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Extreme climate events, migration for cultivation and policies: A case study in the early Qing Dynasty of China

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Based on the historical records of the annual increase in the workforce (men older than 16 years of age), the annual new taxed cropland in the Shengjing area (Northeast China), the extreme climate events in North China, and related management policies in Northeast China during 1661—1680, a case study has been conducted to investigate the relationship between the extreme climate events in North China and the migration to Northeast China for cultivation. This study has found that the migration to Northeast China for cultivation from 1661 to 1680 was a response to the drought events that occurred in North China. The upsurge of migration, which occurred in 1665—1680, was a response to the drought period during 1664—1680 in North China while the fewer disasters period in Northeast China. There were three migratory peaks during the upsurge of migration, which corresponded to the three drought events. The peaks of migration, however, often lagged behind the drought events about 1—2 years. The encouraging-migration policy, which was adopted to encourage cultivation in Northeast China, did not produce much migration into the region in the early Qing Dynasty. It did, however, provide a policy background, which ensured more than 10000 migrants per year to Northeast China when North China suffered from drought/flood disasters. As a response to the highest peak of migration induced by the severe droughts in North China during 1664—1667, a prohibiting-migration policy restricted further migration to Northeast China was carried out in 1668. Although the prohibiting-migration policy could not entirely stop the migrants fleeing from famine in North China to Northeast China, the migrants and cultivation were significantly reduced under the policy. The frequent changes of the policy on the years when taxation started after the land was cultivated were also related to climate events. The extreme climate events in North China, migration to Northeast China for cultivation, and the related management policies showed an impact-response chain, which reflected the interaction among extreme climate events, human behavior, and policies.

migration, cultivation, extreme climate event, Northeast China, Qing Dynasty

The past is the key to the present and future. It has been about one hundred years since Huntington, a famous American Geographer, pointed out that climate change was one of the driving forces in the development of human society in his famous book *The Plus of Asia* published in 1907[1]. In recent years, more and more scientists have engaged in research on the relationship between past global changes and the development of human society and civilization, along with the advancement of past global changes and increasing attention to the potential negative impacts of global warming. It has been found that the climate change was one of basic driving forces that had strong impacts on human civilization. It governed the prehistoric or earlier historic civilization, and even led human cultures to develop or

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collapse[2−10]. Although today it is difficult to repeat the impacts of environmental changes that happened in the past, the past events can be used as an analogy to provide an early warning scenario for the immediate future. The lessons learned from the past are also valuable for today's human beings to face the challenge of global changes.

As an interdisciplinary as well as a multidiscipli- nary field, research on global change impacts and adaptation has involved not only the natural and social sciences, but policy and decision makers as well. So far, research has been limited to the relationship between societal events and climate change events that happened in the same geographic region. Because of the lack of data on the interaction between climate change and humanity's response, most previous research discussed the connections between environment changes and the historical events, such as the rise and fall of civilizations or interruption of cultures by comparing the two sequences of nature and humanity's cultures (mostly obtained from archaeological and historical records). Only a few researchers discussed the issue from the view of interaction mechanisms and connection between different regions.

Northeast China was the birthplace of the Man nationality, the ruler of the Qing Dynasty (1644−1911). After the Qing Dynasty took power and replaced the Ming Dynasty (1368−1644), the Man nationality migrated to south of the Great Wall, and its population in Northeast China declined dramatically. In order to enhance and secure its land base, the Qing Dynasty adopted an encouraging-migration policy to encourage the Han nationality migrating to Northeast China for cultivation during 1653−1667. In 1668, however, a prohibiting-migration policy was adopted to supplant the encouraging-migration policy. This new policy had deeply affected the social and economic development of Northeast China and delayed the exploration of the region for at least 200 years. Many historical materials and the local chronologists of Northeast China recorded these policy changes and the phenomenon of famine refugees migrating to Northeast China for cultivation during the early Qing Dynasty. Historians have also discussed this issue extensively[11−16]. Most discussions attempted to explain the phenomenon from the social and policy points of view. The natural disasters in North China, however, were generally regarded as a background factor in their discussions. Generally, they considered that the reason for the implementation of the prohibiting-migration policy was to protect the land base of the Qing Dynasty and to prevent the Man nationality from being assimilated by the Han nationality[14]. Certainly, such explanation is undoubtedly true in the course of history. Detailed analysis, however, is still needed to answer questions such as why the prohibiting-migration policy was carried out in 1668. Based on historical records of climate change in North China, policies, population, and cultivation in Northeast China during 1661−1680, this paper will attempt to explore the interaction among the extreme climate events in North China, the migration to Northeast China for cultivation, and related policies. This study provides a case study for understanding the process of humanity's response to climate change and its mechanism of interaction.

1 Data and methods

Northeast China is the area where the largest land cultivation activities by migrants had happened in China during the past 300 years. The migrants in Northeast China were mainly the Han nationality who came from North China during the Qing Dynasty[11]. They moved to Northeast China generally along two routes: one was the waterway crossing the Bohai Channel from the Shandong Peninsula to the Liaodong Peninsula[11], and the other was on the land passing the Shanhai Pass of the Great Wall[12]. In the early Qing Dynasty, the main agricultural area in Northeast China, cultivated by the migrants of the Han nationality from North China, was restricted to the Liaodong area (current Liaoning Province, the southern part of Northeast China). A few migrants reached middle Northeast China (current Jilin Province). The local government had provincial level administrative power over the area named Shengjing. The migration and cultivation in Northeast China were influenced by both social and natural factors. In order to better understand the causes of migration, the data used in this paper included the migration to Northeast China for cultivation and related policies, and the extreme climate events (especially changes in precipitation) in North China and Northeast China during the early Qing Dynasty.

1.1 Data preparation on migration and cultivation

(i) Data on the workforce and cultivated land. The data

on migration to Northeast China for cultivation were found in two editions of the *General Chorography of Shengjing* (Northeast China) edited in 1736 and 1778[17,18], respectively. In the 1736 edition, the annual increase of workforce (so called *Ding* in Chinese) was recorded for the period of 1660－1680, and the total workforce in years of 1661, 1668, 1672, 1675, 1680, 1684, 1724 and 1733 (Table 1)[17]. The workforce (*Ding*) as used herein referred to men who were older than 16 years of age[13]. Comparing the two groups of data, it was found that the total workforce (TW, hereafter) in a year was the sum of the annual increase of the workforce (AIW, hereafter) from 1660 to that year. However, from 1661 to 1680, the sum of the AIW was less than the TW recorded in 1680 by 1989 persons, due to the lack of records on the AIW in 1667, 1673, and 1677. From the difference between the TW and the sum of the AIW in each duration, the missing data of AIW in 1667, 1673 and 1677 were interpolated (Table 1).

The annual newly taxed cropland in the Shengjing area in 1658 and during 1665－1683 was recorded in the *General Chorography of Shengjing* edited in 1736[17], and the total taxed cropland (TTC, hereafter) in 1661 and 1683 was recorded in the *General Chorography of Shengjing,* edited in 1778[18]. The newly taxed cropland (NTC, hereafter) referred to the newly cultivated cropland (NCC, hereafter) that began to be taxed. The NTC in a year was theoretically the NCC several years before. So it is reasonable to infer the increase of NCC in a year approximately from the annual NTC by moving the recorded year of the annual NTC several years ahead, according to the taxation policy on the years when taxation started after the land was cultivated in Northeast China during 1661－1680 (Table 2)[13]. Because the standard on the years when taxation started after the land was cultivated in Northeast China was changed several times during 1661－1680, the annual increase of NTC in some years should be regarded as the accumulative NCC of several years, instead of the annual amount of NCC. Among these years, the annual increase of NTC in 1658 was the sum of the NCC before 1655; than in 1665 was the sum of the NCC during 1659－1662; and that in 1676 was the sum of the NCC during 1670－1673.

(ii) Relationship between the workforce (*Ding*) and the total population. The population of the workforce is usually not equal to the total population. Although some scholars indicated that there was a proportion between these two numbers and they found that the ratio was about 1:4 during the period of early the Qing Dynasty (1644－1735)[19], however it has not been wholly agreed by others scholars. The opponents pointed out that the ratio might be true only in certain regions of China,

Table 1 Records on the workforce (men older than 16 years of age) and newly taxed cropland during 1655－1680 in Northeast China[17]

Year	TW (person)	AIW (person)	Annual increase of cultivated cropland (hm^2)[b)]	Year	TW (person)	AIW (person)	Annual increase of cultivated cropland (hm^2)[b)]
1655			3211.0	1670		2958	
1660		3723		1671		491	3.3
1661	5602	1879		1672	25723	1904	6.7
1662		1113	669.5	1673		167[a)]	3466.8
1663		2195	302.5	1674		120	
1664		575	139.5	1675	26713	703	2324.6
1665		489	683.7	1676		690	73.1
1666		154	1485.7	1677		514[a)]	53.0
1667		2308[a)]	2650.0	1678		561	1042.5
1668	16643	4207	4345.8	1679		358	205.3
1669		2568	2318.3	1680	28724	1047	236.7

a) The AIW in 1667, 1673 and 1677 is interpolated by comparing the sum of AIW with the TW in each phase; b) the annual increase of cultivated cropland in a year is approximately equal to the annual newly taxed cropland three years after the year according to the taxation policy.

Table 2 Conversion from the recorded year of the newly taxed cropland (NTC) to the year when the cropland was cultivated during 1658－1683 in Shengjing

Recorded year of the NTC	1658	1665－1672	1673－1675	1676－1683
Years when taxation started after the land was cultivated[13]	3	3	10	3
The year when the cropland was cultivated	Before 1655	(1659 to 1662)－1669	－	(1670 to 1673)－1680

while in most regions of China, the population of the workforce in early Qing Dynasty (as the taxation population copied from the records of the Ming Dynasty) was independent of the population number[20,21]. Since Northeast China was governed by the Man nationality in the late Ming Dynasty and was then exploited in the Qing Dynasty, the records on the population of the workforce in Northeast China could not copy from the Ming Dynasty. So far, few studies have been conducted on whether the ratio of 1∶4 was true in Northeast China.

In this study, the annual increase of cropland per new workforce capita (NWC, hereafter) (annual increase of cropland area divided by the increase of the workforce for the year) and accumulative cropland per workforce capita (WC) (accumulative cultivated cropland area divided by accumulative workforce till the year) in 1661－1680, were calculated. The results showed that, during 1661－1680, the annual increase of cropland per NWC varied from year to year, which could be divided into two groups. One was less than 0.24 hm^2 per NWC, the average of which was about 0.20 hm^2 per NWC in 1662－1664. The other was more than 0.58 hm^2 per NWC, most of which could reach 0.67－1.33 hm^2 per NWC, and few of which even arrived at 9.65 hm^2 per NWC indeed. The annual accumulative cropland per WC was steady around 0.80 hm^2, and the largest could reach 0.84 hm^2. It was much closed to the 0.80 hm^2 per WC calculated from the total cropland in 1683 and the total workforce in 1684.

In ancient China, the main purpose of cultivation for a farmer was to raise food for the whole family. Under the productivity given, the required farmland to raise food for one person in a region is relatively steady[11]. In Northeast China, the annual NCC must be able to raise food for the new increased farmers themselves at least. If the 0.2 hm^2 of the smallest annual NCC per NWC averaged during 1662－1664 could be treated as the average level to feed one person, and 0.80 hm^2 of the average cultivated cropland per WC as the level to feed the whole family, the ratio of the two was 1:4. This ratio could represent the proportion between the workforce and the population on average in Northeast China in the early Qing Dynasty, though it might vary a little in different years. Based on this ratio, the growth rate of the population in Northeast China might be inferred from the growth rate of the workforce on average.

(iii) Migration and population increase. Whether the growth of the workforce was mainly composed of migrants (or not) could be inferred from the records of the AIW. During 1660－1680, 1674 was the year of the smallest increase of the workforce, with only 120 persons in Shengjing. Assuming the increase of the workforce in the year 1674 was due to natural growth, in order to reach such a number of 120 persons, the expected natural growth rate of the workforce was calculated starting from the years 1660, 1661, 1668, and 1672 to 1674, respectively. It was found that the annual growth rate could not be more than 2.38%, and the ten-year average growth rate should be lower than 0.7% in Northeast China, which was the same as the national growth rate of population in the early Qing Dynasty and the highest rate of the Ming Dynasty[21]. Therefore, migration should have occurred if the AIW was more than 140 persons, or if the annual growth rate of the workforce was more than 0.7% on average in a more than 10 years duration.

It should be pointed out that the migration of the workforce and population (including the other members of the farmer's family) was not the same proportion every year. So, the annual increase of population could not be simply converted from the AIW with the proportion of 1∶4. The annual increase of population could be inferred from the annual increase of cultivated cropland with the standard of 0.2 hm^2 per person. Comparing the AIW and the inferred increase of population, it could be deduced that the migrants might be mostly made up of the workforce if the two were similar; otherwise the migrants might be mostly made up of the other members of the farmer's family.

1.2 Data on droughts and floods in North China and disasters in Northeast China

(i) Droughts and floods in North China. Based on the dry/wet grades converted from the drought and flood records in historical documents, a great deal of research had been made on the historical precipitation change in North China[22－26]. Those studies provided good background for this paper, although they did not discuss the period concerned in this paper in detail.

From the *Atlas of Dry/wet in China in Recent 500 Years* and the Database of Historical Environment Change of the Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences[27,28], dry/wet grade series of 17 stations in North China were selected, including Beijing, Tianjin,

Tangshan, Baoding, Cangzhou, Shijiazhuang, Hejian, Xingtai, Handan, Dezhou, Laiyang, Ji'nan, Linyi, Heze, Laizhou, Yidu, Yanzhou. The regional annual drought index (P_d) and flood index (P_w) of North China from 1661 to 1680 were then calculated based on these series.

$$P_d = (n_4 + n_5)/N,$$

$$P_w = (n_1 + n_2)/N,$$

where n_1 and n_2 represent the number of wet stations (grades 1 and 2), n_4 and n_5 represent the number of drought stations (grades 4 and 5), and $N=17$ represents the total number of stations. The drought index (P_d) and flood index (P_w), varying from 0 to 1, described the spatial extents of drought and flood of the region in a year for the anomalous climate, respectively. The drought index (P_d) and flood index (P_w) may separate the information of droughts from floods, and avoid them canceling each other in the regional average dry/wet grade. It is defined in North China that a drought year refers to the drought index (P_d) of more than 0.5; a drought event refers to the interval of two drought years in 2 years; and a drought period refers to the interval of two drought events in less than 5 years. A similar definition was given to the flood year, flood event and flood period according to the flood index (P_w). Finally, the drought (flood) events were identified, and the drought period and lesser drought period were divided. In addition, considering that some of the drought or flood information might be lost in the dry/wet grade series, severe flood records in North China were collected as a supplement[29,30].

(ii) Disasters in Northeast China. Records on disasters in Northeast China in the early Qing Dynasty were far less than that in North China. The most available disaster records were obtained mainly from the *General Chorography of Shengjing* edited in 1736 and the *General Chorography of Fengtian* edited in 1927[17,31]. In these two books, disasters occurred in Shengjing during 1650－1735 and during 1650－1927 in Fengtian (currently Liaoning Province) were recorded year by year, respectively. Based on the disasters records in Northeast China, the decadal frequency of disastrous years was calculated, so that identification was made that the duration of 1661－1680 belonged to a more disaster period or a lesser disasters period.

1.3 The management policies on cultivation and taxation in Northeast China

The management policies in Northeast China during the Qing Dynasty mainly contained policies on migration and land exploitation, and taxation policies after the land was cultivated. In our study period of 1661－1680, the policies on migration and land exploitation in Northeast China had spanned two different phases. The first phase was the encouraging-migration policy phase during 1653－1667, which was in the permitting-migration policy period that was favorable for migration to Northeast China for cultivation from 1644 to 1667. The second phase was the prohibiting-migration policy phase during 1668－1740, which was in the banning-migration policy period that prohibited migration for cultivation from 1668 to 1860[12,14,15].

The taxation in Northeast China started in 1658, and the policy on the years when taxation started after the land was cultivated changed several times in the 1670s. All the NCC before 1671 started to be taxed 3 years after it was cultivated; after 1672 started to be taxed 10 years after it was cultivated; after 1676 was still started to be taxed 3 years after it was cultivated; and after 1679 was started to be taxed 6 years after it was cultivated. The annual taxation was forty-five fen (an ancient China monetary unit) silver per hectare for all cropland[13].

1.4 Analysis on the interaction among climate change, migration for cultivation, and policies

As a tradition, ancient Chinese people often preferred to stay in their homeland, and it was very hard for them to move to new places. If the migration was not ordered or forced by the authorities but chosen by the migrants themselves, two factors might have played an important role, i.e., good social and economic prospects in the target area, or unbearable living pressures in their own habitat. By comparing the sequences of drought and flood events in North China, the taxed (cultivated) cropland and the growth of the workforce in Northeast China, the interaction among climate change, migration for cultivation, and management policy is investigated in this study.

2 Results and analysis

2.1 Three phases of migration for cultivation in Northeast China

According to the records of the total workforce[17], the average annual growth rate was 9.0% during 1661－1680, and the average annual growth rate of the total workforce in each duration was more than 1.2%. Such a

growth rate was obviously higher than the natural growth rate, which was less than 0.7%, as discussed in previous section. Therefore, it can be inferred that the increase in the workforce was mainly caused by a growth in migration. The taxed cropland in Shengjing had expanded from 3688.9 hm^2 to 20858.4 hm^2 with an annual growth rate of 8.2% in 1661－1683[18], which was close to the annual growth rate of the total workforce (9.0%) in the same period (1661－1680). Therefore, the increase in cropland mainly came from the cultivation by the new migrants. As discussed in the previous section, migration occurred in the year when the AIW was more than 140 persons during 1661－1680. Therefore, migration occurred in almost all the years during 1661－1680, except the referenced year 1674. Based on the records of the AIW and the NCC, the period of 1661－1668 could be divided into the following 3 phases (Table 3; Figure 1).

Table 3 Comparison of extreme climate events in North China, peaks of cultivation and peaks of new increased workforce in Northeast China during 1661－1680

Period	Less migration for cultivation dominated by workforce (1661－1664)	Maximum of migration for cultivation (1665－1670)	Decrease of migration for cultivation (1671－1680)	
Peak of workforce increase	1661－1663	1667－1670	1672	1680
Peak of cultivation	1662－1663	1665－1670	1673－1675	1678
Extreme climate events in North China	Extreme flood in the Yellow River basin in 1662	Drought in 1664－1667, and extreme flood in the Haihe River basin in 1668	Drought in 1670－1674	Drought in 1678－1680

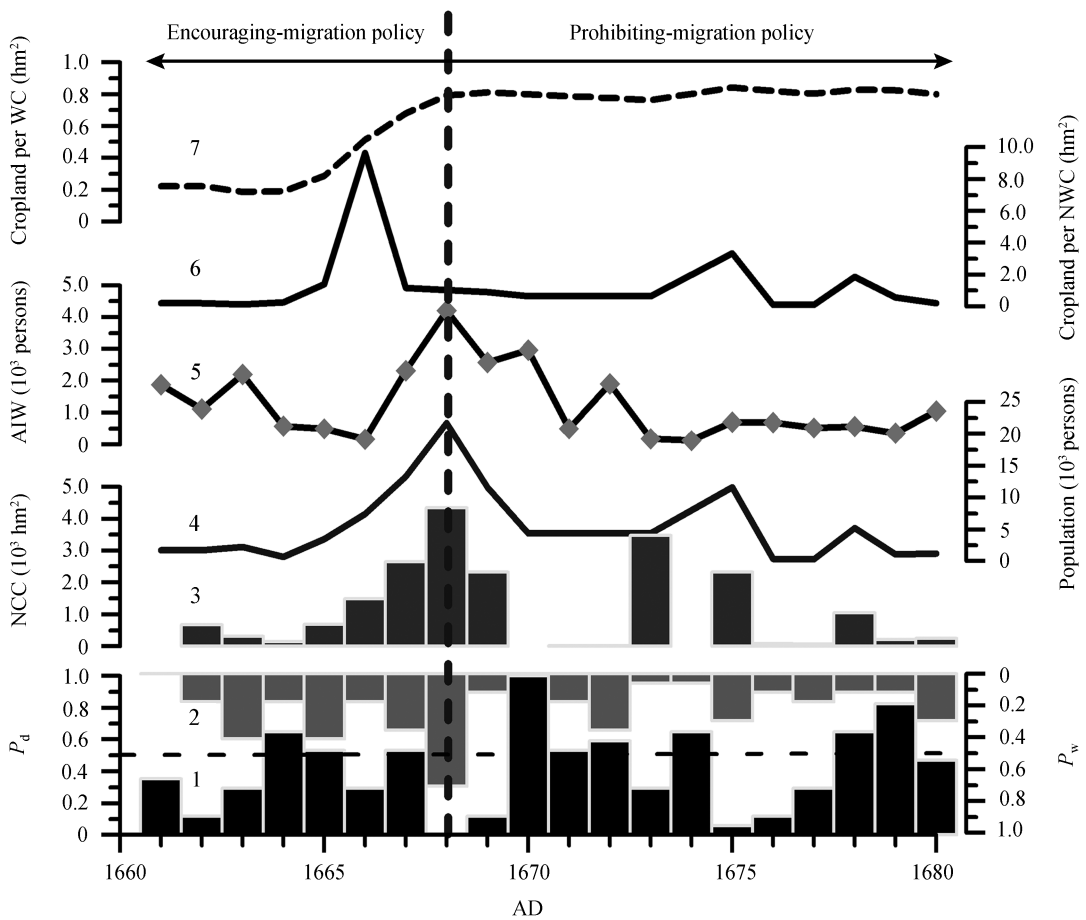

Figure 1 Changes of drought/flood in North China, annual increase of the workforce, population and land cultivation in Northeast China during 1661－1680. 1, Drought index (P_d); 2, flood index (P_w); 3, increase of newly cultivated cropland (NCC); 4, inferred annual increase of population; 5, AIW; 6, NWC; 7, WC.

(i) Less migration for cultivation dominated by the workforce in 1661－1664. The average annual increase in cultivated croplands from 1661 to 1664 was 0.14－0.24 hm^2 per NWC, which means that the migrants were mainly made up of the workforce, instead of the entire family. The total NCC in 1659－1662 was only 669.5 hm^2. The peak of migration for cultivation in this phase occurred in 1662－1663. The AIW were more than 2195 persons in 1663.

(ii) Maximum of migration for cultivation in 1665－1670. The maximum of migration and cultivation occurred in 1665－1670. Inferred from the cultivated cropland records, in 1665 and 1666, the newly increased population was more than 3000 and 7000 persons, respectively, and the newly cultivated cropland per NWC was 1.40 hm^2 and 9.65 hm^2. That means that the non-workforce was the main component of migrants of the two years. In 1667－1669, the migration and cultivation reached the highest peak during 1661－1680. The increase in the workforce reached 2308－4207 persons per year. The NCC increased more than 2300 hm^2 per year. And the total increased population was about 11000－22000 persons per year. The newly increased workforce still reached 2958 persons in 1670. Unfortunately, there was no record of cropland for the same year.

(iii) Decrease of migration for cultivation in 1671－1680. There was an obvious decrease in both the AIW and the NCC after 1671. The average AIW was no more than a quarter of that in 1667－1670. There were two relatively high peaks of migration and cultivation in 1672－1675 and 1678－1680. During 1670－1673, the total cultivated cropland was 3466.8 hm^2 (according to the taxation record of 1676). Besides the area cultivated in 1670, 1672 should have been a peak year for cultivation, with 1904 new workforce for the year. Inferred from the cultivated area, the newly increased migrants in 1675 were more than 10000 people, most of whom were not workforce (Figure 1). There was lesser migration in 1676－1677. The annual increased cropland per NWC during 1676－1677 was only 0.1 hm^2, which showed that the migrants were dominated by the workforce. It should be noted that the record included the workforce who were not counted in earlier years. There was another peak of migration, with more than 5000 new people dominated by non-workforce in the year 1678, based on the records of NCC. In 1680, the newly increased workforce recorded more than 1000 persons, but less increase in non-workforce.

2.2 The upsurge of migration to Northeast China for cultivation as a response to the extreme climate events in North China during 1661－1680

As a result of the war in successive years with the Ming Dynasty, and the Man nationality migrating southward into the Great Wall following the Emperor of the Qing Dynasty, the population in Northeast China declined sharply. For the purpose of enhancing its homeland, the Qing Dynasty not only strengthened its military defense capability in Northeast China, but also encouraged the Han nationality to move to Northeast China in order to cultivate cropland. The government of Qing Dynasty carried out an encouraging-migration policy to attract migrants to cultivate land in Northeast China during 1653－1667. But, even though the policy included many favorable offers such as official titles, food, seeds, and no taxes for the first 3 years, most people still felt less enthusiasm to migrate to Northeast China for cultivation[14]. The total amount of the workforce was only 3723 persons till the year 1660[17]. The total area of taxed cropland was only 3666.67 hm^2 till 1661[18]. It was obvious that the new policy had not induced large amounts of migrants to Northeast China. The order of prohibiting-migration to Northeast China for cultivation in 1668 was implemented during the phase of maximum migration and cultivation (1665－1670) in Northeast China. The migration was not stopped immediately by the prohibiting-migration policy. In some years, there were still upsurges of more than 1000 newly increased workforce and more than 10000 migrants after 1671. The prohibiting-migration policy did not entirely prevent people from moving into Northeast China either. Therefore, no matter whether the policy was encouraging or forbidding, the amount of migration and cultivation was not entirely controlled by the policies. It is difficult to explain the large-scale migration and cultivation in Northeast China wholly by the policy.

In the early Qing Dynasty, there was no shortage of cropland resources in North China. Farmers in Shandong Province could own 0.56 hm^2 per person in 1661, while 0.27 hm^2 of cropland was able to raise enough food for one person in North China at that time[12]. So the stress of lacking cropland resources could not be the essential cause of the migration. On the other hand, the

much colder climate in Northeast China had little attraction to the people in North China.

During 1661－1680, there were frequent droughts and floods in North China, while Northeast China had very few disasters during the same time period. The only records were found in Northeast China including an earthquake in 1662, floods and strong winds in 1663. As to North China, according to drought index (P_d) standard of more than 0.50, the duration of 1664－1680 was a drought period, which was reported to be one of the most severe drought periods in the Qing Dynasty[24−26]. In the drought period, 9 drought years, and 3 drought events lasted 3－5 years, were identified. The 3 drought events occurred in 1664－1667 (which had 3 drought years), 1670－1674 (which had 4 drought years), and 1678－1680 (which had 2 drought years). In the peak years of the three drought events, the drought index (P_d) reached 0.647 (in 1664), 1 (in 1670), and 0.824 (in 1679). Percentages of stations which suffered severe drought (grade 5 of the drought/wet grade) were 35.3% (in 1664), 52.9% (in 1670), and 29.4% (in 1679), respectively. The drought in Shandong Province was more severe than that in current Hebei Province[24−26]. In addition, there were 14 flood years in the Yellow River basin from 1660 to 1676[30], of which the most extreme flood occurred in the year 1662. 1668 was another extreme flood year in North China, especially in the Haihe River basin[29].

Comparing the migration to Northeast China for cultivation with the drought and flood events in North China in 1661－1680, it was found that the period of more migration to Northeast China for cultivation in 1665－1680 connected with the drought period in North China in 1664－1680. The 3 peaks of migration in 1665－1670, 1672－1675 and 1678－1680 corresponded with the 3 drought events in North China, with the time of migration peaks often lagging behind to the drought events by about 1－2 years. During 1661－1664 and 1676－1677, the fewer migrants dominated by the workforce, corresponded to the relatively lesser drought years of 1661－1663 and 1675－1677. The relative high peak of migration for cultivation in 1663 might correspond with the extreme flood of the Yellow River in 1662. Therefore, though the government started to carry out the encouraging-migration policy and had established a local administrative system in order to govern the migrants of the Han nationality since 1653[32], a large number of migrants did not come to Northeast China until they were forced to move by the continuous severe drought in North China after 1664. It was the extreme climate events (mainly droughts and floods) that brought about the upsurge of migration to Northeast China for cultivation. Migration was the way that people adapted to extreme climate events and reduced conflicts between the environment and human beings by escaping from the disasters. Plentiful uncultivated cropland and less natural disasters in Northeast China made the migration more possible to take place when people faced disasters in North China. After 1668, the migration to Northeast China for cultivation was more difficult, due to the implementation of the prohibiting-migration policy. But migration still continued when droughts occurred in North China. Therefore, for people living in North China, the migration was an adaptive behavior to the extreme climate events. For Northeast China, the migration and cultivation was a response in far distance to the extreme climate events in North China.

2.3 Magnitude of migration forced by extreme climate events under different migration policies

The migration to Northeast China for cultivation in 1661－1680 spanned two different policy phases of the encouraging-migration for cultivation (in 1653－1667) and the prohibiting-migration for cultivation (in 1668－1740)[12,14,15]. The encouraging-migration policy did not induce large numbers of migrants at the beginning, but the policy did provide an opportunity for the upsurge of more than 10000 migrants per year to Northeast China for cultivation when North China suffered from drought event in 1664－1667. Since the year 1668, the encouraging-migration policy was supplanted by the prohibiting-migration policy. Actually the prohibiting-migration policy did not entirely stop the migrants moving to Northeast China when droughts occurred in North China. The magnitude of migration and cultivation during the prohibiting-migration phase was, however, obviously less than that during the encouraging-migration phase. The newly migrated workforce after 1671 was less than a quarter of that in 1667－1670, even though the drought in North China during 1670－1774 was more severe than that during 1667－1670 in both extent and intensity.

2.4 The change of policies adapting to extreme climate events

(i) From the encouraging-migration policy to the prohibiting-migration policy. The year 1668 was a critical year for the development of Northeast China. It was the year when the policy was converted from encouraging migration to Northeast China for cultivation to prohibiting migration. In general, it is thought that the reason for implementing the prohibiting-migration policy was for the purpose of protecting the homeland of the Man nationality and preventing them from being assimilated by the Han nationality. Such an explanation is undoubtedly true in the course of history. It is, however, difficult to explain why the prohibiting-migration policy started around 1668. As discussed above, that year had in the highest upsurge (1665－1670) of migration to Northeast China for cultivation in 1661－1680 driven by drought in North China. Notice that there were only 3723 people in the newly increased workforce who came to Northeast China until 1660 since the encouraging-migration policy was carried out. Inferred from annual NCC per NWC, the migrants were dominated by the workforce, and the total population was no more than 2500 people per year in 1661－1664. The peak of migration for cultivation in 1663 might be related to the extreme flood of the Yellow River in 1662. Under the subsequent severe drought in 1664－1667 and floods in 1668 happened in North China, the new migrants into Northeast China reached more than 3000 people in 1665, and more than 7000 in 1666, which were dominated by the non-workforce. There was a sudden increase of annual increased population, reaching more than 10000－20000 people per year in 1667－1669. The unexpected upsurge of migration was mainly driven by the drought/flood events in North China, which made the government of the Qing Dynasty too worried to continue its encouraging-migration policy. The prohibiting-migration policy was then implemented in 1668 in order to prevent the migrants moving to Man's homeland and to protect Man's own culture. The behavior of the government was actually an over-adaptation to the huge numbers of migrants driven by the drought in North China. When the migration decreased after 1671, the setting of a local administrative system to govern the migrants of the Han nationality was stopped, and it was not resumed again until the year 1725[32].

(ii) The taxation policy. The policy on years when taxation started after the land was cultivated had been changed many times in Northeast China. Every change was corresponding to droughts in North China. After the drought event in 1664－1667 and the flood year in 1668 in North China, the years when taxation started after the land was cultivated were changed from 3 years to 10 years in 1672, following the sharp decrease of migrants and NCC in Northeast China under the prohibiting-migration policy[13]. But this policy was not executed because another even more severe drought event occurred in North China from 1670 to 1674. There were a great number of people who escaped from North China to Northeast China, though the migrants were fewer than before because of the prohibiting-migration policy. So years when taxation started after the land was cultivated were changed again from 10 years to 3 years in 1676[13]. Following the less severe drought years of 1675－1677 in North China, the years when taxation started after the land was cultivated in Northeast China were changed again to 6 years after the year 1679 because of the decrease in migration[13].

2.5 The time lag of humanity's response to extreme climate events

As discussed above, extreme climate events in North China, migration to Northeast China for cultivation, and the policies on migration and taxation were interconnected in an impact-response chain. People had to take one or more countermeasures to escape or reduce the damage caused by the extreme climate events. The response in policy, for example, encouraging, conniving, or forbidding cultivation in this case study, to people's adaptation on natural disasters may bring feedback into the adaptation. This process only stops when it reaches a balance among climate change, the adaptation behavior, and the policy. Because it is a process for humans to recognize the impact of the event and to take adaptive behaviors, there is a time lag during different stages. For example, the peaks of migration to Northeast China for cultivation often demonstrated a 1-2 year lag behind the drought events in North China, while the response of policy lagged even more behind the migration. The prohibiting-migration policy took place in 1668 when the drought event (1664－1667) had ended, and its impact on preventing the new migration was observed to work only after 1671.

3 Conclusion

Based on the records of annual increase of the workforce and newly taxed cropland in Shengjing area (Northeast China), information on climate change in North China, and management policies related to Northeast China during 1660－1680, a case study has been constructed in this paper on the interaction among extreme climate events in North China, migration to Northeast China for cultivation, and related management policies. The study provided a clue for understanding the process and feedback mechanism of mankind's response to climate change. The main conclusions are:

(1) A large-scale migration to Northeast China took place during 1661－1680. There were 4 peaks of migration for cultivation in 1662－1663, 1665－1670, 1672－1675, and 1678－1680. The maximum of migration for cultivation was in 1667－1670, when the migrants were more than 10000 per year.

(2) The migration to Northeast China for cultivation was closely related to the extreme climate events (droughts and floods) in North China. The migration was mainly forced by the drought in North China. The relative high peak of migration and cultivation in 1663 might correspond with the extreme flood of the Yellow River in 1662. The upsurge of migration for cultivation in Northeast China during 1665－1680 correspond with the drought period from 1664 to 1680 in North China and lesser disasters period in Northeast China at the same time. The 3 peaks of migration in 1665－1680 were in response to the 3 drought events in North China, respectively, with a 1－2 year time lag behind. However, the years of fewer migrants dominated by the workforce during 1661－1664 and 1676－1677 corresponded with the fewer-drought years of 1661－1663 and 1675－1677 in North China. From the point of view of North China, the migration was an adaptive behavior to the extreme climate events. From the view of Northeast China, the migration and cultivation was a response to the extreme climate events in North China in a far distance region.

(3) The encouraging-migration policy in the early Qing Dynasty did not induce a large amount of migration to Northeast China. But the policy ensured the upsurge of more than 10000 migrants per year when North China suffered from severe drought/flood. The prohibiting-migration policy that was started in 1668 could not entirely prevent the migrants moving to Northeast China. However, the migrants and cultivation during the phase of prohibiting-migration policy was obviously less than that during the phase of encouraging-migration policy. The number of migrants after 1671 was less than a quarter of that in 1667－1670.

(4) The change of the policies in Northeast China, such as the prohibiting-migration policy carried out since 1668, and the policy on years when taxation started after the land was cultivated changed frequently during the 1670s, was a reaction to the impacts of extreme climate events in North China. The extreme climate events in North China, migration to Northeast China for cultivation, and the related management policies were all connected in an impact-response chain. It reflected the interaction among extreme climate events, human behavior, and policy.

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