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CLIMATIC ANOMALIES, FOOD SYSTEMS AND SUBSISTENCE CRISES IN MEDIEVAL NOVGOROD AND LADOGA

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Abstract

Climatic factors have affected subsistence strategies throughout human history. In northern Europe and Russia, short-term climatic anomalies and weather extremes are commonly thought to underlie famines in the Middle Ages. However, medieval subsistence crises were not just natural disasters and medieval people were not passive victims of climatic anomalies. In addition, the capacity to cope with climatic anomalies has varied temporally and spatially throughout the Middle Ages. Yet only a few studies have explored the climatic impact on regional medieval food systems comprehensively. This paper examines the significance of climate variability on subsistence crises in medieval Novgorod and Ladoga (Russia), focusing on the relationship between short-term climate anomalies and crop cultivation. In addition, this paper evaluates the impact of crop failures, frosts and other weather phenomena on the food system. The materials are drawn from medieval sources, paleoclimatological reconstructions and archaeological evidence. The results show that short-term climatic anomalies alone rarely lead to severe subsistence crises, and during every famine period there is evidence of other contributing factors, such as unfavourable weather phenomenon, disease or social unrest. The variety of cultivated crops and agricultural techniques is shown to increase the region's resilience to climatic anomalies and to crop failures.

Keywords

Climatic anomalies, weather, subsistence crisis, food system resilience, medieval Russia

Introduction

In recent decades the possible impacts of climate change on human wellbeing have gained ever-increasing interest in science, politics, and everyday life alike. As climatic factors have affected subsistence strategies throughout human history, the understanding of human responses to climate change is commonly drawn from past experience. Therefore, it is rather surprising that the long-term focus of the scholarship of climate history (or historical climatology) has been on reconstructing climatic variability from documentary sources, whereas exploring the social impacts of climate has gained little interest among historians over the last few decades.[1]

This paper examines the impact of short-term climatic anomalies and weather extremes[2] on the medieval food system in western Novgorodian land (Russia) from 1100 to 1500.[3] The materials

[1] Pfister, 'The Vulnerability'; Carey, 'Climate and History'.

[2] Climate is the average of prevailing weather patterns, like temperature and precipitation, of a given region over long period of time, whereas weather is the experienced day-to-day variations of these elements. Climate anomalies, which are analysed here, are the seasonal or annual departures from the

used here are drawn from contemporary narrative sources and from paleoclimatological reconstructions.

The connection between climate and famine remains problematic in medieval history. Short-term climatic extremes, unfavourable weather conditions and frosts have been seen as key causes of famine in pre-modern agrarian societies. Climate-driven harvest failures are considered to be one of the main factors contributing to subsistence crises. However, it is widely agreed that medieval subsistence crises were not just 'natural disasters', and medieval people were not passive victims of climatic anomalies. Instead, famines of the time were social phenomena, just as they are today. Social and environmental conditions created situations with which society was not able to cope, and subsistence crises developed. Non-environmental factors, such as war, governmental policies, social structure and transportation, had an effect on creating and shaping the characteristics of famine. These two sides of the climate-famine relationship are widely known, but it seems that short-term climatic extremes and unfavourable weather conditions still have a profound status in the understanding of medieval food systems.[4]

The most comprehensive records of medieval famines are usually found in contemporary chronicles and annals: yet the significance of environmental and social factors cannot easily be discerned by studying only narrative sources. Thus, how to evaluate the significance of these factors? In this paper, one approach is introduced. Instead of trying to identify these significant, though hidden, factors from the narrative sources, this paper will focus on the only detectable (natural) factor of medieval subsistence crises: short-term climatic extremes and unfavourable weather events. Whereas medieval sources mainly record occasional weather events, paleoclimatological reconstructions provide evidence of annual climate variability.[5] In this paper, paleoclimatological reconstructions are at the centre of the examination, and they are considered as valuable a form of evidence as written historical sources. By carefully evaluating the role of short-term climatic anomalies on food systems, this paper highlights the significance of the 'hidden' social and environmental factors that may be evaluated in further research.

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long-term climatological average (minimum of 30 years), while weather extremes are unusual, severe or unseasonal phenomena, lasting from couple hours (like hailstorms) to weeks (like heat waves).

[3] Although medieval Russia used the Anno Mundi (AM) calendar system, in this paper all dates are converted to Gregorian Anno Domini (AD) dates. This was done because the medieval sources needed to be compared to the paleoclimatological data, which follow the Gregorian Calendar.

[4] Lamb, *Climate, History and the Modern World*, 195, 206–207; Jordan, *The Great Famine*, 15–23; Fraser, *Food system vulnerability*, 329–330. The term 'famine' refers to a catastrophic subsistence crisis, albeit the definition of famine has differed through time. The medieval chroniclers in particular may have used the term loosely, recording temporary local food shortages as famines, even though famine is understood as a widespread catastrophic scarcity of food with high mortality: see Jordan, *The Great Famine*, 7, 11; Ó Gráda, *Famine: a Short History*, 6–7.

[5] Paleoclimatology creates estimations of past climatic fluctuations from natural proxy data: for example, from tree rings, sediment varves or ice cores.

The area of study is located in north-east Europe, in an area roughly between the easternmost Baltic Sea, Lake Ilmen, and Lake Ladoga (Figure 1). The area held two large demographic centres in the Middle Ages: Velikii Novgorod and Ladoga. The land between these centres and smaller towns was covered with impenetrable woods and bogs, although, as a result of agricultural expansion, the landscape became more open during the Middle Ages. Lakes and rivers were the major routes, as roads were not generally well maintained. In addition, rivers and lakes provided significant resources for peasant livelihoods. Owing to a scarcity of arable land, people were dependent on supplies from the forest, especially in rural areas. Novgorod was able to bring these remote resources to markets effectively and gain wealth through international trade. Trade was an important part of the boyar economy, whereas common people gained their livelihood from agriculture, animal husbandry, fishing, hunting and crafts.[6]

The climate of the studied area is moderate continental, divided between the hemiboreal south and the boreal north on the Karelian Isthmus. The present climate is mostly influenced by the Westerlies. The warm season (May-September) mean temperature is approximately 15 °C, and the annual precipitation is 650–700 mm, of which around 450 mm fall during the warm period of the year. The northern location has influenced the farming practices of the region, as the climate possesses substantial challenges to agricultural production. The growing season is approximately five months long. At these latitudes, even small changes in climate and weather patterns can lead to significant shifts in agricultural potential. In addition, agriculture under Russian conditions in the Middle Ages may have been much less productive than it was in western Europe owing to socio-environmental factors. Technology available to peasants was rather simple and agricultural practices were less intensive than in the west. In addition, soil fertility was low due to lack of manure, which was related to the difficulties of keeping livestock (especially feeding the livestock during the long winter months).[7] Thus, the example from medieval north-western Russia might provide an interesting basis for further inter-regional comparison. Moreover, the worst European climate-driven crises, such as the Great Famine in 1315 (see below), famines of the late-1690s or the Year Without a Summer in 1816, did not extend all over the continent. Research on lesser-studied regions and more distant past are needed in order to draw a comprehensive picture of the climate-human relationship in the European history.

[6] Nosov, 'The river systems', 175, 178; Nosov, 'A Typology', 7, 9; Makarov et al., 'The Beginning of Rus'', 215; Shaw, 'Russia's geographical environment', 32–35; Ianin, 'Medieval Novgorod', 189, 196. When the whole studied area, the western parts of the medieval principality of Novgorod, is concerned, the area is referred to as Novgorodian land: see Halperin, 'Novgorod and the "Novgorodian Land"'. Ladoga is usually referred to in literature as '*Staraya* [old] Ladoga' to distinguish the medieval town from the modern-era town '*Novaya* [new] Ladoga', which is situated a few kilometres downstream from the medieval town.

[7] Klimenko and Solomina, 'Climatic Variations', 71–72; Korpela, *The World of Ladoga*, 38; Yeremeyev, 'The natural environment', 142–3; Shaw, 'Russia's geographical environment', 38–39; Holopainen and Helama, 'Little Ice Age Farming in Finland', 216; Smith, *Peasant Farming in Muscovy*, 2.

Agriculture, diet, and food system vulnerability

To be able to explore possible climatic impacts on the food system, one must first review the climatic vulnerability of the main food products. This can be done by combining modern knowledge of agricultural and ecological sciences with the evidence gathered from narrative sources and archaeological studies.

The peasant diet in medieval Novgorod and Ladoga was based on grain, fish, and vegetables, which was supplemented by products from animal husbandry, gathering, and hunting. The crops cultivated include rye (*Secale cereale*), barley (*Hordeum* sp.), wheat (*Triticum* sp., including bread wheat, emmer and spelt), oats (*Avena* sp.), and millet (*Panicum miliaceum*). On the basis of documentary and archaeological evidence, rye and barley were the most common cereals in Novgorod and Ladoga. In archaeological findings the proportion of each cultivated cereal varies considerably through the centuries and depending on the location. The temporal and spatial variance of cultivated cereals indicates an adaptive society, which was capable of changing agricultural practices if conditions so required. Rye was dominantly sown in autumn, and both barley and oats were spring sown. The fact that some crops were sown in autumn and some in spring increased the food system's resilience to climatic anomalies. If climatic conditions were unfavourable for the wintering of rye, peasants still had a chance of having a sufficient harvest from spring-sown barley.[8]

A short growing season set limitations on crop production and a cool growing season was unfavourable for all of the crop species cultivated in the area. Night frosts during autumn caused considerable crop failure and summer frosts damaged plants. In addition, abundant precipitation at the end of the growing season caused poor harvests and crop failure. A mild and rainy winter could destroy the wintering of the autumn-sown crops. Alternatively, when the permanent snow cover fell on unfrozen soil and the snow cover remained thick, the soil temperature under the snow remained above zero throughout the winter. This was optimal for snow mould fungi, which constituted a significant threat to the winter rye. Furthermore, ice cover or surface water could kill the plants during winter. In addition, a long and severe winter had an effect on spring-sown crops. If the ground stayed frozen or covered with snow long into the spring, the fields were sown late and the growing season might have been too short for certain crops to mature (Table 1).[9]

One cultivated crop has received little attention in previous research, although the cereal might significantly have increased the region's resilience to climatic anomalies. Millet is the most ubiquitous crop find in archaeological excavations from early medieval Novgorod and Ladoga.

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[8] Smith and Christian, *Bread and Salt*, 26; Monk and Johnston, 'Perspectives', 295, 309; Rybina, 'The Birch-Bark Letters', 128; Kiryanov, 'Agriculture in the Novgorod', 90; Alsleben, 'Early Medieval Agriculture', 111. The variances of different crops in archaeological material most likely also reflect the socio-economic status of the inhabitants of the different sites.

[9] Solantie, *Ilmaston*, 27, 35; Korpela, *The World of Ladoga*, 40; Jaakko Mukula and Olli Rantanen , 'Climate Risks', 4–8. However, for the spring-sown barley, an early but relatively cool spring is optimal.

However, millet is absent from the Novgorodian birch-bark letters, which document medieval tribute and rent practices and other products of the domestic economy. Millet has been a basic component of the Slavonic diet throughout historical times, and it still is. As millet is absent from the birch-bark letters, it has been proposed that this may indicate that the crop was not commonly paid as a rent or a tribute at the time. Therefore, even when the harvest was poor and the peasants had to pay a notable share of the cereal yield as rent or taxes, millet provided an alternative subsistence through the following winter. In addition, millet requires a shorter growing season than other crops cultivated in the area and the crop tolerates drought well.[10]

Novgorod and Ladoga were able to utilize two different agricultural techniques. In the hinterlands arable cultivation was the main cultivation technique, but in the rural woodlands slash-and-burn agriculture was practised alongside arable cultivation. Slash-and-burn agriculture provided higher crop yields than arable cultivation, as the burning of wood and humus released valuable nutrients. The yield-to-seed ratio of arable fields was approximately four to one, whereas the yield-to-seed ratio of slash-and-burn fields could be as high as 10 to one. Owing to the mobile lifestyle associated with slash-and-burn agriculture, people were able to exploit food supplies from the wilderness effectively. However, wild plants, fruits, nuts and berries, as well as a wide range of edible fungi, were part of the everyday diet in urban areas as well.[11]

Besides crop cultivation, fishing and animal husbandry were also essential elements in the food system in Novgorod and Ladoga. Fish was a trade item, tribute payment and the most important source of animal protein in a peasant's diet. The Baltic Sea, Lake Ladoga, Lake Ilmen and the many

[10] Monk and Johnston, 'Perspectives', 295–6, 314–5; Aalto and Heinäjoki-Majander, 'Archaeobotany and Palaeoenvironment', 21; Rybina, 'The Birch-Bark Letters', 127; Motuzaite-Matuzeviciute, Hunt and Jones, 'Experimental approaches', 8; Alsleben, 'The Plant Economy', 327.

[11] Alsleben, 'Early Medieval Agriculture', 108; Kiryanov, 'Agriculture in the Novgorod', 89; Solantie, *Ilmaston*, 13–14; Jääts et al., 'Fire Cultivation', 173–4. Contemporary sources from the city of Novgorod mention crop cultivation 'in the forests'; thus, the centres must also have been able to draw the profits of the higher-yielding slash-and-burn rye from the periphery into their own food systems: see, for example, *The Chronicle of Novgorod 1016–1471*, 204. It is difficult to estimate how important gathering was in relation to agriculture in the studied area, although rough estimations can be made based on macrofossil evidence. From four macrofossil sample sites (Novgorod, Kexholm, Georgii and Gorodishche, see Map 1), the majority of identified remains are from nonedible plants, such as weeds and meadow plants. Cereal remains usually constitute 3–30% of the total remains, whereas collected fruits, nuts and berries constitute approximately 5% of the total remains. In comparison, other cultivated plants, such as flax, hop, hemp and turnips, usually altogether constitute 1–3% of the remains (Monk and Johnston, 'Perspectives'; Alsleben, 'The Plant Economy'; Lempiäinen, 'Medieval Plant Remains'). Yet, these figures are only suggestive, as some plant remains are better preserved in the soil samples than are others. For example, these samples hardly held any remains of garden vegetables, such as garlic, onions, turnips, peas, cabbages and cucumbers, which were all an essential part of the Russian diet (see Smith and Christian, *Bread and Salt*, 8–9).

rivers of the region provided a rich source of, and easy access to, fish. Beef was the most important type of mammal meat consumed. Meat from pigs, goats, and sheep also provided protein.[12]

The proportion of fish and meat consumed was dependent on the socio-economic status of the people, just as the proportion of different species of fish was (Table 2). In remote areas, people relied on the meat of wild mammals, and beef was only consumed in small quantities. In the cities of Novgorod and Ladoga, however, meat consumption from wild animals was marginal. During the first half of the second millennium, the importance of wild animals for meat supply decreased even in remote areas, although wild animals were still hunted in large quantities for their pelts. Additionally, dairy products, eggs, and honey were available for consumption, and these products were both trade items and paid as tribute.[13]

Materials and methods: paleoclimatological evidence and narrative sources

The description of weather, harvest, and famine events in medieval chronicles is usually rather difficult to interpret, as these records are always relative by nature. They lack information on the extent and severity of the phenomena, as events are usually written down in only a few words. The medieval documents do not usually report favourable or reasonable weather conditions or years with good harvests. Instead, they emphasize extreme and exceptional conditions and weather-related phenomena like frosts and famines. In spite of these drawbacks, medieval chronicles and annals are, for most parts of Europe, the only source of information on subsistence crises of the Middle Ages.[14]

A list of regional food crises and crop failures was compiled for this article from medieval Russian chronicles and annals (Table 3). Famine references that specified the calamities taking place outside Novgorod or the Ladoga district, for example in Moscow or Pskov, were not included in the

[12] Maltby, ‘From *Alces* to Zander’, 360, 366–9; Smith, *Peasant Farming in Muscovy*, 66; Rybina, Fishing and Hunting, 124–30; Rybina, ‘The Birch Bark Letters’, 128–9; Korpela, *The World of Ladoga*, 200.

[13] Maltby, ‘From *Alces* to Zander’, 365, 371–3; Smith, *The Origins of Farming in Russia*, 46, 113–5; Smith, *Peasant Farming in Muscovy*, 66–70. At the Gorodishche site, which is considered to be the craft-trade and military-administrative center of early medieval Novgorod (Ianin, ‘Medieval Novgorod’, 190), mammal elements constitute approximately 63% and fish elements 33% of all of the zooarchaeological evidence. On other sites, fish elements can constitute up to 75% of all zooarchaeological elements (Maltby, ‘From *Alces* to Zander’, 360). The majority of fish consumed by peasants belonged to the *Cyprinidae* family, such as bream and roach. Valuable fish, such as sturgeon and salmon, were an important trade item and only consumed by the elite; thus, these species contribute only a minor part of the total fish elements retrieved from archaeological excavations (Smith, *Peasant Farming in Muscovy*, 60–62; Rybina, ‘The Birch Bark Letters’, 129).

[14] Pfister, Schwarz-Zanetti and Wegmann, ‘Winter Severity in Europe’, 93; Helbling, ‘Coping with “Natural” Disasters’, 431; Lamb, *Climate, History and the Modern World*, 82; McCormick, Dutton, and Mayewski, ‘Volcanoes and the Climate Forcing’, 876–8. Also, climatic data differ quantitatively and qualitatively in medieval sources. A lack of climatic data from one year or decade might not mean favourable climatic conditions, as records might have been lost, destroyed or not even written down for one reason or another.

investigation. In addition to direct references to famine, other indicators of food scarcity (for example, mentions of expensive prices) were also included in the list.[15] The list was compiled from two narrative source compilations: *The Chronicle of Novgorod* and an index of Russian chronicle and annals records, *Utdrag ur ryska annaler*.

The Chronicle of Novgorod (or *The Novgorod First Chronicle*, hereafter *N1*) is a group of manuscripts based on the annals of Velikii Novgorod, which were kept year-by-year.[16] The *Utdrag ur ryska annaler* (hereafter *URA*) is a selected collection of Russian chronicle texts that concern the northeastern Baltic region.[17] The collection was compiled by Matthias Akiander, who gathered the information from a dozen Russian chronicles and annals. Akiander paid special attention to remarks about food crises, social unrest, and natural phenomena when collecting the records from the Russian sources. The compilation can be criticized as fragmentary, however, since many records that are documented in the original chronicles – for example, in *N1* – cannot be found in Akiander's compilation. Thus, the *URA* cannot be considered a primary source in itself. However, the *URA* holds a large number of primary source records, and concerning the focus of this study, Akiander's compilation can be regarded as an adequate source index for medieval food crises and climate records. Both the *N1* and the *URA* are translations, edited versions, and compilations.

The possible contextual deficiency, resulting from the editing and translation processes of the sources, was not a significant concern in this study, as the aim was to collect a quantitative data set of historical food crisis and climate mentions, and not to analyse the content or meaning of these records qualitatively. If the intensity or geographical extent of these food crises had been under examination, primary sources would have been used, although estimating the intensity or the extent of the medieval food crises may have been rather challenging, if not entirely impossible. Chroniclers changed, their interests altered over the centuries and contemporaries had no common standards to

[15] Grain and food prices are determined by both demand and supply, and thus price records are considered good indicators of agrarian economy. In general, high grain prices indicate a poor harvest: see, for example, Ó Gráda, *Famine: a Short History*, 144; Le Roy Ladurie, *Times of Feast, Times of Famine*, 92; Pfister, 'Climatic Extremes', 42; Campbell, 'Nature as historical protagonist', 297. Data regarding demographic variations would have been extremely interesting to include in the analysis. However, the existing estimations of demographic variability in medieval Novgorod indicate multicentennial variations, and therefore are incongruent with the short-term events examined in this article.

[16] *The Chronicle of Novgorod 1016–1471* (hereafter *N1*). Translated by Michell, Robert and Forbes, Nevill (London: Camden History Society, 1914). When referring to *N1*, a page number is given first, which is followed by an Anno Domini (AD) year in parentheses. This edition holds both an earlier and a later version of the chronicle. Entries from 1016–1271 and 1299–1332 are from the earlier text, and those from 1272–1298 and 1333–1446 are from the later text. The earlier text was written in the thirteenth and fourteenth centuries and the oldest manuscripts of the later text are from the mid-fifteenth century: Guimon, 'Novgorodian First Chronicle', 1158–9; Shakhmatov, 'An Account', xl–xli.

[17] Akiander, Matthias, *Utdrag ur ryska annaler*, in *Suomi, Tidskrift i fosterländska ämnen 1848* (Helsingfors, 1949) (hereafter Akiander, *URA*). When referring to Akiander's compilation, a page number is given first, which is followed by a cross-checked reference to the original primary source, which is given in parentheses with Anno Mundi (AM) years.

indicate the degree of these events. Hence, due to the relative nature of the contemporary sources, one can only say when consulting the records of any given year, and still with some uncertainty, whether there was a food crisis or not. Yet it is unlikely that records of food crises would have been lost in the editing or translation processes. Nevertheless, the list collected from the *N1* and the *URA* was cross-checked with selected Russian primary sources from the *Polnoe sobranie russkikh letopisei* (hereafter *PSRL*) collection[18] and with Arcadius Kahan's catalogue[19] of natural calamities in Russia.

Paleoclimatological reconstructions are created by transforming climate-sensitive data into paleoclimate estimates. The principles, methodology and prospects of paleoclimatology and the different kinds of proxy records are reviewed and discussed elsewhere and thus are not introduced in detail in this paper. When evaluating the significance of climatic impact on historical events, the climatological and historical events should be examined on congruent temporal and spatial scales. Thus, the climatic data should indicate year-to-year climate variability when annual food crises are under investigation.[20]

The paleoclimatic data for this article was derived from two tree-ring-based studies which present high-resolution temperature and precipitation reconstructions for southeast Finland (Figure 2). The paleotemperature signal for the first reconstruction was attained from maximum latewood densities and the reconstruction[21] indicates annual warm season (May–September) temperature variations. The second reconstruction[22] is based on data from moisture-sensitive tree-ring widths and the reconstruction indicates annual May–June mean precipitation anomalies. The distance between Novgorod and the sites at which the tree-ring data for both reconstructions was gathered is approximately 400 kilometres.

Because the distance between the study area and the paleoclimate data sites is a few hundred kilometres, the spatial extent of the reconstructions needed to be investigated. This was carried out

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[18] The selected Russian chronicles included: *Patriarshaya ili Nikonovskaya letopis'* [The Chronicle of Nikon] (hereafter *NL*); *Pskovskaya pervaya letopis* [The Pskov First Chronicle] (hereafter *PsL I*); *Sofiiskaya vtoraya letopis'* [The Sofia Second Chronicle] (hereafter *S2L*); *Novgorodskaya chetvertaya letopis'* [The Novgorod Fourth Chronicle] (hereafter *N4L*). As dates are given in the *PSRL* collection in Anno Mundi years, the same AM years are given here when referring to these chronicles. The cross-check with the Russian chronicles was conducted by Jukka Korpela.

[19] Kahan, Arcadius, "Natural Calamities and Their Effect upon the Food Supply in Russia," *Jahrbücher für Geschichte Osteuropas*, 16 (1968): 353–77. For years of food crisis when Kahan's list contradicted the list presented here, these specific years were cross-checked again with the selected chronicles from the *PSRL* collection.

[20] Squatriti, 'The Floods of 589', 809. For paleoclimatology, see, for example, Bradley, *Paleoclimatology: Reconstructing Climates of the Quaternary*; Bradley and Philip J. Jones, *Climate since A.D. 1500*.

[21] Helama, Samuli et al., "A Palaeotemperature Curve for the Finnish Lakeland Based on Microdensitometric Variations in Tree-Rings," manuscript submitted for publication, *Geochronometria* (2014), data received from the corresponding author.

[22] Helama, Samuli et al., "Multicentennial Megadrought in Northern Europe Coincided with a Global El Niño–Southern Oscilliation Drought Pattern during the Medieval Climate Anomaly," *Geology*, 37 (2009): 175–8, data received from the corresponding author.

with time-series correlation. Pearson correlation between the reconstruction data and the measured monthly mean station data[23] from Novgorod were investigated over the period 1892–1990. The temperature reconstructions correlated positively with April through September mean station data, and the precipitation reconstruction correlated positively with May and June mean station data.[24]

In addition to unfavourable climatic conditions, unexpected and sudden climatic changes may also have caused hunger in pre-modern agrarian societies. Therefore, the relative change from the previous year's conditions was examined. Thus, the paleoclimatic data were also transformed into a first difference (FD) series, which indicates the intensity of interannual climatic variability.[25]

All of the narrative records of food crises, crop failure, and climatic conditions and the paleoclimatological data were compared and analysed statistically and descriptively. The medieval records were transformed into a nominal scale, as the extent and intensity of the food crises could not be evaluated.

The relationship between climatological data and historical records of food crisis and crop failure was investigated statistically with logistic regression analysis, which computed the probability of a year of food crisis or crop failure occurring under certain climatic conditions. Because climatic anomalies may not have an immediate effect on the food system, the climatic data was also transformed into a time series that lagged one year. In the descriptive analysis the significance of the climatic anomalies for years of food crisis were evaluated qualitatively, but rigorously. However, some quantitative elements were included in the descriptive analysis. For example, the magnitude of an anomaly was quantified in relation to the mean value of the studied period. In addition, special attention was paid to annual and interannual extremes: in years with the highest and lowest temperature and precipitation anomalies and in years with the highest FD values. If the results held evidence of food crises being connected to certain climatic anomalies, these specific anomalies were examined in more detail.[26]

Results

Statistically significant connections were not found between any of the different paleotemperature and -precipitation variables and the food shortage variables (expensive prices, famine, need, crop failure, and frost). This may be due to the scarcity of the medieval data. The number of years of food crisis is rather low when compared with the total number of examined years.

[23] Lawrimore et al., 'An Overview', monthly station data were downloaded from the National Oceanic and Atmospheric Administration online database (http://www.ncdc.noaa.gov/ghcnm, accessed October 2013). The Novgorod datasets have been corrected for urban effects and other biases.
[24] The correlation ($r = 0.721$) between the measured and reconstructed April–September temperature data and the correlation ($r = 0.464$) between the measured and reconstructed May–June precipitation data are statistically significant ($p < 0.001$).
[25] Dybdahl, 'Climate and Demographic Crises', 1166; McMichael, 'Insights', 4732, 4736.
[26] For this 'semi-descriptive' method, see Ingram et al., 'Past Climates', 26.

As the statistical tests gave no results, descriptive analysis was applied in examining the data. In the descriptive analysis, annual records of food crisis and crop failure were investigated in relation to the paleoclimatological data, case by case. In addition, the climate and weather records from historical sources were included in the analysis. After this, the significance of the climatic impact was evaluated qualitatively (Table 4).

Through descriptive analysis, most of the food crises were found to have a connection with some climatic anomaly. Figure 3 illustrates the distribution of annual food crisis records that are connected to certain short-term climatic anomalies. Yet the chart does not represent the significance or the intensity of the climatic impacts, as all of the food crisis records have been included. Hence, the figure includes the both incidents, when climatic conditions were significant factors and contributing factors only.[27]

Both climatic extremes, hot/dry and cool/wet years alike, contributed to food crisis. Therefore, it is no wonder that the statistical analysis did not find a significant connection between climatic and food crisis variables. The statistical tests could not recognize the wide variety of different climatic anomalies that had an effect on the food system. Moreover, the statistical analysis was carried out with an annual resolution, owing to the lack of natural and historical data. However, the results of the descriptive analysis seem to suggest that the outcome of a climatic anomaly was determined by the season in which the anomaly took place. Thus, it can be argued that statistical analysis alone may not be adequate when studying the impact of climatic anomalies on regional famine and food shortages in a relatively short time span, especially when data on seasonal resolution are not available. In addition, the statistical comparison between climate and food crisis data was not sensitive to other determinants of hunger, such as different social factors. Some of these social factors will be discussed later in this paper.

In some years of crop failure and food crisis, the narrative sources imply that adverse climatic anomalies caused the food shortage, but the reconstructions do not indicate such conditions. One such year is 1161, when *N1* records summer heat and drought ‘scorching the corn’,[28] but the paleoclimatological reconstruction indicates high precipitation figures in May and June. Therefore, some of the food crises may have been caused by local short-term climatic anomalies or weather extremes. The data for the reconstructions was gathered from sites a few hundred kilometres from Novgorod, so the summer drought in 1161 may have been local, extending only over Novgorodian land. Thus, when studying the impact of climate on regional subsistence crises, even a distance of a few hundred kilometres between climatic data and study area might affect the results. Moreover, the reconstruction indicates early summer precipitation anomalies, whereas the yield was more likely

[27] For every year of food crisis, only the most evident climatic trend has been included in Figure 3. The chart does not indicate whether other climatic trends or weather events, such as overnight frost, were contributing factors for hunger.

[28] *N1*, 23 (1161). Drought forces the ripening of grain and decreases the seed size and yield.

affected by drought during mid- and late summer. Nevertheless, in most years of food crisis the climatic information from narrative sources and from the paleoclimatological reconstructions supported each other, as it did in the years 1126, 1228, 1298, 1366, and 1371. The dating and results of climate and weather events underlying the most well-known food crises[29] were in agreement with Arcadius Kahan's catalogue of natural calamities in Russia. However, some climate-driven famines that were considered to take place in Novgorodian lands in the catalogue were not found in the narrative sources. Such events were cross-checked with the climate reconstructions. Kahan's catalogue marks a poor harvest in 1408 and a famine in 1409, which were caused by cold weather. The reconstructions indicate extremely cold summer temperatures in 1407 and 1408 and extremely rainy summers in 1408 and 1409. Therefore, most likely during these years the region was suffering, if not from a famine, at least from a poor harvest. In contrast, in 1468 when Kahan found a 'famine caused by cold and rains in the North'[30], the reconstructions indicate mild weather and moderate rainfall.

For the years of the most extreme climatic conditions, when the reconstructions indicated the 50 warmest, coolest, driest or wettest years, records of food crises were found in a few corresponding (or successive) years.[31] However, the narrative sources did not hold evidence of food crises on each year when the reconstructions indicate extreme climate events. Moreover, famines usually developed during the second or third consecutive years of adverse climate or weather extremes.[32] Thus, subsistence crises in medieval Novgorod and Ladoga were most likely never caused by unfavourable climate alone.

Climate, weather, and crop failures

Based on the narrative sources, the contemporaries considered night frost in summer or harvest time as the main cause of crop failure and poor harvest. In the medieval sources, a mention of summer or autumn frost usually preceded or followed a record of crop failure or food crisis. Frost was at least a contributing factor for food shortage in 1127, 1161, 1215, 1230, 1314 and 1453. All of these frosts occurred during early autumn. However, weather records from the narrative sources (although not always connecting weather events directly to the food crises) and the evidence from the paleoclimatological reconstructions suggest that frost alone never caused hunger or famine. During these years the studied area was also suffering from unfavourable climatic anomalies or weather extremes (see Table 4). Because frost as a dramatic short-term phenomenon fits into the religious

[29] In the 1120s, 1215, 1228, 1230s, 1314, 1366, 1371, 1420s and 1450s.
[30] Kahan, 'Natural Calamities', 370.
[31] The years in which records of food crisis coincide with or succeed the 50 coolest and/or wettest years in the reconstructions are 1170, 1215, 1228, 1230, 1272, 1303 (precipitation), 1314, 1452 and 1453; and years in which records of food crisis coincide with or succeed the 50 warmest/driest years are 1123, 1188, 1303 (temperature) and 1420.
[32] Kahan, 'Natural Calamities', 361.

narrative of the chronicles, frost events might be overemphasized in the medieval sources. Long-term climatic stress on crop cultivation due to, for example, slightly cooler or drier climatic conditions might have been more difficult to observe or fit into the chronicle narratives.

The famines in 1127–1128 and 1230–1231 were most likely caused by short and rainy summers. In addition, in 1314 cool summer temperatures and the previous year's increased rainfall during harvest time were most likely the reasons for the food shortage. All of these food crises represent a similar pattern. First, the rainy summer or autumn affected harvests negatively. The harvest was probably not ruined everywhere and there may have been enough grain for the coming winter, but the peasants may not have had enough seed corn for the following year. The next growing season was short, cool or disturbed by summer frosts. Thus, the second successive harvest failure caused unbearable stress to the food system. The climatic conditions behind the famines in the 1120s and 1230s resemble those of the European Great Famine: rains destroying the crops, long and severe winters, and cool summers which were disturbed by unusual frosts. Therefore, it can be argued that a rainy harvest time and a short growing season were especially destructive for European medieval agrarian societies across the continent.[33]

It has been proposed that the most important results concerning medieval food shortages are usually connected with rainfall anomalies.[34] However, when the precipitation reconstruction indicates the most extreme rainfall, a mention of food shortage was found only in six corresponding (or successive) years in the narrative sources. Nevertheless, the sources indicate that people of the time considered abnormal rainfall patterns a serious challenge to agricultural production. For example, the *N1* records that in the autumn of 1228 'great rain came down day and night, on our Lady's Day, and till St. Nicholas Day [from August until December], we saw not the light of day; the people could not get the hay nor do the fields.' Yet it appears that although the harvest was undoubtedly affected by rainfall anomalies, abundant rainfall was rather a contributing factor than an actual cause of food shortages in medieval Novgorod and Ladoga. When the crop production was damaged by heavy rainfall, in the late 1120s, 1215, 1228, early 1270s, 1303, 1314, and 1450s, the temperature reconstruction indicates cool summers and/or the narrative sources record other weather-related events, like frosts or unfavourable overwintering conditions.[35]

As suggested above, rye was most likely sown in autumn in Novgorodian land; thus, climatic conditions during the wintering period had an effect on the next year's harvest. Because the tree-ring-based reconstructions indicate climatic variability only during the growing season, the impacts of climatic anomalies during winter have to be studied solely from narrative sources. According to the chronicle records, a rainy or snowless winter was the biggest threat for the wintering of crops. For

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[33] Jordan, *The Great Famine*, 18–19; Behringer, *A Cultural History of Climate*, 104–5; Pfister, 'Climatic Extremes', 44.
[34] Brown, *History and Climate*, 267.
[35] *N1*, 71 (1228).

example, the *N1* reports that 'on January 3 [1447, January 12 in the Gregorian Calendar], there were heavy clouds with rain, and wheat and rye and corn were beaten down altogether, both in the fields, and in the forest.'[36] Severe winter conditions also had an impact on the food system, since in the winter of 1389–1390 a record mentions extremely cold temperatures as the reason for the food shortage.[37] Quite interestingly, although snow mould fungi are today considered one of the biggest threats to the wintering of rye, nothing indicating this disease was found in the narrative sources or in the literature. This does not prove that the disease would have not been a threat for the medieval agriculture, as the slowly progressing plant disease might not have fit in the chronicle narratives. Moreover, even when the rye yield was damaged by the fungi, the peasants had a chance for sufficient harvest, by investing in the cultivation of barley and other spring-sown crops.

Overall, the twelfth century, especially its first two decades, seems to have been exceptionally dry. The warmest year during the whole period studied was 1123. In general, summer heat and drought have not been considered a significant threat to medieval agriculture in the region.[38] Yet, the number of times drought and heat are mentioned in the sources indicates that people of the time considered these climatic conditions noteworthy. Mentions of hot and/or dry summers were found in 14 annual records, whereas, for example, cold and/or rainy summers were recorded in only seven years.[39] Thus, perhaps drought events, like frosts, fit in the chronicle narratives. However, in years in which summer heat and drought caused food crises, the narrative sources usually also indicate other factors contributing to the food shortage, as in 1161 when Novgorod was also suffering from autumn frost and a mild and rainy winter.

Evidently, medieval Russian agriculture was sensitive to variations of the climate and weather, most likely due to the low output-seed ratio which was close to subsistence level, as Robert E. F. Smith has calculated.[40] Medieval chronicles contain evidence of certain links between food systems and climate variability, although dramatic weather events are emphasized in the narratives. Therefore, studying the climatic impacts solely from narrative sources might undermine the long-term impacts of climatic anomalies in favour of the short-term weather extremes. Here, paleoclimatology provided valuable supplementary information on the possible climatic factors underlying the medieval subsistence crises.

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[36] *N1*, 204 (1446). The record is under the year 1446, but it most likely took place in 1447 AD. Novgorod used the Anno Mundi calendar system, in which the new year started on 1 March (from 1492 AD, on 1 September).
[37] *N1*, 115 (1303); Akiander, *URA*, 1389, 117 (*NL* 6897).
[38] See, e.g. Shaw, 'Russia's geographical environment', 38–43; Smith, *Peasant Farming in Muscovy*, 33–34.
[39] *N1*, 23 (1161). In this paper, mentions of wildfires are also considered indicators of dry or hot summers. Forest or bog fires are commonly related to hot and dry summers in the documents: see, for example, *N1*, 193 (1430). In addition, as wildfires require relatively dry conditions to spread, the four mentions of extensive summer forest fires (without any records of weather conditions) in the years 1298, 1324, 1330 and 1364 have been interpreted as indicators of hot and/or dry summer weather.
[40] Smith, *Peasant Farming in Muscovy*, 86–95.

The Great Famine

The Great Famine (1315–1322) was one of the most severe climate-driven catastrophes of the Middle Ages. Presumably, the Great Famine spanned from the British Isles to Russia, and from Scandinavia to the Mediterranean. The climatic conditions of the time – cool and rainy summers and severe winters – have been proposed as one of the main reasons for the outbreak of the famine. According to the paleoclimatological reconstructions, in northeastern Europe the rainfall was also extremely heavy in 1313 and the growing season extremely cool in 1314. In addition, Livonian chronicles record a 'horrifying famine' in 1315 in Livonia and 'all surrounding regions'.[41] Thus, at least some regions in northeast Europe were troubled by the Great Famine.[42]

The narrative sources do not record famine between the years 1315 and 1322, but a mention of a lack of bread and expensive prices can be found in 1314. If contemporaries considered the scarcity of food in 1314 noteworthy, why did they not record the following famine? Thus, the situation most likely did not develop into a severe subsistence crisis in Novgorod and Ladoga. Therefore, there must have been certain social and/or environmental factors that made the people of the region more resilient than western Europeans to the climatic anomalies and crop failures in the 1310s.[43]

Four possible causes have been considered as the main factors for the outbreak of the Great Famine in Europe: demographic pressure, unfavourable weather causing repeated harvest failures, food distribution problems due to social unrest and an agricultural system that was not able to adjust to new environmental conditions.[44] Based on the historical and archaeological evidence available, it is impossible to evaluate adequately the probability of demographic pressure in Novgorod in the 14th century. However, Velikii Novgorod was densely populated, and the population doubled between the eleventh and thirteenth centuries.[45] As discussed above, the paleoclimatological evidence implies that the area studied was suffering from extraordinarily unfavourable climatic conditions on the eve of the Great Famine. In addition, the *N1* records many incidents of social unrest in the 1310s.[46] Thus, climatic and social factors contributed to the probability of the Great Famine breaking out in the studied area. Hence, the last cause, the agricultural system's capacity to cope with changing

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[41] Wartberge, *Chronicon Livoniae*, 50; Russow, *Chronica der Prouintz Lyfflandt* , 32–33; see also Raudkivi, 'Maa – meie ema', 3–23.

[42] The Great Famine is also known as the 'European Great Famine' (see Lucas, 'Great European Famine', 343–77). Jordan, *The Great Famine*, 18–19; Behringer, *A Cultural History of Climate*, 104–5.

[43] *N1*, 119 (1314); Akiander, *URA*, 83 (*PsL I* 6822).

[44] Behringer, *A Cultural History of Climate*, 104.

[45] Nosov, 'The River Systems', 178. Nosov estimates that the population of Novgorod was 10,000–15,000 in the eleventh century, and 27,000–30,000 at the beginning of the thirteenth century; in the twelfth and thirteenth centuries Novgorod covered 150 ha, whereas the second largest city of the region, Ladoga, covered only approximately 16 ha.

[46] *N1*, 117–21 (1310–1318): in 1310 and 1312 there was plundering around Novgorod, in 1313 and 1314 violence around Lake Ladoga and in 1315–1318 violence in Novgorod.

environmental conditions, might have been the key factor in why the unfavourable climatic and social conditions did not culminate in a famine in the early fourteenth century.

A large variety of different cultivated plants increased the society’s resilience to climatic anomalies. For example, in medieval Estonia the peasants usually concentrated on only two of three main crop species: rye, wheat and barley. In Novgorod and Ladoga, as discussed earlier, the variety of cultivated crops may have been up to three times larger. In addition, diverse agricultural techniques, such as slash-and-burn cultivation and the cultivation of winter crops, reduced the climatic vulnerability of food production. Thus, the agricultural system in Novgorod was perhaps better able to cope with changing climatic conditions than those in western Europe were.[47]

Permanent agriculture was introduced in Novgorod and Ladoga far later than in western Europe.[48] Therefore, perhaps the environmental degradation was not at the same stage in the studied area as it was in the West. Moreover, the food system did not consist of crop cultivation alone, as fish was an extremely important component of the system. About 10 years before the notorious mid-1310s, the paleoclimatological reconstructions indicate warm summers with moderate rainfall, which were beneficial for most fry populations (Table 2). As it takes quite a few years for fish to mature to a size suitable for harvesting, the climatic impact on the stock size can lag several years. Thus, during the cool period, the fish catch was most likely still fairly satisfactory, owing to favourable climatic conditions during the previous decade.

Social factors and disease

Records of food crisis and crop failures in the fifteenth century differ from those of previous centuries. A direct impact of short-term climatic anomalies is less evident, and the length of food shortages is prolonged. Before the fifteenth century, subsistence crises lasted a year or two at the most. In the 1420s the famine lasted for four years, and from the mid-1440s the region was suffering from food shortages for the next 10 years. These prolonged crises indicate that the food system resilience was weakened during the 15th century. As society matured, it became more vulnerable.[49] Thus, non-climatic factors, such as wars, governmental policies, social structure, diseases and environmental degradation, became ever more important factors in food system resilience in the 15th century. Although unfavourable climatic conditions most likely contributed to these food shortages, the original cause of the food crisis (as well as the reason behind the weakened resilience) was most likely societal.

[47] Pfister, ‘Climatic Extremes’, 42; Poska and Saarse, ‘Vegetation Development’, 555–68; Niinemets, Saarse and Poska, ‘Vegetation History’, 241–58; Fraser, ‘Can Economic’, 1276.
[48] Permanent agriculture was introduced into Novgorod and Ladoga during the sixth and seventh centuries (see Alsleben, ‘Early Medieval Agriculture’, 107; Kiryanov, ‘Agriculture in the Novgorod’, 89).
[49] Gunderson, Holling and Peterson, ‘Surprises and Sustainability’, 332.

The longest famine period lasted from 1420 until 1423. During these years the reconstructions indicate rather warm (although slightly cooling) summer temperatures and moderate rainfall. Yet the *URA* has notes of an early snowfall in the autumn of 1420, a mild winter in 1420–1421 and a rainy summer in 1421. Therefore, the long but mild winter, rainy summer and cooling temperatures most likely affected the harvest negatively. However, famine is first mentioned in the records in 1420, when the climate reconstructions indicate rather favourable conditions.[50]

The Black Death, which broke out in Europe at the end of the 1340s, was the most severe pandemic in the Middle Ages. The plague reached Novgorod in 1352, and it reoccurred in the studied area many times during the fifteenth century.[51] A substantially greater number of plague records is found in 1417–1427 than in other periods (Figure 4). During this period, plague is mentioned in the records almost every year. As discussed above, the role of climate in the emergence of the famine in the 1420s is unclear. Instead, the contributory effect of disease seems evident. Because of the recurrent pandemics, society became weaker and more vulnerable, and even a minor factor could trigger a famine. The society was struggling, and unfavourable climatic conditions extended and deepened the crisis. Therefore, the reason for the extended famine period in the 1420s is most likely the collaborative effect of disease and unfavourable climatic conditions. The pandemic weakened and reduced the population, there was not enough labour for the fields and food production decreased. As the society became more vulnerable because of the plague pandemic, even minor climatic anomalies, which the society could have coped with during 'normal years', led to famine. Alternatively, the famine and disease epidemics might have coincided because the food shortage caused a higher degree of mobility, which 'might be sufficient to convert a local outbreak of a contagious disease into a nationwide epidemic' as Arcadius Kahan has proposed.[52]

Although the Black Death was the most devastating pandemic in the Middle Ages, food security was also affected by diseases before the mid-fourteenth century. Epidemics, animal murrains, plant diseases and pests were common threats to human well being. In 1308–1309 the temperature and precipitation reconstructions indicate rather average conditions, but, among the documentation of famine, records of 'plague,' 'dying horses and other animals', and 'mice destroying the grain stocks' are found.[53] Thus, epidemics, animal murrains, and poor storage could have underlain the food crisis in 1308–1309. Yet this famine was shorter by half than the food crisis in the 1420s.

In 1445, a 10-year period in which Novgorod was suffering from lack of bread and expensive prices started. The paleoclimatological reconstructions indicate figures close to the mean in the mid-1440s, although temperatures started to cool down and precipitation increased at the

[50] Akiander, *URA*, 140–141 (*NL* 6928–6929; *PsL I* 6929; *N4L* 6929).
[51] *N1*, 145 (1352); Akiander, *URA*, 104–5 (*NL* 6860); see also Crummey, *The Formation of Muscovy 1304–161*, 42–43.
[52] Kahan, 'Natural Calamities', 366.
[53] Akiander, *URA*, 80 (*NL* 6816, *NL* 6817).

beginning of the 1450s. The first mentions of bad weather in the chronicles are from 1447.[54] Thus, the pivotal reason behind the food shortage was most likely not climatological. The *N1* records in 1445 that ‘there was no law or justice in Novgorod; calumniators arose and turned obligations and accounts and oaths to falsehood; and began to rob in the town and in the villages and districts’[55] and in 1446 that ‘there was tumult and rebellion and animosity amongst them [the men of Novgorod].’[56] Social distress weakened human security, which most likely affected negatively the food system’s resilience to climatic anomalies and other disturbances. In addition, the paleoclimatological reconstructions indicate exceptionally high precipitation and cool summer temperatures in the early 1430s. These conditions are unfavourable for many fry populations, which perhaps negatively affected the fish catch in the 1440s. Thus, the root of the food shortage in 1445–1454 was most likely social insecurity, which was extended by unfavourable climatic anomalies.

In the fifteenth century, Novgorodian land was perhaps suffering from the same land degradation and institutional challenges as western Europe had in the previous century. Unfavourable climatic conditions were contributing factors for the food shortages, but the initiatory factor was something else, such as a plague pandemic or social disturbance, as in the examples above. Unstable social conditions made the food system more vulnerable to climatic anomalies and extreme weather events, and if the society was not able to cope with the scarcity of available foodstuff, these situations developed into prolonged subsistence crises.[57]

Not only internal vulnerability but also external disturbances affected food security in the fifteenth century. Relations with Moscow worsened, both centres launched numerous military campaigns against the other and finally in January 1478 the Grand Prince of Moscow, Ivan III Vasilyevich, took complete control over the Novgorodian land.[58] Surely food security was affected by internal and external violence during earlier centuries as well, but these incidents very seldom ended up in subsistence crises. Moreover, when social unrest was a contributing factor for the food crisis, the climate reconstructions hold evidence of coinciding unfavourable climatic conditions, like cold summer temperatures and heavy rainfalls in 1170 and the early-1270s, respectively. Only the food shortages in 1137 and 1282 may have resulted from social unrest alone, although Arcadius Kahan has noted that Novgorod suffering from drought in 1137. Similarly, Kahan sees a drought as the cause for the famines in 1282 and 1332, whereas the narrative sources used here suggests the famines resulted from storage problems and social distress.[59]

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[54] N1, 204 (1446). The record is found under the year 1446 AD, but it most likely took place in 1447 (see n. 35).
[55] *N1*, 202 (1445).
[56] *N1*, 204 (1446).
[57] See Fraser, ‘Can Economic’, 1274–5.
[58] Ianin, ‘Medieval Novgorod’, 202–6.
[59] In 1136 the boyars revolted against the prince of Novgorod and in 1137 dynastic struggles caused turmoil in the city (*N1*, 15 [1136, 1137]; Ianin, ‘Medieval Novgorod’, 195). Thus, food security may have been affected by the prolonged social insecurity. A couple decades later, in 1169, Suzdal’

Coping with food shortages

Institutions play an important role in climate-driven subsistence crises. Institutional policies can reduce the food system's vulnerability to climatic anomalies, but also exacerbate the problems. The rich and powerful, who controlled tributes, trade and grain stores, could prevent or aggravate a subsistence crisis.[60] However, there is no written evidence regarding whether the ruling class in Novgorod and Ladoga had strategies to cope with food shortages. It is not known if the tax burden was eased during years of bad harvest or, for example, if the princes provided food aid during times of trouble. Likewise, whether the monasteries and churches in medieval Novgorodian land provided food aid is not known. As famines and other food shortages were seen by contemporaries as punishments of God, prayer was most likely a common coping strategy. However, medieval people were not unfamiliar with adverse climatic phenomena, and they had practical knowledge of how to cope with unfavourable climatic anomalies and crop failures.[61] As the climate-driven famines in 1127–1128 and 1230–1231 took place during the second or third consecutive year of unfavourable climatic conditions, contemporaries must have had some backup stocks in case of harvest failure. People had strategies to cope with climatic anomalies, and adverse climatic anomalies only occasionally resulted in subsistence crises.

In addition, the variety of cultivated crop species and agricultural techniques increased food system resilience to climatic anomalies, as discussed above. Forests provided alternative food supplies as well. When the usual food supplies were scarcest, common people had to rely on substitute foodstuff, although in the long run the deficient nutritional value of these usually weakened further the physical health of people. Birch- and pine-bark bread and pounded wood pulp mixed with husks or straw were common famine foods in the area. During the famine in the 1230s, the *N1* documents that 'some fed on moss, snails, pine-bark, lime-bark, lime and elm-tree leaves, and whatever each could think of'. In this same entry from 1230, a mention of cannibalism is also found: 'some of the common people killed the living and ate them; others cutting up dead flesh and corpses and ate them; others ate horseflesh, dogs and cats'.[62] However, such allegations of cannibalism found in medieval chronicles may well be (only) allegories to emphasize the horrors of famine.[63] Additionally, stealing was one of the coping strategies, and this was practised at both the individual and the societal level. One example can be found in 1282 when Novgorodians surrounded Torzhok and 'sent all the crops to Novgorod in boats; for in Novgorod the bread was dear [scarce]'.[64]

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launched a campaign against Novgorod and besieged the city. In the following year, the *N1* records 'dearness' and expensive prices (*N1*, 26 [1169]). In 1332 the grain began to germinate in the store (*URA*, 89 [1132]) and 'Turbulent men rose in Novgorod' (*N1*, 127, [1332]).

[60] Fraser, 'Travelling in Antique Lands', 508; Jordan, *The Great Famine*, 14–15.

[61] Helbling, 'Coping with "Natural" Disasters', 430.

[62] *N1*, 76 (1230).

[63] Ó Gráda, *Famine: a Short history*, 75; Jordan, *The Great Famine*, 148–150.

[64] *N1*, 109 (1282).

Conclusion

When the social impacts of climate in peripheral areas or in the distant past are investigated, the limited number of written sources may pose considerable challenges for historical research. Here, by combining written and non-written evidence, the significance of short-term climatic anomalies on subsistence crises in medieval Novgorod and Ladoga was evaluated. The results suggest that short-term climatic anomalies had a negative effect on the food system, although the magnitude of the impact was substantially affected by temporal variables, such as the season or length of a climatic anomaly.

High precipitation in summer or autumn, a short and cool growing season, summer heat and drought, and mild and rainy winters were found to be significant threats to the food system. The climatic anomalies were usually at least contributing factors in famines and food shortages, and the anomalies could prolong subsistence crises. The results imply that the combined effect of temperature and precipitation anomalies led to subsistence crises more often than adverse temperature or rainfall factors alone did. In addition, harvest failure caused by overnight frost alone never led to a severe subsistence crisis. Only during those times when the region was suffering from other contributing factors, which negatively affected the crop production prior the frost, may the situation have developed into a famine. In addition, in years when the region was suffering from the most extreme climatic anomalies, hunger was rarely recorded at the same time. Thus, food crises in medieval Novgorod and Ladoga were most likely never caused by unfavourable climate alone. Therefore, past food crises cannot be detected solely from paleoclimatological evidence. The region was able to cope with one unfavourable factor, but when several climatic anomalies, frost or other unfavourable weather events, disease or social distress occurred at the same time, the situation could develop into a subsistence crisis.

The variety of cultivated crops and agricultural techniques increased the region's resilience to climatic anomalies and crop failures. The findings imply that the impact of climatic anomalies on fish populations may have been a significant factor in why adverse conditions sometimes resulted in famine. To prove this, there is a need for further research that would enhance current understanding of medieval fishing practices, fish populations and climatic factors. Furthermore, as historical materials imply that climatic conditions outside the warm season also had a significant impact on food security, there is a need for further study of seasonal climatic anomalies of the past, especially anomalies related to harvest time and the winter months. Finally, as the results suggest that climatic anomalies only partially underlie medieval subsistence crises in northeast Europe, the significance of social and other non-climatic factors should be evaluated in future research.

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TABLE 1 Climatic risks to the crops cultivated in medieval Novgorod and Ladoga

Crop			**Critical seasons and unfavourable climatic factors**
Rye *(Secale cereale)*	Autumn sown	Slash-and-burn	Wet summers (difficult to burn the forests); mild and rainy or excessively snowy winters; frost in June and early autumn.
		Arable	Mild and rainy or excessively snowy winters; rainy autumn; frost in June and early autumn.
Barley (*Hordeum* sp.)	Spring sown	Slash-and-burn	Frosts in spring, early July and autumn; wet summers (difficult to burn the forests).
		Arable	Frosts in spring, early July and autumn; early summer drought; abundant rain.
Oat (*Avena* sp.)	Spring sown		Temperature too low and/or night frost; abundant rain; early summer drought.
Wheat (*Triticum* sp.)	Spring sown		Wet summers (especially at the ripening and/or harvest time); cool summers; frost in June and early autumn.
	Autumn sown		Mild and rainy or excessively snowy winters; rainy autumn.
Millet *(Panicum miliaceum)*	Spring sown		Frost in spring, summer and autumn; cool and wet summers.
Hay (winter fodder)	Not sown		Rainy late summer and autumn (unable to harvest and dry the hay); floods.

Source: Solantie, *Ilmaston*; Mukula and Rantane, 'Climatic Risks'.

TABLE 2 Most commonly consumed fish in medieval Novgorod and Ladoga, and potential climatic factors affecting fish populations

Fish	**Climatic impact**	**Share of the total fish consumed**
Cyprinids *(Cyprinidae)*	Suffers from cool summers; benefits from warm summers.	47%
Pike *(Esox lucius)*	Tolerates cool temperatures rather well; benefits from profuse spring floods.	21%
Pikeperch *(Stizostedion lucioperca)*	Suffers from cool summers; benefits from warm summers.	25%
Perch *(Perca fluviatilis)*	Suffers from cool and windy summers. Tolerates warm temperatures rather well (less than Cyprinids).	5%
Other species		2%

Source: Koli, *Suomen kalat*, 70, 134, 178, 281; Maltby, ‘From *Alces* to Zander’, 367.

Note: Because fry and juvenile fish are the most vulnerable to climatic anomalies, the effects of climatic anomalies on fish catch usually lag a few up to 10 years.

TABLE 3 Years of food crisis (famine, expensive prices and need), crop failure and frost in Novgorod and Ladoga 1100–1500

	Dating (AD)	No. of recorded incidents
Famine	1127, 1128, 1215, 1230, 1231, 1308, 1309, 1366, 1371, 1420, 1421, 1422, 1423	**13**
Expensive prices	1123, 1127, 1128, 1137, 1161, 1170, 1188, 1215, 1228, 1230, 1273, 1303, 1308, 1309, 1314, 1332, 1366, 1371, 1423, 1445–1454	**29**
Scarcity/need	1170, 1188, 1272, 1282, 1298, 1303, 1314, 1332, 1390, 1445–1454	**19**
Crop failure/ bad harvest	1127, 1145, 1161, 1228, 1230, 1251, 1291, 1436, 1447, 1453, 1466, 1477	**12**
Frost	1127, 1161, 1215, 1230, 1251, 1259, 1291, 1314, 1436, 1453, 1466, 1467, 1477	**13**

TABLE 4 Food crises and short-term climatic anomalies

I Famine
II Expensive prices
III Scarcity/need
IV Crop failure/bad harvest

+ FD (first difference) value above the 1100–1500 mean
++ FD significantly above the 1100–1500 mean (the 50 highest FD values)

Temperature:	Warm/cool:	One of the 100 warmest/coldest years in 1100–1500
	Extremely warm/cold:	One of the 50 warmest/coldest years in 1100–1500
Precipitation:	Low/high:	One of the 100 driest/wettest years in 1100–1500
	Extremely low/high:	One of the 50 driest/wettest years in 1100–1500

* Climatic impact contributing factor
** Climatic impact significant factor

AD **Food crisis**		**Temperature**	**Precipitation**	**Narrative sources**	**Frost**	**Climatic impact**
1123 **II**	Anom.	Extremely warm	Below the mean; extremely low in 1122			**
	AFD	++	+			
1127–1128 **I, II, IV**	Anom.	Close to the mean	High in 1126	Rainy summer 1126; snow until late 1127	x (1127)	**
	AFD	+	++			
1137 **II**	Anom.	Close to the mean	Close to the mean			
	AFD		+			
1161 **II, IV**	Anom.	Close to the mean	High	Summer drought; mild and wet winter	x	*
	AFD					
1170 **II, III**	Anom.	Close to the mean; extremely cool in 1169	Close to the mean			*
	AFD	+				
1188 **II, III**	Anom.	Close to the mean	Extremely low (for the last 10 years)			*
	AFD		+			
1215 **I, II**	Anom.	Close to the mean (extremely cold in 1214)	Extremely high		x	*
	AFD	++	+			
1228 **II, IV**	Anom.	Extremely cool	Extremely high	Rainy autumn and early winter		**
	AFD	++				
1230–1231 **I, II, IV**	Anom.	Extremely cool	Close to the mean	Rainy spring and summer 1230	x (1230)	**
	AFD	+ (1230)	+ (1230)			
1272–1273 **II, III**	Anom.	Below the mean	High in 1272; extremely high in 1271			*
	AFD	+ (1272)	+ (1272)			

1282 (and the following winter) **III**	Anom.	Close to the mean	Close to the mean			
	AFD		+			
1298 **III**	Anom.	Close to the mean	Close to the mean	Summer drought		*
	AFD					
1303 **II, III**	Anom.	Extremely warm	Extremely high	Mild winter		** (Winter)
	AFD	++	++			
1308–1309 **I, II**	Anom.	Warm	Close to the mean	Mice destroyed the grain store		
	AFD					
1314 **II, III**	Anom.	Extremely cool	Close to the mean (extremely high in 1313)		x	**
	AFD	++	++			
1332 **II, III**	Anom.	Extremely cool				*
	AFD	+				
1366 & 1371 **I, II**	Anom.	Warm	Low in 1365 & 1370	Extensive forest and bog fires 1365; summer heat and drought 1366 & 1371		*
	AFD	+ (1366)	+ (1371)			
1390 **III**	Anom.	Warm	Close to the mean	Rainy September 1389; severe winter 1389–1390		* (Winter)
	AFD	+	+			
1408–1409 **IV**	Anom.	Extremely cold (in 1407 & 1408)	Extremely low			*
	AFD	+	++			
1420–1423 **I, II**	Anom.	Extremely warm 1420; warm 1421; cool 1422	Close to the mean	Early snowfall 1420; mild winter 1420–1421; rainy summer 1421		*
	AFD	+ (1420 & 1422)	++ (1422) + (1421)			
1445–1454 **II, III, IV**	Anom.	Close to the mean; cool in 1450, 1452; extremely cool in 1453	Close to the mean; high in 1451, 1453; extremely high in 1452	Rains in January 1447 destroyed the crops	x (1453)	*
	AFD	+ (1445, 1450, 1451, 1452 & 1454)	++ (1451) + (1445, 1448, 1450 & 1454)			

Note:

I,Famine; **II**,Expensive prices; **III**,Scarcity/need; **IV**,Crop failure/bad harvest.

Warm/cool (temperature), one of the 100 warmest/coldest years in 1100–1500; Extremely warm/cold, one of the 50 warmest/coldest years in 1100–1500; Low/high (precipitation), one of the 100 driest/wettest years in 1100–1500; Extremely low/high, one of the 50 driest/wettest years in 1100–1500.

+,FD (first difference) value above the 1100–1500 mean; ++,FD significantly above the 1100–1500 mean (the 50 highest FD values).

*,Climatic impact contributing factor; **,Climatic impact significant factor.

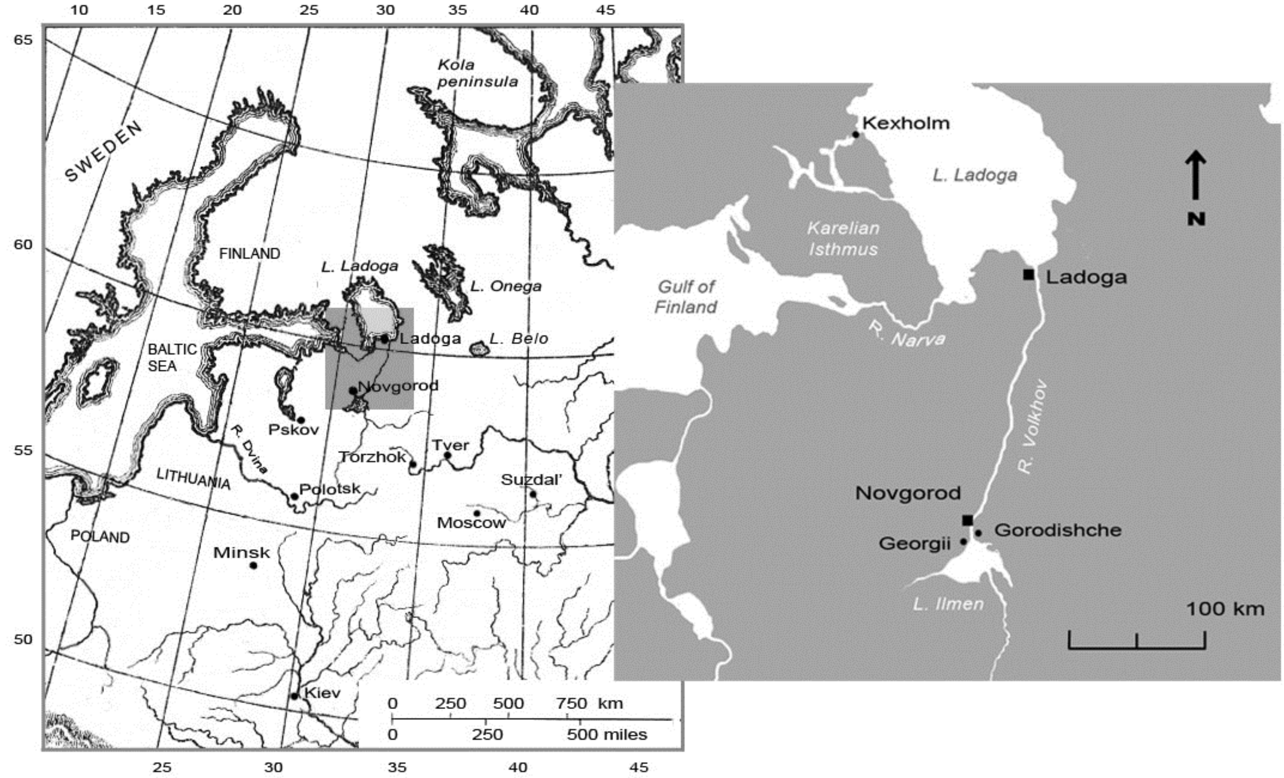

FIGURE 1 The area of the study and places referred to in the text

Source: Reproduced from Magnus, *The Tale of the Armament of Igor*.

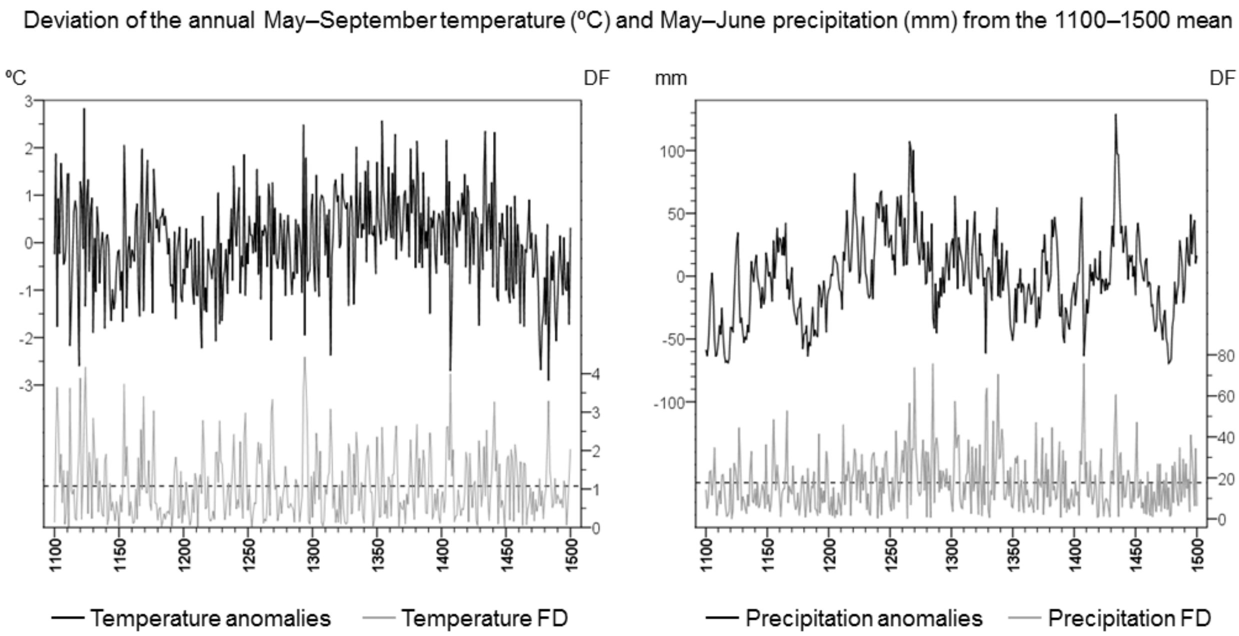

FIGURE 2 Warm season (May–September) temperature (left, black line), May–June precipitation (right, black line) anomalies and interannual climatic variability (grey lines) in northeast Europe 1100–1500.

Source: Helama, Meriläinen, and Tuomenvirta, 'Multicentennial'; Helama et al., 'Palaeotemperature'.

Note: In the first difference (FD) series, high values indicate a significant change from the previous year's temperature/precipitation figures (dashed lines indicate the 1100–1500 mean).

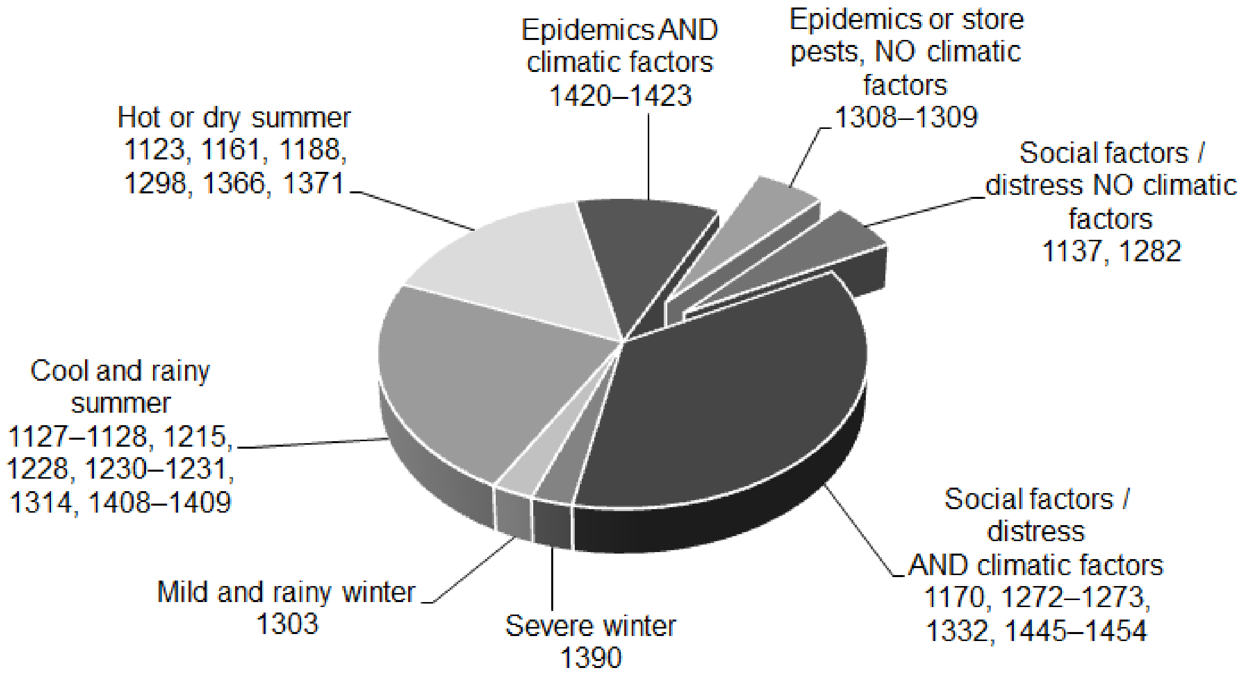

FIGURE 3 Years and causes of the food crises in Novgorod and Ladoga 1100–1500.

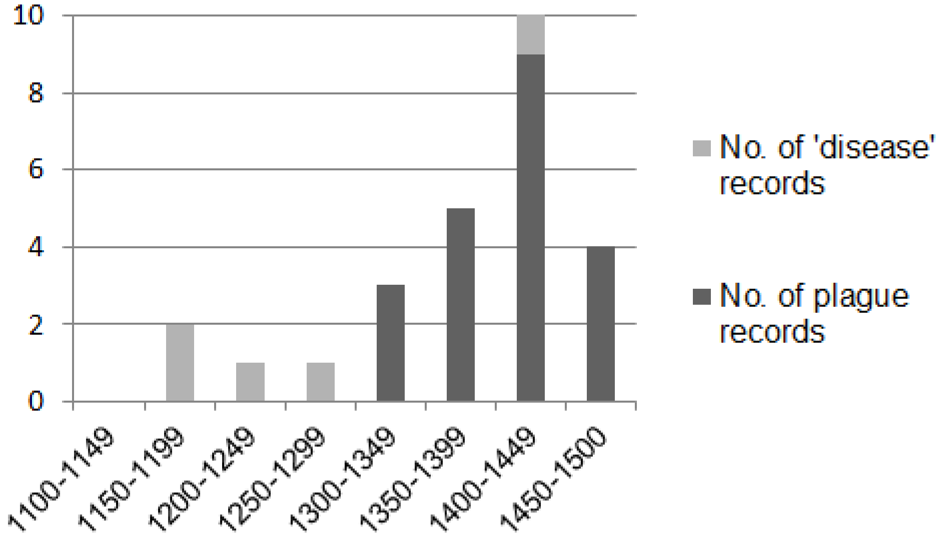

FIGURE 4 Number of years which hold a record of disease or plague from *N1* and from the *URA*.