By comparing the data on the desert area at Qira (Mikami *et al.*, 1995) to the data of near oasis, Hotan Meteorological station, the effect of the oasis on air temperature can be observed clearly. Fig. 3 shows the comparison of monthly mean air temperature between Hotan oasis, China (cf. Fig. 1) and the surrounding desert from November 1991 to October 1992. It is obvious that the air temperature inside the oasis was lower in July and higher in December. Monthly mean air temperature at the desert station at Qira in July, 1992 was 1.8°C higher than at an oasis station at Hotan and that in January, 1992 was 0.4°C lower than at Hotan. This phenomenon is the same as the climate change in the recent years. All the meteorological stations used in this paper are situated inside of oases. The greater the effects of the oases on climate become, the more the climate will change.

4. Oases development concerning the climate change

There are 4 aspects related to climate change:

Fig. 4 Inter- annual variations of population and cultivation area in Xinjiang, China from 1949 to 1990.

(1) Expansion of the area of oases: Cultivation area in Xinjiang Uygur Autonomous Region increased from 1297,900ha in 1949 to 4201,350ha in 1990 according to the Chinese Statistics Agency. In Tarim River valley, for example, many new oases (new state farm) were built up and the cultivation area increased about 350,000 ha during 1951-1958. The cultivation area has increased 7.5 times around the Kaidu River in Tarim Basin. The main reason for the increase of the cultivated area is to feed the increased population as shown in Fig. 4. The most rapidly increasing region was northern part of Xinjiang and then was around Taklimakan Desert. However, the increasing cultivation area was mainly due to artificial oases instead of natural oases during the early 1950's and 1960's. Although the cultivation area per person in most counties has slightly decreased from 1980 to 1988, the areas of oasis were increased at some places in the recent 15 years.

(2) Increase in artificial forestry and windbreak forest in an oasis: Windbreak forests play an important role in the cultivation of crops in oases in China. It is considered that agriculture would be impossible without the use of windbreaks in the arid lands of China, due to the climate improvement effects of windbreak forests and oasis itself. Windbreak forests planted in 1950's have grown in the recent years around the new oases in the Taklimakan Desert. Most of the windbreak forests have reached higher than 20 m. Many new windbreak forests and artificial forests have been also developing in the oases in the recent years. Due to the air temperature and humidity differences exist which as mentioned above, there would be heat and water vapor exchange between an oasis and its peripheral desert area. The role of windbreak forests and other forests on climate improvement of an oasis is to intensify the effects, reducing the exchange of heat and water vapor due to decreasing wind velocity. Therefore, the more and the bigger the windbreak forests are, the greater the climate improvement of an oasis will be.

(3) Variation in vegetation cover and cutting wood in desert area: Living in the arid land, people need trees or grasses for fire wood and buildings materials. During earlier reclaiming in 1950's, much of the sandy land with vegetation cover was changed into farmland. Some natural forests and grass lands also changed into farmland, especially in northern part of Xinjiang. According to Tang *et al.* (1992), the natural forest area of Poplar trees had decreased 285,000ha in the Tarim River valley during 1958-1978. This may be responsible for a precipitation decrease in the earlier period mentioned above. However, the recent reclaiming has carried out at the desert area and people have become use coal instead of wood. According to Yoshino *et al.* (1993, 1996), there are three types of fuel utilization: a) fire wood from the desert only, b) coal in winter and fire wood in summer and c) coal only. Using coal instead of wood has a close relationship with the economic development. Almost 100% of the farmers' families in the northern and western parts of the Taklimakan Desert nowadays use coal in the winter or use coal only. A family used to cut wood in the desert twice a week to once a month. However, they have been changing to using coal instead of wood with their income increasing since 1970's. Several ten thousands' of families have stopped cutting wood in the desert so that a huge amount of vegetation was rescued.

(4) Control of desertification: Decrease in natural forest and cutting vegetation around oasis had led about 2,192,000 ha of desertification area occurred in the Tarim River during 1958-1978. However, cutting vegetation within the peripheral area 10 km away from the oases has been forbidden since 1978. Using coal instead of cutting wood has become more and more prevailing as described above. Thus, the decrease of the natural forests and severe desertification has been controlled. Zhu *et al.* (1989) treated the desertified area in Taklimakan Desert as extremely or heavily desertified area in 1989. However, Zhu and Chen (1994) treated the most pace of desertified land as relatively stable district the Taklimakan Desert in 1994 when they study on the development trend of the desertified land in the last decade, and showed a result of the control of desertification.

If we assume that the bigger the oasis is and the more there are windbreak forests and other vegetation, the greater the effect of the oasis on the climate will be, it can be concluded that the decrease in air temperature and increase in precipitation in summer in the recent years is mainly caused by such human activities in the oases.

5. Discussion on relationship between oases development and climate change

As mentioned above, the tendency of recent climate change in Xinjiang is better for oases development due to the oases effect. Fig. 5 shows a sketch of the relationship between Oases Development and Climate Change. If the oases develop more,

the climate will become more favorable for agriculture activities. There is a feedback relation between them as shown in Fig. 5, oases development => climate becomes favorable => more development of oases => more favorable the climate becomes. The past oases development and climate change have been effected by this feedback action. However, Oases development greatly depends on natural resources, especially water resource. Oases can be developed only when the natural resources are used properly. Otherwise, expanding oases without proper use of natural resources will create land degradation or even oases disappear such as land salinization due to grand water lever increase or salt movement, vegetation degeneration due to careless water use and fire wood cutting and sandy desertification due to wind erosion and vegetation degeneration.

On the other hand, if oases degradation occurred, there would be another feedback reaction due to the oases effect on climate reduction as shown in Fig. 5, oases degradation => climate becomes worse => more degradation of oases => the climate becomes more worse. Concerning climate change, past oases development is good as mentioned above. However, increasing the cultivation area will accelerate an increase of the utilization of irrigation water from river water and ground water. This will be connected to desertification and salinization of farmland directly. Furthermore, accumulation of salt in the lowest courses of rivers has been not yet considered in the Desert as a whole. The expansion of cultivated areas using irrigation water may let this feedback action and result in serious problems in future. On the other hand, due to the increasing population, collecting fuel, building materials and grasses in the desert, and over-grazing around the oasis are coming to a limit to utilize. It is important to introduce more use of coal or other fuel instead of the wood through increasing farmers' income in the Taklimakan Desert.

6. Conclusions

The local climate in Xinjiang has become favorable for agriculture activities as temperatures increase in winter and decrease in summer and precipitation increase in summer.

The local environment change is the main cause of the climate change in recent years due to expansion of oases, the increase and grown of windbreak forests, and control and decrease of cutting fire wood.

There are two different feedback relations between oases development and climate change: (1) oases development => climate becomes favorable => more development of oases => climate will becomes more favorable and (2) oases degradation => climate becomes worse => more degradation of oases => climate becomes even worse. Which feedback effect occur mainly depends on how people use the natural resources, especially water resources in arid land. The increase of the local population including migration is a cause for the expansion of oases and this will accelerate an increase in the utilization of water. Although the recent development of oases in Xinjiang was good for climate change, for further development, there have been some problems of land degradation such as salinization and sandy desertification. It is very important to have an efficient use of water resources but not to expand the area of oasis in future.

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Fig. 5 A sketch of relationship between Oases Development and Climate Change.