FROSTS, FLOODS, AND FAMINES

- Climate in Relation to Hunger in North-East Europe

A.D. 1100–1550

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ABSTRACT

This Master's thesis examines the relation between climatic conditions and hunger in North-East Europe in A.D. 1100–1550. The focus of the research is on the interpretation of the climatic fluctuations of the Middle Ages and on their impacts on food systems.

The climatic information was collected from historical sources and paleoclimatological reconstructions. As medieval sources from the studied time and area, such as chronicles and administrative records, had not previously been used as a source of climatic information, this paper had a special emphasis on the evaluation of the medieval documents' climatological value. This paper introduced a method to combine and compare climatic information from historical documents with paleoclimatological reconstructions. It was found that historical documents may provide new information of temporal, regional and low-frequency climatic fluctuations.

Hunger records for this study were collected from the same sources as the historical climate data. It was found that long-term climatic trends did not have a significant effect on the frequency of hunger or famine. Rapid and unexpected climatic phenomena were more likely to cause hunger. Medieval hunger did not exist only because of unfavourable climatic conditions, and the pivotal reason for hunger was usually found in socially produced vulnerability. The level of vulnerability was in relation to the transformation processes of the medieval North-East European societies. When administrative power grew stronger and/or agricultural economy became permanent and more specialized, vulnerability most likely increased.

The results of the research show that it is inadequate to study climatic changes in relation to hunger without taking into consideration the social processes that happen simultaneously. In future research, special attention should be given to the variations of vulnerability and its impacts on food systems, especially from a historical perspective.

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1. Introduction

Climate is a constantly changing system. Contemporary awareness of global climate change and extreme weather events has increased the interest in climatic patterns of the past and climate's impacts on human well-being. To be able to understand the current climatic phenomena and climate's temporal and spatial variations, we need to familiarize ourselves with the climatic conditions in a long-term context. However, continuous meteorological weather observations have been made only since the eighteenth and the nineteenth century, and the records cover only certain parts of North America and Europe. Thus the characteristics of past climate have to be studied from paleoclimatological[1] research, which derives climatic information from natural systems, and from historical sources, which either record directly the weather events or indirectly indicate the climatic conditions of the past.[2]

Climate varies on all timescales, always, to a greater or lesser degree. Climatic trends are temporal tendencies to certain kind of climatic conditions, such as warm or cool surface temperatures, or high or low precipitation levels. A change from one dominant climatic trend to another is an evidence of this continuous change of the climatic system. In recent research especially the climatic variations of the Middle Ages have been in special focus. It has been estimated that approximately in A.D. 1000–1300 the weather was more optimal in Northern Hemisphere than in the previous or following centuries. This period has been called the Medieval Warm Period (MWP). From the fourteenth century onwards the climate started to cool, culminating in a period called the Little Ice Age (LIA, c. A.D. 1550–1800). However, especially the interpretation of the medieval warmth has been criticised for incorrect source analysis and inadequate measurements.[3]

Paleoclimatogists, historians, and archaeologists, among other scientists, use a wide variety of methods to study climatic fluctuations of the past. Climate has left its evidence in nature, for example in tree rings and sediment varves, which paleoclimatologists analyze. Paleoclimatology focuses in long-term and wide-scale climatic changes, whereas historical sources give information about sudden and local climatic anomalies. Yet, only recently the

[1] palaeo = ancient, old, before known or written history.

[2] Jones, Mann 2004, 1–3; Brázdil et al. 2005, 388, 391–392.

[3] Ogilvie 2010, 39–43; Bradley et al. 2003, 404–405.

value of historical sources has started to be appreciated, even though the documentary sources provide climatic information that cannot typically be obtained from natural archives. The evaluation process of climatic information from historical sources has just begun, and a notably quantity of historical sources is still unused in the research on past climates.[4]

Climate has generally been considered as a trigger for societies to change. However, climate is a chaotic system and most situations allow the societies to make some choices. Thus it is difficult to connect certain climatic conditions to certain human behaviour indisputably. Nevertheless, through history, climate has brought disaster to the societies, for example, by crop failures, flood or drought. Climatic phenomena have disturbed societies. People have been able to adjust to certain climatic changes, but other anomalies have caused disasters. The famines of the Middle Ages have usually been linked with harvest failures, which have been interpreted to result from unfavourable climatic conditions, such as cold temperatures, drought, or heavy rains. Especially the change to cooling climate from the fourteenth century onwards has been interpreted to cause suffering and famines to the societies of the time.[5]

Famine is a catastrophic subsistence crisis, a situation where a wide range of shortages has come to their limits. However, the definitions of famines within time have included events and processes that would not qualify as famine in this catastrophic sense. Thus, to avoid misinterpretations of the term famine, the term will be seen in this study as the upper end of the continuum whose average is ‘hunger’. Yet, the term hunger can be as difficult to define as ‘famine’. Here, hunger will mean an involuntary condition where one could not intake the kind and quantity of food required for growth, for activity, and for the maintenance of good health.[6]

As the climatic change from the MWP to the LIA has been interpreted to have caused famines and hunger among people of the time, and the famines of the Middle Ages have been linked with crop failures caused by unfavourable climatic conditions, research that focuses on climate’s impact on the medieval food system is valid. However, as the medieval society was neither homogenous nor static, the research must be scoped to focus on certain time and

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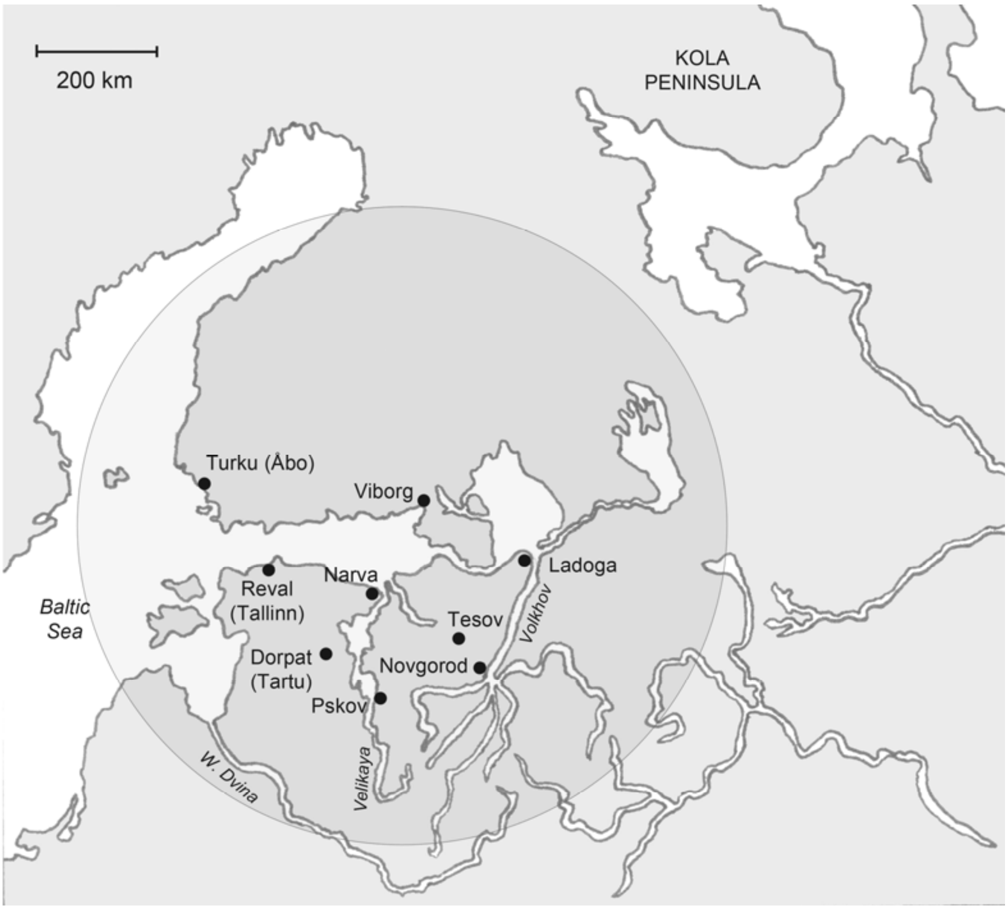
[4] Brown, 1999, 6; Robertson et al. 2009, 412; Brázdil et al. 2005, 375.

[5] Lamb 1995, 1–6; Gráda 2009, 14–16.

[6] Gráda 2009, 6; William 1996, 7; Millman & Kates 1992, 3.

place. In this thesis, I will examine climatic phenomena in relation to hunger in the medieval North-East Europe (modern day Finland, Estonia, northern Latvia, and North-West Russia). The area was rather sparsely populated, especially when compared to Western Europe. The area held a few bigger towns, whose population varied regionally and temporally between 2 000 and 30 000 inhabitants (see Map 1). The source for livelihood was gained from agriculture, hunting and fishing. Slash-and-burning and arable cultivation alike were practiced in the area.[7]



Map 1. *The area of the study and place names.*

Paleoclimatological research has made a relatively good number of climate reconstructions covering the area of North-East Europe, thus the climatic information can be drawn from both, natural and documentary evidence. This will direct me to pay special attention also on the methodological part of this thesis, on how to combine and compare scientific and historical climate -data. In addition, as the medieval historical sources from North-East

[7] Holopainen & Helama 2009, 213, Taavitsainen et al. 1998, 246, Martin 2007, 68.

Europe have not been used as a source of climatic research before, the evaluation of the sources' climatic information is necessary. My objective is to discuss the relation between climatic conditions and hunger on a wide spectrum, and identify possible factors that interact with this relation.

By studying the impact of climatic variations upon the past food systems, we may improve our understanding of the current issues concerning climate change and hunger. Especially research which would focus on a specific geographical region has been noticed to be in demand. By focusing on a certain region in a specific time period, generalizations and vague wide-scale theories can be avoided, and local variations and their impacts can be identified. All the academic fields which study the impacts of climate have noticed the significance of multidisciplinary approach. Thus, only by getting acquainted with the achievements of other disciplines[8], and by applying this knowledge to historical research, we can achieve progress in the investigation of climate's impact on human well-being.[9]

2. Materials and methods

2.1. Climate reconstructions

A climate reconstruction is an estimate of past records of temperatures, humidity and other climatic conditions. Reconstructions are made by filtering climatically sensitive data from an enormous quantity of information, which can be collected from historical sources or from natural evidence. To create as an accurate climate reconstruction as possible, the climate data must be collected from various sources and locations, and the researcher must be able to combine quantitatively and qualitatively differing data.[10]

The paleoclimatological research has improved enormously during the last 20 years. The discipline studies climatically sensitive natural phenomena, which are indirect indicators of

[8] such as meteorology, paleoclimatology, economics, archaeology, anthropology, and social sciences.

[9] Brázdil et al. 2005, 410; Brown 1999, 6; Bradley et al. 2003, 405, Fraser 2011, 1269.

[10] Ogilvie 2010, 33; Bradley & Jones 1995, 3–4.

climatic variations. These indicators of climatic variations are, for example, macrofossils, pollen data, diatoms, sediment structure, isotope records and tree rings. These materials contain a climatic record which must be filtered out from non-climatic information. The filtered, climatically sensitive record is called proxy data. Proxies that are used in this study are represented in Appendix A (Nature's archives). Proxy data is the basic source of paleoclimatological reconstructions, and a reliable climate reconstruction requires combination of various records. Paleoclimatological reconstructions represent climatic variations usually on long-term scales, decadal to centennial time periods.[11]

To create a climate reconstruction, measured proxy records must first be dated[12], then calibrated[13] and finally cross-verified against instrumental climate data overlapping certain time.[14] All proxy data types represent climatic phenomena in their own way. Each proxy type has advantages and limitations that are generally specific to each type (see Appendix A). Thus a so called "multiproxy" approach is advisable if a climate reconstruction needs to be more accurate on a temporal scale. However, as climatically sensitive proxy data is not available everywhere, and collecting, measuring, calibrating and verifying the data is time-consuming, multiproxy studies are rarely accurate on a spatial scale as the data is collected from a wide geographical area. As a result, the paleoclimatological reconstructions most accurately represent long-term climatic fluctuations on a large scale, usually on a continental or a hemispheric scale.[15]

However, it is widely agreed that some of the climatic variations might be very spatial and temporal by their nature. This makes the existing global and hemispheric climate reconstructions of the last millennium suggestive, but inaccurate when smaller areas, like North-East Europe, are studied. Paleoclimatological reconstructions that are more accurate on a spatial scale, that is, those reconstructions that focus on a limited location like Northern

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[11] Bradley, 1999, 1–4; Burroughs 2001, 154.

[12] Dating is made usually by radiocarbon method or by comparing to annual chronologies.

[13] Brázdil et al 2005, 380: *"The aim of calibration is to determine the relation between the proxy indicator and the meteorological element for the calibration period in which both values of the given proxy and the measured values of the meteorological element (such as temperature or precipitation) are available."*

[14] Bradley & Jones 1995, 3–4; IPPC 4, 439.

[15] Jones & Mann 2004, 143–159.

Fennoscandia[16] or the Kola Peninsula[17], show that European climate has a great spatial variability in all time scales when compared to Northern Hemispheric and global reconstructions.[18]

In this thesis I will use twelve different paleoclimatological reconstructions, which all represent annual or decadal variations. The data type, research site, and the type of the reconstructed climatic anomalies are presented in Table 1. The data used in these reconstructions is collected from Finland and North-West Russia, and one reconstruction is from Estonia[19] (Table 1, Appendix B.). As the data used in the reconstructions is collected from a relatively small area, the reconstructions represent a relatively accurate image of the climatic variations of the region. However, time scale variations make a direct comparison between different reconstructions challenging, and combining these reconstructions is impossible without adequate climatological knowledge and access to the original data. Thus, I will study each reconstruction individually. This way misinterpretations caused by the lack of scientific knowledge can be avoided, yet multiproxy approach can be achieved. Furthermore an individual analysis is necessary because each study represents not only a different time scale, but also differing parameters. Some studies represent climatic changes in annual July temperatures, some in decadal mean temperature anomalies, some in precipitation means, some in relative spring flood possibility, etc.[20]

As variations in climate have had a considerable impact on societies, characteristics of the past climates can also be studied from historical documents. Research which is based on historical sources is called historical climatology. Climate reconstructions that are based on historical data are usually more spatially and temporally accurate than paleoclimatological reconstructions, and may even represent seasonal variations. However, using historical sources as climatic data requires expertise in understanding old documents, as essential

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[16] Weckström et al. 2006, 84

[17] Kremenetski et al. 2004.

[18] Bradley et al. 2003, 405; Brázdil et al. 2005, 394; Bradley 1999, 11–15.

[19] Other climate reconstructions from the Baltic states region represented too long-scale variation, and thus are unsuitable for this study (see, eg. Seppä & Poska 2004).

[20] Holopainen 2006, 7, 13.

information might be hidden in the texts. Correct interpretation requires careful evaluation and analysis.[21]

Study	Site	Data	Reconstruction
Bjune et al. 2009	11 sites over northern Fennoscandia	Sediments, Pollen analysis	Summer temperatures
Briffa et al. 1990	Torneträsk region (Northern most Sweden)	Tree rings	Summer temperatures
Haltia-Hovi et al. 2007	Lehmilampi, Karelia, Finland	Varved sediments	Winter temperatures & snow accumulation
Helama et al. 2009a	South East Finland	Tree rings	Precipitation
Helama et al 2009b	Northern Finland and Norway.	Tree rings	Temperatures
Helama et al. 2010	Fennoscandia, Lapland & Kola Peninsula	Pollen stratigraphy & tree rings	Temperatures
Kremenetski et al. 2004	Khibiny Mountains, Kola Peninsula, Russia	Megafossils & Isotope analysis	Summer temperatures & winter precipitation
Luoto & Helama 2010	Lake Pieni-Kauro, eastern Finland	Sediments, Fossil midges & Tree rings	Temperatures & precipitation
Ojala & Alenius 2005	Nautajärvi, Finland	Varved sediments	Winter temperatures & snow accumulation
Sillasoo et al. 2007	Männikkäjärve bog, Estonia	Plant macrofossils	Water-table depth (humification)
Väliranta et al. 2007	Kontolanrahka bog, Finland	Plant macrofossils	Wet or dry climatic trends
Weckström et al. 2006	Lake Tsuolbmajavri, Finland	Sedimentary diatoms	Temperatures

***Table 1**. Paleoclimatological studies and climate reconstructions used in this thesis.*

[21] Brázdil et al. 2005, 363–364, 374–375.

2.2. Problematic climate history

Combining scientific theories to a historical research is a challenging task, and historians take advantage of paleoclimatologic research in their studies quite rarely. *"The adoption of powerful physical theory to extract meaning from unlikely data is far beyond their ordinary concerns,"*[22] writes historian Theodore Rabb about his fellow scholars, and is undoubtedly right. However, even though there might not be any specific technique to combine the recorded events of our past and the paleoclimatological data, these two can be approached in the same study. History and natural sciences can be combined, as long as both maintain their relevancy by the standards of their own discipline.[23]

From the 1990's, a few attempts have been made to create a method to combine climatological and historical research. Historians have created historical climatology and climatologists have familiarized themselves with historical sources. Nevertheless, climatologists generally question the value of historical documents as a source. Climatologists try to analyze the historical data like they would analyze nature's proxy data, and require the same time resolutions, parameters and regularities from historical documents as they would do from natural data.[24] This cuts down the number of usable historical documents and misrepresents the data's quality. Weak accessibility of older historical documents and difficulties to read old languages and manuscripts leads climatologists ever further from historical data.

In addition, the most recent historical research, as well as paleoclimatological research, has not reached wider audience. Thus, the latest improvements in the field are not known. Instead, the climatologist might only be familiar with an outdated, populist and romantic image of the past. Moreover, when non-historians do use historical documents, they usually face fulmination by historians against inadequate source criticism. Foundations of history and climatology are rather different, and therefore data analyses start from a differing base. Consequently, many climatologists dismiss historical data as a reliable source for climate reconstructions.[25]

[22] Rabb 1980, 835.

[23] Rabb 1980, 831-837.

[24] Jones & Mann 2004, 149–151.

[25] Jones & Mann 2004, 150; Brázdil et al. 2005, 370–375; Ogilvie 2010, 36.

2.3. Climate data from medieval documents

Medieval documents usually record so called "parameteorological" events, such as floods, storms, heavy rain, drought, autumn frosts and hot summers. These records are always relative, as meteorological parameters were not standardized or measurement instruments (e.g. thermometer) did not yet exist in the Middle Ages and thus the records are dependent on the observer. The medieval documents do not usually report favourable or reasonable weather conditions. Instead, they emphasize extreme and extraordinary weather conditions and weather-related phenomena, like floods and famines. Misinterpretations, especially on medieval documents, are common in climatic research, and without a proper source analysis, documents' climatic information might provide false impression of the seasonal or annual fluctuations. In addition, the texts usually describe the main characteristics of the weather or phenomenon in just a few words. Moreover, climatic data differs quantitatively and qualitatively in medieval sources. The lack of climatic data from one year or decade might not mean favourable climatic conditions, as records might have been lost, destroyed or the climatic conditions might have been considered not to be important events and thus be never written down.[26]

For this study, I have collected all records of climatic conditions, weather-related phenomena, and events dependent on weather from sources mentioned below. I will collect also all records of famines, crop failures, scarcity of bread or grain, and mentions of expensive food. In addition, I will pay attention to documentation of plagues and other diseases, as my aim is to examine climate's impact on human well-being on a wider scale. However, I do not speculate whether social disturbances or warfare marked in the documents act as indirect indicators of certain climatic conditions.

The Novgorod First Chronicle[27] (N1) consists of two groups of manuscripts, the older (1016–1333) and younger (854–1447) editions. The older has been written in the thirteenth and fourteenth centuries and the oldest manuscripts of the younger edition are from the mid-fifteenth century.[28] The Chronicle of Livonia[29] (*Chronica der Provinz Lyfflandt*) has been

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[26] Lamb 1995, 82; Jones & Mann 2004, 149; Pfister et al. 1996, 93.

[27] The 1914 edition: *The Chronicle of Novgorod 1016-1471*. Intr. C. Raymond Beazley, A. A. Shakhmatov, London

[28] Korpela 2009, 343.

written in 1578 and the revised edition was reprinted in 1584. The chronicle was written by Balthasar Russow and it covers the years AD 1158–1583 of the (modern day) Baltic states region. The events recorded in the chronicle prior to A.D. 1561 have likely been collected from secondary sources.[30] The Chronicle of Henry of Livonia[31] (*Heinrici Cronicon Lyvoniae)* likewise describes the events of the Baltic states region, covering the years 1184–1227. In contrast to Russow's chronicle, the events in the Chronicle of Henry of Livonia are mostly based on the writer's observations. However, the original manuscript has been destroyed, and the modern editions have been compiled of copies written in the fourteenth century onwards.[32] Matthias Akiander has collected mentions about Finland from Russian chronicles[33] in his 1849 published compilation called the *Utdrag ur Ryska annaler*[34]. Yet, this compilation does not only focus on Finland, as there are records covering the whole Eastern Baltic region and Western Russia. The compilation can be criticized to be fragmentary, however, as many records that are documented in the original chronicles, for example in the Novgorod First Chronicle, can not be found in Akiander's text. Akiander collected his information from qualitatively varying manuscripts, as the edited chronicles, like the Novgorod First Chronicle, had not been published at the time.[35]

Chronicles have been written backdated, have been compiled by multiple writers, and they have gone through multiple editorial proceedings. The texts have been copied in various occasions within times, and the editors might have dropped some records that have been considered as unwanted or unimportant at the time. The chronicles served as a political manifesto at the time, rather than an accurate description of the events bygone.[36] However, climatic data can be collected from medieval chronicles with adequate source criticism. Chronicles record a relatively good number of climatic events, such as droughts, floods,

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[29] The 2004 Finnish edition: *Liivinmaan kronikka*. Translated and edited by Timo Reko. SKS, Jyväskylä.

[30] Reko 2004, 21–25.

[31] The 2003 Finnish edition: *Henrikin Liivinmaan kronikka*. SKS, Helsinki.

[32] Fonnesberg-Schmidt 2007, 13–14.

[33] Including *the Chronicle of Bygone Years; the Laurentian Chronicle; the Nestor's Chronicle; the First Sophia Chronicle; the Nikon Chronicle; the Suzdal' Chronicle; the First Novgorod Annals (not the same as 1914 edition used in this study); the Second Novgorod Annals; the Third Novgorod Annals; the Pskov Annals; the Arkhangelsk transcript; the Annals of Solovetsky; the Annals of Dvina.*

[34] Akiander 1849. In *Suomi, Tidskrift i fosterländska ämnen 1848*.

[35] Akiander 1849, 5.

[36] Korpela 2009, 342; Reko 2003, 21–23.

severe winters, hot summers, frosty nights and other events dependent on weather, including famines and crop failures. When climatic data is collected from the medieval chronicles, the worst errors are usually related to incorrect dating. It has been established that the error is usually one year early or late.[37]

It is essential to keep in mind that the climatic events mentioned in the chronicles are characterized by Christian principles of universality, of providential guidance, of prophetic revelation, and of periodization. Weather phenomena were interpreted as omens of God's will or as punishments of sins. Thus some of the records of weather may be extremely symbolic by their nature.[38] The chronicles reported outcomes of God's wrath or mercy, not natural phenomena. Thus, even though the chronicles hold a good amount of climatic data, this data must first be 'filtered out' from the traditional medieval Christian 'noise' that might distort the climatic data. For example, a phenomenon that has happened on a certain religious feast day should be considered with adequate prudence, as the climatic event might have been recorded only to emphasize the significance of the feast day.[39]

The *Diplomatarium Fennicum* (DF) is a Finnish National Archive's online database[40] of medieval documents which focus on Finland. The database was build up on two primary source compilations: The Black Book of Åbo[41] (*Åbo Domkyrkas Svartbok*) and the *Finlands medeltidsurkunder* compilation (FMU). The FMU is a collection of 6714 medieval documents, whose eight volumes were published between 1910 and 1935. In addition to these, the *Diplomatarium Fennicum* includes some other fragmentary documents from medieval Finland.[42] Most of the Finnish medieval documents have been destroyed, and if compared to the chronicles, the DF's climatic data is sparse.[43] Mentions of famines, crop failures, scarcity of bread, and plague can be found in the DF database however.

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[37] Brázdil et al. 2005, 373–375; Pfister et al. 1996, 96.

[38] Hanak 1970, xliv, lvii–lix.

[39] Surprisingly, the documents did not have any records of unusual climatic phenomenon, famine, hunger, or diseases on A.D. 1492, the year of the new millennium (A.M. 7000) in the Anno Mundi calendar system, which was used in the medieval Russia.

[40] http://extranet.narc.fi/DF/index.htm

[41] Compilation of 727 copied ecclesiastical documents from AD 1229–1515.

[42] E.g. the Novgorod First Chronicle. Documents mentioned in Diblomatarum Fennicum online: DF -projekti (http://extranet.narc.fi/DF/DFprojekti.HTM [Accessed March 2, 2011])

[43] Diplomatarum Fennicum online (http://extranet.narc.fi/DF/index.html [Accessed March 1, 2011])

The historical sources I am using are all translations, edited versions, and compilations. The Novgorod First Chronicle is translated into English, the Livonian chronicles into Finnish, and the compilations *Diplomatarium Fennicum* and *Utdrag ur Ryska annaler* are written in Swedish. I had to use these editions, as it is impossible to get access to the original manuscripts. However, the edited copies and compilations are adequate for this study, as my aim is to collect all possible information of weather- or climate-related phenomena of the area at the time.

2.4. Method and questions

In this thesis I will examine whether famines or hunger did occur in certain climatic conditions in North-East Europe between A.D. 1100 and 1550. In order to do that, I first have to review the characteristics of the climatic variations of the period in the studied area and evaluate the sources' climatic data. I will draw this image from paleoclimatological climate reconstructions and from medieval sources. As medieval documents from the studied area are sparse and diverse, special attention to adequate source criticism is required. I will scope my analysis to cover the years 1100–1550, as historical sources from the time before are too sparse by number, and I want to exclude the impact of the great wars[44] of the late sixteenth century. Examining several paleoclimatological reconstructions is essential, as reconstructions vary on a temporal and spatial scale and different paleoclimatological reconstructions represent different climatic phenomena.[45]

The biggest challenge in combining climatic information from historical documents and paleoclimatological reconstructions is in the temporal and spatial differences of the climatic data. The medieval documents represent climatic variability on a seasonal or an annual scale. These sources record, for example, the unusually late beginning of summers or severe winters, but do not analyze the fluctuations on a wider scale. For example, documentation of late summer is dependent on the writer's own experience, and, thus proportional to a few decades. Paleoclimatological reconstructions are based on standard measurements and parameters, thus comparable to a centennial or even millennial scale. However,

[44] Livonian War 1558–1583 and Northern Seven Years' War 1563–1570.

[45] Ogilvie 2010, 38. Jones & Mann 2004, 156–160.

paleoclimatological reconstructions are not usually accurate in representing annual fluctuations, as these are usually smoothed (for example, see Appendix C e) because decadal or centennial climatic information is more valuable for paleoclimatological research.[46] Moreover, if paleoclimatological reconstructions are studied on an annual scale, forest fires, human activity, etc. might affect the climatic information of the proxy data. Some multiproxy reconstructions might be accurate enough to be investigated on an annual scale, but these reconstructions do not represent spatial variability as the data has usually been collected from various locations.[47] These spatial and temporal variations lead me to compare each paleoclimatological reconstruction individually to the medieval documents.

Comparing the individual reports of weather or weather-based phenomena from the historical documents to the paleoclimatological reconstructions would be misleading, as the historical sources are more accurate on a temporal scale than the reconstructions, and more sensitive to climatic anomalies. Probably all weather-related phenomena can be found in some of the reconstructions because the variability of the reconstructions is huge. This kind of approach would invalidate the medieval documents as a source of climate data. Instead, I will try to identify climatic trends, which are tendencies of certain kinds of climatic conditions over a period of time, from the medieval data, and compare and evaluate these trends in relation to paleoclimatological reconstructions. With this method, it may be possible to identify long-term climatic variation also from the medieval sources. I will focus on identifying temperature and precipitation trends from the medieval data, as the paleoclimatological reconstructions usually represent fluctuations of these climatic conditions.

After analyzing and evaluating climatic data from the medieval sources and paleoclimatological reconstructions, I will investigate hunger data from the medieval sources. I will examine if famines, crop failures, reports of shortage of bread, etc. can be linked to certain climatic conditions. I will investigate, if these have been linked in the historical documents to certain phenomena and if they can be linked to certain climatic conditions that are shown in the paleoclimatological reconstructions or historical climate data. My aim is to find climatic circumstances that have had a large impact on medieval food systems, which

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[46] Paleoclimatology is used as a tool e.g. in contemporary climate change research and discussion. Thus seasonal or annual local and short term climatic anomalies are insignificant or even misleading.

[47] Jones & Mann 2004, 165–166; Väliranta 2007, 1102.

will lead me to a further analysis on climate's impact on medieval society in North-East Europe.

Questions:

1) What kind of climatic information historical documents used in this study provide?
2) What do paleoclimatological reconstructions and historical sources tell about the climatic conditions or trends of North-East Europe in A.D. 1100–1550?
3) Was hunger connected to specific climatic conditions?
4) What was the connection between climate and hunger in the societies of the medieval North-East Europe?
5) Did other factors have an effect on the relation between climate and hunger?
6) In the research on climate and its impact on food systems, what is the value of medieval sources?

2.5. Climatic fluctuations in relation to famine: previous research

Most of the medieval famines have been linked in historical research to poor harvests, which have been interpreted to result from unfavourable climatic conditions. Medieval food systems were vulnerable to climatic changes, and in temperate zones, the cause of bad harvests was usually in rapid climatic changes, such as too much or too little rain or unusually cold temperatures. In addition, long-term climatic fluctuations may have had an effect on food systems, and especially the shift from the so called Medieval Warm Period to the Little Ice Age has been seen have caused famines and food crises in Northern Europe.[48]

Eighteenth century demographer and economist Thomas Malthus considers famine as a *natural* phenomenon, which occurred when human population grew faster than food production in a certain location. He also has a rather considerable emphasis on climatic factors: natural environment imposed the population growth. Favourable climatic conditions

[48] Lamb 1995, 1–6; Gráda 2009, 14–16, 31–35; Jordan 1996, 15.

were a prerequisite for population and food production to grow. He argues that, as population is capable to grow exponentially and food production only linearly, famine is the natural way to control population growth, like diseases and wars. Even though Malthus claims in *An Essay on the Principle Population* (1807) that climatic conditions, especially cold weather, may cause, and have caused famines, famines overall result from overpopulation.[49] Malthus's theory has been highly influential among historians until recent days, especially when explaining the climate's impact on population decline of the mid-fourteenth century Europe.[50]

The pioneer of the approach that combined historical sources and climatological research, Hubert H. Lamb, follows to a certain extent in Malthus's footsteps. In his book *Climate, History and the Modern World* (1995) he interpreted the famines in Europe to result from unfavourable climatic conditions, especially from the cooling trend in European climate from the fourteenth century onwards. Even though he did not state famines to be a natural *phenomenon* like Malthus, he argued that famines occurred because of natural *factors*, such as early autumn frosts or cool and rainy summers.[51] Lambs work is one of the few studies that review medieval North-West European climatic conditions, famines and climate's impact on societies. Lamb's review of Europe's climatic conditions has been cited in various studies, and his research is greatly respected in academic world. However, his book is largely based on numerous older (even outdated) studies, in climatology and history alike, and his use of historical data has received criticism of incorrect source analysis.[52]

Also historians tend to see medieval famines as resulting from unfavourable climatic conditions, sometimes even in deterministic manner.[53] *The Danish Resources c. 1000–1550* (2007) by Nils Hybel and Bjørn Poulsen studies the economic history of medieval Denmark, and the book also has a quite extensive review of climatic conditions of Northern Europe from the eleventh to the sixteenth century. This climate analysis is based on primary sources, mainly on medieval chronicles, although it reviews climatic fluctuations from paleoclimatological research as well. There is no particular method mentioned to combine these two types of climatic information, but it seems that Hybel and Poulsen have collected

49 Malthus 1807, 1–29.

50 Gráda 2009, 8; Jordan 1996, 7.

51 Lamb 1995, 195, 206–207.

52 Ogilvie 2010, 39–43.

53 Jordan 1996, 15.

the climatic information from medieval documents and have drawn their impression of climatic conditions of the time directly from that data. Famines are in a key role in Hybel and Poulsen's analysis: *[b]ad harvests were caused by too much rain, drought, or a long hard winter. These climatic circumstances did not always give rise to famine […] although it is true that most food shortages were caused by unfavourable weather"*[54]. Further on in the book they consider records of famines even as indicators of bad weather.[55]

However, more recent studies, especially the ones that focus on contemporary famines, have questioned the climate's direct impact on food scarcity. A universal model which would link certain climatic conditions unquestionably to famines has not been established. Societies' food systems have always evolved, as farmers have constantly seeked new strategies to cope with changing climatic circumstances. It has been argued that rather than just environmental factors, the interaction between social and environmental forces creates situations where society is vulnerable to sudden climatic changes.[56] Geographers Watts and Boyle (1993) have created a frequently cited conceptual model that links climatic changes (among other environmental factors) to the possibility of famines. According to them, the probability of famines is dependent of three factors: the exposure to a climatic hazard, the capacity to adapt to this risk, and the potential of the problem to have severe consequences.[57] The emphasis has shifted, especially in social sciences[58], from the analysis of the direct connection between climate and famines to the examination of societies' vulnerability to climatic changes.[59] Yet, this approach has rarely been exercised in historical research.[60]

Historian William C. Jordan has analysed the North European 'Great Famine' (A.D. 1315–1322) in his book *The Great Famine: Northern Europe in the Early Fourteenth Century* (1996). The study impugns the dominant interpretations of bad weather being the central reason for medieval famines to breakout, and of man being the passive victim of nature's

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[54] Hybel & Poulsen 2007, 64–65.

[55] Hybel & Poulsen 2007, 59–78.

[56] Fraser 2006, 329–331.

[57] Watts & Bohle 1993, 118.

[58] In human geography, development and population studies, and environmental and social sciences, inter alia.

[59] Look e.g. Vogel et al. 2007, Fraser 2006; IPPC: Climate Change 2007 – Impacts, Adaptation and Vulnerability

[60] Jordan 1996, 15.

hazards. Although he agrees that climatic conditions may have had a role in famines to develop, he also lays emphasis to other possible factors, such as war, governmental policies, social structure, and transportation, which he concludes to have had a rather great effect on creating and shaping the characteristics of the famine.[61] These factors have not been unknown in previous historical research[62], but Jordan lays peculiar emphasis on these, by suggesting that the ability to adapt to the climatic phenomenon may have been the bigger factor than the severity of the climatic phenomenon itself.

Thus, the connection between climate and famines continue to be a paradigm in historical research: medieval hunger, scarcity of bread and famines are linked to bad harvests, which are linked to bad climatic conditions, but there is not an undisputable theoretical framework to prove this connection. Moreover, as recent studies of contemporary hunger have proven, climate might be the trigger but not the ultimate reason for hunger. Therefore, further analyses on linkages between climate and famines in the past are needed.

All of the presented theories and studies on climate's impact on famine consider medieval societies to have practised permanent arable cultivation, while in reality, the majority of North-East European people gained their livelihood , especially in the beginning of the era, in various ways: hunting and gathering, fishing, and slash-and-burn agriculture.[63] However, it is important to include this previous research in this study: although the majority of people did not practice only arable cultivation (and thus these theories may not be applicable to analyze medieval North-East European people as a whole), all of the written sources from the medieval North-East Europe originate from the societies that practiced permanent agriculture. As the historical sources I have used in this study cover the part of society that practiced permanent agriculture, it is valid to extend the above-mentioned theories of medieval famine to cover North-East Europe.

[61] Jordan 1996, 15

[62] See e.g. Jutikkala 1987, 64–67.

[63] See chapter 5.2. *Population and land*.

3. Climate of the Middle Ages in North-East Europe

3.1. The Medieval Warm Period and the Little Ice Age

Of the twelve climate reconstructions selected for this study, the majority had evidence of a climatic shift in the thirteenth or fourteenth century. In general, climate started to slowly become cooler or wetter. This shift corresponds with the European-wide climatic phenomena, the Medieval Warm Period and the Little Ice Age.

The term Medieval Warm Period was first used by the British climatologist Hubert Howard Lamb in 1965. He discovered a period of generally warmer temperatures in Western Europe between A.D. 1000 and 1300 from evidence he had compiled from various mixture of sources, such as historical documents, vegetation changes, records of cultivation of vine and changes in the northern most tree line.[64] The Medieval Warm Period quickly became an established term in the academic world, and it spread widely into different fields of research, from anthropology to geology. Even though the term MWP was first used to describe the temperature rise that occurred in Europe during the high Middle Ages, the MWP phenomenon quickly became the explanation of any weather-related anomaly or watershed that occurred in the first half of the second millennium in any part of the globe[65]. An image of gentle and warm summers, and generous harvests became an established and unquestioned interpretation, especially among populist historians:

> *"For the five centuries of the Medieval Warm Period, from A.D. 900 to 1300, Europe basked in warm, settled weather, with only occasional bitter winters, cool summers, and memorable storms. Summer after summer passed with dreamy days, golden sunlight, and abundant harvests."*[66]

Yet, from the late 1990's, the unwarranted use of the term Medieval Warm Period has confronted harsh criticism from several scientists. Climatologists Bradley, Hughes and Diaz

[64] Lamb 1977; IPCC 2007, 468.

[65] Jones & Mann 2004, 162.

[66] Fagan 2004, 214.

dispute the whole existence of the MWP in their article *Climate in Medieval Time* (2003) and point out that the term has lost its original meaning: *"The problem is confounded by numerous studies that have used the term 'Medieval Warm Period' for any climatic anomaly that occurred at some time in the historical medieval period (500 to 1500 AD) -even if the record is unrelated to temperature"*[67]. Some other terms have also been introduced to replace the MWP, like Medieval Climatic Anomaly (MCA) or Medieval Climatic Optimum (MCO), but none of them have been established like Lamb's expression.[68]

Since Lamb's analysis, paleoclimatology and historical climatology have improved remarkably, and more accurate timing and measuring methods have been invented. More recent studies, based on the examination of more quantitative evidence, show that the MWP was heterogeneous by its nature, and occurred in a different time and with different characteristics in different parts of the world.[69] Moreover, it has been argued that some of the historical records which Lamb used in his climate reconstruction were unreliable, thus the interpretation of medieval warmth may be inadequate.[70]

Even though the majority of the climate reconstructions selected for this study has evidence of a cooling trend from the thirteenth or the fourteenth century onwards, the reconstructions are not unambiguously congruent with each other. They show that, during the period of A.D. 1100–1300, cooler and warmer phases alternated, that the shift from the MWP to the LIA was not extraordinarily dramatic, and that the timing of the beginning of the cooling trend varies between three hundred years (see Table 2). In addition, due to the multi-centennial or -millennial scale of the reconstructions, some minor-scale temperature variations are not considered noteworthy in the reconstructions. For example, some of the reconstructions[71] have evidence of a cooler and wetter phase in the 1120's, which however is not considered as a notable temperature shift in relation to the cooling trend of the fourteenth century.

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[67] Bradley et al. 2003, 405.

[68] Jones & Mann 2004, 163; Brázdil et al. 2005, 391.

[69] IPCC 2007, 468–469.

[70] Ogilvie 2010, 39–43

[71] Briffa et al. 1990; Helama et al. 2009a; Helama et al. 2009b; Helama et al. 2010.

Study	Temperature	Precipitation
Bjune et al. 2009	Cooling trend in summer temperatures 1200 onwards, cold peak c. 1400–1500.	
Briffa et al. 1990	No notable shift from warm phase to colder. (See Appx. C e.) Colder periods c. 1110–1140, 1200–1210, 1330–1360, 1380–1400; Warmer phases 1160–1190, 1400–1440.	
Haltia-Hovi et al. 2007	Cooling trend from 1280 onwards.	1060–1280 mild winters with little snow accumulation.
Helama et al. 2009a		Dry phase till 1220, Wet phase 1220 onwards. Dry peaks c. 1100–1140, 1170–1200 & 1460–1480. Wet peaks 1240–1275, 1425–1450 & 1500–1550.
Helama et al. 2009b	Warm trend till 1180, transient warmth 1391–1440. Cool trend 1300–1390 and 1441 onwards.	
Helama et al. 2010	Warm phase till the end of 13th century, cool from 14th century onwards. Modest warmer peak early 15th century.	
Kremenetski et al. 2004	Warm summers 1000–1300, decreasing temperatures from 1100, and cold climate from 1300 onwards.	1000–1300 lower winter precipitation and thinner snow cover, and lower lake levels. From 1300 onwards increased precipitation.
Luoto & Helama 2010	Till 1300 warm summer temperatures, cool phase from 1300 onwards.	Dry summers & high snow accumulation during winters prior to 14th century. Wetter summer climate from 1300 onwards, less snow on winters.
Ojala & Alenius 2005	Warm winters 1000–1200.	Wet winters 1000–1200.
Sillasoo et al. 2007		Wet period from the 12th century onwards, culminating c. 1410.
Väliranta et al. 2007		Wet shift 1130–1150, dry shift 1290–1450, and wet shift 1450 onwards.
Weckström et al. 2006	Warm phases 1200–1300 and 1380–1550, warmest peaks 1220–1250 and 1470–1500.	

Table 2*. Variations of cool and warm, and wet and dry climatic phases in the paleoclimatological reconstructions used in this study (generalized summary, see also Appendix C).*

The term Little Ice Age (LIA) was first introduced by François E. Matthes in 1939. The LIA is used to demonstrate the colder climate that occurred in Europe from the mid-sixteenth to the end of the nineteenth century. However, it has been difficult to define the beginning or the termination of the LIA, as in the case of the MWP, the characteristics of the LIA varied considerably regionally. There is evidence of a significant cooling prior to A.D. 1550, and estimates of Northern Hemisphere mean annual temperatures show gradual temperature decline already in the first half of the millennium.[72] This view corresponds to the climate reconstructions used in this thesis, which in general note a cooling trend from the fourteenth century onwards. However, cooling of the climate started at different time in different regions, also within a relatively small area like North-East Europe.

The Little Ice Age has not received as harsh criticism as the MWP, probably because the dating of the period is more flexible. As a result, some paleoclimatologists and historians try even to avoid precise dating of the onset and end of the LIA. In historical research, some of the most well-known catastrophes and events of the Middle Ages have been linked to the beginning of the LIA, such as the Great Famine (A.D. 1315–1322), decline of European population, desertion of settlements (especially in the north), and even the Black Death. Especially the scarcity of bread has been seen to result from the cooling climate, also in the North-East Europe.[73] However, the shift from the MWP to the LIA was not evident in the North-East European medieval documents (see pp. 29–30).

3.2. Analyzing climatic records from historical sources

The Novgorod First Chronicle (N1), the Chronicle of Livonia, the Chronicle of Henry of Livonia, the *Utdrag ur Ryska annaler*[74] (URA) and the *Diplomatarium Fennicum*[75] (DF) hold altogether 111 mentions of weather- or weather-related phenomena. However, some of the records are irrelevant for the study. The N1 has three mentions of storms on 31st of December

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[72] Nesje & Dahl 2003, 139–140; Bradley 1999, 462–463.

[73] Lamb 1995, 195–206; Jordan 1996, 7–8, 15; Brázdil et al. 2005, 390.

[74] When referring to the URA, the page number of Akiander's text (1849) is reported first in the footnote, followed by Akiander's original source in brackets. For Akiander's abbreviations, see Appendix D.

[75] Footnotes referring to the DF indicate the records' signum on the DF database page (http://extranet.narc.fi/DF/df.php), and when provided on the DF database, the original source in brackets.

1134, 9th of March 1138, and 7th of November 1157, and the URA holds three records of storms on the day after St. Peter's day[76] A.D. 1406, and 9th of April 1419. The Chronicle of Henry of Livonia has three mentions of storms or heavy rains in A.D. 1191, 1196, and 1204, and the Balthasar Russow's Chronicle of Livonia holds one mention of a storm in A.D. 1158.[77] Dating these storms only with an accuracy of a whole year vitiates the climatic information from the Livonian chronicles. In contrast, the Russian chronicles precisely date the storms, but as these lasted only for one day, and some of them took place on a religious feast day, the climatic information must be considered either marginal or specious in these cases. Therefore, the collected weather data narrows down to 102 records.[78]

The climatic data provided in the sources do not spread equally to the time span of A.D. 1100–1550, and many of the phenomena are reported in the same year. Thus only 76 individual years have weather records. Between the years 1100–1150 there is six mentions of weather, A.D. 1151–1200 three mentions, A.D. 1201–1250 twelve mentions, A.D. 1251–1300 five, A.D. 1301–1350 ten, A.D. 1351–1400 fifteen, A.D. 1401–1450 twelve, A.D. 1451–1500 seven, and between the years 1501–1550 there is six mentions of weather (Figure 2).

Even thought climatic data is relatively accurate on an annual scale, correct dating is still rather difficult. Seasonal events may give just one year for identification. For example, the Novgorod First Chronicle records that in the year 1303 *"there was no snow all through the winter"*[79], and the *Diplomatarium Fennicum* holds a document that states *"A.D. 1306 has been the uttermost winter, thus the sea between Öland, Gotland and Estonia has frozen"*[80]. With both of these records, it is almost impossible to conclude whether the 'old' or the 'new' year is meant. Thus, the dating of a climatic phenomenon that has happened in 'winter' may alter over eleven months. In addition, as the general dating error of medieval documents is

[76] 29th of June.

[77] N1: 1914 ed., 13, 15, 22; URA, 133 (Sof. I, 429. Nik. IV, 317. Susd. II, 238. Kar. V not 254), 138 (Nowg. I, 108. Nowg. II, 138. Nik. V, 73. Arch. 132.); CHL 2003 ed., 47, 49, 65; CL 2004 ed., 60.

[78] The records of 'heavy rain' are always dependent on the observer, and thus may indicate relatively minor weather phenomena of a small geographical location. Especially summer storms and rains may be extremely regional by their nature.

[79] N1: 1914 ed.,115.

[80] DF: 247 (original in Visby minor. kronologi. Script. Rer. Svec. I 1, sid. 33): "*Anno Domini MCCCVI fuit hyems maxima, ita quod mare inter Ölandiam et Gutlandiam et Estoniam extitit congelatum*". Translation by H. Huhtamaa.

one year too early or late[81], the analysis of the historical climatic data will not be overwhelmingly strict, especially when compared to paleoclimatological reconstructions.[82]

Paleoclimatological climate reconstructions represent annual or decadal climatic variations usually in a form of histogram or diagram, where attention is drawn to high or low anomalies, which deviate from the mean climatic conditions (see Appendix C). The paleoclimatological reconstructions used in this study mainly represented variations in temperature patterns and precipitation ratio. In order to identify the climatic anomalies from the medieval sources, and to compare this data to paleoclimatological reconstructions, the medieval climate data was divided into 7 categories: 1) hot and/or dry summers or extensive forest fires, 2) cold and/or rainy summers, 3) cold and/or snowy winters, 4) mild and/or rainy winters, 5) late summers 6) early autumn frosts and/or crop failures, and 7) floods (Table 3).

In five cases out of nine, forest or bog fires were related in the documents to hot and dry summers, as in the Novgorod First Chronicle: *"[t]he same autumn [A.D. 1430] the water was exceeding low; the soil and the forests burned"*[83], or as in the URA in the year 1365: *"summer warmth and heat was intense, forests, bogs, and soil burned, rivers dried out and other watery places became utterly dry"*[84] Thus, as the forest fires are connected to hot and dry summer conditions in the texts, and require relatively dry conditions to spread, the four mentions of extensive forest fires (without any records of weather conditions) in the years 1298, 1324, 1330, and 1364 can be interpreted as indirect indicators of hot and/or dry summer weather.[85]

Low net accumulation of snow usually indicates mild and rainy winter conditions, thus two mentions of 'winter without snow' in the URA (A.D. 1404[86] and 1453[87]) can be interpreted as

[81] Besides, the new year could have started in Novgorod either on the 1st of March or on the 1st of September.

[82] Brázdil et al. 2005, 374.

[83] N1: 1914 ed., 193.

[84] URA, 108–109 (Nik IV, 8. Kar. V not 137. Arch 83): *"sommarvärmen och hettan voro starka, skogar, kärr och marken uppbrunno, floder torkade ut och andra vattenrika ställen blefvo alldeles torra"* Translation from Swedish to English by H. Huhtamaa.

[85] Sillasoo et al. 2007, 34; Väliranta et al. 2007, 1102; Luoto & Helama 2010, 2418.

[86] URA, 132 (Sof. I, 427. Nik. IV, 314 year 1405. Susd. II, 235. Kar. V not 254).

[87] URA, 151 (Psk. 79. Kar. V not 386)

indirect indicators of mild or rainy winters.[88] The Novgorod First Chronicle holds three mentions of 'water flooding backwards' in the years 1373, 1376, and 1414, which were interpreted by the editor as floods[89], these will be considered as flood records also in this study.

Climatic trend	Year
Hot / dry summer or extensive forest fires	1143, 1161, 1223, 1298, 1324, 1330, 1340, 1364, 1365, 1366, 1371, 1374, 1403, 1430, 1525, 1533
Cold / rainy summer	1201, 1230, 1251, 1421, 1455, 1468, 1518
Cold / snowy winter	1165, 1212, 1215, 1216, 1219 (sp), 1221/1222, 1227, 1274, 1306, 1334/1335, 1378, 1389/1390, 1393/1394, 1402 (sp), 1408, 1495
Mild / rainy winter	1143 (au), 1145/1146, 1161 (au), 1217/1218, 1251 (sp), 1303, 1370, 1404, 1453
Late summer	1127, 1477
Early autumn frost / crop failure	1127, 1145, 1161, 1215, 1228, 1230, 1251, 1259, 1291, 1314, 1315, 1389, 1420, 1436, 1442, 1445, 1453, 1466, 1467, 1477, 1507, 1518
Floods	1108, 1125, 1127, 1128,1143, 1176, 1208, 1228, 1291, 1314, 1335, 1337, 1338, 1356, 1370, 1373, 1375, 1376, 1387, 1394, 1404, 1415, 1421, 1436, 1446, 1455, 1495, 1518, 1525, 1540, 1544

Table 3. *Annual deviation of different climatic records from the medieval sources (seasonal records; sp: spring, au: autumn).*
Sources: URA, N1, DF, CHL, CL.

The medieval sources contain a different amount of climatic data. The URA has 59 mentions of weather or weather-related phenomena, the N1 has 32 mentions, Russow's the Chronicle of Livonia four mentions, the Chronicle of Henry of Livonia eleven mentions, and the *Diplomatarium Fennicum* five mentions of weather or weather-related phenomena (Figure 1).

[88] E.g. Ojala & Alenius 2005; Haltia-Hovi et al. 2007.

[89] N1: 1914 ed., 183.

As the *Utdrag ur Ryska Annaler* contains records from the Novgorod First Chronicle, in some cases the same climatic phenomenon is mentioned in both. If the records are similar, I have used the primary source, which is the N1. In cases the phenomenon is mentioned in both, but the record in the URA is in more detail, I have used the URA.

The fact that the climatic records from the URA, the N1, and the *Diplomatarium Fennicum* differ from each other, even though all of them contain parts of some edition of the Novgorod's Chronicle, proves that some climatic information has been lost during the editing processes of the chronicles and complications. Thus the medieval sources do not provide a comprehensive record of climatic phenomena and weather related events of the time.

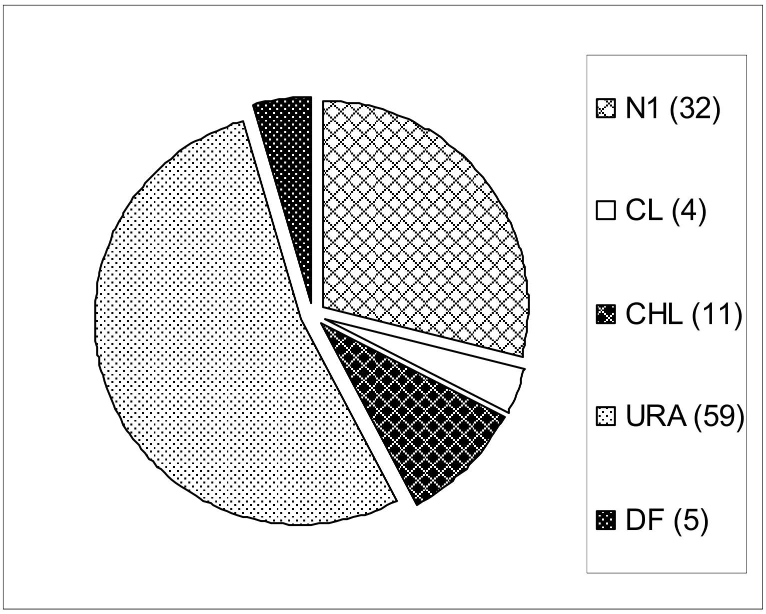

Figure 1. *Deviation of climate-related records from medieval sources (N1: The Novgorod First Chronicle; CL: The Chronicle of Livonia; CHL: The Chronicle of Henry of Livonia; URA: Utdrag ur Ryska Annaler; DF: Diplomatarium Fennicum).*

In addition, the climatic data was also qualitatively differing, depending on the sources the data was collected from. The *Utdrag ur Ryska Annaler* contained almost solely all the records of summer weather conditions and extensive forest fires. Three descriptions of summer weather were also found in the N1. In addition, the URA contained many records of floods, early autumn frosts and some records of weather conditions in winter. The majority of the N1's climatic data describes the anomalies in hydrology, such as floods or unusual seasonal rains. The *Diplomatarium Fennicum* has some records of remarkably cold winters and crop failures. The Livonian chronicles mainly recorded unusually cold winters and extraordinary storms.

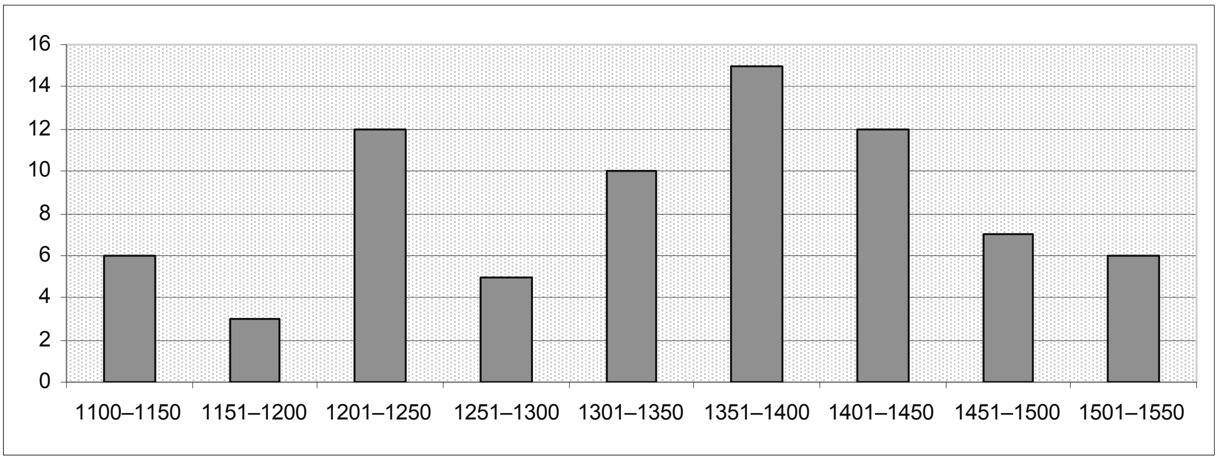

Figure 2. *Multi-decadal deviation of the weather records or weather related phenomenon from the medieval sources: number of years with climatic data on a time span of 50 years. Sources: URA, N1, DF, CHL, & CL.*

The medieval sources do not give strong evidence of the extensive climatic shift from the MWP to the LIA. The sources hold records of both warm and cooler weather from A.D. 1300 onwards when the climate should have started to cool down. If the medieval sources mostly emphasize extreme or unfavourable climatic conditions, as it has been argued[90], there should be a peak in weather mentions during the climatic shift. In fact, there is a relative peak in weather records in A.D. 1300–1450 (Figure 2), but as the data is extremely sparse and diverse, it is inadequate to draw conclusions weather this peak corresponds to the climatic shift from the MWP to the LIA. The period of A.D. 1201–1250 also has a peak in climatic records. The shortage of weather records in the years 1100–1200 and 1251–1300 can be a result of numerous factors, for example, climatic phenomena may have been considered as

[90] Jones & Mann 2004, 149.

unimportant at the time, or the documentation may have been lost or destroyed.[91] When analyzing seasonal variations, the records concerning weather conditions in late summer or autumn were highest in number.

Most of the climatic anomalies from the paleoclimatological reconstructions can be connected to the medieval climatic data, e.g. when climate reconstructions provide evidence of a period of warmer temperatures, medieval records have records of warm summer. Even though most of the climatic anomalies from the individual reconstructions were not to be found from medieval data, each reconstruction had *some* climatic variation which was congruent with *some* medieval records. Thus most of the medieval climate records had correspondence in some of the reconstructions. However, this direct comparison between paleoclimatological and medieval climatic data was proved to be inadequate in closer examination.

As most of the paleoclimatological reconstructions represented climatic variations in rather a wide scale, relative to decadal or centennial variations, and as the dating error of historical data can be plus/minus one year, the correspondence between paleoclimatological and historical climate data can be just a coincidence. Moreover, none of the reconstructions were clearly congruent with the historical climate data. Even though one reconstruction may have represented similar climatic conditions as the medieval records in certain years, the same reconstruction may have had contradictory climatic information to the medieval records in some other years. Thus the actual correspondence between paleoclimatological reconstructions and medieval climatic records is rather low. This may result from the different temporal scale that the data represent: the paleoclimatological reconstructions represent anomalies on an annual or a decadal scale, and the medieval records represent seasonal variations. Thus, in the following chapters, rather than analyzing an individual climatic phenomenon on an annual scale, the focus of the analysis will be on seasonal climatic trends.

[91] Brázdil et al. 2005, 374–5; Pfister 1996, 92–94.

3.3. Blistering summers and bitter winters?

Half of the records of hot and/or dry summer conditions or extensive forest fires are dated to the fourteenth century, between A.D. 1324 and 1374, to a time span of just over fifty years.[92] This is in a contradiction to the general image of the LIA starting in the fourteenth century. Moreover, the mid-fourteenth century period of warm and dry summers is in a contradiction to the paleoclimatological studies of the area. The majority of the reconstructions did not identify a warm phase during that period, but most of them had evidence of descending temperatures. Only the study by Luoto and Helama (2010) had evidence of a warm trend in the mid-fourteenth century (Appendix C c). However, the reconstruction by Briffa et al. (1990) might present an explanation for this contradiction. Their tree ring -based study shows that there was indeed a trend of descending temperatures in the mid-fourteenth century, but during that period, some warm years occurred (Appendix C e). Most of the records of warm and dry summer conditions from the medieval documents correspond to the years of warm summer temperatures in the reconstruction by Briffa et al. Thus, the mean annual temperatures might have been colder than average, especially when viewed on a decadal scale, but this does not exclude the possibility that the period may have included some warmer summers. Moreover, if the general climatic trend of the period was rather cold, a few warm summers must have stood out, and the chroniclers may have considered that the extreme summer weather worth documenting.

Consequently, even though a climatic trend stands out from the medieval data, it might not represent the dominant climatic trend. Rather, the climatic trends found in medieval data may actually represent anomalies in the actual climatic trends. Even though eight of the sixteen records of warm and dry summer conditions dated from a time period of just over 50 years, it may not tell that the period was extraordinary warm. Instead, it may tell that these eight years were extraordinary warm *in relation* to other years in the period. This view corresponds to the argument that medieval documents emphasize extreme climatic conditions: the records of warm and dry summer conditions were written down, as they differed from the predominant, in this case cooler, climatic conditions.

[92] Years: 1324, 1330, 1340, 1364, 1365, 1366, 1371, 1374; URA, pp. 88–114.

There are seven mentions of cold and/or rainy summers, which all are found in the URA, except the years 1201 and 1251, which are in the N1. Three of these mentions are spread on a time period A.D. 1201–1251 and other three on A.D. 1421–1468 (Table 3). As with warm and dry summer conditions, the records of cold and/or rainy summers did not correspond with the paleoclimatological reconstructions. However, one temperature reconstruction (Helama et al. 2009b) corresponded with the first cold period, but none of them with the later. On the contrary, all but one[93] of the reconstructions indicate modest peak in temperatures in the later period. Nevertheless, the precipitation reconstruction by Helama et al. (2009a) corresponded with both wet phases, as it shows increased summer precipitation figures in the first half of the thirteenth century and in the second quarter of the fifteenth century. It appears that, like in the case of warm summer conditions, the records of cold summer temperatures from the medieval sources do represent quite the opposite image as the paleoclimatological temperature reconstructions. Precipitation reconstructions, however, seem to correspond with the medieval climatic data, although the climatic data of rainy summers is too sparse to make definite conclusions.

The Livonian chronicles hold mentions of armies marching on frozen rivers, lakes and sea, and of battles on ice. This would require rather severe winter conditions, as the ice needs to be thick enough to carry heavy troops.[94] These mentions have been interpreted in this study as indirect indicators of severe winters, and similar records have been proved to be suitable as historical climatic data in previous research.[95] In the Chronicle of Henry of Livonia (CHL) there were four mentions of troops marching across frozen waters and roads, A.D. 1212, 1215, 1216, and 1227, all took place in the beginning of the 'new' year. In the Russow's Chronicle of Livonia (CL) there was one mention of battle on ice near to Saaremaa in the year 1274. Other mentions of cold winters were direct descriptions of severe winter conditions, which were found in the URA (A.D. 1165, 1378, 1389/1390, 1393/1394, and 1495), in the N1 (A.D. 1402), in the CHL (A.D. 1219 and 1221/1222), in the CL (A.D. 1334/1335), and in the *Diplomatarium Fennicum* (A.D. 1306 and 1408). Thus, there are six records of cold winters on a time span of A.D. 1212–1227, the majority of which is indirect weather records, and five

[93] Luoto & Helama, 2010.

[94] Considering the area of Livonia, warfare during the winter time might have been the only option, as solid and permanent routes did not exist in the area. All the same, even if warfare could have taken place only during the winters, the climatic information of these descriptions is still adequate.

[95] Pfister et al. 1996, 97.

records of direct descriptions of severe winter conditions during a period of A.D. 1378–1408. The first cold winter period corresponds with the period of cold summer conditions discovered from the medieval documents (see above), and the later period corresponds to the image of cooling temperatures of the fourteenth century, the shift from the Medieval Warm Period to the Little Ice Age.

As with warm summer temperatures, the two periods of cold winter records did not correspond with any of the climate reconstructions, although the contradiction of medieval records and paleoclimatological reconstructions was not as clear as in the case of warm summer records. In fact, two reconstructions[96] that reviewed the climatic conditions on an annual scale note a minor drop in temperatures during those two periods. However, these reconstructions were based on tree ring data, and therefore represented variations in summer temperatures. Thus, the congruence between historical climate data of cold winters and the cool trend in the paleoclimatological temperature reconstructions is most likely a coincidence.

3.4. Floods and snow

Generally, drought has been related to the characteristics of the Medieval Warm Period, and the Little Ice Age has been considered to have wetter climatic conditions than the MWP.[97] All of the paleoclimatological reconstructions used in this study, which reviews wetness dynamics or precipitation variations, correspond with this notion (Table 2). Summers have been interpreted to be warmer and dryer during the MWP than during the following LIA phase. However, the reconstructions differ slightly when winter precipitation is in question. Luoto and Helama (2010) found that even though the MWP summer conditions were warm and dry, prior the A.D. 1300 there was increased stream flow activity, which implies enhanced spring floods after snowy winters.[98] Conversely, all the other studies interpreted that the winters during the MWP were warm and less snowy.

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[96] Briffa et al. 1990; Helama et al. 2009b.

[97] Lamb 1995, 195; Helama 2009a, 176.

[98] Luoto & Helama 2010, 2418.

Four paleoclimatological studies[99] include variations in winter precipitation and snow accumulation in the climate reconstructions; and two of them, by Luoto and Helama (2010), and Ojala and Alenius (2005) concentrate especially on the spring flood anomalies. Ojala and Alenius found that between A.D. 1000 and 1200 there was very low catchment erosion and sediment transportation in sediment varve data, which can be interpreted as evidence of attenuated spring floods. Spring floods are the consequence of snowmelt discharge, and thus, proportional to winter precipitation in a form of snow. Thick snow cover can not be formed if the mean winter temperature is not cold enough or the winter is rainy.[100] In contrast to Ojala and Alenius, Luoto and Helama found evidence of increased stream flow activity between A.D. 1000 and 1300, which can be interpreted to indicate enhanced spring floods. The reconstruction was the only one which was based on fossil midge data (see appendix A). However, Luoto and Helama proposed a possibility that the spring floods may not have resulted from extraordinarily snowy winters, but because of early spring, which would have caused more rapid ice breakup.[101] This alternative explanation corresponds to the other paleoclimatological reconstructions.

As spring floods are the consequence of snowmelt discharge, mentions of flood in the medieval documents can be interpreted as indirect indicators of snowy winters. Also in the medieval documents the spring floods have been frequently linked to cold and snowy winters.[102] The records of floods or ‘high water’ constitute the biggest group from the medieval climatic data (Table 3). Most of the data is either from the N1 or from the URA. More than two thirds of the records date from the later half of the studied period (A.D. 1325–1550). On a decadal scale, in the 1120’s, 1330’s, and 1370’s there was at least three records of floods on a ten-year time scale. However, when investigating the records in more detail, it can be seen that all of the floods were not a consequence of snowmelt discharge and did not occur in the springtime. The floods in the years 1125, 1143, 1208, 1228, 1356, 1370, 1387, 1404, and 1436 occurred during the summer or autumn, and were a result of heavy rains, instead of considerable snowmelt discharge. Thus, there are only six mentions of floods which were likely caused by snowmelt discharge in the first half of the studied period (A.D.

[99] Ojala & Alenius 2005; Luoto & Helama 2010; Kremenetski et al. 2004; Haltia-Hovi et al. 2007.

[100] Alenius, Ojala 2005, 300.

[101] Luoto & Helama 2010, 2418.

[102] E.g. URA, 161.

1100–1325). This emphasizes further the difference between the first and the second period, as 72 per cent of the spring floods occurred after A.D. 1325.

Therefore, unlike with other medieval climatic data that has been analyzed above, the spring flood data seems to correspond to the paleoclimatological reconstructions, especially to the ones that report anomalies in winter snow accumulation. Kremenetski et al. (2004) reported increased avalanche activity from A.D. 1300, which suggests higher winter precipitation in a form of snow and thicker snow cover, and Haltia-Hovi et al. (2007) found evidence of low deposit of mineral matter in A.D. 1060–1280 in lake sediment varve data, which implies mild winters and minor snow accumulation. In addition, there is a notable peak in the mineral matter accumulation parameters *c.* 1330's.[103] As mentioned above, also the reconstruction by Ojala and Alenius (2005) corresponds with the medieval flood -data, and even the two flood periods in the 1330's and 1370's can be traced in the study, as it represents evidence of increased organic matter accumulation during these periods.[104] Thus, it can be concluded that the spring floods mentioned in the medieval sources are congruent with the paleoclimatological winter precipitation reconstructions.

The flood records also correspond with the temperature reconstructions. If spring floods result from a heavy snowmelt discharge, and thick snow cover requires cold winter temperatures to formulate, the temperature reconstructions should have evidence of colder temperatures after A.D. 1325. The reconstructions by Bjune et al. (2009), Helama et al. (2009b), Helama et al. (2010), and Weckström et al. (2006) all had evidence of a cool trend in the fourteenth century. Although Weckström et al. identify the cool period to last only from A.D. 1300 to 1380, the two phases of profuse spring flood activity in the 1330's and 1370's are placed on this 80-year cold period. Moreover, Weckström et al. identify two warm periods in A.D. 1220–1250 and 1470–1500, and during these periods, there is just one spring flood mention, during the later period in the year 1495.[105] Only the reconstruction by Briffa et al. (1990) did not identify a cool trend in the fourteenth century and onwards. However, the reconstruction is based on

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[103] Kremenetski et al. 2004, 113; Haltia-Hovi et al. 2007, 683–685.

[104] Ojala & Alenius 2005, 291, 299. Rich concentration of organic matter in sediment varves with low catchment erosion is usually related to a long open-water season caused by milder winters.

[105] Weckström et al. 2006, 85; Akiander 1849, 161.

tree ring data, and represents April–August temperature mean anomalies[106], thus the relevance of the reconstruction's climatic information is minor when studying the winter temperatures.

However, the flood data from the medieval documents does not correspond with the precipitation reconstruction by Helama et al. (2009a), which represents a dryer phase between A.D. 1300 and 1500, including only one anomalous wet peak circa A.D. 1425–1450. This reconstruction is based also on tree ring data, thus it may have emphasis on summer precipitation, and therefore heavy winter precipitation in a form of snow may not be evident in the reconstruction.[107] In addition, the documents' flood data does not fully correspond with the bog-based reconstructions of wetness dynamics by Väliranta et al. (2007), and Sillasoo et al. (2007). Changes in bogs' wetness dynamics correlate with precipitation anomalies, even though the variations in wetness dynamics are very sensitive to disturbance, such as human activity. The reconstruction by Väliranta et al. (2007) shows evidence of increasing wet conditions from A.D. 1130, which is interrupted by a transient dryer phase between A.D. 1290 and 1450, which again is followed by wetter conditions starting *c.* A.D. 1490. The reconstruction by Sillasoo et al. (2007) also provides evidence of wetter conditions from the twelfth century onwards, culminating *c.* A.D. 1410. [108] Thus the latter reconstruction corresponds with the shift to cooler and wetter conditions in the beginning of the LIA, but neither of these reconstructions identifies profoundly wet conditions in the fourteenth century. Furthermore, the dry phase during A.D. 1290–1450 identified by Väliranta et al., is neither congruent with any of the other paleoclimatological reconstructions nor corresponds to the medieval document data.

Thus, the flood data from the medieval documents seems to correspond with the paleoclimatological reconstructions that represent variations in winter precipitation or spring flood frequency. In addition, as discussed above (Chapter 3.3.), medieval records of wet summer conditions seem to correspond with summer precipitation reconstructions. Thus, the medieval sources and paleoclimatological reconstructions are congruent with each other when hydrology-related changes are examined. These climate reconstructions represent specific anomalies, focusing only on one variable (e.g. flood frequency or precipitation) during one

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[106] Briffa et al. 1990, 435.

[107] Helama at al. 2009a, 175–177; Briffa et al. 1990, 435.

[108] Väliranta et al. 2007, 1104; Sillasoo et al. 2007, 33–34.

season (winter or summer), and the medieval records do not allow a variety of interpretations. This narrow and specific nature of the climatic information from both source types is most likely the reason for the congruency. Generally, temperature related mentions (e.g. severe winters or hot summers) are rather relative and dependent on the observer, unlike e.g. the flood records. Flooding during a certain season either happened or not, and even though there is always the possibility that the chronicler may have decided not to record every flood down, flooding was probably easier to observe than, e.g. ‘hot summer’, especially as there was neither standard parameters nor criteria of what qualifies as ‘hot’. Flooding must have been easier to report, as observing the phenomenon was not greatly dependent on the observer: water was there, where it should not have been.

3.5. Evaluation of the climatic information from the medieval documents

It seems that comparing and combining the paleoclimatological reconstructions and historical records is impossible, as temperature reconstructions and historical records represent climatic anomalies on a different temporal scale, and historical records are not comprehensive but tend to represent climatic aberrations rather than actual and predominant climatic conditions. However, the fact that historical and paleoclimatological climate data represent climatic phenomena on a different temporal scale might be the *strength* rather than the weakness in the research on past climates.[109]

The fact that the historical climatic data was not in controversy itself, that is, it did not represent e.g. hot and cool summer weather trends overlapping in the same time period, strengthens the notion that medieval sources can hold accurate climatic data. In addition, as historical climate data corresponded to the reconstructions that represent the hydro-meteorological conditions, the possibilities of historical sources as climatic data cannot be ignored. However, as medieval climatic records are scarce in their number, it is impossible to construct an image of the climatic conditions in North-East Europe only from this information. In addition, also paleoclimatological reconstructions, which represent annual or decadal variations, might sometimes be biased in favour of a specific season, like

[109] Holopainen 2006, 21.

dendrochronological reconstructions to summer temperatures. Thus it is essential to include both sources of climatic information when studying the characteristics of past climates.[110]

The notion that the climatic mentions (especially records concerning temperature variations) in historical sources may represent extraordinary conditions in relation to the dominant climatic trend proposes new perspectives on the use of historical sources as climatic data. This challenges the old view[111] of the invalidity of the historical climate data: instead of ignoring the data because it emphasizes extreme weather conditions, historical climate data may provide new information of temporal (low-frequency) climatic variations which are not evident in the paleoclimatological proxy data.

Even though the documents hold a seasonally highest number of late summer or autumn climatic records, this may not indicate abnormal weather phenomena happening more often during autumn than during other seasons. As people of the studied time and area lived in agrarian societies, the interest in and importance of weather at the harvest time is logical. A climatic phenomenon which did not have an impact on the food system or the economic life may have been considered as insignificant to report down.[112]

In addition, the comparison between the paleoclimatological reconstructions and historical climate data may propose new perspectives on interpretation of historical climate data. The fact that the medieval hydro-meteorological data corresponds with the paleoclimatological reconstructions, and temperature data does not, proves that it is important to pay attention to *why* different climatological events were written down at different times. By studying why certain climatic phenomena were written down, we may be able to identify the climatic events that had an impact on human life.

These results suggest that an approach which creates the image of past climate directly and only from historical sources may not be adequate. Similarly forming an image from the paleoclimatological reconstructions may not be sufficient, as these ignore the temporal and

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[110] Holopainen 2006, 21.

[111] E.g. Jones & Mann 2004, 6.

[112] Pfister et al. 1998, 537; Holopainen & Helama 2009, 214.

seasonal changes. Both sources of climatic information are required, if we want to understand the past climate as accurately and comprehensively as possible.

4. Famines

4.1. Famines and medieval sources

The term *famine* refers to a catastrophic subsistence crisis, albeit the definition of famine has differed through time. Especially the medieval writers may have been loose in their use of the term, recording temporary local food shortages as famines, even though famine is understood as widespread catastrophic scarcity of food with high mortality in contemporary historical research. Also the sources used in this study most likely referred to regional food shortages as famines. Thus, in the research that focuses on the Middle Ages, the broader definition of famine may be necessary to study the past in its own right. Famine should be seen as the culmination of the phenomenon called *hunger*, which includes malnutrition, food's expensive pricing, usage of substitute foods, and other characteristics of food shortage.[113]

Therefore, this study does not only examine climatic conditions in relation to famines, but also in relation to hunger, shortage of food, and grain and bread prices. However, in order to compare the medieval data quantitatively, some classification of data is necessary. Thus mentions of famine, scarcity of food, and expensive grain or bread have been divided into their own groups. The mentions of 'expensive bread or grain' are essential to include in this analysis, as in the Middle Ages, during food shortages and after crop failures, prices tended to rise, and hence the mentions of grain price can be interpreted as indirect indicators of food scarcity.[114] The mentions of 'hunger', 'shortage of food', or 'need for bread' in the documents all indicate the effects of hunger, and are thus considered in quantitative analysis as records of 'food scarcity'.

[113] Jordan 1996, 11; Gráda 2009, 6–7.

[114] Jordan 1996, 48; Lamb 1995, 89, 207.

In general, the medieval sources, both chronicles and administrative records, contain a relatively high number of mentions of famines, hunger, expensive grain or bread, and crop failures. Hence, also the Russian and Livonian chronicles and the *Diplomatarium Fennicum* have decent number of these mentions, altogether 68 records during the years A.D. 1100–1550 (Figure 4). This is 40 per cent of all the collected data from the selected sources. All of the sources hold mentions of food scarcity, the majority of which were found in the *Utdrag ur Ryska Annaler* and in the Novgorod First Chronicle. Roughly one-third or one-fourth of the collected data from each source refers to famines, expensive grain, or famine. The mentions of frost or crop failures constitute *c.* 20 per cent of all the collected data from the Russian chronicles, whereas the Livonian chronicles Balthasar's hold only one mention of crop failure. Even though Walter K. Hanak has proposed in the new introduction of the N1 that the mentions of 'frost' may have sometimes been portent of famines in the chronicle, the chronicle's records of summer or autumn frosts are interpreted here simply as frosts, not as indirect records of famine.[115]

Some of the records of hunger, famines, expensive grain, or crop failures were documented in the same year, thus the records were spread only in 55 single years. On the other hand, for example the URA holds a mention of famine lasting for two or four years in A.D. 1230, depending on the original source[116]. A record from the year 1445 documents that: *"[i]n this year the grain was rather expensive in the Great Novgorod, and not only during that year, but for ten years"*[117]. Thus, the famines, food scarcity, and crop failures must have occurred in truth more often than only during those 55 years. From the 68 mentions of food scarcity related events, 16 recorded famines, 15 expensive pricing of bread or grain, 15 food scarcities, and 22 crop failures. From the records that implied hunger (famine, expensive grain, and food scarcity), 12 records from 42 were connected in the texts directly to unfavourable climatic conditions, predominantly to droughts or to early autumn frosts. From the famine records, six cases were directly connected to unfavourable climatic conditions, from the expensive bread or grain records one case, and from the food scarcity records five of the mentions were explained to reasult directly from the unfavourable climatic conditions. Thus, hunger most

[115] Hanak 1970, lvii–lviii.

[116] URA, 51 (original record of famine lasting for four years in Nowg. II, 128; for two years in Nowg. III, 219; Sof. I, 236; Susd., N. Forts; Arch., 66).

[117] URA, 149 (Nowg. III, 240. Kar. V, 174 not 313), *"[p]å detta år var spanmålen I Stor Nowgorod ganska dyr, och icke allenast under ett år utan under tio år"*.

likely resulted from the climatic conditions (at least) in one case out of four (Figure 3). However, the reason for famines was not mentioned or was imprecise in 25 cases, and with five records hunger was linked to other factors. Warfare caused hunger or expensive prices in the years 1123, 1181, and 1231; and in A.D. 1308 mice ate a significant amount of grain, which rised grain prices that year, and developed into famine in the following year.[118]

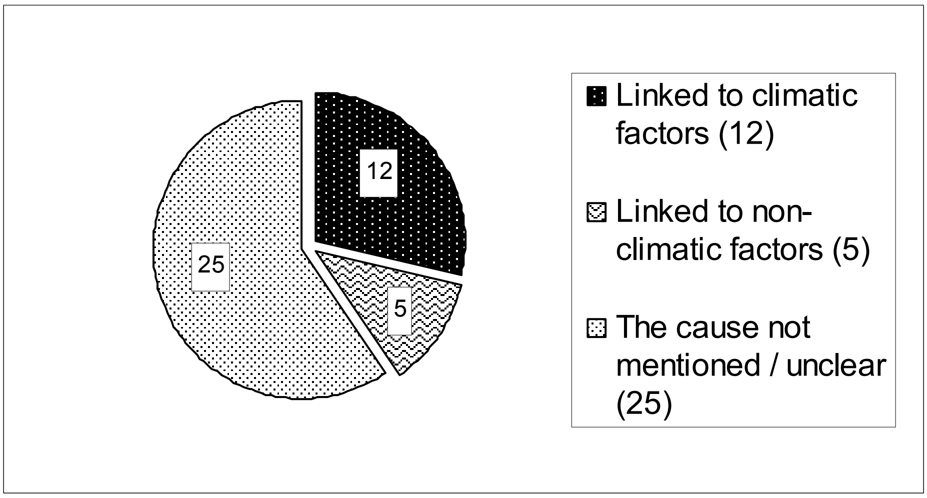
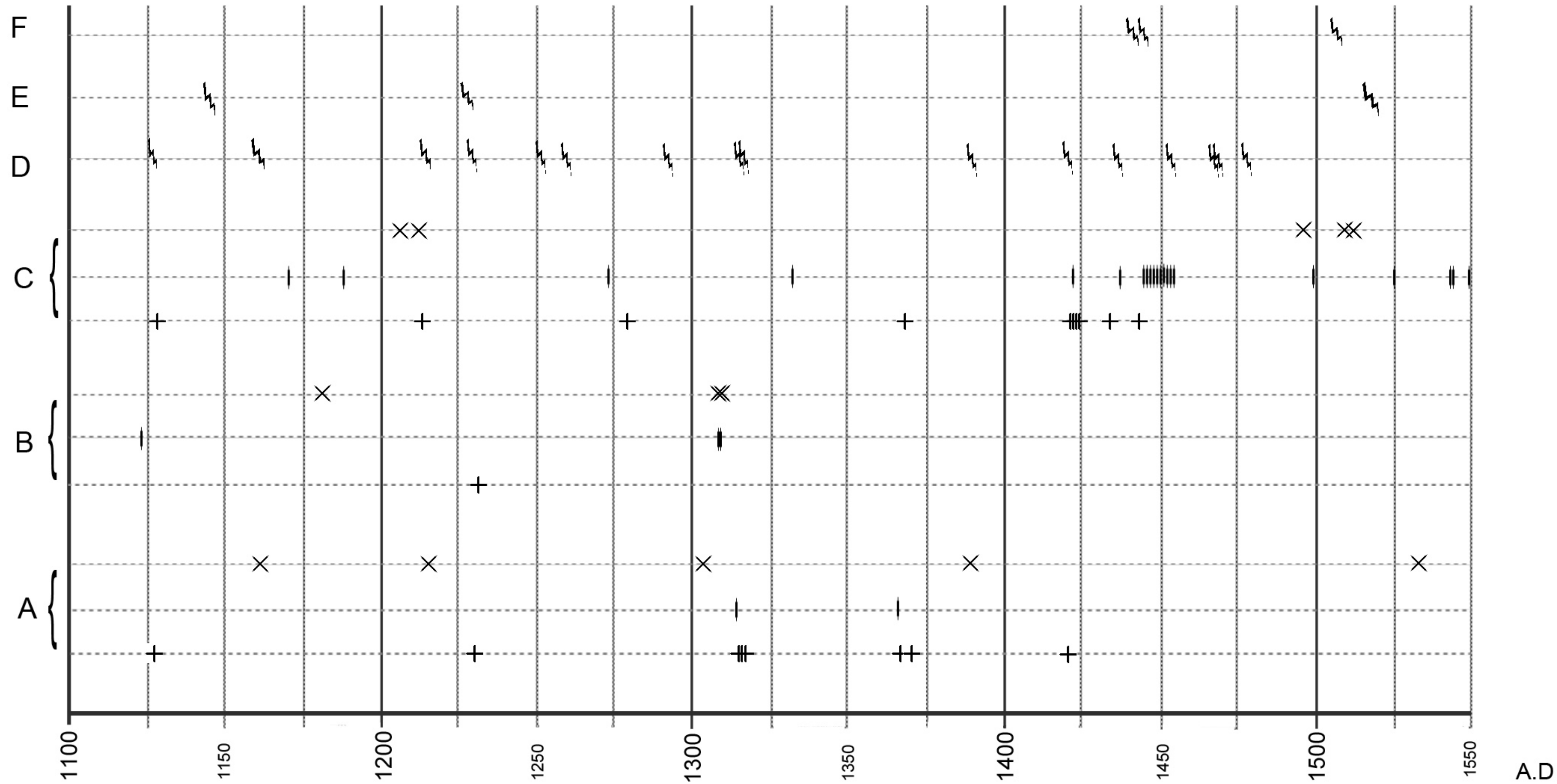


Figure 3. *Yearly hunger records (famines, expensive bread or grain, and food scarcity), which have been linked directly to climatic conditions in the sources.*
Sources: URA, N1, DF, CHL, CL.

Even though hunger and crop failures occurred in every century, the sources hold greater number of records in certain decades. Especially the mid-fifteenth century (A.D. 1421–1460) had significantly many mentions of famines, expensive grain, and crop failures (Figure 5). Other periods with a high number of hunger or crop failure records were in the 1120's, between the years 1211–1240, and 1301–1320. However, the hunger period in the fourteenth century might not have been as severe as the statistics represent. This will be discussed in more detail in Chapter 4.4.

[118] N1, 1914 ed., 10, 31, 77; URA, 80 (Nik III, 105; Kar. IV, 120 not 247).



+ = Famine

| = Expensive grain / bread

× = Food scarcity

ϟ = Crop failure

A = Phenomenon linked to unfavourable climatic conditions in the sources

B = Phenomenon linked to non-climatic factors

C = Phenomenon's cause not mentioned or is uncertain in the sources

D = Crop failures caused by frost in summer or early autumn

E = Crop failures caused by floods or heavy rains

F= Crop failures caused by other factors or the factor is unknown

Figure 4. *Records of famines, hunger and crop failures A.D. 1100–1550 from medieval sources. (URA, N1, DF, CHL, CL)*

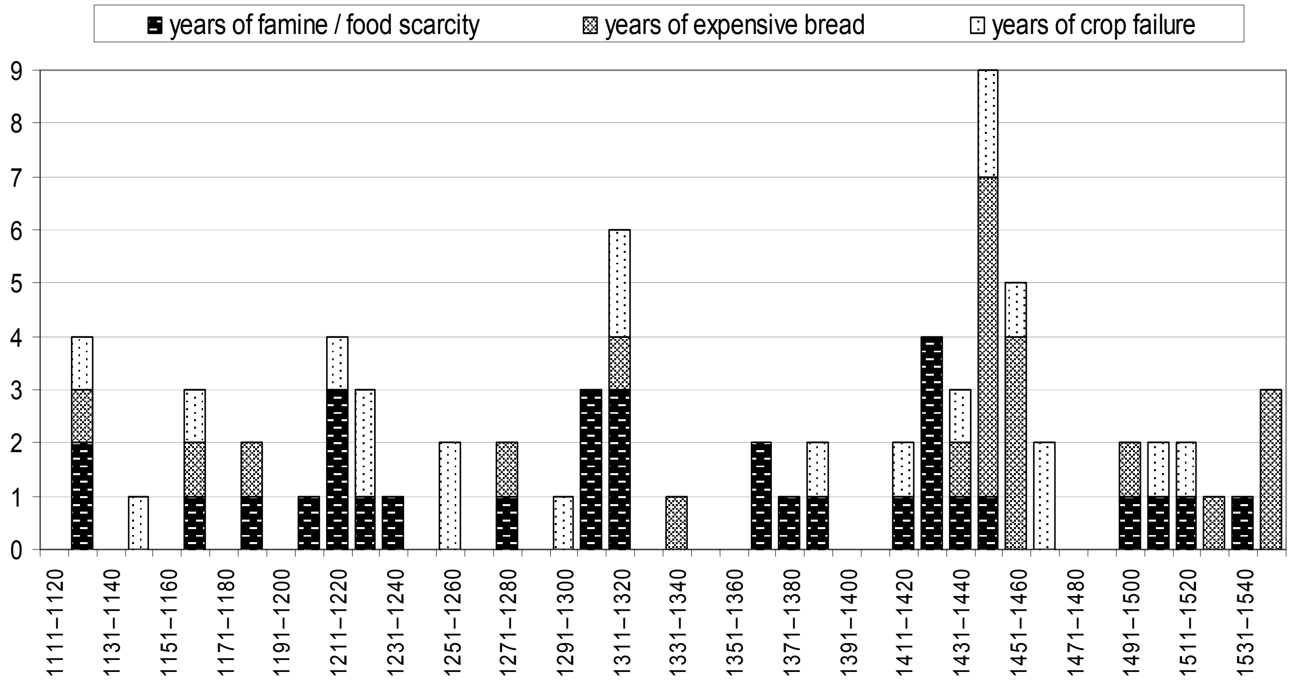


Figure 5. *Decadal deviation of the records of famine or food scarcity, crop failures, and expensive prices. When famine / food scarcity and expensive prices were both documented in the same year in the same source, resulting from the same phenomenon (A.D. 1308, 1309, 1366, and 1422), the year has only a single record on 'famine / food scarcity'.*
Sources: URA, N1, DF, CHL, CL.

The *Utdrag ur Ryska Annaler* holds a mention of famine that resulted from autumn frost in the year 1230, and lasted for two or four years, depending on the original source.[119] As most of the sources Akiander used described the famine to last only for two years, the famine is considered here to last for two years, although the mention has been considered as a single mention in quantitative analysis above. In addition, even though the URA holds a mention of this famine lasting multiple years, the N1 did not have any mention of the matter, but it holds a mention of warfare destroying the crop in A.D. 1231. Similarly, the mention of the famine in A.D. 1315 will now be extended to cover all three years the record documented, even though the following years by definition did not have mentions of famines. Finally, as the mention of expensive bread lasting ten years has been previously considered as a single

[119] URA, 51. The mention of famine lasting for four years was in Nowg. II, and for two years in Nowg. III, Nik, Sof, Susd, and Arch.

mention, the record of expensive bread will hence be spread to cover all of the years, A.D. 1445–1454. (These are examined in Figure 4 and onwards.)

Despite the noteworthy fact that 29 per cent of the records of hunger in the medieval documents were directly linked to climatic conditions, *c.* 60 per cent of hunger records, which do not name the cause of food scarcity, require further analysis. Are these records also related to climatic conditions? In addition, as previous research and the above mentioned mice incident imply, famines and hunger can be complicated processes, which may arise a long time after the original trigger or root cause has occurred.[120]

4.2. Crop failures and hunger

The crop failures which are documented in the historical records to result from climatic conditions were mainly caused by frost which occurred either after sowing or before harvest. Only in three years (A.D. 1145, 1228, 1518) the crop failure resulted from heavy rains and floods in the late summer or autumn, but these events did not culminate in hunger according the texts. The crop failure records from the DF did not identify any particular reason for the failures (A.D. 1442, 1445, 1507), even though the cause has most likely been the autumn frost (see below). Thus, *c.* 73 per cent of the documented crop failures are connected in the texts to the frosts untypical of the season. The crop failures occurred quite regularly, although the period between A.D. 1431 and 1470 hold the highest number of crop failure records (Figure 5).

Crop failures were the main factor that was named to cause famines or food scarcity in the medieval documents. Crop failure resulting from early autumn frost was the reason for hunger in eight of the twelve hunger records which were linked in the documents with unfavourable climatic conditions (A.D. 1127, 1161, 1215, 1230, 1314, 1315, 1389, and 1420). Other reasons were summer heat and drought (A.D. 1366, 1371, and 1533), and warm and snowless winter weather (A.D. 1303). The majority (73 per cent) of the recorded crop failures resulted from frost, which usually took place during the harvest time, but the sources hold records of summer frost as well (A.D. 1259, 1291, and 1467). Only the frost record of A.D. 1314 did not

[120] E.g. Gráda 2009; Milliman & Kates 1990, 3–15.

specify during which season the frost occurred.[121] The frost in the year 1291 was dated to take place in 'summer' [122], but the summer frosts of the years 1259 and 1467 were dated to specific dates, first one to the eve of the Saint Boris Day[123], and the later to 2nd of June. If specific dates are mentioned in the chronicles, like in these two cases, it may be that the records of summer frosts have been recorded only to emphasize the significance of these certain days. As summer frosts (among other unfavourable climatic phenomena) were interpreted to be God's punishment for people's sins, the record of frost may have been written down to highlight a feast day or to symbolize the dissatisfaction of the social or political situation of the time.[124]

As mentioned previously, the sources hold 42 mentions of famines, expensive grain or bread, or food scarcity, 29 per cent of which were linked directly to unfavourable climatic conditions in the texts, mostly to autumn frosts. Only twelve per cent of the records named a particular non-climatic factor as the reason for hunger, and in 59 per cent of the cases the reason of famines, expensive grain, or food scarcity was not mentioned or was unclear. However, a few of these records may have resulted from autumn frost, even thought the sources did not name this particular phenomenon as the reason for hunger.

The fifteenth century records hold the highest number of crop failures and hunger, which culminated in two decades, in the 1420's and in the 1440's. However, only the *Utdrag ur Ryska Annaler* holds a record of a famine, which was documented to result from a crop failure and early snowfall in September A.D. 1420. Other fifteenth century records did not name a crop failure as the reason for hunger, even though the period had a relatively high number of crop failure records (Figure 5). However, in A.D. 1421 the Novgorod First Chronicle recorded famine lasting for two years, and in A.D. 1422 the URA recorded three years' famine. Neither of these famine records was linked in the texts to unfavourable climatic conditions, even though the URA holds a mention of a rainy summer in the year 1421.[125] However, the trigger for the A.D. 1421–1424 famine may have been the unsuccessful harvest in the year 1420. Because of the bad harvest, there may not have been enough seed grain for

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[121] URA, 83 (original in Psk 37)

[122] URA, 76 (original in Kar. IV not 182).

[123] 15th of May, thus the famine occurred on 14th of May.

[124] Hanak 1970, xliv, lvii–lix.

[125] N1: 1914 ed., 141; URA, 141, 142 (Psk. 54, Kar. V, not 222, Nowg. II, 140).

the following years, which has affected the rate of crop yields in the following years. Also, the URA has a record of expensive bread in A.D. 1437, which was not connected to unfavourable climatic conditions in the text, but in the previous year there was a mention of crop failure, which may have caused the expensive prices in the following year due to poor harvest in 1436.[126]

Also the mention in the Novgorod First Chronicle of ten years' expensive grain prices from A.D. 1445 may have resulted from a crop failure of the year 1442, the documentation of which is found in the *Diplomatarium Fennicum*. In addition, the DF holds a record of famine in Russia in 1443, and a crop failure in 1445. The crop failure record only documented, however, the unsuccessful harvest of horse fodder, but if the reason of the crop failure was the autumn frost, like in the majority of the cases mentioned in the documents, then the unfavourable weather must have affected the harvest ratio of other variety of grain as well.[127] In addition, the hunger in the 1440's may have been rather severe, as the DF holds many documentations of Viborg requesting Reval to send some food aid in the years 1442, 1443, and 1445.[128] However, the N1 records distress and warfare in A.D. 1445, and does not mention anything about unfavourable climatic conditions, thus the crop failure may not be the only cause for the hunger in the mid-fifteenth century. In addition, from the mid-fourteenth century onwards, the sources have a noteworthy rise in plague records, which may have affected the societies' ability to cope with the crop failures. The connection between climate, hunger and diseases will be discussed in more detail in Chapter 5.4.

Sometimes hunger may have resulted from the previous year's crop failures when low yield-to-seed ratios of one year might have had a long-term effect on food supplies in the following years.[129] For example, the N1 holds a record of famine in A.D. 1128, whose trigger is unmentioned, but in the previous year *"in the autumn the frost killed all the corn*[130] *and the winter crop; and there was famine throughout the winter"*[131]. Thus, if the famine lasted for the whole winter, the famine of A.D. 1128 most likely resulted from the crop failure and

[126] URA, 145–147.

[127] N1: 1914 ed., 202; DF, 2517, 2512, 2520.

[128] DF, 2476–2477, 2517, 2640, 2668.

[129] Gráda 2009, 32.

[130] grain

[131] N1: 1914 ed., 11.

hunger of the previous year. Three records from the DF represent this long-term outgrowth of crop failures quite proficiently. In the autumn of 1507 south-west Finland suffered a crop failure, which contributed to the next year's quantity of seed grain, and in the year 1509 the DF holds a record of 'hunger and squalidness' in western Finland.[132] Thus, even though the hunger record of A.D. 1509 was not connected in the source to climatic conditions, it probably resulted from the crop failure in 1507, which most likely, as it happened in autumn, was a result of early autumn frost.

However, the crop failures did not always lead to hunger. All of the years 1251, 1259, 1291, 1453, 1466, 1467, and 1477 hold a record of unusual frost or crop failure, but none of the years have a documentation of hunger or famine. Even when crop failures occurred in two following years, in A.D. 1466 and 1467, the unsuccessful harvest did not lead to hunger or famine (or at least it was not documented in any of the sources). Thus, even though crop failures and autumn frosts were the main *named* reason in the medieval sources for hunger, crop failure was not a *tantamount* to hunger in the medieval North-East Europe. In addition, based on the hunger records from the fifteenth century, albeit crop failure may have been the trigger for hunger, some other factors might have increased the vulnerability of societies, and in the end transformed food scarcity into famine.

4.3. Climatic change and hunger

The medieval sources were very accurate about the relation between hunger and climate when the sources named a reason for hunger. In addition, the climate data from the medieval sources corresponded with the hunger data. During a period when the medieval documents hold a high number of records of warm summer conditions (A.D. 1324–1374), the documents do not report any autumn or summer frosts, and hold only four mentions of hunger or expensive bread. Two famine records of these (A.D. 1366 and 1371) are connected to dry and hot summer conditions in the texts, and the expensive bread (A.D. 1332) was proposed to result from the *"growing wetness in the grain stock"*[133]. Only the famine of A.D. 1368 is not

[132] DF, 5324, 5329, 5368.

[133] URA 89 (Kar. IV, 136 not 291).

connected with any climatic condition. During the period of warm summer conditions, none of the sources hold mentions of crop failures.[134]

During the periods when the sources hold a high number of mentions of cold or rainy summer conditions (A.D. 1201–1251 and 1421–1468), the sources also hold a greater number of crop failures. However, the first period holds fewer records of hunger than average, but the later period has profoundly greater number of records of famines or expensive bread. Also during the first period of recorded cold winters (A.D. 1212–1227) the sources a hold greater number of hunger and crop failure records than average, but during the later period (A.D. 1375–1408), there are extraordinarily few mentions, just one crop failure and one food scarcity record (Figure 4).

Consequently, based on the medieval climate and hunger data, crop failures and hunger seem to be connected to the unfavourable climatic conditions, primarily to cold and wet weather. However, as the chronicles are compilations and have gone through multiple editorial proceedings, and because the quality and quantity of the North-East European medieval documents is low, the congruity between the climate and hunger data might be just a coincidence. Yet, this congruity proposes new possibilities for analyzing the historical climate data. Instead of being an accurate indicator of past climate, historical climate data represents the climatic anomalies that have had an impact on human societies. These changes in weather may have been small from a climatological perspective, and paleoclimatological reconstructions may not have noticed them, but nevertheless, these changes affected the societies of the time.

Conversely, the paleoclimatological climate reconstructions do not correspond unanimously to the hunger data. In addition, five of the climate reconstructions[135] represent climatic anomalies on a too wide scale to compare with the hunger data. During the periods when the reconstructions record the highest peak in wetness dynamics or precipitation, and the sharpest drop in temperatures, medieval sources do not hold a considerably greater number of crop failure or hunger records. The climate reconstruction by Helama et al. (2009a) discovered

[134] URA 109 (Nik IV,12. Kar. V not 137I); URA, 112 (Nik. IV, 30. Susd. II, 142. Kar. V, 14 not 22)

[135] Bjune et al. 2009, Haltia-Hovi et al. 2007; Kremenetski et al. 2004; Luoto & Helama 2010; Sillasoo et al. 2007.

peak in precipitation anomalies during all of the famine periods that stood out from the medieval data (A.D. 1121–1230, 1206–1231, 1303–1317, and 1420–1454). Especially during the first half of the fifteenth century precipitation rates were high (see Appendix C f). However, the wetness dynamics reconstruction by Väliranta et al. (2007) noticed a wet phase only during the first famine phase in the 1120's, and dry phase in A.D. 1290–1450, during a period when medieval documents hold a relatively high number of famine records.

The connections between the temperature reconstructions and hunger records were rather diverse. All of the comparable temperature reconstructions[136] noticed a drop in the temperatures in the 1120's and early 1310's, during the periods when the historical data hold relatively high amount of crop failure and hunger data (Figure 5). Also, the reconstructions by Briffa et al. (1990) and Helama et al. (2009b) noticed a drop in temperatures during the years that had hunger and crop failure data in the early thirteenth century, but conversely a reconstruction by Helama et al. (2010) noticed a minor peak in temperatures during the late 1220's. All of the reconstructions have evidence of a rising trend in temperatures in the first half of the fifteenth century, during a time period that hold the highest amount of crop failure and hunger data.

Thus, the majority of the climate reconstructions have evidence of a temperatures drop or precipitation peak during the periods when the medieval documents hold a higher amount of hunger and crop failure data. Only the hunger period in the fifteenth century could not be connected to colder or wetter climatic conditions. The reconstructions have evidence of warmer-than-average temperatures in the first half of the fifteenth century, especially in the 1420's. This strengthens the interpretation of famine as not resulting in the medieval North-East Europe only because of the unfavourable climatic conditions. Besides, the medieval hunger and crop failure data did not correspond to every cold and wet phase, of which the paleoclimatological reconstructions had evidence. If hunger would result directly (and only) from cold and wet conditions, the medieval data should hold records of hunger and crop failures in each decade when paleoclimatological reconstructions have evidence of unfavourable climatic conditions.

[136] Briffa et al. 1990; Helama et al. 2009b; Helama et al. 2010; Ojala & Alenius 2005; Weckström et al. 2006.

4.4. The Great Famine

The European Great Famine, or the Seven Years' Famine, which started in A.D. 1315, has been considered as the most significant famine of the medieval Europe, and even one of the turning points of the entire history of the Middle Ages.[137] In addition, the rainy and cool trend that started at the beginning of the fourteenth century has been viewed as the pinpoint of Europe's climate history, and the Great Famine as the prologue of the Little Ice Age.[138] The extremely rainy and cool summers in 1314 and 1315 have been viewed as the main triggers for the famine to breakout, and during the famine years of A.D. 1315–1322, the weather was the force that carried the famine on.[139]

No matter how significant the Great Famine has been to European history, the medieval sources analyzed in this study do not highlight the period. Quite the opposite, during the years 1315–1322, there is noticeably few mentions of weather conditions or crop failures. The *Utdrag ur Ryska Annaler* hold one mention of crop failure and expensive grain prices in A.D. 1314[140], and the *Diplomatarium Fennicum* has a document of Stockholm asking southern Finland to send some grain due to shortage of their storage in the same year[141].

The Livonian Chronicle by Balthasar Russow is the only source that mentions the famine, and indeed the text corresponds to the Western European descriptions of the causes and the horrors of the famine:

> *"A.D. 1315 in Livonia, and all surrounding areas, the shortage of grain and of all other necessary food stuff caused horrifying famine unparalleled in misery. Hundreds of people died of hunger, and the dead bodies were thrown and buried into huge mass graves. Some parents killed and ate their own children, and when there was no more bread, some parents locked their children into saunas, thus the children suffocated. […] This famine and time of crop failures lasted three years,*

[137] Fagan 2004, 247–249; Lamb 1995, 195; look also Fraser 2011.

[138] Lamb 1995, 195.

[139] Jordan 1996, 16–19; Hybel & Poulsen 2007, 67; Lamb 1995, 195.

[140] URA, 83 (original in Psk 17 & Nik. III, 109).

[141] DF: 295.

> *and the reason was that rye and barley alike froze each and every year on the fields."*[142]

However, the editor and the translator of the 2004 Finnish edition, Timo Reko, has questioned the authenticity of the description above. He suggests that the description of the 1315's famine originates from other chronicles, and has ended up to the Livonian Chronicle through long and diverse detours.[143] Thus the occurrence of the Great Famine in Estonian and Livonian regions can be questioned, as the narrative of the famine may originate from other chronicles.

The Great Famine has been explained to result from rainy summers and severe winters, and in fact, most of the temperature reconstructions covering North-East Europe noted a cooling trend. However, the wetness and precipitation reconstructions differed from each other, and did not present an unanimous image of the rainy beginning of the fourteenth century. This is a significant fact, as the increasingly wet conditions have been considered as the main trigger for the Great Famine in Western Europe. The precipitation reconstruction by Helama et al. (2009a) noted a declining precipitation trend starting in the end of the thirteenth century, and culminating in the mid-fourteenth century. However, the reconstruction discovered a transient peak in precipitation anomaly between *c.* A.D. 1301 and 1320. Also the wetness dynamics reconstruction by Väliranta et al. (2007), which was based on bog data, noted a dry trend beginning from the end of the thirteenth century.[144] However, the reconstruction from Estonian bog noted a shift to wetter conditions *c.* from A.D. 1300 onwards, like the multiproxy reconstruction from the Kola Peninsula had evidence of increased avalanche activity and higher lake levels starting around the same time.[145]

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142 Russow 2004 ed., 85: *"Vuonna 1315 Liivinmaalla ja kaikilla sitä ympäröivillä alueilla viljan ja muun välttämättömän ruuan puutteesta johtunut ennen kokemattoman kauhistuttava nälänhätä. Sadat ihmiset kuolivat nälkään, ja kuolleet heitettiin ja haudattiin suuriin joukkohautoihin. Jotkut vanhemmat tappoivat ja söivät omat lapsensa, ja kun leipää ei enää riittänyt, telkesivät jotkut lapsensa kuumiin saunarakennuksiin, niin että lapset tukehtuivat. […] Tämä nälänhätä ja katoaika kesti kolme vuotta, ja syynä siihen oli se, että sekä ruis että ohra paleltuivat joka ainoa vuosi pelloille*". Translation from Finnish to English by H. Huhtamaa.

143 Reko 2004, 23.

144 Helama et al. 2009, 176; Väliranta et al. 2007, 1104.

145 Sillasoo et al. 2007, 32; Kremenetski et al., 2004, 113.

Thus, neither the climate reconstructions nor medieval documents hold undisputable evidence of rainy summer conditions at the beginning of the fourteenth century. However, the majority of the climate reconstructions found a colder shift in temperatures, and increased *winter* precipitation. Sediment records from Finland had evidence of increased spring flood activity and severer winter conditions from the fourteenth century onwards.[146] In addition, as mentioned above, the majority of the climate reconstructions discovered cooling trend starting from the beginning of the century and the medieval documents can be interpreted to indicate colder climate in the fourteenth century (see pp. 32–33). Thus, to a certain extent, also North-East Europe underwent the same shift from warmer to cooler temperatures as Western Europe. This shift has been linked to the Great Famine in other parts of Europe.

The existence of the Great Famine is a fact.[147] But did the famine occur in North-East Europe as well? Hubert H. Lamb interpreted the famine to occur in Russia and in other parts of Eastern Europe, but he did not see the Great Famine as the most striking famine in the medieval East Europe.[148] Also, even though Danish medieval sources did not hold any evidence of the Great Famine in Denmark, Hybel and Poulsen believed the famine to have struck Northern Europe:

> "*[t]here are no traces of abnormal weather, famine, epidemics, or rising mortality in any Danish letter or other document existing from the years 1310–1321. […] On the other hand there is, as we have seen, plenty of evidence from other parts of Europe which confirms the sparse information in Danish annals about the years of unusual weather in the second decade of the fourteenth century, evidence that fits Denmark into the general European pattern.*"[149]

In contrast to general view, William Jordan questions the existence of the Great Famine in the North-East Europe: *"[t]o be sure, the far eastern Baltic was not affected directly by harvest shortfalls, but it felt some of the economic, especially trade, repercussions of the famine"*[150]. According to him, the famine did not struck the area so hard due to differing agricultural

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[146] Haltia-Hovi et al. 2006, 685; Ojala & Alenius 2005, 300.

[147] E.g. Jordan 1996.

[148] Lamb 199, 206–207.

[149] Hybel & Poulsen 2007, 68.

[150] Jordan 1996, 12.

methods: "*[n]either the Finns nor other eastern Baltic inhabitants on the northern and southern shores of that sea had as yet gone over entirely to permanent arable fields from slash-and-burn agriculture, a fact that afforded them a temporarily higher rate of yields on crops*"[151]. Thus, the agricultural method may have given North-East European people better resilience to cope with climatic changes in the fourteenth century. (The importance of diversified agricultural methods will be discussed in more detail in Chapters 5.2 and 5.3)

Hence, based on strong evidence from Western Europe, can the Great Famine be interpreted to extend also to North-East Europe? When examining both the paleoclimatological and historical evidence, the famine of A.D. 1315–1322 did not occur in the studied area. However, the temperature most likely started to cool down as in Western Europe, the winters may have had thicker snow cover, and some early autumn frosts may have occurred. Neither the historical sources nor the climate reconstructions hold evidence of unusually rainy summers, thus if some food scarcity did occur, it probably did not result from rainy summers.

Either the summers of A.D. 1314 and 1315 were not rainy like in Western Europe, or the agricultural systems of the area were not vulnerable to heavy summer rains. In addition, hunting and fishing probably gave important nutritional supplement in the sparsely populated areas. However, it is most likely that the temperatures started cooling from the beginning of the fourteenth century. Maybe the North-East European societies were not that vulnerable to cooling climatic conditions, and maybe due to the agricultural methods, the societies could cope better with the cool and wet summers.

4.5. Linkages between hunger and climate

The climatic conditions that created hunger in the medieval North-East Europe laid stress mostly upon agricultural system, whether during winter, sowing or growing seasons, harvest, or during the time of storage of the grain. From the medieval sources used in this study, five challenges to the food production can be identified: 1) short growing season, 2) summer and autumn frosts, 3) extensive precipitation in the summers and autumns 4) moist storing conditions, and 5) summer drought. Reijo Solantie's study, which examined the linkages

[151] Jordan 1996, 192.

between climate, land use, and population in Finland prior to the industrial period, corresponded to this notion. In addition, Solantie listed the occurrence of snow mould fungus (*Calonectria graminicola*) as a significant challenge for the agriculture in the region. If the snow cover was thick during the winter, the ground stayed unfrozen more often through the winter. This exposed the wintering grain to snow mould fungi, whose most important precondition is the unfrozen ground. Even though the sources did not name snow mould fungi destroying the wintering crops, the disease most likely occurred in the area.[152]

Thus, crop failures, which usually resulted from cold or wet conditions, were the most common single factor for hunger to breakout in the medieval North-East Europe. The paleoclimatological reconstructions and medieval documents used in this study both support this notion. From the medieval data, two different processes of hunger and famine, which resulted from unfavourable climatic conditions, can be identified:

> A) **Direct outgrowth from crop failure to hunger**: crop failure in summer or autumn, which caused hunger in the same year (hunger resulting from frost in the years 1127, 1161, 1215, 1230, 1314, 1315, 1316, 1317, 1389, 1420, and 1436; hunger resulting from summer heat and drought in the years 1371, 1366, and 1533). The crop failure could also result from multiple years' climatic stress, like in the years 1364–1366 when the URA holds records of extensive forest fires, summer heat, and drought, which culminated in famine and expensive pricing of bread in the year 1366.[153]
>
> B) **Long-term outgrowth from crop failure to hunger**: crop failure in the first year, which caused shortage of the seed grain in the next year, and poor harvest on the third (or second) year, which in the end culminated in famine or hunger (the years 1127–1128, and 1507–1509, and probably the famine periods in the 1420's and 1440's).

In addition, the study by Holopainen and Helama (2009), which examined the agriculture in Finland during the Little Ice Age, noted that "*[h]istorical documents show a qualitative*

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[152] Solantie 1997, 27–28, 65, 67; Korpela 2008, 40.

[153] URA 108–109 (original in Nik IV 7–8, Kar not 137, Arch 83).

correspondence between years of crop failures and times of famine"[154]. Hence it seems quite likely that crop failures were the reason for hunger in the Middle Ages, just like the paradigm in historical research states. However, the medieval and paleoclimatological climate data had evidence that similar climatic conditions may have caused different outcomes, as in the years 1466 and 1467 when two successive summer frosts did not lead to hunger. Sometimes hunger developed only after continued climatic stress, as in the years 1364–1366, and sometimes after just one relatively small weather phenomenon.[155]

Therefore, the famines in the Middle Ages could not result from poor harvest alone, and there must be other factors that may have made the medieval societies vulnerable to climatic changes. Crop failure may have been the trigger for famine, but the situation most likely needed some fuel to develop into severe hunger. The following chapter will examine these other possible factors that may have interacted with the relation between crop failures and hunger.

5. Climatic stress and food systems

5.1. Vulnerability

Famine and hunger are complex phenomena, whose causes, effects and severity are dependent on spatial and temporal factors. Therefore societies' *vulnerability* to famine and hunger has been in focus in increasing degree in contemporary famine research: how do social and environmental forces interact to construct situations vulnerable to climatic changes or how are societies able to adapt to these climatic changes.[156] As the hunger data from the medieval sources implies, climatic changes were not the only factor for famines and hunger to breakout. Therefore, the emphasis on medieval North-East European societies' vulnerability is reasoned.

[154] Holopainen & Helama 2009.

[155] Fraser 2006, 330.

[156] Gráda 2009, 15–39, Fraser 2006.

However, as mentioned before, the societies' vulnerability to famines has not been in focus in historical research, as the centre of attention in history is more often in the causes and consequences of famines. Food production in North-East Europe has been able to adapt to changing environmental circumstances, such as to the shift to cooler climate during the Little Ice Age, but sometimes relatively small climatic anomalies, like autumn frost or summer drought, have had severe consequences. Thus sometimes, and for some reason, the food system in North-East Europe must have been more vulnerable to climatic changes. The following chapters will discuss the conditions that might have increased the vulnerability within food systems to climatic changes.

5.2. Population and land

The area of North-East Europe was sparsely populated compared to Western Europe between A.D. 1100 and 1550. However, due to little historical and archaeological evidence, an accurate estimation of population density is difficult to make. The rural areas were dominated by forest with low population density, and the highest density of permanent settlement was located in close proximity to the few bigger towns (Map 1). The population most likely grew between A.D. 1100 and 1550, even though there is rather limited evidence of this growth. Rapid changes in the vital rate of the population were normal, and population growth varied regionally. The death rate was more important for the population growth than the birth rate, albeit economical growth probably affected the birth rates positively. The population growth was restricted by the capacity of food production and disease epidemics.[157]

Taavitsainen et al. (1998) have estimated that the population approximately doubled in each century during the first half of the second millennium in the Northern Boreal forest regions (Finland and North-West Russia). On southern and eastern sides of the Gulf of Bothnia, population growth was probably more moderate (due to higher population density already from the beginning of the second millennium), albeit the population increased in that area alike. The Estonian population probably increased gradually from 150 000 / 180 000 to 250 000 inhabitants during the studied period. Novgorod, which was the biggest town in the area, underwent rapid population growth in the first two centuries of the second millennium,

[157] Philman 2004, 49.

and had about 20 000 to 30 000 inhabitants by the early thirteenth century. Unlike in other regions of the studied area, Novgorod's size of population stopped growing in the thirteenth century (or at least was much more moderate), as the Mongol invasion, diseases, and disturbances kept the mortality rate high.[158]

It has been proposed that the population growth of the medieval times in North-East Europe resulted from favourable climatic conditions. However, the regular and reliable seasonal rhythm might have been more important than the moderate warming of the MWP. Favourable climatic conditions secured surplus in agricultural production, which enabled trade and the growth of towns. In addition to climatic conditions, new technology and social conditions may have contributed to the population growth.[159]

The area of North-East Europe was agricultural periphery, and climatic conditions had *"markedly influenced farming practices and crop variations"*[160]. Permanent agriculture was introduced in the area late by European standards, generally during the first millennium or in the first half of the second millennium A.D. In Finland and North-West Russia the primary farming method was slash-and-burn cultivation, which was supplemented by hunting and fishing. On the southern side of the Gulf of Bothnia both farming methods, slash-and-burn and arable cultivation alike, were practiced in the beginning of the Middle Ages, but arable cultivation soon became the dominant farming method. Also in southern Finland and some parts of western Russia arable cultivation was established during the Middle Ages. Archaeological evidence has proof of arable cultivation around the Novgorod district from the beginning of the second millennium. Animal husbandry was practiced at least in the Novgorod district, Baltic area, and the most southern part of Finland, as archaeological excavations have proven, and the Russian and Livonian chronicles hold mentions of keeping livestock. People of the northern parts of North-East Europe were probably not as dependent on livestock as Russian and Livonian people, as the extensive forests provided good resources of game. Fish was an important supplement to people's diet around North-East Europe.[161]

[158] Korpela 2008, 202; Taavitsainen et al. 1998, 245–247; Raun 1987, 19; Martin 2007, 68, 162, 305.

[159] Philman 2004, 49.

[160] Holopainen & Helama 2009, 216.

[161] Korpela 2008, 42–46, 129–135; Jordan 1996, 192; Alsleben 2001, 111.

Rye was the dominant grain species, and barley was the second most cultivated crop. In the hinterlands of Novgorod archaeological research has found evidence of cultivation of millet, which has been considered to be food for the poor. The *Diplomatarium Fennicum* holds mentions of cultivating oat and hop, and paleobotanical research has found evidence of cultivating both species also in the eastern and southern sides of the Gulf of Bothnia. Oat was primarily cultivated as horse fodder, and hop was important for brewing beer. Also cabbage, peas and beans were probably cultivated, even though these have not left archaeological evidence. In addition, various kinds of beets were most likely cultivated in the both sides of the Gulf of Bothnia. The Russian chronicles used in this study hold mentions of summer frosts also killing fruits and vegetables, thus people most likely had small-scale vegetable gardens, also in towns. The societies were self-sufficient in food production, and the Baltic region even had surplus grain to export to European markets.[162]

The source of livelihood varied spatially in North East Europe. The people of the northern parts of the studied area either practiced small-scale slash-and-burn cultivation combined with fishing and hunting, or were nomadic hunter-gatherers till the end of the sixteenth century. The people of the eastern parts of the studied area practiced slash-and-burn cultivation, which required broad land mass and people's seasonal cycle between settlements, thus the method was possible only in sparsely populated areas. It is characteristic for North-East Europe that the cultivation methods and the source of livelihood were connected to the extent of state administration. As grain cultivation was uncertain due to changing climatic conditions, and the northern forests were rich in game and fish, farming was not the first choice for food acquisition, and it became stabilized only after states established their power in the region. When population density increased[163], or when the state administration took aim to bound people more tightly to certain locations and obliged people to pay taxes, the societies most likely switched over to arable cultivation in order to produce a surplus in grain yields.[164]

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[162] Zetterberg 2007, 135; Holopainen & Helama 2009, 213; Korpela 2008, 132–133. DF, 2512, 2640; Alsleben 2001, 111; Rybina 2001, 127–130; URA 156 (Kar. VI not 629).

[163] This classical interpretation has been however criticized in some of the most recent studies. The switching to arable cultivation in the northern parts of the Baltic Sea might have resulted from the changes in cultural, technological, political or economic circumstances, not because of the population growth. See e.g. Korpela 2008, 44–45; Pihlman 2004; Orrman 1999.

[164] Solantie 1997, 11–14; Korpela 2008, 199–202; Taavitsainen et al. 1998, 236–240.

The societies that practiced slash-and-burn cultivation are considered to be less vulnerable to climatic changes. The method provided a higher rate of yields on grain, and due to the mobile lifestyle of the cultivation method, the people were probably able to exploit other food supplies from forests and waters, better than people who practiced permanent arable cultivation. The diversity in food acquisition minimized the risks that severe climatic conditions of the area imposed. This might be the reason why the Great Famine did not struck North East Europe so hard, as only a small part of the population was dependent solely on grain that was produced by arable cultivation.[165]

5.3. Agricultural systems and vulnerability

Environmental conditions set limits to the food systems of the medieval North-East Europe. Climatic conditions, such as short growing season, determined the possible agricultural methods and cultivable crops in the area. Soil, geographical landscape and other environmental factors also shaped the agricultural system. However, the environmental conditions alone did not make North-East European societies vulnerable, as farmers of the time were able to adapt to these circumstances. Evan D. G. Fraser has examined the linkages between food systems and climate change by studying the characteristics of past famines[166]. He observed that social conditions, rather than just environmental factors, were the main reason why some food systems were more vulnerable than others. Even though Fraser studied the past famines only to identify the contemporary food systems' vulnerability to climate changes, his notions of the characteristics of vulnerability can be used to examine the medieval North-East European food systems as well.[167]

Frasier noticed that when a certain region was increasingly dependent on a fragile and specialized agricultural system, the society's vulnerability increased outstandingly. From an ecological perspective, the society's vulnerability to environmental factors was increased by: 1) high degree of connectivity of ecosystems, 2) low diversity in ecosystem, and 3) high productivity of ecosystem. However, these characteristics are not only shaped by nature, as

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[165] Jordan 1996, 192; Fraser 2006, 331.

[166] Fraser, E.D.G., Food system vulnerability: Using past famines to help understand how food systems may adapt to climate change. Ecological Complexity 3, 2006, pp. 328–335.

[167] Fraser 2006, 328–335.

they are also results of socio-cultural processes. Economic and institutional factors may have led the agriculture to move away from fuelling local needs to answering the demands of foreign trade. For example, the emergence of a Western European grain market may have affected the Livonian (modern day Estonia and Latvia) grain production by decreasing the variety of crop species cultivated. In addition, the control of the state administration may have determined the cultivated species, as only certain crops and food products were accepted as taxes or duties. Also population growth and grain prices may have led farmers to favour certain species to maximize the crop productivity. All of these factors decreased the variety of cultivated species and thus lowered the diversity of the ecosystem. These actions also increased the productivity, which may have increased the vulnerability, as landscapes productive in terms of high biomass are more vulnerable to fires, pests and diseases. Trade, transportation networks, and state administration promoted the connection within and between ecosystems, which also increased the vulnerability, when e.g. crop diseases spread more easily.[168]

In addition to agro-ecological landscape, Frasier highlights the significance of economic factors when evaluating the vulnerability to climate change within an agricultural system. The distribution and allocation of resources in times when the food system is under stress has a huge impact on the severity of the consequences. The poorest are invariably the ones that suffer the most from environmental changes, and the actions of the rich and powerful play an important role in how severe the consequences of climatic anomalies develop. Vulnerability is linked with economical status, as the poorest may not have an alternative option for food acquisition. For example, the fall in grain prices increases the poor people's vulnerability, whereas it may not affect the wealthier people's vulnerability status at all.[169]

In addition to Frasier's study, Gunderson et al. (2002) have made an interesting notion of vulnerability in their research on how human and ecological processes interact across space and time. They argue that:

[168] Fraser 2006, 331; Raun 1987, 21; Holopainen & Helama 2009, 214, 217; Alsleben 2001, 111, Rybina 2001, 127–128.

[169] Fraser 2006, 331–332.

> *"[a]s new institutions (social rules, norms, and structures) matured, they became more and more vulnerable to disturbances or perturbations from the outside. In some cases, those disturbances were part of unforeseen or nonrecorded variation in key processes of the ecological system. In other cases, the effects of those disturbances were exaggerated by previous management action, leading to an increased vulnerability of the social system."*[170]

Thus, vulnerability within food systems increased because of both hazards created by climatic change and perturbations produced by human behaviour. If the society did not pursue actions to minimize the impacts of these disturbances, even a relatively common or small-scale climatic problem could cause massive hunger. In other words, the severity of hunger was determined by environmental and socio-cultural factors, which either increased or decreased the society's vulnerability to hazards, climatic or man-made alike.[171]

Another interesting notion by Gunderson et al. was the temporal dimension of vulnerability. They argued that the vulnerability of ecological and social systems increased, as the systems matured. Poor quality of soil, erosion, and low ecological diversity (among others) were all conditions that increased vulnerability, and required time to develop. This could happen as a consequence of environmental or socio-cultural factors, or both. Phenomena that increased the social vulnerability, such as power struggles, tax burden, increased population density, warfare, and grain prices also deepened over time. Thus, it is essential to pay attention also to the maturity of the societies when analyzing the impact climatic conditions had on food scarcity in the medieval North-East Europe. For example, the relatively late transition to permanent agriculture in the area, the authorities' weak control over the northern regions, and even the formation of the Hansa League all affected the temporal maturity of the area.[172]

Population growth is a part of a society's maturity process, and undoubtedly the size of the population has an impact on the level of vulnerability. However, the social phenomena, which are prerequisites and consequences of the population growth, probably have a bigger impact on the level of vulnerability than the population vital rates by themselves. For example,

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[170] Gunderson et al. 2002, 332.

[171] Gunderson et al. 2002, 332; Holling 2001, 396.

[172] Gunderson et al. 2002, 332;

because of the taxation and administrative actions, the need of grain and labour surplus increases. This creates new systems in food production, and hence affects the level of vulnerability, as a part of the maturity process.[173]

The maturity of society might have contributed to the outbreak of the severe famine periods in the 1420's and 1440's in the Novgorod region. Prior to these decades, the longest famine periods lasted only a few years. The temporal factors also explain why the people of the northern parts of the studied area can be considered to be less vulnerable to climatic changes: the hunter-gathering and slash-and-burn cultivation required mobile lifestyle, which most likely slowed down the ecological and social maturity processes. Therefore, for example, the Great Famine of the fourteenth century most likely did not occur on the northern side of the Gulf of Bothnia, whereas it may have had potentiality to arise (or at least experience some its effects) in the south, where the people practiced arable cultivation and foreign trade.

5.4. Climate, hunger, and diseases

The Black Death, which broke out in Europe in the end of the 1340's, was the most severe pandemic in the Middle Ages. All of the sources, which covered the time, note the plague. The Novgorod First Chronicle and the *Utdrag ur Ryska Annaler* have a considerably greater number of plague records from the 1340's onwards, even though the sources also hold mentions of plague prior to the 1340's, like the Chronicle of Henry of Livonia. In addition, the *Diplomatarium Fennicum* and Balthasar Russow's Chronicle of Livonia hold mentions of plague only from the sixteenth century. Thus, all of the mentions of *plague* can not refer to the Black Death, which was caused by the bacterium *Yersinia pestis*. However, identifying the actual cause of the disease or the precise epidemic is irrelevant for this study. It is more important to identify when the disease broke out in the studied area. The sources mention plague relatively regularly between A.D. 1341 and 1550, with a substantially greater number of plague records in A.D. 1417–1426. During this period, almost every year had a record of plague. In general, each decade between A.D. 1341 and 1550 had three or four plague mentions.

[173] Philman 2004, 48–52.

The connection between climatic change and diseases has been discussed in a rather great extent, also in historical research. While it is evident that some of the diseases occurred more likely in certain climatic conditions, the Black Death was probably not connected to climatic change, even though Hubert H. Lamb, among others[174], proposes this possibility. In addition, the connection between hunger and diseases from a historical perspective has been in special focus. The *Yersinia pestis* that caused the plague was such a strong bacterium that the victim's nutritional condition was irrelevant. Some other diseases, however, may have transmitted more easily to a body that was weakened by malnutrition. Demographically, diseases killed more people in the medieval North-East Europe than hunger, even though it is sometimes extremely difficult to specify whether the cause of death was a disease or hunger.[175]

Thomas Malthus believed that the plague and other diseases, like famine, were a natural way to control the population growth, as the diseases rebalanced the levels of population and food production. According to this approach, a severe plague pandemic would hence decrease the possibility of famines in the long run, as the disease would dramatically reduce the population and there would be fewer mouths to feed.[176] Nevertheless, the medieval sources do not support this interpretation: the famine mentions did not decline after the 1340's. Quite the opposite, the majority of the years that hold famine mentions after the 1340's also record a plague. Only the years 1308 and 1309 in the URA holds mentions of both, famine and plague, prior to 1340. In addition, when the sources hold a considerable number of plague mentions A.D. 1417–1426, the sources also hold a record of a severe famine period. The sources hold seven mentions of plague or diseases prior to A.D. 1340, and after A.D. 1340 these records were found in 53 single years.

Thus, it seems that diseases increased societies' vulnerability to hunger. As the diseases weakened and reduced the population, the food production most likely also decreased, as there was not enough labour on the fields. In addition, the disease epidemics were rapid to

[174] Look e.g. Jutikkala 1987, 67. Jutikkala proposed that as the grain supplies were decreased due to unfavourable climatic conditions of the LIA, rats died of hunger, and the plague carrier fleas transmitted from those more easily to the human population.

[175] Lamb 1995, 198–200; Kallioinen 2009, 126–130; Brown 1999, 9–10; Gráda 2009.

[176] Malthus 1807, 19–20, 480.

spread and caused death in a short time, thus the societies most likely had to struggle to cope with these sudden changes in population.[177]

5.5. Hunger in relation to climatic and social change

Population, agricultural methods, diseases, and socio-cultural factors all had an effect on the vulnerability within food system to climatic changes. Most of North-East Europe was sparsely populated in the medieval times, thus overpopulation (in Malthusian terms) was not an actual challenge. However, the relative size of the population mattered, and the societies that lived close at to the margin of subsistence, or were dependent on imported food (the few bigger towns), were the most vulnerable. Thus the cultivation method and source of livelihood shaped the optimal size of the population. A cultivation method which was not the most advantageous in relation to the population and land mass in use increased vulnerability. In addition to this, diseases reduced the population size, but as the cultivation method was usually selected to maintain the optimal balance between the size of population and levels of food production, diseases did not create surplus of food, but shortfall of labour in the fields, which affected the food production negatively.[178]

Evan D. G. Fraser argued that the shift from the subsistence agrarian economy to the specialized agricultural system, which was controlled by strong institutions, was one of the key factors in why medieval society became more vulnerable to climatic changes.[179] The medieval North-European society underwent this transformation between A.D. 1100 and 1550, although on a time span which varied regionally.[180] The sources used in this study support this notion: as the control of the authorities increased, the number of administrative records increased. The processes of social inequity and environmental degradation made the societies more vulnerable to the changing climatic conditions. Thus, the level of vulnerability varied considerably, both temporally and spatially, within the medieval North-East Europe. Even though the environmental conditions set limits to the food production in the area, the economical and social processes, which happened in varying time and in with variable

[177] Gráda 2009, 121; Jordan 1996, 182.

[178] Fraser 2011, 1269, 1274–1276.

[179] Fraser 2011, 1270, 1276.

[180] See e.g. Korpela 2008.

intensity in the different parts of the area, set limits on how the society could cope with the climatic changes.

A society whose vulnerability level was high could not cope efficiently with hazards and disturbances, climatic and man-made alike. Thus, a climatic hazard or anomaly rarely caused severe hunger or famine by itself in the medieval North-East Europe. Climatic anomaly, such as unusually early autumn frost, was usually the trigger for hunger, as it affected the harvest ratio, but the society's level of vulnerability determined whether the shortage of food developed into famine. Cultural, political, and institutional factors shaped the landscape and the society, which either increased or decreased the vulnerability to the climatic anomalies. The level of vulnerability had an impact on the outcomes of harvest failure, such as expensive grain prices and shortage of food, and these could, in turn, affect the level of vulnerability. This interaction between climate, vulnerability and hunger is represented in Figure 6.

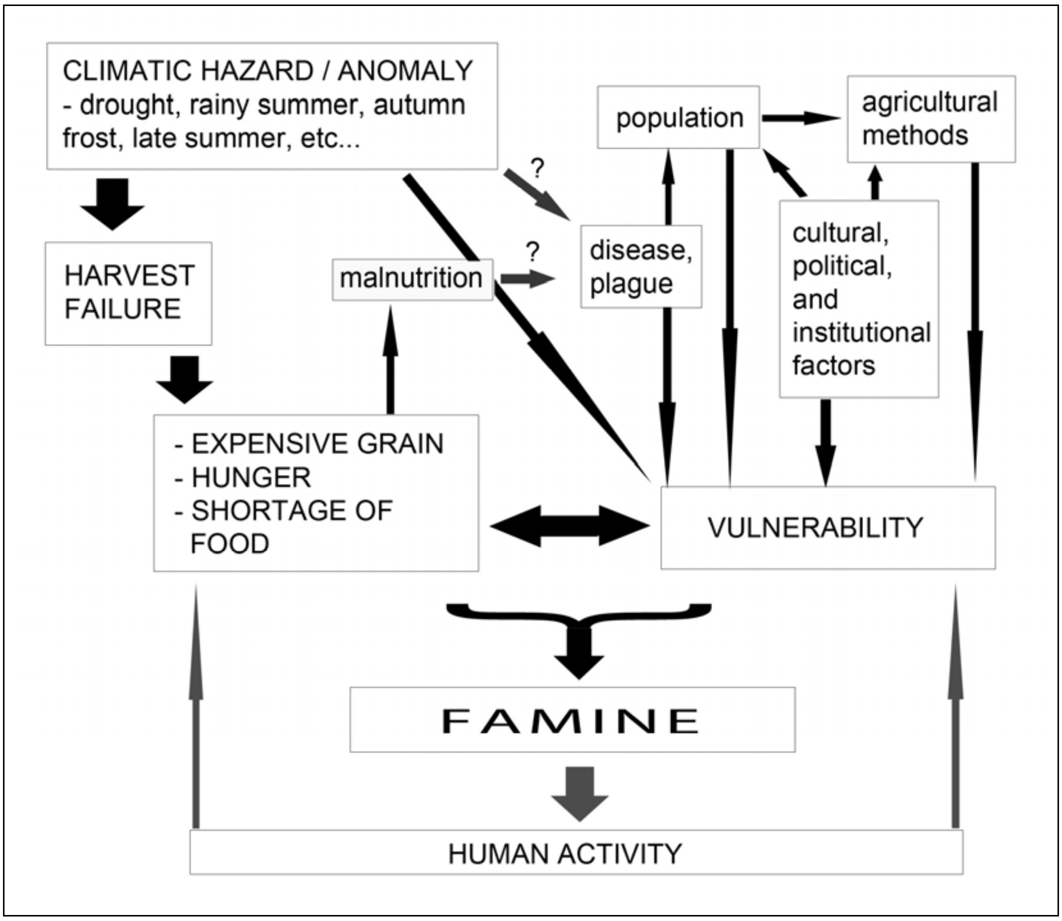

Figure 6. *The connections between climate, vulnerability, and hunger in medieval North-East Europe.*

The climatic conditions that caused hunger most often in the medieval North-East Europe were linked to the short growing season and cold weather, such as autumn frosts and floods. Societies were most vulnerable to the climatic hazards during the harvest time[181], as unfavourable climatic conditions in late summer and autumn did not only affect the food supplies during the year-ending, but also had an impact in the food system on the following years. The food system had the biggest difficulties when trying to cope with rapid and short term changes, and the practiced cultivation method or source of livelihood determined how able the society was to adapt to these changes. The long-term climatic shifts, like the cooling trend from the fourteenth century onwards, did not increase the number of famines notably.

The change from the Medieval Warm Period to the Little Ice Age most likely had some kind of effect on ecological landscape, but this was not evident in the medieval sources, which did not identify the long-scale, relative on a centennial time-scale, changes in food and economic systems. The cooling, which was moderate by its nature[182], did not increase the occurrence of the climate related famines in the studied area. This finding corresponds with the notion by Emmanuel Le Roy Ladurie, who questioned whether long-term climatic variations could *"have any influence on agriculture and other activities of human society"*[183] in medieval times. Thus, the main climatic stress came from rapid climatic changes, which the society did not have time to adapt to and create coping mechanisms for. These events are not visible in the paleoclimatological reconstructions, which emphasize long-term climatic variations on a large scale, and the reconstructions that represent annual or decadal temperature and precipitation means often conceal seasonal variations, no matter how radical these were.

However, the mentions of famine and hunger slightly increased from the mid-fourteenth century onwards. Yet, this could not result (only) from the cooling climate of the LIA, as hunger became less often connected *directly* to unfavourable climatic conditions or crop harvests in the medieval sources, especially from the fifteenth century onwards. The same climatic phenomenon that had previously caused famines lasting a year or two could then have an impact on the food system even for a decade (like the famine periods in the 1420's and 1440's). The relation between climate and hunger shifted from a direct connection

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[181] See chapter 4.4.

[182] The annual mean temperature cooled less than one Celsius degree according to most of the paleoclimatological reconstructions used in this study.

[183] Le Roy Ladurie 1972, 293.

between unfavourable climatic conditions and hunger to a process where the level of vulnerability determined the severity and length of the climate-related hunger. The notion of linkages between society's maturity process and vulnerability by Gunderson et al. supports this finding, as does the increased number of recorded plague epidemics in the medieval sources.

Thus, based on the medieval data, the level of vulnerability most likely rose from the fifteenth century onwards, at least in the regions where different institutions had been established for rather a long time. However, the limited amount and discontinuous structure of the medieval climate and hunger data may have influenced this result, and therefore the level of vulnerability may have had a bigger role already prior to the fifteenth century. Nevertheless, the landscape, institutions, and population became more vulnerable to climatic changes within time as the societies matured. Thus, it is inadequate to study the climatic changes in relation to hunger without paying attention to the processes that happen within time in the societies. The medieval North-East European societies went through a social transformation between A.D. 1100 and 1550, on a different temporal scale in different places of the region, which eventually changed the relation between climatic change and hunger. The severity of hunger was not determined anymore only by the severity of the climatic hazard, as the level of socially produced vulnerability became more and more essential in how efficiently societies could cope with the climatic changes.

6. Conclusion

The objective of this thesis has been to investigate the relation between climatic conditions and hunger in the medieval North-East Europe. In order to do that, I first had to review the characteristics of the climatic variations and to evaluate the sources' climatic data.

Both source types of climatic information, the medieval document data and paleoclimatological reconstructions, proved that temperatures and precipitation rates have fluctuated between warmer and colder conditions on inter-decadal and inter-annual timescales. Most of the paleoclimatological reconstructions noted a shift to cooler and wetter climate from the thirteenth or fourteenth century onwards. This corresponds to the long-term climatic trends observed in other parts of Northern Europe, known as the Medieval Warm Period (MWP) and the Little Ice Age (LIA). However, the evidence of the medieval warmth and its level was not clear or unambiguous, but the evidence of the cooling climate of the LIA was congruent in some degree in every reconstruction. The medieval document data did not hold clear evidence of neither of the climatic trends, the MWP or the LIA, but it indicated unstable climatic conditions from the fourteenth century onwards.

The paleoclimatological reconstructions and historical climate data represented different climatic phenomena on different scales. The analysis of these sources showed that paleoclimatological and historical data do not correspond unambiguously with each other. However, a closer examination demonstrated how these two can be combined and compared when investigating the past climate and its impact on food systems. It was found that historical data may provide new information of temporal, regional, and low-frequency climatic variations, which are not evident in paleoclimatological data. In addition, the findings suggest that the climatic trends that are represented in historical data might have a greater impact on societies' wellbeing than the long scale climatic trends that are represented in the paleoclimatological reconstructions.

The analysis provided evidence of the correspondence of hydro-meteorological events between the paleoclimatological reconstructions and the medieval climate data. However, the paleoclimatological reconstructions and historical data which demonstrated changes in temperatures did not correspond with each other. This may result from the different level of relativity of the data. Whereas paleoclimatological reconstructions are based on standard parameters and measurements, the relativity of the historical climate data depends on the person who makes the climatic observations at the time. Thus, when analyzing climatic data from medieval sources, it is essential to pay attention to *why* certain climatic phenomena have been written down at different times. In addition, historical records tend to represent climatic aberrations rather than the predominant climatic conditions. However, in close examination, this was found to be a significant strength of the historical climate data, not a weakness. These findings challenge the old view, dominant especially among paleoclimatologists, of the invalidity of historical climate data.

A method which creates an image of the past climate directly (and only) from historical sources is not adequate. Likewise, constructing an image from the paleoclimatological reconstructions may not be sufficient, as the reconstructions are not sensitive to the temporal and seasonal changes. Thus, to understand the past climate and its impact on man, it is essential to use both sources of climatic information when studying the fluctuations of past climate. The method of comparing and combining historical climate data and paleoclimatological reconstructions, which was introduced in this thesis, proved to be applicable, when the focus was on climate's seasonal trends which were multi-annual or decadal by their nature. The findings highlighted the importance of focusing on temporal seasonal trends in future research, rather than studying the impacts of the long-term climatic trends, like the MWP or the LIA.

As mentioned above, the paleoclimatological and historical climate data did not correspond unambiguously with each other, but this did not vitiate the value of the historical climate data. In addition, it was found that the famine data corresponded with the historical climatic data. Thus historical sources may represent climatic fluctuations which have had an impact on societies even better than paleoclimatological reconstructions. Paleoclimatological reconstructions have an emphasis on long-term climatic shifts, which might be too wide a time span to identify the fluctuations that have an impact on food systems. Yet, it is essential to include paleoclimatological research historical study on climate and its impacts, as it provides climatic information on a long scale, and helps to identify climatic variations in accurate perspective.

The second part of this thesis investigated the climatic changes in relation to hunger. Inevitably climatic conditions and hunger had a connection, although a complex one. Crop failures, which resulted from summer or autumn frost, were the main reason for climate-related hunger in the medieval North-East Europe. However, the societies' vulnerability to crop failures varied temporally and spatially. Societies which practiced slash-and-burn cultivation were most likely less vulnerable to crop failures than societies which practiced arable cultivation. In addition, hunger in the Middle Ages did not usually result from poor harvest alone, and other factors, which may have increased the vulnerability to crop failures were identified. A closer examination showed that the crop failures may have been the trigger for famine, but the situation most likely required some other factors to breakout into severe hunger.

Based on the findings of this paper, no specific climatic conditions can be named to cause hunger in the medieval North-East Europe. In addition, it appears that the long term climatic trends, the MWP and the LIA, did not have a significant impact on the occurrence of hunger or famines. Presumably the medieval society could cope better with slow and long-scale changes, like the LIA, as people had time to adapt to the changing environment, but rapid, unexpected climatic changes seemed disastrous. In general, any sudden change or unpredictable weather phenomenon could have caused hunger in the medieval North-East Europe. Cold conditions, in specific, seemed to lay stress upon food systems. The more severe and atypical the weather phenomenon was, the more likely it led hunger. Yet, the definitive factor for climate related hunger was found to be the level of society's vulnerability.

The level of vulnerability was in proportion to social conditions. The society's vulnerability to climatic hazards increased during the studied period, although on a different temporal scale in different places of the region. The medieval North-East Europe went through a social process between A.D. 1100 and 1550, which eventually changed the relation between climatic change and hunger: the severity of hunger was not determined anymore only by the severity of the climatic hazard, as the level of socially produced vulnerability became more and more essential in how efficiently societies could cope with the climatic changes. The main determinants of this socially produced vulnerability were found to be in economy (e.g. in the shifts from hunter-gathering to agriculture and from slash-and-burn cultivation to arable cultivation) and in administrate power (e.g. in need for taxes and labour). The vulnerability increased in most parts of the studied area in the fourteenth and fifteenth centuries. A closer examination proved that this did not result from the climatic change from the MWP to the LIA, as increased vulnerability went hand in hand with the transformation process of the societies, the strengthening of the administrative power and the transition to permanent agriculture.

Previous studies have proved that arable cultivation and specialized agricultural production increased vulnerability. Thus, famines were most likely more severe in towns and populated areas than in the rural areas where the sustenance was gathered from various sources, like slash-and-burn cultivation, fishing, and hunting. In addition, the alternative sources for livelihood were more accessible in the rural areas than in towns. Thus, it was essential to pay attention to temporal and spatial factors when studying the climate in relation to hunger in the medieval North-East Europe. For instance, the Great Famine did not most likely occur in

North-East Europe, at least in the same extent as in Western Europe, due to the diversified sources of food production and gathering.

This research has proved that it is inadequate to study climatic changes in relation to hunger without taking in the account the social processes that happen simultaneously. This notion is essential to keep in mind in future research. In addition, it was found that the theories of vulnerability from ecology and social sciences can be more appropriate to the historical research on climate and its impacts than the old historical paradigm of climate-related hunger. Although the findings did not invalidate the old paradigm, this paper proposed new areas of emphasis for historical research, when the connection between climatic conditions and hunger is examined. Medieval hunger did not exist only because of unfavourable climatic conditions, and the pivotal reason for hunger was usually found in socially produced vulnerability. Thus, focusing on the systems of vulnerability in historical perspective may provide new interpretations about the relation between climate and hunger in future research.

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List of Abbreviations

CHL	=	Chronicle of Henry of Livonia
CL	=	Chronicle of Livonia
DF	=	Diplomatarium Fennicum
FMU	=	Finlands medeltidsurkunder (Finnish Medieval Sources)
MWP	=	Medieval Warm Period
N1	=	Novgorod First Chronicle
LIA	=	Little Ice Age
SKS	=	Suomalaisen kirjallisuuden seura (Finnish Literature Society)
URA	=	Utdrag ur ryska annaler (The Extract From Russian Annals)

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APPENDIX

Appendix A: *Nature's archives.*

RECONSTRUCTING PAST CLIMATES FROM NATURE'S PROXY DATA

TREE RINGS

Trees' response to climatic variations is recorded in the annual growth rings. Tree ring widths, structure (density), isotope information and changes in the upper tree line limits are proxy indicators, which are used in dendroclimatological reconstructions. The reconstructions are made trough cross-dating, removal of non-climatic trends from individual tree ring series, averaging the series into chronology, and transforming the measured variability into climate variability. When directly calibrated against the instrumental records, reconstructions provide high accuracy and precision on temporal scale. Tree rings provide both long-term (low-frequency) and short term (high-frequency) climatic information. In Polar Regions (e.g. in Lapland) ring widths are relatively sensitive to variations of temperature, whereas in Torrid Zone, non-climatological hydrologic changes (e.g. ground water levels) can affect notably on the tree's growth.

Climatic events concerned: Temperature, precipitation.

Time of resolution of the observations: Ring width one year, cell structure one to five weeks.

Lags in response: Ring width depends on up to 15 months previous weather, cell structure a few days.

SEDIMENT VARVES

Annually varved lake sediments, formed from the deposition of clastic and organic matter, are controlled by seasonal precipitation, floods and summer temperature. Due to varves' precise chronological control and seasonally discernible laminae, they provide proxy material for high-resolution climate reconstructions. In addition, sediment varves contain organic material, e.g. pollen, midges, and diatoms, which contain additional quantitative climatic information (see bellow).

Climatic events concerned: Summer temperature, precipitation, stream flow.

Time of resolution of the observations: One year.

Lags in response: Days or weeks.

PEAT BOG DEPOSITS

Bogs contain vegetation history and hydrological signal, which can be generated from peat records with high temporal and taxonomic precision. Reconstructions made by bog data represent long scale and long term processes of hydrological conditions and humification. In addition, bogs can contain information of forest fires and human activity. However, the bog data may not respond undoubtedly to large-scale climatic changes, as local factors associated with microtopographical dynamics are more evident in the data.[184]

Climatic events concerned: Wetness dynamics, mean water depth (when used pollen analysis: temperatures).

Time of resolution of the observations: —

Lags in response: —

[184] Väliranta et al. 2007.

PLANT FOSSILS (here: diatoms, pollen stratigraphy)

Pollen is the most widely studied proxy in the lake sediments, and it provides a record of past vegetation changes, which may have caused by the changes in climate. Certain flora (e.g. some cereals, weeds, and trees) requires certain climatic conditions to survive, and plants can be extremely sensitive even to small scale temperature and precipitation variations. By analysing the deposited pollen data from varved sediments, paleoclimatologist can identify changes in past climate. The dating of the data is made by age-depth models and usually verified by radiocarbon dating. As with tree rings, the pollen data is calibrated against the instrumental records. Besides pollen, the lake varves hold organic fossils from lake flora, which is climatically dependent, at least to some extent. Diatom assemblages have been related to lake water temperature in summer. Oxygen isotopes in the silica of diatoms can be also used in reconstructions (see below). Pollen data provides information of broad-scale climatic changes (centennial to millennial), where as diatoms can indicate shorter term (multi-decadal) climatic patterns.

Climatic events concerned: Temperature, precipitation.

Time of resolution of the observations: Pollen about 100 years (in places where sediment laid down rapidly, or with rapid bog growth, 20—50 years); Diatoms five to 20 years[185].

Lags in response: Quick response to unfavourable conditions, although due to the slow migration of vegetation, can be centuries or even millennia.

INSECT FAUNAS (here: fossil midges)

Insects are able to occupy new territory fairly rapidly following a climatic amelioration, and thus provide a more sensitive response to climatic variation than plants, which have much slower migration rates. The assemblages of midges in the lakes varves are related to the surface water temperature of the lakes in the summer.

Climatic events concerned: Stream flow, summer air temperature.

Time of resolution of the observations: About 100 years.

Lags in response: Sometimes negligible. Most likely few decades, or at most centuries.

AVALANCHE CONES

Snow avalanche cones hold clastic material, isotope and pollen data, and naturally, ice. Changes in the layering thickness can be used to estimate changes in temperature and precipitation. The stratigraphy of buried soils in cones indicates avalanche activity, and as this activity depends upon the amount of snowfall, it indicates the amount of winter and spring precipitation. In addition, avalanche cones hold isotope and pollen data, which can be used as a proxy in temperature and precipitation reconstructions.

Climatic events concerned: Temperature, duration of the melting season, snowfall.

Time of resolution of the observations: Determined by the time resolution by the dating technique.

Lags in response: About 10 to 20 years.

[185] Weckström et al. 2006, 79.

STABLE ISOTOPE MEASUREMENTS

Climatic factors, such as temperature and humidity, as well as local factors such as light conditions and soil moisture, affect the fractionation of the isotopes. These isotopes can be found on annually layered lake sediments, ice-sheets, tree rings, peat bogs, and other fossil material (among other, for other possible sources, look Bradley 1999, 129). By measuring the isotope ratio from the proxy matter, paleoclimatologists can estimate low frequency climatic changes, like temperature anomaly and hydrologic changes.

Climatic events concerned: Temperature, precipitation (snow: ice-sheets, rain: tree rings).

Time of resolution of the observations: At best on ice-sheets: few days or weeks, at best on tree rings: about 30 years, on sediments and bogs: from 100 to 2500 years.

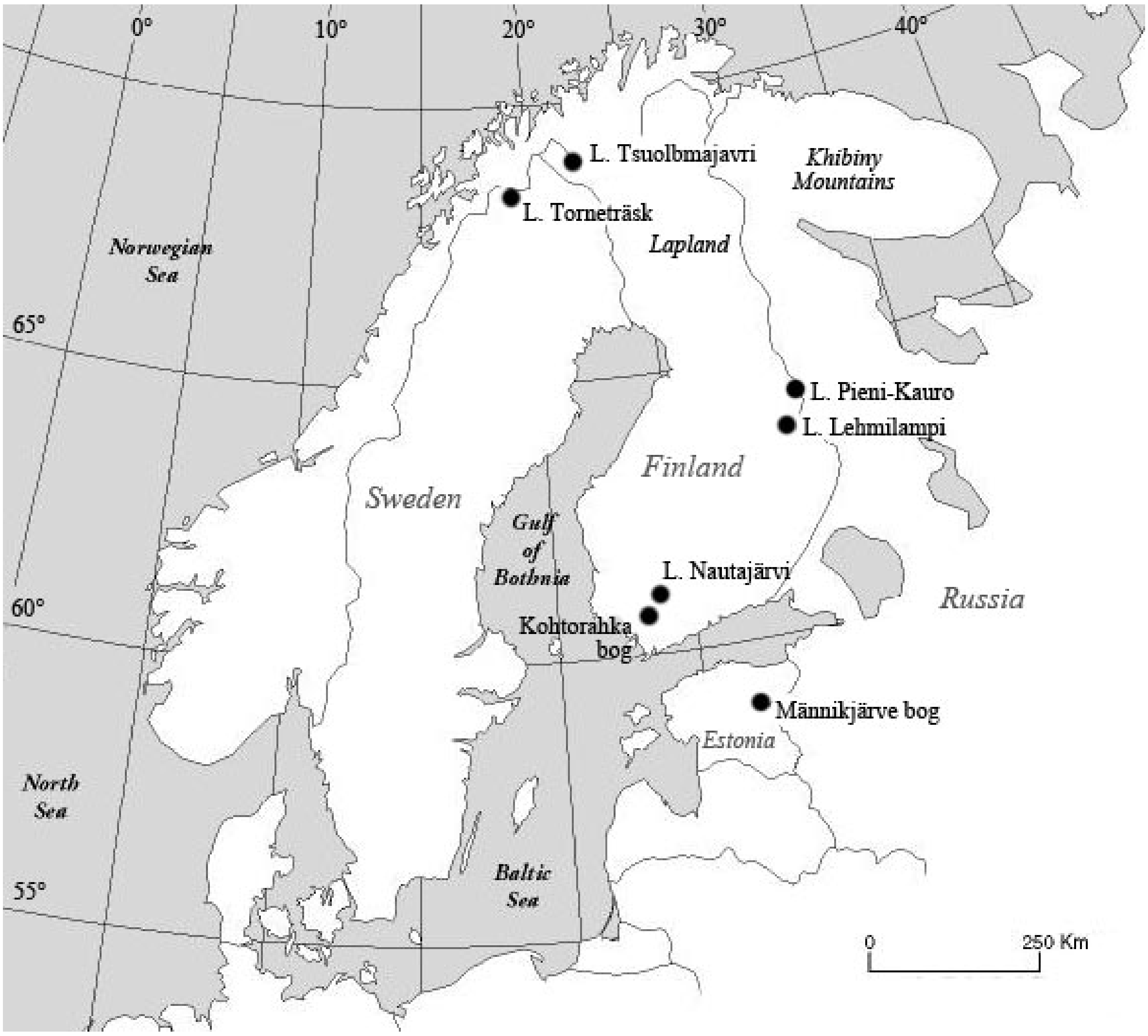
Lags in response: —

Sources:

Bradley, R. S. 1999. *Paleoclimatology: Reconstructing Climates of the Quaternary*, pp. 125—436. 2nd ed. Academic Press, San Diego, CA.

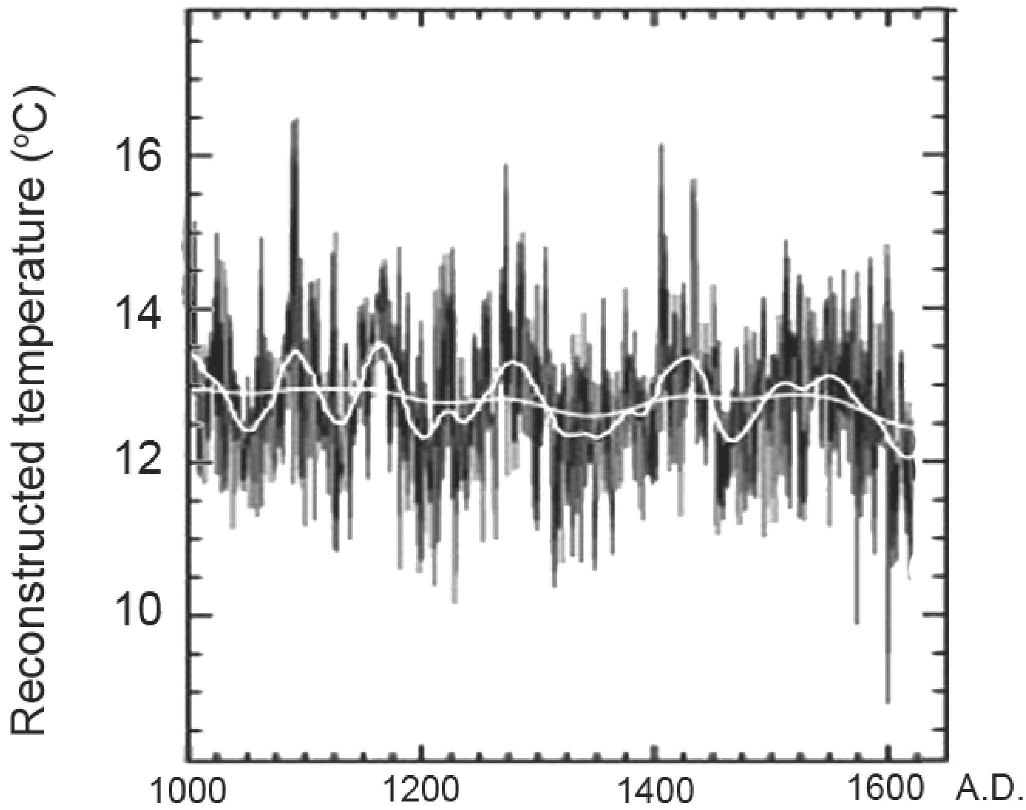
Lamb, H. H. *Climate, History and the Modern World*, pp. 102—107. Routledge, Guildford, Surrey.

Appendix B: *Map 2. Locations of the paleoclimatological reconstructions.*

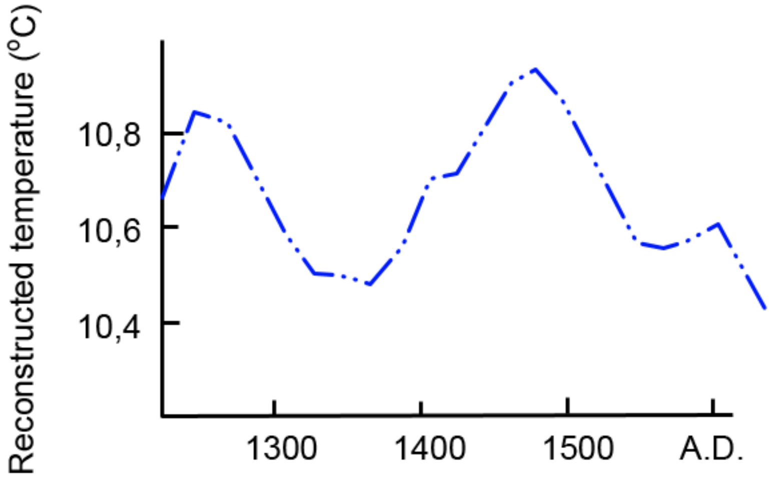


Appendix C: *Climate reconstructions*

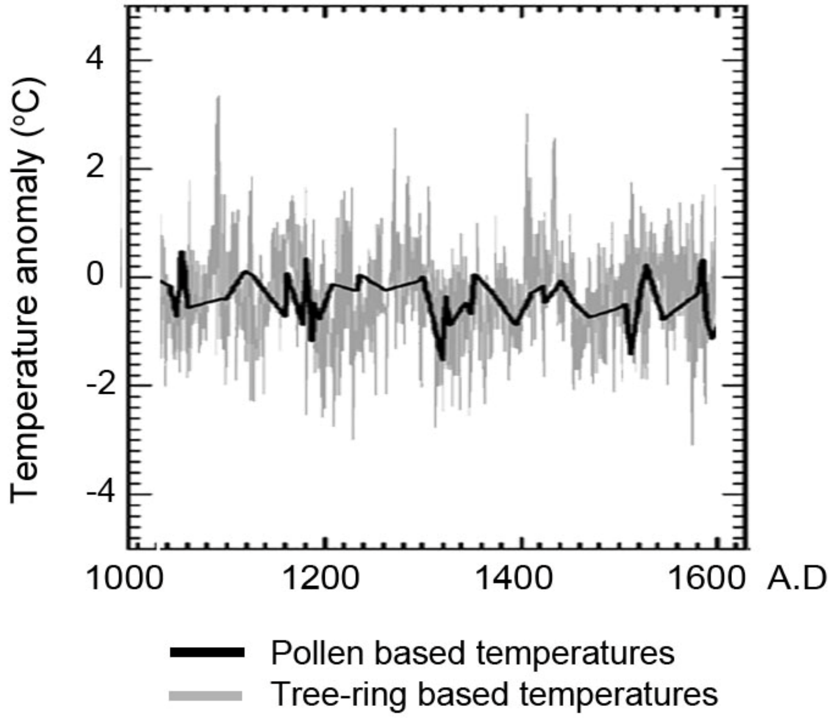
a) Helama et al. 2009b. Reconstructed temperature variability depicts total variations (black line), decadal (white line), and centennial (gray line) variations.



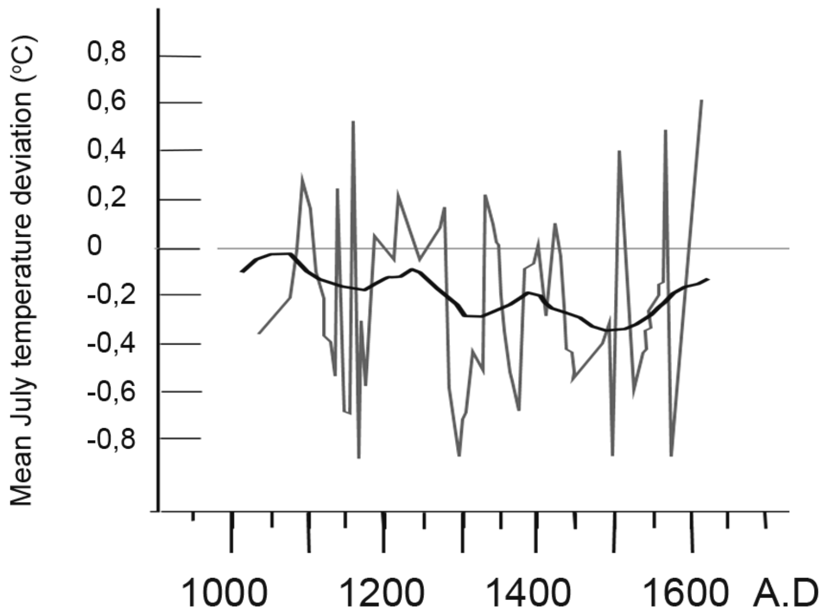
b) Weckström et al. 2006. Reconstructed temperature variability on decadal time scale.



c) Helama et al. 2010. Reconstructed temperature anomaly. Comparison of the paleoclimatic reconstruction of July temperature variability based on palynological and dendrochronological evidence.

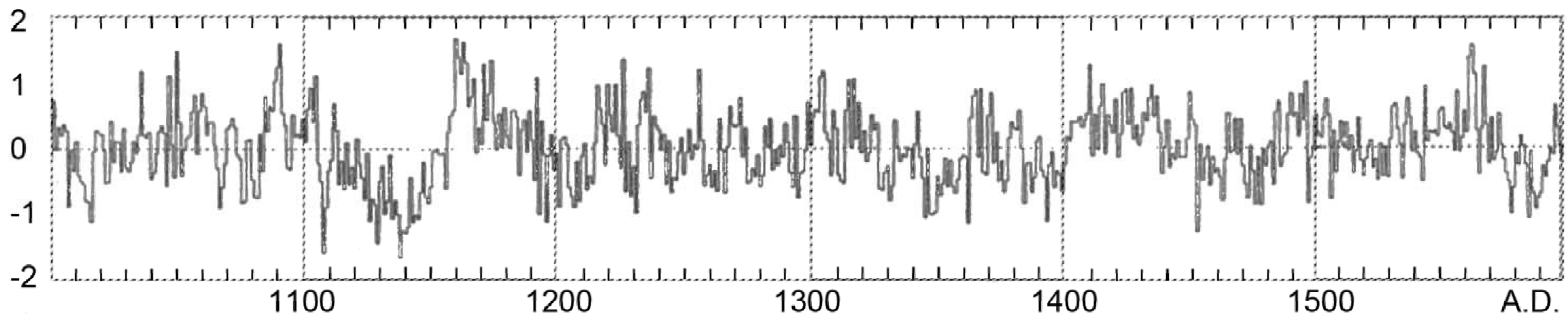


d) Bjune at al. 2009. Reconstructed mean July temperature deviations (gray line) and smoothed temperature variations (black line).

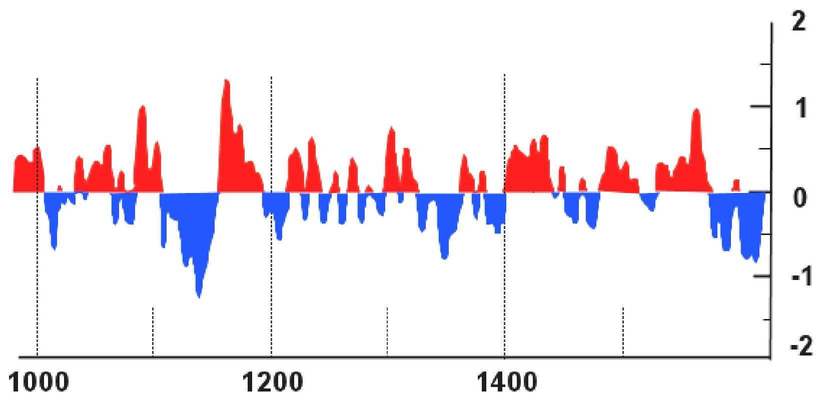


e) Briffa et al. 1990.

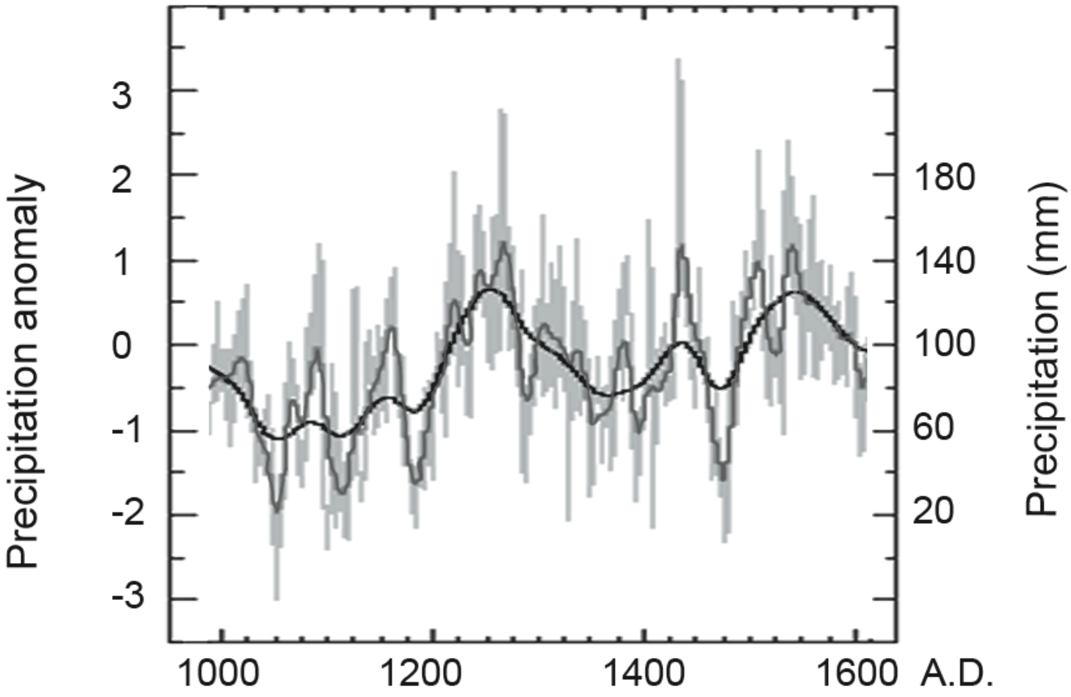
I) Reconstructed April-August mean temperature anomalies (^oC).



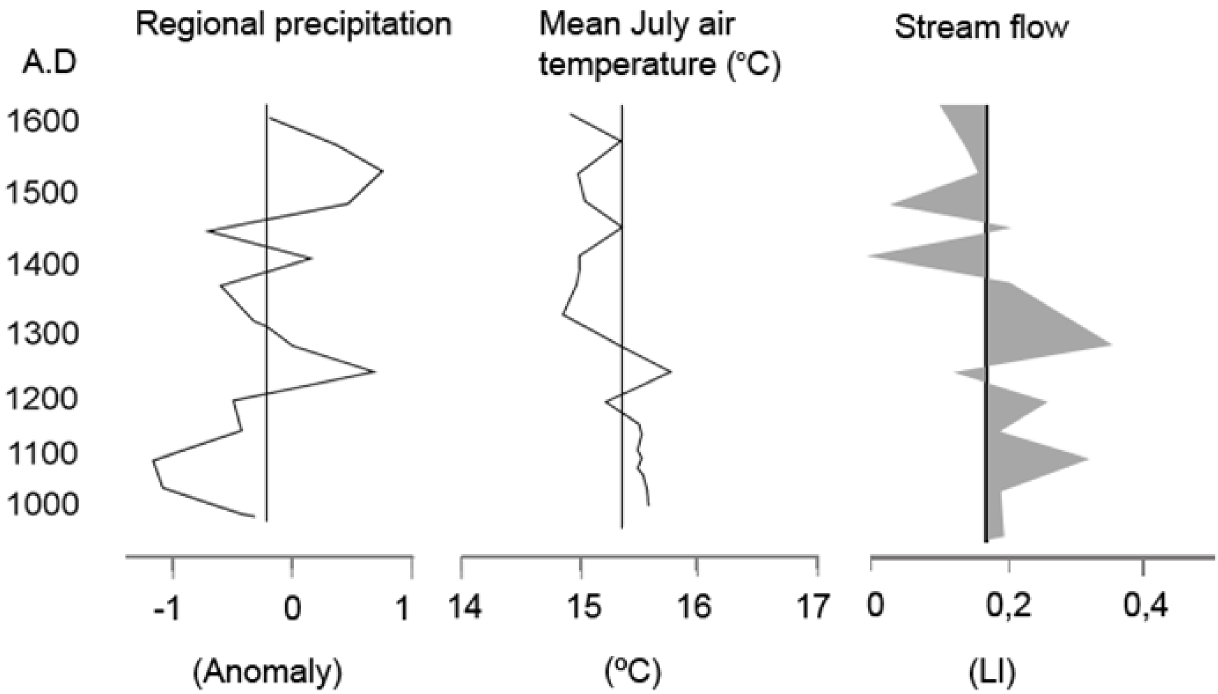
II) Reconstruction smoothed with a 10-year filter.



f) Helama et al. 2009a. Precipitation variations on interannual (light gray line), multidecadal (dark gray line), and centennial (black line) time scales.



g) Luoto & Helama 2010. Tree-ring based precipitation reconstructions, and midge inferred summer temperature and stream flow reconstructions.



Appendix D: *Akiander's abbreviations (the year of access in brackets).*

N. Kgsb	=	the Chronicle of Bygone Years (Moscow 1784)
N. Lawr.	=	the Laurentian Chronicle (Moscow 1824)
Forts.	=	undefined transcript of "the Nestor's Chronicle" (Saint Petersburg 1767)
Sof.	=	the First Sophia Chronicle (Moscow 1820)
Nik.	=	the Nikon Chronicle (Saint Petersburg 1767–1792)
Susd.	=	the Suzdal' Chronicle (Saint Petersburg 1792)
Nowg. I	=	the First Novgorod Annals (not the same as 1914 edition used in this study) (Saint Petersburg 1841)
Nowg. II	=	the Second Novgorod Annals (Saint Petersburg 1841)
Nowg. III	=	the Third Novgorod Annals (Saint Petersburg 1841)
Psk.	=	the Pskov Chronicle (Moscow 1837)
Arch.	=	the Arkhangelsk transcript (1819)
Sol.	=	the Annals of Solovetsky (1847)
Dwin.	=	the Annals of Dvina (1774)

Most of these above mentioned annals, chronicles, and transcripts have been compiled and edited after Akiander's days, and republished as new editions in the 1990's and 2000's.

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