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ORIGINAL ARTICLE

Cannibalism in northern China between 1470 and 1911

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Abstract

Despite the effort made by historians and archaeologists to investigate cannibalism in human societies, large-N statistical analysis of cannibalism and its triggering factors in pre-industrial societies is still missing in the literature. In this study, I base on 1194 cannibalism incidents in northern China in 1470–1911, together with other fine-grained paleo-climate and historical war datasets, to verify quantitatively the driving factors of cannibalism in pre-industrial societies. Granger causality, wavelet coherence, and phase analyses are employed. The key findings are that in historical northern China, cannibalism was primarily caused by drought and war, but their relationship is non-stationary and is mediated by environmental and socio-political contexts. The positive feedback between war and cannibalism is also revealed, indicating that they are mutually reinforced. The above findings supplement Malthusian theory with empirical evidence of the non-stationary influence of natural disasters on positive checks and how positive checks interact with and reinforce each other. The results also refine our knowledge about the regional environment-human nexus in northern China.

Keywords Drought · War · Cannibalism · China

Introduction

Cannibalism is an inherent part of natural history and a natural feature of the animal world. The phenomenon is found in more than 1500 species, including humans (Schutt 2017). There are an increasing number of studies demonstrating that cannibalism was practiced widely by our ancestors (Stoneking 2003), not only in prehistoric times (Cole 2017; Rougier et al. 2016), but also in historic and recent times (Diamond 2000). The practice of cannibalism is often a desperate response to starvation.

In China, incidents of cannibalism are recorded in historical documents including official dynastic histories (e.g., *Historical Records*, *New Tang Books*, *Zizhi Tongjian*, *Ming History*) and local chronicles. Some of the records are translated as follows:

> In the autumn in the 20th year in Chenghua Reign (1484), there was severe drought and hunger in Sha'anxi and Shanxi. People ate each other. (Volume 14, History of the Ming Dynasty)
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> In the 14th year of Chongzhen Reign (1641), Zuo Maodi managed and monitored water transportation. During his journey, he mumbled: "When I travelled from Jinghai to Linqing, I saw three people who died of hunger, three people who died of epidemic, and four people who stole. Rice per stone costed 24 tales of silver, people ate dead body. Hope that our emperor would care about it." (Volume 295, History of the Ming Dynasty)
>
> In the 12th year of Daoguang Reign (1832), there was great famine in Ziyang, and people ate each other. (Volume 44, Historical Manuscripts of the Qing Dynasty)

Despite the abundance of historical records of cannibalism, historians tend to illustrate cannibalism from a general point of view (Huang 2005; Ke 2012; Zhao 2011). In parallel, cannibalism has also been investigated by archaeologists. Their primary focus is to prove the ancient practice of cannibalism based on human remains in archaeological sites (Boulestin et al. 2009; Mead et al. 2003; Rougier et al. 2016). Despite their efforts in

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researching the topic, the temporal pattern of cannibalism overextended consecutive periods has not been precisely traced. And large-N statistical analysis of cannibalism and its triggering factors in pre-industrial societies is still absent in the literature. In this study, I seek to quantitatively verify the driving factors of cannibalism in historical China by using fine-grained historical data and statistical methods. The verification is done in two steps. First, as climate-induced starvation and subsistence crisis are often cited as the triggering factors of cannibalism (Ballard 1986; Billman et al. 2000), I will compare statistically the effect of various climatic variables on cannibalism. In addition to climatic factors, war is also identified as an important human catastrophe and a factor in causing famine (Ó Gráda 2010). Therefore, the effect of war on cannibalism will be included for comparison. Second, for those factors that are proven to have a significant effect on cannibalism, the temporal consistency of their effect on cannibalism will be further explored. The ultimate purpose is to determine in a scientific manner under what circumstances humans turn to (or turn away from) "abnormal" behaviors.

Scope of research, study area, and study period

The practice of cannibalism can be related to survival. Also, it can be out of psychotic or criminal activities, aggressive behaviors, spiritual or ritual practices, gastronomic or dietary preferences, and medicinal objectives (Cole 2017). In this study, I will focus on the one for survival or necessity, as the overwhelming majority of historical cannibalism incidents are caused by starvation (Huang 2005). Furthermore, this study seeks to measure the influence of various factors in inducing cannibalism in history in a macro perspective. The associated findings are mainly for the aggregate of cases, not for individual cases.

The study focuses on northern China, which is delineated as the current territories of the following provinces in China: Gansu, Ningxia, Sha'anxi, Shanxi, Shandong, Henan, and Hebei (including Beijing and Tianjin) (Fig. 1). This is because northern China is the region with the highest number of reported historical cannibalism incidents, including more than 40% of the records in the period of 1470–1911 (Zhang 2004). The region locates north of the Yangtze River, which is also

Fig. 1 Map showing the study area, which is highlighted in yellow color

the fringe belt of the East Asian monsoon and an area marked by high rainfall variability and drought hazards (Xiao et al. 2018). Northern China is traditionally considered as the wheat-cultivating region in China, in contrast to the rice-cultivating region south of the Yangtze River. The two regions are significantly different in terms of agricultural practices as well as the psychology of people (Talhelm et al. 2014). The study period is delimited as 1470–1911 (Ming and Qing dynasties), which is commonly covered in all our datasets (see the "Data" and "Methods" sections). Such spatio-temporal setting places this research within the context of historic agrarian society. In addition, the study period is overlapped with the "Little Ice Age" (c. 1400–1900), which can help control the centennial to multi-centennial effect of climate change on cannibalism.

Data

The variables employed in this study are climate, war, and cannibalism. Climate consists of flood, drought, temperature, and precipitation. Details of those variables are provided below:

Drought and flood

The data of drought and flood are obtained from the *Yearly Charts of Dryness/Wetness in China for the Last 500-year Period* (Chinese National Meteorological Administration 1981), which contains dryness/wetness grade series for 120 sites in China in 1470–1979, and the *Yearly Charts of Dryness/Wetness in NW China for the Last 500-year Period (AD 1470–2008)* (Bai et al. 2010), which contains the updated dryness/wetness grade series of the 12 sites and the dryness/wetness grade series of seven new sites in northwestern China. The above year charts apply a five-point grading system to describe local climatic conditions ranging from extremely wet to extremely dry (1–5). In this study, I combine two yearly charts, with 35 sites located in our study area. The quantification of drought and flood is done by counting the number of sites that have data in any given year whose dryness/wetness grade is 5 (extremely dry = drought) and 1 (i.e., extremely wet = flood) in the study area, respectively (Lee 2018; Lee et al. 2017).

Temperature and precipitation

The temperature and precipitation data are obtained from Yi et al. (2012), who combine tree-ring chronologies and historical flood/drought records to reconstruct the summer growing season (June–July–August) climatic conditions covering the main part of north-central China (108–115° E, 33–41° N). So far, Yi et al.'s (2012) reconstructed temperature and precipitation indices are the only publicly available regional paleo-climate indicators for the study area.

War

For war, the data come from a multi-volume compendium, *Tabulation of Wars in Ancient China* (Editorial Committee of Chinese Military History 1985), which exhaustively records information on the wars in China in 800BC–AD1911. This dataset has been employed repeatedly in previous studies (Zhang et al. 2005, 2007). In this study, I define war as different types of organized violent conflicts, including the invasion of nomadic tribes such as Mongol and Manchu, peasant rebellions, or miscellaneous armed conflicts taking place within the study area. It is counted in terms of the number of battles (Lee 2018; Lee et al. 2017).

Cannibalism

The cannibalism data are obtained from a multi-volume compendium *Collection of Meteorological Records in China over the Past Three Thousand Years* (Zhang 2004). As the cannibalism incidents in the compendium are closely related to starvation, they have been taken as an indicator of famine (Lee 2018; Lee et al. 2016b; Xiao et al. 2015). Following the previous practice (Lee 2018; Lee et al. 2016b), cannibalism is counted according to the number of counties with cannibalism in a year (Figs. 2b and 3b).

Methods

Two statistical methods are employed in this study:

Granger causality analysis

Granger causality analysis (GCA) is a method designated in analyzing the relationship of two time series by including their lagged values in bi-variate regression modeling (Granger 1988, 2001). It is grounded on the principle that the cause should have happened before the effect. Such method has been applied to validate the conceptual models pertinent to historic climate-society nexus (Lee 2018; Lee et al. 2016a; Pei et al. 2016). The carry-over effect of the independent variable on the dependent variable, which is revealed by their time lag, is statistically identified and compared based on the chosen lag length in GCA. Akaike's information criterion (AIC) lag is employed to determine the appropriate lag length (Akaike 1974). Before GCA, Augmented Dickey-Fuller (ADF) test is employed to check the stationarity of the data (Zhang et al. 2011). The GCA analysis is conducted via Stata version 15.

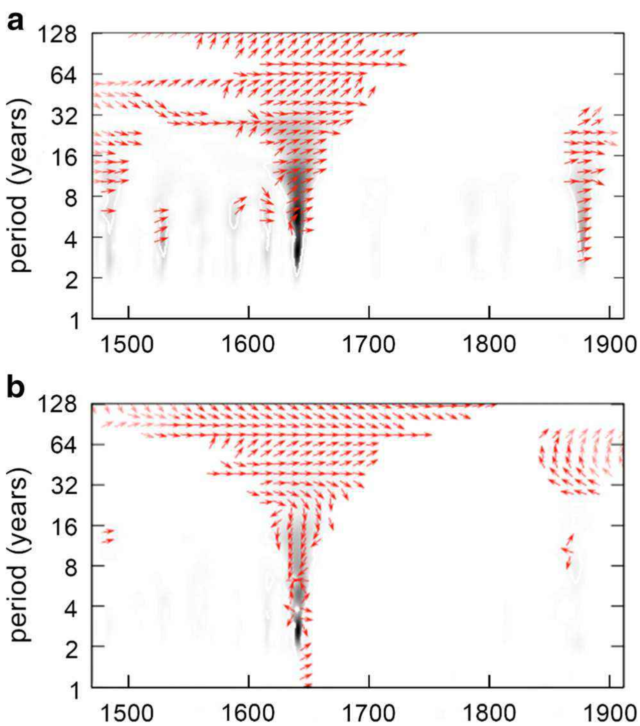

Fig. 2 Wavelet coherence analysis. **a** Wavelet coherency between drought and cannibalism. **b** Wavelet coherency between war and cannibalism. The statistically significant wavelet coherency and its relative phase relationship are indicated by the red arrows ($p < 0.1$)

Wavelet coherence and phase analyses

Those significant causal linkages (i.e., an association between cannibalism and its driving factors) identified via GCA will be further examined by wavelet coherence analysis to sort out the non-stationary relation between, and the temporal evolution of, cannibalism and its driving factors. The mechanism of the wavelet coherence analysis is that by performing continuous wavelet transformation, the signal in time series is decomposed into both time and frequency components. The association and synchrony between two time series in specific periodic cycles can be found by calculating the wavelet power spectrum in the time-frequency domain and the distribution of the variance of the time series (Cazelles et al. 2008; Grinsted et al. 2004). Furthermore, the dependency between the two time series in terms of their association (in phase or out of phase) and synchrony (positive or negative) can be further revealed by phase analysis (Cazelles et al. 2008, 2007; Torrence and Compo 1998). Wavelet coherence and phase analyses have been applied to scrutinize the association between climate change and Malthusian checks in pre-industrial China (Lee et al. 2016b, 2017) and Europe (Yue and Lee 2018a, b). Morlet wavelet is employed to decompose signals, which is generally regarded as an efficient means of detecting variations in the periodicities of geophysical signals along time series in a continuous manner (Rigozo et al. 2008). The significance level is set as the 10% level ($P < 0.1$) based on 1000 bootstrapped series. The wavelet coherence and phase analyses are conducted via R version 3.5.1.

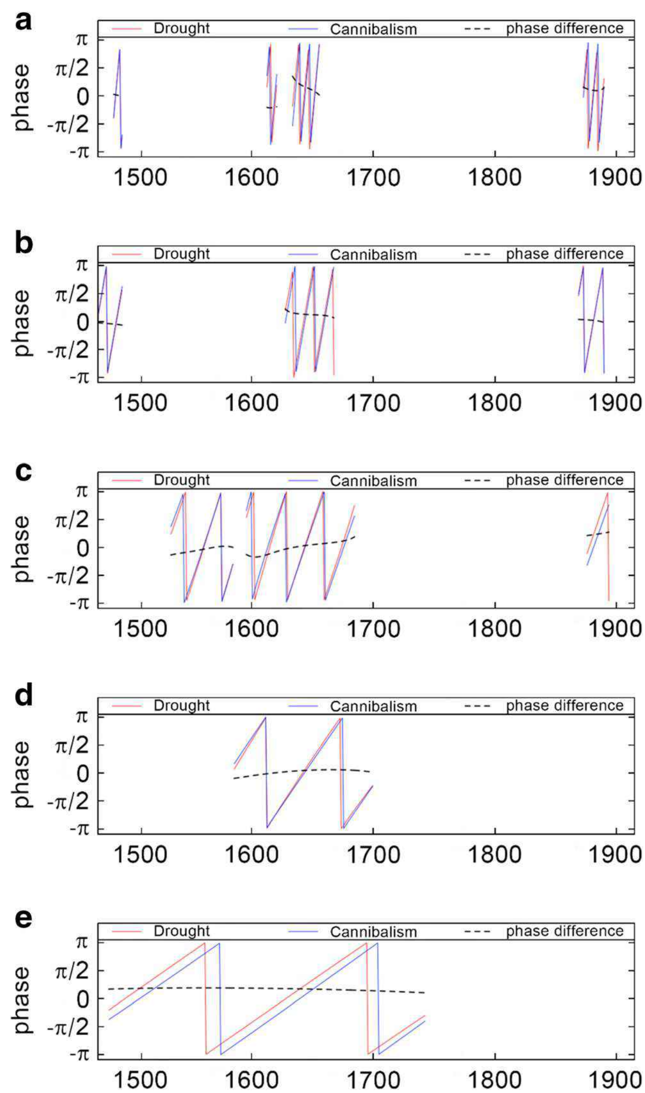

Fig. 3 Phase analysis between drought and cannibalism. The phases of drought and cannibalism are computed in the **a** 8-year, **b** 16-year, **c** 32-year, **d** 64-year, and **e** 128-year periodic cycles, respectively. The red solid lines show the drought phases, the blue solid lines indicate the cannibalism phases, and the black dashed lines represent their phase differences. Only the statistically significant phase differences are plotted ($p < 0.1$) (cf. Fig. 2a)

Results

Figure S1 presents graphically the variables employed in this study, while Table S1 presents the descriptive statistics of those variables. Focusing on cannibalism, there are 1194 incidents in northern China in 1470–1911. There are nine peak years of cannibalism during which the reported cannibalism incidents occur in more than 30 counties in 1 year, namely 1484 (42 counties), 1485 (34 counties), 1528 (36 counties), 1615 (36 counties), 1639 (31 counties), 1640 (199 counties), 1641 (112 counties), 1877 (52 counties), and 1878 (32). Pinpointing to the year 1640 that has the highest count of cannibalism incidents, in terms of the number of counties affected, approximately 24% of northern China was in extreme starvation in that year. Using the year 1644 in which the Ming dynasty is transited to the Qing dynasty as the divide, seven out of the nine peak years of cannibalism occur before 1644, while the remaining two occur after 1644. Besides, the maximum number of cannibalism incidents before 1644 is 199, while the one after 1644 is 52. Furthermore, 80% of the cannibalism incidents in northern China in 1470–1911 concentrate in the Ming period. Such differences between the two periods may reflect the advancement of human societies in buffering subsistence shortage over time.

The temporality of the possible linkages from climate change and war to cannibalism is verified by GCA. ADF test results show that all the time series employed in this study are stationary. Hence, the differencing of the time series is not required (Table S2). The GCA lag of the linkages (null hypotheses) is determined by AIC lag (Table S3). Generally, the AIC lag between those climate variables and cannibalism is shorter, indicating the effect of climate change on cannibalism to be more instantaneous. The GCA results show that only drought ($p < 0.1$) and war ($p < 0.05$) Granger-cause cannibalism in northern China in the historical period (Table 1). The linkages between flood and cannibalism, temperature and cannibalism, and precipitation and cannibalism could not pass the GCA ($p > 0.1$). Considering the possible positive feedback between war and cannibalism, I also test the link from cannibalism to war. The result shows that cannibalism, which may imply the occurrence of extreme starvation, could Granger-cause war in northern China ($p < 0.05$) (Table 1).

Given that only drought and war have a significant effect in triggering cannibalism as indicated by GCA, I proceed to investigate the temporal consistency of their influence on cannibalism by using wavelet coherence analysis. The results are presented in Fig. 2. The regions of statistically significant wavelet coherency are covered with red arrows on the wavelet coherence plots. The drought-cannibalism coherency is mainly significant in the decadal to multi-decadal periodic cycles (Fig. 2a), while the war-cannibalism coherency is mainly significant in the multi-decadal to centennial periodic cycles (Fig. 2b). On the two wavelet coherence plots (Fig. 2a, b), both of the significant wavelet coherency regions are largely located in the first half of our study period. Also, in the period of 1600–1700, the era during which the Manchu invaded China, the drought-cannibalism and the war-cannibalism nexus exhibit strong coherency in various periodic cycles (ranged from decadal to centennial).

Table 1 Granger causality analysis (GCA) about the influence of climate and war in causing cannibalism in northern China

Null hypothesis	*F*	*P*
Drought does not *Granger-cause* cannibalism	2.640**	0.048
Flood does not *Granger-cause* cannibalism	2.072	0.101
Temperature does not *Granger-cause* cannibalism	0.827	0.479
Precipitation does not *Granger-cause* cannibalism	0.202	0.895
War does not *Granger-cause* cannibalism	10.245***	0.000
Cannibalism does not *Granger-cause* war	5.714***	0.000

All of the data are in annual units. **$p < 0.05$; ***$p < 0.01$

I further examine the drought-cannibalism and the war-cannibalism nexus by looking into the relative phase relationship between two time series. On the wavelet coherence plots, the relative phase relationship between the two time series is indicated by the direction of the red arrows. The arrows point to the right (left) when the two time series are in-phase (anti-phase) or are positively (negatively) correlated. The arrows also show the phase lead-lag relationship. The arrows point down (up) when the first variable leads (lags) the second variable.

For the drought-cannibalism coherency (Fig. 2a), all of the arrows point right, meaning that drought and cannibalism are in-phase and positively correlated. More drought events will cause more cannibalism incidents. For the war-cannibalism coherency (Fig. 2b), the directions of the arrows are more diversified. The majority of the arrows point right, meaning that they are in-phase and positively correlated. More wars will cause more cannibalism incidents. Besides, in the seventeenth century, for the inter-annual to decadal (2–16 years) periodic cycles, the arrows point down, meaning that war leads cannibalism (i.e., war happens before cannibalism). But, in the late Qing period, for the multi-decadal (32–64 years) periodic cycles, the arrows point up, meaning that war follows cannibalism (i.e., war happens after cannibalism).

I further compute the five specific periodic cycles (including 8-year, 16-year, 32-year, 64-year, and 128-year) of the drought-cannibalism coherency (Fig. 3) and the war-cannibalism coherency (Fig. 4), respectively. Those periodic cycles cover the variability ranged from decadal to centennial time scale. On the phase evolution plots (Figs. 3 and 4), phase differences are indicated by the black dashed lines. A zero phase difference means that the periodic cycles of the examined time series overlap and move together. Positive (negative) phase difference means that the first variable leads (lags) the second variable. It should be noted that the phase differences that are not statistically significant should be ignored. Therefore, only statistically significant phase differences are shown on the phase evolution plots.

As shown by the drought-cannibalism phase evolutions, the two variables co-vary significantly in the decadal (8-year and 16-year) periodic cycles in three alternative periods, namely the Chenghua Reign (c. 1465–1487), the late Ming period (1600–1644), and the late Qing period (1870–1911)

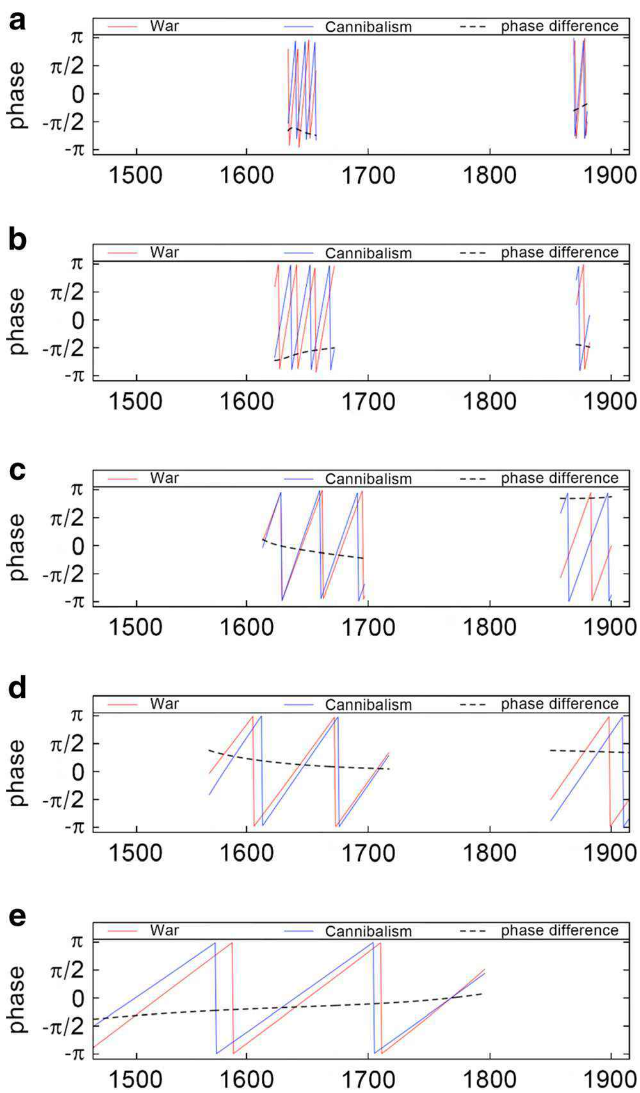

Fig. 4 Phase analysis between war and cannibalism. The phases of war and cannibalism are computed in the **a** 8-year, **b** 16-year, **c** 32-year, **d** 64-year, and **e** 128-year periodic cycles, respectively. The red solid lines show the war phases, the blue solid lines indicate the cannibalism phases, and the black dashed lines represent their phase differences. Only the statistically significant phase differences are plotted ($p < 0.1$) (cf. Fig. 2b)

(Fig. 3a, b). For the 32-year periodic cycle, the coherency is significant in 1530–1680 and the late Qing period (Fig. 3c). For the 64-year periodic cycle, the coherency is significant in the seventeenth century period (1600–1700) (Fig. 3d). For the abovementioned coherency, drought and cannibalism are phase-locked (i.e., phase difference centers on 0, with the drought and cannibalism phases overlapped), indicating that they move together synchronously. For the centennial (128-year) periodic cycle, the drought-cannibalism coherency is significant from 1470 to 1740, and drought leads cannibalism (Fig. 3e).

Regarding the war-cannibalism phase evolutions, there are apparent time gaps between war and cannibalism (phase difference deviate way from 0) in general. For the decadal (8-year and 16-year) periodic cycles, war and cannibalism co-vary significantly in the late Ming (1600–1644) and the late Qing periods (1870–1911), and war follows cannibalism (Fig. 4a, b). For the multi-decadal (32-year and 64-year) periodic cycles, the war-cannibalism coherency is significant in the seventeenth century and the late Qing period, and war leads cannibalism, except for the coherency in the 32-year periodic cycle in the seventeenth century (Fig. 4c, d). For the centennial (128-year) periodic cycle, the coherency is significant in 1470–1790, and war follows cannibalism (Fig. 4e). However, as the positive feedback between war and cannibalism at the interannual to decadal-scale has been detected by GCA (Table 1), the phase difference between war and cannibalism for their 8-year and 16-year periodic cycles may be a chicken-and-egg situation, say war lags cannibalism by π (phase difference = $-\pi$) could also be interpreted as war leads cannibalism by π relative to the in-phase (phase difference = π) (Grinsted et al. 2004). Hence, the short-term war-cannibalism connection should be interpreted with caution.

Discussion

The key findings in this study are as follows: in northern China in 1470–1911, cannibalism is caused by drought and war. There is also positive feedback between war and cannibalism, which are mutually reinforced (Table 1). But, their relationship is non-stationary (i.e., only significant in certain periods) (Figs. 2, 3, and 4). My findings are in accord with the fact that drought and war are prime catalysts in contributing to significant human-ecological catastrophes in human history (Ballard 1986; Billman et al. 2000; Liu et al. 2018).

The decadal and multi-decadal coherency of the drought-cannibalism (Fig. 3a–d) and the war-cannibalism (Fig. 4a–d) relationship is significant in alternate periods, which may be attributable to governance matters. It should be noted that those periods of significant coherency are coincident with the downturn of the government, particularly the late Ming and the late Qing periods. In historical China, governmental capacity is critically important for reducing the vulnerability of the social system to natural disasters and external shocks. For instance, in the heydays of the Qing dynasty, the government played a very active role in disaster relief in northern China. The government could mitigate the negative impacts of floods and droughts through the allocation and distribution of funds and food, in addition to conventional means such as tax cuts (Fang et al. 2013). Yet, during the downturn of the Ming and Qing dynasties, financial crisis, nomadic invasion, and peasant rebellion are often in evidence, and hence, the capacity of the government is drastically weakened. Disaster relief is also debilitated (Xiao et al. 2015). Hence, when both mega-droughts and immense wars occurred in northern China in the late Ming and late Qing periods, there are peak years of cannibalism incidents during the time.

My findings help to sort out the vicious cycle between famine and war proposed in previous studies (Lee 2014; Lee and Zhang 2010, 2013) and illustrate its associated dynamics. At the decadal scale, cannibalism leads war (Fig. 3a, b). At the multi-decadal scale, war leads cannibalism (Fig. 3c, d). At the centennial scale, it switches back to cannibalism leading war (Fig. 3e). The relationship "cannibalism leads war" generally follows the Malthusian theory, which states that subsistence shortage is the root cause of positive checks in historical China. This has been substantiated by empirical studies (Lee 2014) and mathematical modeling (Chu and Lee 1994). But, historical evidence also shows that war can disrupt agricultural production by greatly shrinking the agrarian workforce, leaving a serious carry-over effect on the harvest level (Zhang et al. 2006). This may explain why war can cause cannibalism, resulting in positive feedback between famine and war.

There exist an unusually strong drought-cannibalism and war-cannibalism coherency across different periodic cycles in the seventeenth century period (Fig. 2a, b). The seventeenth century period is the coldest period in China and in the Northern Hemisphere over the last two millennia (Mann and Jones 2003; Yang et al. 2002). In this period, structural change in the macro-economy in Europe is also observed, which is brought by temperature change (Pei et al. 2015). In northern China, cold climate and its associated agricultural shrinkage significantly worsen the socio-economic well-being of people, which may have further exacerbated the effect of drought and war in elevating subsistence pressure. Together with the exogenous shock brought by the Manchu invasion during this time, such synthesis may have made human societies very vulnerable to natural disasters and human catastrophes at whatever time scales. This explains why the drought-cannibalism and the war-cannibalism coherency also extends to cover the shorter periodic cycles in the seventeenth century period.

Human beings can use various institutional devices to relieve subsistence pressure brought by drought and war. But, this is true only if governance is sufficiently strong and vibrant, as revealed in my findings. Indeed, my findings do not deny the progress achieved by historical societies. In the Ming dynasty, the food production system in northern China was more sensitive to perturbations, as the dominant cropping system was one crop a year. In the Qing dynasty, with the cultivation of winter wheat, soybean, and millet/sorghum, the dominant cropping system was changed to three crops per 2 years. Besides, the widespread cultivation of American crops such as maize, potato, and sweet potato, which are characterized by high yield per unit area and high adaptability to cropland, significantly increases the resilience of agriculture to any perturbations in northern China (Xiao et al. 2015). On the other hand, institutional measures may play a part in detaching the drought-cannibalism and the war-cannibalism nexus. For instance, after the Boxers Movement in 1900, the central government formally terminated the quarantine policy for Manchuria and Mongolia. When any perturbations happen, people in northern China can obtain a piece of arable land and resettle outside the Great Wall as a buffer (Xiao et al. 2015). This matches the drastic reduction (both the mean and the maximum number) of cannibalism incidents in the Qing dynasty (Fig. S1f), which may help to explain why the low-frequency (centennial) coherency in the drought-cannibalism and war-cannibalism nexus disappears in the late imperial period (Figs. 3e and 4e).

This study contributes knowledge in two aspects. First, previous studies demonstrated the linear relationship among various positive checks such as war, famine, and epidemics in the whole of China as a single spatial aggregate (Lee 2014; Lee and Zhang 2013). This study enriches the understanding of Malthusian theory with the empirical data of the northern China region in history. Also, it supplements the Malthusian theory (Malthus 1798) by measuring the non-stationary influence of natural disaster (which is considered as an external shock by Malthus) on the positive checks and assessing how different types of positive checks interact with and reinforce each other in different periodic cycles. Second, in previous studies, the proposed environment-human nexus in northern China can be summarized as drought/flood ⇨ famine ⇨ war, which is contingent upon the vitality of social systems and institutional measures (Fang et al. 2013; Xiao et al. 2018, 2015). This study complements the finding that famine is mainly caused by drought and war as shown in the following paths: drought ⇨ famine ⟺ war.

Nowadays, human societies have been getting more developed and civilized. Cannibalism incidents are extremely rare. But, in underdeveloped regions such as sub-Saharan Africa, food insecurity is currently driven by more frequent climatic extremes and social instability, which is in line with the topic investigated in this study. This is also the issue upfront waiting to be resolved (Sasson 2012). Perhaps the results presented in this study may serve as a sample for analyzing the link between food insecurity and its driving factors in a quantitative manner.

Conclusions

So far, large-N statistical analysis of cannibalism and its triggering factors in pre-industrial societies is still absent in the literature. Based on 1194 cannibalism incidents in northern China in 1470–1911, together with fine-grained historical datasets and statistical analyses, I find that drought and war play a significant role in causing cannibalism in history. But, the relationship is not stationary and is mediated by the environmental and socio-political context. The positive feedback between war and cannibalism is also shown. The above findings supplement the Malthusian theory with empirical evidence of the interaction among natural disasters and positive checks. This study is grounded on the historical data of northern China and focuses on cannibalism as a survival necessity. Further research should be conducted to learn whether the above findings hold in different geographic regions and at different geographic levels. Also, it may be equally important to interpret historical cannibalism in social and cultural perspectives.

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