Social Resilience to Nuclear Winter: Lessons from the Late Antique Little Ice Age.

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Key Points:

- The climatic conditions of the Late Antique Little Ice Age (ca. 536CE to 560CE) mirror those expected to be produced by a regional nuclear war, and thus provide the context for naturalistic experiment on social resilience to nuclear winter.
- Cross-cultural analysis of 20 societies impacted by the Late Antique Little Ice Age suggests that broad political participation creating bridging social capital was a key factor in social resilience.

Abstract

The threat of nuclear winter from a regional nuclear war is an existential hazard that must be addressed to ensure the shared future of humanity. Here a cross-cultural analysis of 20 societies that experienced the Late Antique Little Ice Age (ca. 536-556CE) is performed. The climatic conditions of the Late Antique Little Ice Age are strikingly similar to those modeled as resulting from a regional nuclear war employing low-yield nuclear weapons, and thus provides a context in which mechanisms of resilience to nuclear winter might be empirically identified. It is argued that broad political participation fostering bridging ties between communities, agencies, and organizations was a key elements of social resilience to the Late Antique Little Ice Age, and may indicate a means to foster resilience to nuclear winter today.

1 Introduction

In 1983 *Turco* and colleagues put forward the idea that one result of a nuclear war would be a period of extreme cooling across the globe, a phenomenon they referred to as a “nuclear winter” (also *Aleksandrov and Stenchikov*, 1983). Their idea was and remains controversial (e.g. *Thompson and Schneider,* 1986; *Marshall,* 1987; *Seitz*, 2011), but in recent years several groups have used climate modeling to argue that even a small, regional nuclear war would cause at least several decades of cooling across much of the globe (*Mills, Toon, Lee-Taylor, and Robock*, 2014). The threat of nuclear winter, then, is a serious one, and one that must be considered as a pressing hazard to address (*Sagan*, 1984). In particular, mechanisms that might provide social resilience to the hazard of nuclear winter need to be actively sought (*Scouras*, 2019). This paper attempts to identify sources of resilience to nuclear winter by examining social responses to the Late Antique Little Ice Age (hereafter LALIA), a period between roughly 536 CE and 560 CE that saw rapid cooling and diminished solar irradiance across the northern hemisphere (*Buntigen et al.*, 2016). These climatic changes led to widespread social disruption, but that disruption was not universal, and indeed some societies seem to have flourished both during and after the LALIA, even when neighboring groups collapsed. It is argued that the LALIA thus provides a naturalistic experiment to identify patterns and test hypotheses about social resilience to nuclear winter (*Peregrine*, 2020a, 2020b).

The idea that a nuclear war could create a nuclear winter was rooted in the idea that smoke from fires caused by the nuclear explosions would create a volume of sunlight-blocking aerosols great enough to significantly cool the planet and alter precipitation patterns (*Aleksandrov and Stenchikov*, 1983; *Turco et al.*, 1983). The first models developed to test this idea suffered from a lack of reliable data on the behavior of atmospheric aerosols and from simplistic climate models, a key reason the idea of nuclear winter was controversial (*Thompson and Schneider*, 1986). In the 50 years since the first models of nuclear winter were published climate scientists have developed a far better understanding of the atmosphere and far more accurate climate models (*Robock and Toon*, 2012). Current research suggests that even a small nuclear exchange could trigger dramatic cooling and changes in precipitation (*Robock, Oman, and Stenchikov*, 2007; *Robock et al.*, 2007)

In this paper the cross-cultural method is used to explore resilience to nuclear winter, using the LALIA as a proxy for the anticipated climatic conditions. The cross-cultural method differs from more common case-study analyses in that a systematic sample of cases displaying a wide range of variation on variables of interest are examined rather than cases that exemplify particular variants. A systematic sample allows the potential to explore theories and hypotheses probabilistically rather than simply illustrating answers anecdotally. The logic of the cross-cultural method is that if an hypothesis about cultural stability or change has merit then the hypothesized causes and effects should be strongly associated across a wide range of cultural and ecological variation (*Ember and Ember*, 2000; *Smith and Peregrine*, 2012). The societies analyzed here represent a wide range of geographic locations across the Northern Hemisphere and a wide-range of social organization and cultural practices. If regular patterns of stability and change can be found among such a diverse group, then there is no *a priori* reason to believe those patterns are not generalizable to other societies, including our own.

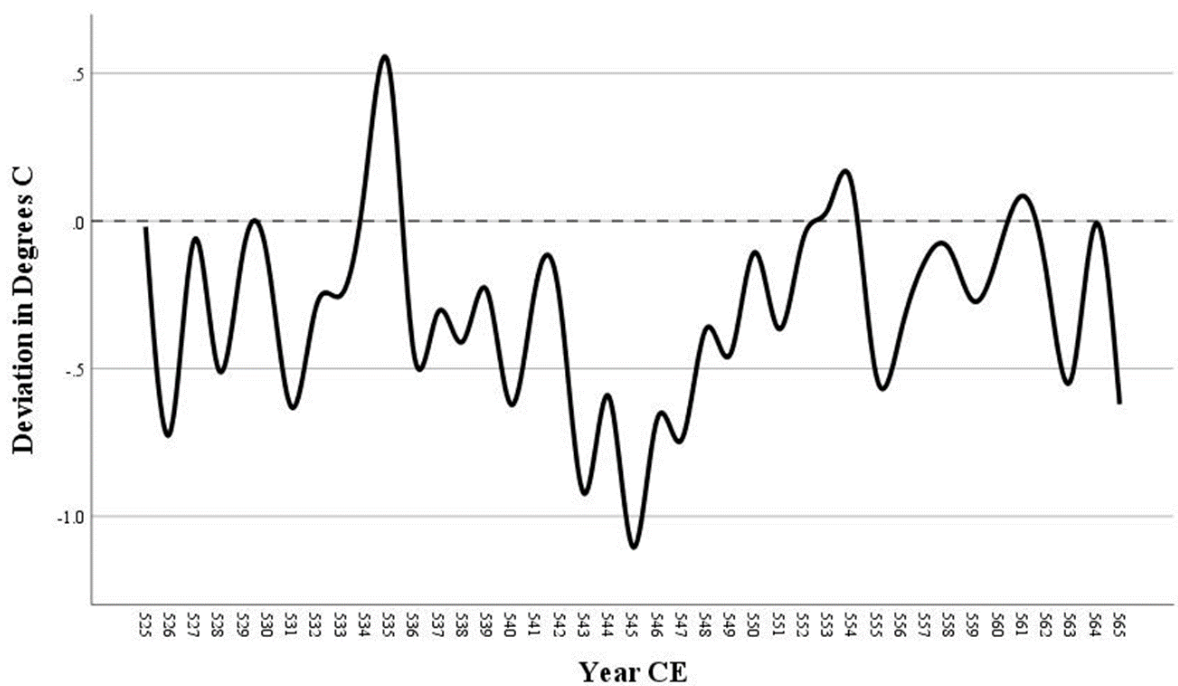
In the following section the specific climatic conditions of the LALIA and their similarity to those expected following a regional nuclear war are discussed. It is suggested that the climatic conditions of the LALIA provide a reasonable proxy for those expected to be created by a limited nuclear exchange.

1.1 The Late Antique Little Ice Age

A series of recent publications (*Büntgen et al.*, 2016; *Helama, Jones, and Briffa*, 2017; *Helama et al.*, 2018; *Toohey et al.*, 2016) have brought renewed focus on the atmospheric catastrophe of 536CE and what historian Michael McCormick called “the worst year to be alive” (*Gibbons*, 2018). That year marks the beginning of the LALIA, as 536CE is the year in which the first of three large volcanic eruptions (the second in 540CE and the third in 547CE) forced dramatic cooling and a marked decline in solar irradiance across the Northern Hemisphere (*Büntgen et al.*, 2016; *Toohey et al.*, 2016; *Gunn*, 2000). While the exact locations of these eruptions are debated (*Nooren et al.*, 2017), it is clear that they produced the largest and longest atmospheric loading event in recorded history (*Dull*, 2019). Previous studies have demonstrated that global and regional temperatures dropped 1 to 2 degrees Celsius during the LALIA and led to more than a decade of significantly cooler temperatures and weaker solar irradiation across the Northern Hemisphere.

Several recent papers have described the climatic conditions of the LALIA in some detail. *Büntgen et al.* (2016) employ data derived from 660 tree-ring width samples from the Altai mountains to demonstrate that 13 of the 20 coldest summers in the last 2 millennia occurred during the LALIA. They attribute this cooling to aerosol particles injected into the stratosphere by volcanic eruptions which lowered solar irradiation by at least 11.3 W/m^2. *Helama et al.* (2018) use evidence from stable carbon isotopes in Northern Hemisphere tree-rings to argue that aerosols from the large volcanic eruptions of 536 and 540CE created a multi-year period of low solar irradiance (a decline of 12-20 W/m^2) that would have exacerbated the associated cooling in terms of photosynthesis and, in turn, crop yields. Finally, *Peregrine* (2020b) employed climate data from *Neukom et al.* (2019) to create temperature reconstructions for the period from 486CE to 586CE for 20 locations occupied by societies thought to have been impacted by the LALIA. These temperature reconstructions indicated a period of rapid cooling of roughly 1.5 degrees C beginning at 536CE and continuing until at least 556CE (Figure 1), and comparison of mean annual temperatures for the period 486 to 526CE with those of the period from 536 to 556CE yielded a statistically significant difference (t = 9.410; df=19; p<.000). These papers suggest the LALIA was a period in which the climate cooled by 1 to 2 degrees C over the course of only a few years, and solar irradiance decreased by 10 to 20 W/m^2 in the period of only a few months.

Figure 1. Mean annual temperature variation for the 20 cases used in the analysis by *Peregrine* (2020b). Data were derived from *Neukom et al.* (2019)



The climatic conditions of the LALIA seem remarkably similar to those expected to occur following regional nuclear exchange (*Coupe et al.*, 2019; *Mills et al.*, 2014; *Pausata et al.*, 2016; *Reisner et al.*, 2018; *Robock et al.*, 2007a, 2007b). Table 1 presents the output of four models used to estimate the climatic impact of a regional nuclear war involving roughly 100 15kt warheads. Examining the table one can see that, in general, a regional nuclear war would lower the mean global temperature by about 1 degree C, and decrease surface solar irradiance by 10 to 15 W/m^2. The similarities between the predicted climatic effects of a regional nuclear war and the LALIA are obvious, and this suggests that the LALIA provides a context in which theories of social resilience to the climatic effects of a nuclear winter produced from a regional nuclear war might be evaluated. The remainder of this paper attempts to use the LALIA to explore one such theory of social resilience to nuclear winter.

Table 1. Estimated production of black carbon aerosols from a nuclear exchange of roughly 1500kt and related climatic effects in the first several years following the exchange.

Source	**Aerosol loading**	**Mean surface temperature**	**Mean surface irradiation**
Pausata et al., 2016	5Tg black carbon	-1^{o}C	-8W/m^2
Mills et al., 2014	5 Tg black carbon	-1.1^{o}C	-12W/m^2
Reisner et al., 2018	1 Tg black carbon	-0.25^{o}C	-2W/m^2
Robock et al., 2007a	1-5 Tg black carbon	-1.25^{o}C	-15W/m^2

The LALIA took place during a period where both good archaeological and historical data are available, and thus offers a unique context for conducting a naturalistic quasi-experiment through which hypotheses about social vulnerability and resilience to nuclear winter might be tested (*deMenocal*, 2001). A naturalistic quasi-experiment can be performed when one has a sample of cases that have been differentially impacted by a "treatment" (in this case, the onset of the LALIA) and where the differential effects of that treatment can be systematically measured and evaluated (*Leatherdale*, 2019). Here some societies, such as the Ostrogoth kingdom of Latium, collapsed while others, such as the Early Merovingian kingdom of the Paris Basin, experienced little change. Both were impacted by similar climatic changes, but the effects of the climatic "treatment" differed greatly. The question one can pose in this situation is what differences explain those differing effects, or to put in more directly into the context of this paper, what conditions led to variation in resilience?

In the next section social resilience and the conditions that are hypothesized to improve resilience to climate-related disasters like the LALIA or a nuclear winter are discussed. It is then specifically hypothesized that broad participation in governance will be associated with social resilience.

1.2 Social resilience to nuclear winter

Social resilience as employed here refers to the ability of a social system to absorb disturbances while retaining the same basic structures and processes that will allow the social system to respond to future disturbances with equivalent (or superior) efficacy (see *Parry et al.*, 2007; also *Holling*, 1973). There are many other definitions of resilience or processes involved in resilience (see *Davidson et al.*, 2016, for an overview). The definition used here is commonly called "resistance" or "adaptability" and refers to the capacity of a social system to change in ways that allow survival without significant changes to basic social structures and processes (*Walker et al.*, 2004). This is opposed to "transformative resilience", which refers to the capacity of a social system to create a dramatically new system in the wake of a disaster (*Walker et al.*, 2004). A social system with adaptive resilience will tend to return to a state of equilibrium following a disaster similar to that which existed before the disaster (but not identical to it, as a resilient system will change to reduce future risk—see *Wisner and Kelman*, 2015). A social system with transformative resilience will fundamentally change its pre-disaster social system in order to achieve a new equilibrium state. The assumption made here is that adaptive resilience is preferable to transformative resilience because adaptive resilience tends to retain existing social structures and processes (*Turner*, 2010).

Two major themes have become the subject of increasing discussion in the literature on social resilience to disasters. The first is the importance of "vulnerability"—that the impact of a disaster is in part socially created because societies frequently build structures (both social and physical) that exacerbate the impact of disaster (e.g. *Comfort, Boin, and Demchack,* 2010; *Tierney*, 2014; *Wisner et al.*, 2004). The second is that more "flexible" social structures (again, both social and physical) are more resilient to disasters than more "rigid" social structures (e.g. *Aldrich*, 2012; *Holling, Gunderson, and Peterson*, 2002; *Kahn*, 2005; *Paton*, 2006)—a perspective that is referred to here as "flexibility theory". Both of these themes suggest that flexibility or freedom to adapt are a key to social resilience to disasters (*Hegmon et al.*, 2008; *Redman*, 2005; *Redman and Kinzig*, 2003). This is particularly true for adaptive resilience as flexibility is one of the features that allows societies to adapt rather than transform.

Political participation is employed here as a measure of flexibility. The link between participation in political decision-making and social flexibility is well-established in the disaster resilience literature through the concept of "participative capacity". Participative capacity refers to the ability of local actors to influence decision-making (*Lorenz and Dittmer*, 2016, 47-48). As *Redman* (2005: 72) put it, in order to build social resilience "management has to be flexible, working at scales that are compatible with the scales of critical ecosystem and social functions." Because those scales range from local to societal, participation has to be equal at all those levels. A key element in participative capacity is control and flow of information. In more resilient social systems horizontal (that is, between individuals operating on similar scales) information flow appears more important than vertical flow so that control of information at high levels in a hierarchical system may lead to less resilience (*Redman and Kinzig*, 2003; also *Inkpen and Tsang*, 2005).

Political participation is proxied through an index variable based on a model of governance strategies called the corporate/exclusionary model. As discussed below, key definitional elements of the corporate/exclusionary model focus on both participation in decision making and control over information and material flows, and for this reason the corporate/exclusionary model provides a reasonable proxy for societal flexibility, a proxy that has been well-established in previous research (*Peregrine* 2017, 2018a, 2020a).

The corporate/exclusionary model developed through efforts to explain an archaeological puzzle: when looking at ancient polities of equivalent scale and complexity there are marked differences in the visibility of political leaders. Some ancient polities, such as Classic Mayan, have leaders that are named and glorified on stelae, carved panels, and painted murals. Others, even contemporary ones in regular contact, such as the Teotihuacan polity of the Valley of Mexico (which had important ties to various Classic Mayan polities) are “faceless”, having no clearly identified leaders. *Blanton et al.* (1996) theorized that this puzzling difference stemed from the strategies leaders employed to implement and maintain authority. They argued that broad regularities in political strategies can be identified in the archaeological record, and that these strategies can be characterized as a continuum with two poles. One pole of the continuum is characterized by “exclusionary” political strategies in which leaders attempt to control access to political participation and legitimize their authority through a cult of personality and ties to both local and foreign elites whose loyalty they sustain through control over exotic goods and esoteric knowledge (see *Helms,* 1976). The other pole of the continuum is characterized by "corporate" political strategies in which leaders encourage broad political participation, empower a broad cadre of officials to govern, and who legitimize their authority through their generosity, often displayed in community building activities such as feasts, and an appeal to their being "first among equals" (see *Leach*, 1954).

The corporate/exclusionary model posits that the way power is wielded by authority is what shapes how power is materially manifested in the archaeological record. Such archaeological materials include the way in which leaders are depicted visually on statues or murals; their unique access to exotic goods and symbols of power as found in their residences and graves; variation in material goods and food available to ordinary citizens as compared to leaders; evidence for feasting or other communal rituals and activities; and evidence for multiple levels of decision-making. What can be seen is the degree to which leaders allow or limit access to economic and political participation, and those are is the key concepts used here measure social flexibility

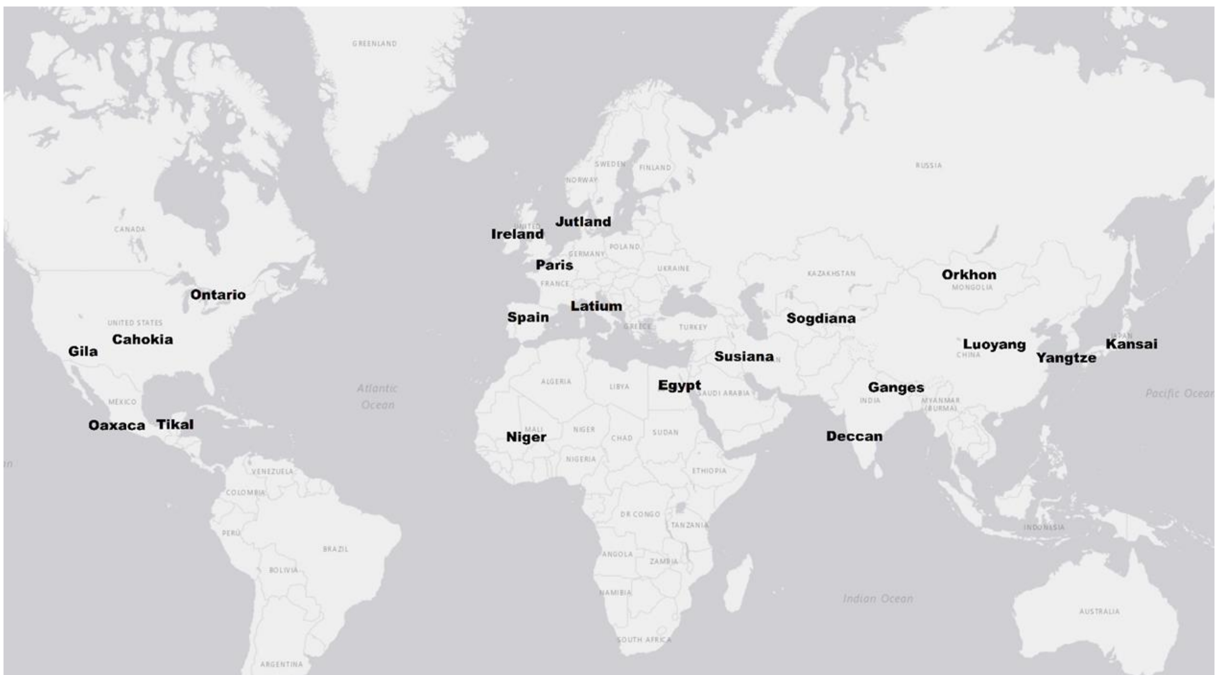
2 Materials and Methods

In this section a brief overview of the sample, variables, and coding protocol used to produce the analyzed dataset is provided. These have been described in some detail elsewhere (*Peregrine*, 2018a, 2018b), and are only be summarized here.

2.1 Sample.

The sample used here was selected to provide a blend of geographical and cultural diversity among those societies that experienced the LALIA. This blend was intended to offer both a sufficient range of variation to allow analysis of similarities and differences in patterns of resilience, and also to avoid the problem of autocorrelation. Autocorrelation occurs in cross-cultural samples when cultures are either geographically or culturally related such that they do not represent independent cases, but rather ones of shared ancestry. Autocorrelation has the potential to significantly impact the results of cross-cultural studies, and must be considered when selecting samples for analysis (*Dow*, 2007). It was also important for this project to select cases with adequate historical and archaeological data to allow for coding.

Figure 2. Locations of the 20 sample cases.



The initial sample of cases were selected from the Seshat World Sample 30 (http://seshatdatabank.info/methods/world-sample-30/), which is ideal for selecting cases for a cross-cultural project of this kind. The Seshat World Sample 30 provides basic information on temporal sequences of societies in 30 geographic locations selected to minimize the problem of autocorrelation (*Turchin et al.*, 2020). Twelve societies in the Seshat World Sample 30 had experienced the LALIA and were selected for the sample used here. Three cases that had been coded for a previous research project (*Peregrine*, 2018a, 2018b) were also incorporated into the sample. These cases had already been coded for the dependent variables, and thus provided a solid foundation for validating the coding protocol used in this study. Finally, 5 additional cases were selected in order to ensure broad geographical coverage of the Northern Hemisphere. The locations and sources of the cases are shown in Figure 2, and more detailed information about each case is provided in Table 2.

Table 2. Cases used in the analyses and associated information. The first column gives the full case name followed by the abbreviated name in parentheses. The second column gives the full time period from which data were collected (although data were focused on the 20 year period before and after 536CE).

Case Name (short name)	Time Frame
North America	
Point Peninsula Complex (Ontario)	300 BCE-700 CE
Mund Phase (Cahokia)	450 CE-600 CE
Pioneer/Formative Phase (Gila)	1 CE-750 CE
Monte Alban IIIB and IV (Oaxaca)	500 CE-900 CE
Early Classic (Tikal)	250 CE-600 CE
Europe	
Early Merovingian (Paris)	486 CE-543 CE
Ostrogothic Kingdom (Latium)	489 CE-554 CE
Migration Period (Jutland)	500CE – 700CE
Brega (Ireland)	Reign of Túathal Máelgarb 533 CE-544 CE
Toledo (Spain)	Reign of Theudis 531 CE-548 CE
Eastern Asia	

Rouran Khaganate (Orkhon)	300 CE-555 CE
Hephthalites (Sogdiana)	408 CE-561 CE
Kofun (Kansai)	250 CE-710 CE
Early Imperial Period (Luoyang)	200 BCE-900 CE
Liang (Yangtze)	Reign of Emperor Wu, 502-549 CE
Southern Asia	
Sasania Period (Susiana)	224 CE-642 CE
Kadamba Empire (Deccan)	354 CE-540 CE
Gupta Empire (Ganges)	Reign of Kumaragupta III 530-540 CE
Northern Africa	
Byzantine Empire (Egypt)	395 CE-631 CE
Jenne-jeno III (Niger)	400 CE- 900 CE

2.2 Variables.

The independent variable used to measure societal flexibility is an index variable based upon the corporate/exclusionary model, as described above. This "Corporate/Exclusionary Index" (hereafter CEI) is the average standardized scores on the 5 variables listed in Table 3, and is described in more detail in *Peregrine* (2008, 2012) and *Peregrine and Ember* (2016). In brief, the index measures the degree to which political agents encourage or discourage political participation and interaction with external polities. In more corporate societies, which score lower on the scale, agents encourage members of the society to participate in political activities, share authority broadly, and allow greater interaction with outsiders. The opposite is true in more exclusionary societies, where agents control access to political authority, share it only among a small group of peers, and prevent most members of society from interacting with outsiders. The CEI has been used to code archaeological data in several previous research projects that have produced statistically robust results (*Peregrine*, 2008, 2012, 2018a, 2018b, 2020a, 2020b; *Peregrine and Ember*, 2016), and is itself is statistically robust, with an alpha of .978 (5 items) and all the variables comprising it correlating to a single factor explaining 92% of the variance (Peregrine 2018a).

Table 3. Variables comprising the Corporate/Exclusionary Index (CEI). All were coded on a 5-point ordinal scale. Specific scale value definitions are unique for each variable. Variable names are those in the dataset archived at the Human Relations Area Files Advanced Research Center (hrafarc.org).

Variable	Question Coded for Corporate/Exclusionary Index
IV-3-1: Differentiation of Leaders and Followers	To what extent do leaders have privileges and/or access to resources that others do not?
IV-3-2: Leader Identification	To what extent do leaders have unique identifiers (e.g. appearance, treatment, symbols of power)?
IV-3-3: Sharing of Authority	To what extent do leaders share power with others?
IV-3-4: Emphasis of Authority	To what extent is the emphasis of authority on the leader and/or leader preservation?
IV-3-5: External Contacts	To what extent do leaders control access to foreign contacts and/or goods?

The dependent variable in the analysis, the Social Change Index (hereafter SCI) was created by summing the 6 measures of social change listed in Table 4. Coding protocols have been published elsewhere and both the 6 variables comprising the SCI and the SCI itself have been demonstrated to be valid and reliable (*Peregrine*, 2018a, 2020b). With the data employed here the SCI has an alpha of 0.776 (*Peregrine*, 2020a). The six dependent variables were coded by contrasting the conditions for the roughly 20-year period prior to 536CE and those for the roughly 20-year period following. Data of fine enough resolution to keep within those 20-year ranges was not always available, and in those cases data with the best temporal resolution available for the periods both before 536CE and after were employed. In all cases the values coded were within a 100-year range of the 536CE date. Data collection was focused, to the extent possible, on a single community or region within the larger case. This is standard practice in cross-cultural research and is done as a way to control for the range of social diversity found in different geographical locations within any given society (*Ember and Ember*, 2005).

Coding was done using the Dacura software platform which allowed both numeric codes and all supporting documentation to be placed directly into Linked Data format. Dacura employs an RDF-triplestore to create semantic links between both textual and coded data and allow for both data harvesting and sharing on the semantic web (*Peregrine et al*., 2018). In the first stage of coding quotes from textual sources providing information about each variable were input along with supporting bibliographical information. Once all the source materials were input each set of quotes were read by two researchers and initial coding decisions were made. These codings were re-visited once all the cases were completed, and experts on each case were invited to review the codings and underlying source materials. Revisions were made based on expert’s responses and suggested additional source materials, and final codes were established.

Table 4. Variables comprising the Social Change Index (SCI). All were coded on a 3-point (1) none, (2) some, (3) much scale. Variable names are those in the dataset archived at the Human Relations Area Files Advanced Research Center (hrafarc.org).

Variable	Question Coded for Social Change Index
DV-1: Change in Population	Was there a change in population size or migration?
DV 2: Change in Famine or Disease	Was there a change in the frequency or intensity of famine or disease?
DV 3: Change in Conflict	Was there a change in the frequency or intensity of conflict?
DV-4.1: Change in Village Organization	Was there a change in the organization of communities?
DV 4.2: Change in Regional Organization	Was there a change in the regional organization of the society?
DV 4.3: Change in Ritual Architecture and Organization	Was there a change in the religious or ritual organization of the society?

It is important to emphasize that there is diversity in all societies, and there is diversity in the inferences made about past societies. This is why focal communities are used in cross-cultural research to the extent possible. But knowledge of the past changes as more information is uncovered, and interpretations of the past change as more is learned. The data employed here represent the best approximation of reality based on the available information and interpretations of that information, but they do not in any way represent the “truth” about the past. It is expected that these data will need correction as more is learned about the coded societies. The evidence supporting individual coded values are provided with the data archived at the Human Relations Area Files Advanced Research Center (hrafarc.org) in the hope that current and future scholars might return to these data, make corrections or provide new interpretations, recode variables based on their own protocols, and either replicate of falsify the results presented here.

3 Social Resilience and Political Participation.

This section presents the results of analyses suggesting that societies allowing greater degrees of political participation experience better adaptive resilience to climate-related disasters such as the LALIA or a nuclear winter than those that do not. It is argued that the resilience of these more corporately-oriented societies is rooted in bridging social capital that creates links between different government agencies and levels providing both information and materiel to flow easily among them. The ease of information and materiel flow allows for rapid decision making and response, which forms the foundation for adaptive resilience.

As discussed above, it has been suggested that more "flexible" societies are more resilient to climate-related disasters like the LALIA or a nuclear winter. Here it is assumed that one aspect or proxy of flexibility is political participation, and that political participation in past societies can be validly measured through the Corporate-Exclusionary Index. Given those assumptions, the hypothesis is that more corporately-oriented polities were more resilient to the climatic changes of the LALIA than were societies in which leaders tightly controlled access to political authority. Table 5 presents the results of Pearson's one-tailed correlations between the CEI, the 6 dependent variables, and the SCI (column a). One-tailed correlations are employed because the hypothesized relationships are directional. There appears to be modest support for the hypothesis that more corporately-oriented societies were more resilient to the climatic catastrophe of the LALIA. All of the correlations are in the expected direction and Change in Conflict is statistically significant ($p < .034$). Change in Population, Famine and Disease, and Communal Ritual are marginally significant. The SCI is also significantly correlated with the CEI ($r = .465$, $p < .020$), and in the expected direction. This would suggest that having a more corporately-oriented political structure tended to minimize conflict during the LALIA and appears to have limited social change in general.

Table 5. Pearson's r correlations between the Corporate/Exclusionary Index (columns) and dependent (rows) variables. Column (a) shows the results of one-tailed Pearson's correlations; column (b) shows the results of one-tailed partial correlations controlling for political hierarchy.

Dependent Variable		(a) **Corporate-Exclusionary Index (CEI)**	(b) **CEI controlling for political hierarchy**
DV-1: Change in Population	r =	.342	.547**
	p <	.070	.008
	N =	20	17
DV-2: Change in Famine or Disease	r =	.353	.099
	p <	.063	.343
	N =	20	17
DV-3: Change in Conflict	r =	.415*	-062
	p <	.034	.400
	N =	20	17

DV-4.1: Change in Village Organization	r =	.239	.460*
	p <	.155	.024
	N =	20	17
DV-4.2: Change in Regional Organization	r =	.235	.554**
	p <	.160	.007
	N =	20	17
DV-4.3: Change in Ritual Architecture and Organization	r =	.322	.584**
	p <	.083	.004
	N =	20	17
Social Change Index (SCI)	r =	.463*	.537**
	p <	.020	.009
	N =	20	17
	Bayes Factor	.716	

In previous analyses it has been shown that variation in political hierarchy is an important mediating variable between the CEI, the SCI, and the individual dependent variables (e.g. *Peregrine*, 2018a, 2020a). With that in mind partial correlations of the CEI with the dependent variables controlling for political hierarchy are also presented in Table 5 (column b). Political hierarchy is defined as the number of levels of jurisdictional hierarchy above the local community, and varies between 0 and 5. Not surprisingly, given that political hierarchy has already been identified as a mediating variable, the correlation coefficients and levels of significance are higher for the partial correlations. Indeed, Change in Population ($p < .008$), Village Organization ($p < .024$), Regional Organization ($p < .007$), and Ritual Organization ($p < .004$) are all significantly associated with the CEI when controlling for political hierarchy (and, interestingly, change in conflict no longer is associated—see *Peregrine*, 2018b for more discussion).

One can conclude from these results that more corporately-oriented polities were more resilient to the climatic catastrophe of the LALIA, and, because the atmospheric conditions of the LALIA are strikingly similar to what has been modeled as the expected climatic conditions following a limited nuclear war, one can also reasonably conclude that more corporately-oriented polities would be more resilient to nuclear winter as well. As these results were derived from a cross-cultural analysis of a wide range of polities representing a diversity of social forms and environments, they should be generalizable to a wide range of societies, including our own. But before moving on to explore how these results might be applied to contemporary societies, one must first ask why corporately-oriented polities were more resilient to the LALIA than more exclusionary-oriented ones.

Earlier it was argued that flexibility is key to resilience, and that corporate orientation fosters flexibility by encouraging broad political participation. Tying this idea to current literature on disaster prevention and management, political participation appears to be closely related to the concept of "social capital" which is widely seen as a central element of resilience. Social capital refers to the social networks and interpersonal relationships that tie communities together (*Putnam*, 1995; *Woolcock*, 1998), and it is widely argued that such ties are central to resilience (e.g. *Aldrich*, 2012; *Norris et al.*, 2008). Three forms of social capital are often discussed: "bridging", "bonding", and "linking" (*Putnam*, 2000, 18-24). Political participation seems most closely related to bridging social capital, which refers to networks of social ties that link diverse individuals and groups together across a community. Indeed *Putnam* (2000) includes political participation in the form of voting, interest in public affairs, and participation in political and civic organizations as measures of bridging social capital (also *Onyx and Bullen*, 2000). Bonding social capital, in contrast, are inter-relational ties that bond together individuals within social groups. Finally, linking social capital refers to ties that connect individuals, organizations, and communities to higher-level structures, such as local or regional governments.

Bridging social capital has been associated with resilience following unpredictable catastrophic disasters, such as those societies that experienced the LALIA and that might experience a nuclear winter, while bonding social capital seems more effective in societies where smaller natural disasters are frequent (*Jordan*, 2014; *Masoud-All-Kamal and Hassan,* 2018). This appears to occur because bridging social capital, by providing a network of ties that link individuals and organizations across a community, allows communities to prepare well for large-scale disasters and to have effective, coordinated response and recovery plans and practices in place. Bonding social capital is more effective in situations where there are frequent smaller disasters because neighbors and family are typically the first responders in any disaster situation. Where disasters are common, strong bonds among individuals in a community provide for rapid response and reconstruction (*Jordan*, 2014). Linking social capital, however, appears not always to be helpful in disaster response and recovery, as higher-level organizations sometimes direct efforts toward more politically powerful communities, and ranking officials may misappropriate funds and materiel for personal gain (*Masoud-All-Kamal and Hassan*, 2018).

The major implication of these analyses is that to limit the societal impact of nuclear winter, policy makers should work to encourage political participation and, in doing so, increase the value of bridging social capital in local communities. This is a broad and, quite honestly, largely un-actionable conclusion. In the conclusions that follow more actionable ideas for building social resilience to nuclear winter are suggested. Specifically, it is argued that policy makers should support and, where possible, implement effort to generate bridging social capital both within and between stakeholders, agencies, and multiple levels of government.

4 Conclusions

Creating bridging social capital seems key to creating a society that is resilient to nuclear winter. Bridging social capital might be most directly constructed by encouraging stakeholders at the local level to participate in decision-making about disaster response and management (*Aldrich and Meyer*, 2015; *Burby*, 2003). In practice this may mean that town or city boards and local disaster management officials hold regular community forums, and even regular meetings should be open to public attendance and participation (*White et al.*, 2015). This should go beyond simply opening meetings to obtain stakeholder input, but rather officials should actively seek input by directly inviting stakeholders to meetings and forums. Officials should undertake an active approach to gaining input, contacting the community of stakeholders directly to encourage them to give input at meetings and forums (*Horney et al.*, 2016).

Indeed the US Federal Emergency Management Agency (FEMA) has already implemented what they call a "Whole Community" approach to disaster response and management (*FEMA*, 2011) as part of the national strategy for disaster preparedness (*FEMA*, 2013). The Whole Community approach is based on the idea that local participation in disaster response and management creates more resilient communities. The effort focuses on three areas: (1) understanding and meeting the actual needs of the whole community; (2) engaging and empowering all segments of the community; and (3) strengthening what is already working well in communities (*FEMA*, 2013, 4-5). To implement the Whole Community approach FEMA encourages local emergency managers to focus efforts on creating engagement strategies and programs directed toward the specific characteristics and needs of the communities within which they work. Emergency managers are encouraged to work directly with local agencies and organizations to empower community action and collective solutions. As FEMA puts it, "Empowering local action requires allowing members of the communities to lead—not follow—in identifying priorities, organizing support, implementing programs, and evaluating outcomes" (*FEMA*, 2013, 14); in short, the Whole Community approach works to increase political participation by encouraging engagement, consultation, and shared decision making.

A second way in which policy makers might generate bridging social capital is by encouraging regular communication between local officials, emergency and disaster response personnel, and disaster response organizations to ensure smooth communication at appropriate levels during a disaster response. Smooth communication requires unfettered information flow within and between levels of disaster response and management, and has both technological and interpersonal aspects (*White et al.*, 2015). The technological ones include devices (radio, telephone, etc.) that allow communication among all the response groups; redundancy so that if one communication technology is made unworkable by the disaster others can be used in its place; and regular training to ensure all users are up-to-date on the active technology. The interpersonal aspects are more complicated and more difficult to implement. They include knowing whom to call given a particular need during response and the specific responsibilities of each person and each agency or organization (*Aldrich,* 2010; *Aldrich and Meyer*, 2015). Collaborative forums have recently been identified as an effective means of creating strong interpersonal connections among disaster response and management personnel (*Nohrstedt*, 2018) and might be usefully employed to strengthen interpersonal bonds. Both the technological and interpersonal aspects of communication should be actively cultivated by developing and implementing specific plans and purchases to build an overlapping, redundant communication technology and to ensure that strong interpersonal relationships are established among disaster and emergency response personnel.

Finally, to generate bridging social capital policy makers should actively support community-based organizations that build capacity for political participation (*Aldrich*, 2012). A community organization specifically focused on disaster management is one idea, but how would one go about developing such a community-based organization in a large community or a society like the United States where political and community participation has been declining for decades (*Putnam*, 2000)? A possibility is through "time banking", in which citizens are provided with incentives to volunteer with community-based organizations (*Collom and Lasker*, 2012). Incentives might be as simple as personal recognition or gift certificates, but even these simple incentives seem to be effective, and may create a "virtuous cycle" of community engagement and mutual aid (*Aldrich and Meyer*, 2015). Support should include both active promotion and political support and, perhaps more importantly, financial aid to ensure these community-based organizations can sustain themselves over the long-term (*White et al.,* 2015).

Nuclear winter is a real and potentially devastating hazard that should be actively addressed by policy makers. The recent development of nuclear weapons by North Korea, their potential development by Iran, and sustained tensions between India and Pakistan make addressing the hazard of nuclear winter all the more pressing. The societies that survived, and even flourished, during the period of the LALIA provide empirical models for building resilience to nuclear winter. This study suggests that one lesson from these societies is that broad political participation that fostered bridging social capital was an important element in their resilience in the face of the climatic catastrophe of the LALIA. It is hoped that this lesson from the past might be used by policy makers today. Our future might depend upon it.

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Data Availability Statement

The project codebook, an Excel file containing all codes and supporting evidence, and the full coded dataset in csv and SPSS format are archived at the HRAF Advanced Research Center at Yale University (hrafarc.org).

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