Chapter 3
Combining Written and Tree-Ring Evidence to Trace Past Food Crises: A Case Study from Finland

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Abstract The lack of written source material on population and food availability has hindered studies on medieval and early modern food crises in many parts of the world. Examining the case of sixteenth and seventeenth century Finland, this article explores how indirect evidence—so called proxy data—could be used to identify past food crises. The proxies of past climate, grain harvest, storage capacity and population variability were derived from tree-ring studies and early administrative accounts. Evidence from "natural" and written archives supplemented each other. The applicability and limitations of using proxy data to trace past food crises is further discussed by comparing the examples of the sixteenth and seventeenth century to the better documented famine period of the 1860s. It was found that tree-ring data and early administrative accounts provides valuable material to identify past food crises.

Keywords Climate · Hunger · Finland · Proxy data · Agriculture

Introduction

Finland is often considered to be the most northern agricultural country in the world (e.g. Mukula and Rantanen 1987; Häkkilä 2002; Hollins et al. 2004), where hunger, frost and crop failures constitute recurring themes in the narratives of its agricultural history (e.g. Jutikkala 2003; Solantie 2006; Lappalainen 2012). Prior the industrial era harvest success was largely mediated by climate fluctuations (Huhtamaa et al. 2015; Huhtamaa and Helama 2016). Estimations from 18th century Finland state that, on average, during two years of any given decade the harvest was lost, while it was poor in three years, mediocre in four, and only one year was expected to bring a good or abundant harvest (Gadd 1785, 3). Later studies on the frequency of early modern crop

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failures are largely based on this 18th century estimation (Weckström 1850; Melander and Melander 1924; Keränen 1931; Myllyntaus 2009). Before the 20th century, 80% or more of the Finnish population gained their livelihood from subsistence agriculture. Thus, if the harvest was lost or badly damaged twice per decade, it may appear that the society was constantly living on the edge of a subsistence crisis.

Therefore, it is rather surprising that past subsistence crises have not gained much attention from Finnish historians. Insight into medieval and early modern subsistence crises is particularly scant, which most likely results from the lack of written contemporary sources. "Natural archives", however, have recorded past environmental changes when men have not. As high resolution tree-ring data from the region is available in large quantities, Finland makes an excellent case study on the connections between climate-sensitive food production and related crises. Not only do tree-ring data indicate temperature and precipitation fluctuations in Finland with high accuracy and precision (Helama et al. 2009, 2014; Matskovsky and Helama 2014), it can also reveal regional harvest fluctuations and years of crop failure (Hustich 1947; Mikola 1950; Huhtamaa et al. 2015; Huhtamaa and Helama 2017). Various administrative registers from the early modern period provide additional information on the economic condition of the population. The medieval and early modern natural or written sources do not provide direct evidence as to whether there was a subsistence crisis or not. Yet, data from these materials can be aggregated into annual time series, where negative anomalies might indicate years of possible subsistence crises. This article explores whether crop failures and subsistence crises can be identified and quantified from these different time series of indirect indicators of subsistence crises in Finland during the "Little Ice Age" (LIA, c. 1450–1900 in Finland; for the dating of the LIA, see e.g. Weckström et al. 2006; Luoto and Helama 2010; Helama et al. 2014).

The only exceptions of the little known history of Finnish subsistence crises are the famines of 1695/1697 and 1867/1868 which have piqued the interest of historians for decades. During these famines approximately 27% (1695/1697) and 8% (1867/1868) of the Finnish population died from malnutrition and related diseases, respectively (Muroma 1991, 292; Pitkänen 1991, 207). Although the frequency and severity of past subsistence crises during the LIA have not received careful examination in Finland, crop failure and hunger are widely used as explanations for social distress, especially during the early modern period. In this context, the turn of the sixteenth and seventeenth century is particularly interesting, as a peasant uprising raged in Finland in 1596/1597 and a civil war shook the whole kingdom in 1598/1599. In both incidents, crop failure and hunger have been connected to the events, although they have not been regarded as their primary causes (see, e.g., Lappalainen 2009, 67, 165, 216). Moreover, the 1601 food crisis is known as "the great straw year"[1] in Finland, and although no reliable estimates of the human consequences of the crop failure exist, the year has been compared to the fatal crop

[1]Finnish: *Suuri olkivuosi*. Replacing grain flour with grounded straws was a common practice during famines in pre-modern Finland.

failures of 1695 and 1867 (Voipio 1914, 1). In fact, the existing chronologies of Finnish crop failures paint a gloomy image of the turn of the century. According to estimates, Finland was suffering from major crop failures from 1595 to 1598, in 1600/1601 and 1609 (Melander and Melander 1924, 352; Myllyntaus 2009, 83). The chronologies may be unreliable, however, as they are spatially biased and misleadingly include Russian and Swedish events (Huhtamaa et al. 2015, 719). In order to identify and quantify the possible crises, this article compares the indirect evidence of the "hunger-ridden" turn of the sixteenth and seventeenth century to the better known famine periods of the 1690s and 1860s.

Finland's geographical location at the northern margin of agriculture, where long winters disrupt trading routes over the Baltic Sea for several months, influenced the country's food system (Holopainen and Helama 2009, 216–217; Huhtamaa and Helama 2017). As the majority of the population gained its livelihood from subsistence agriculture, imported grain constituted a minor share of the total grain demand of the country (less than 2% in the eighteenth century, approximately 14% in the 1860s).[2] Thus, the country was more or less self-sufficient in food production up until the late nineteenth century.[3] Cultivation was limited mainly to winter rye (*Secale cereale* L.) and spring sown barley (*Hordeum vulgare* L.), two principle grains which tolerate the shortness of the growing season. In pre-industrial Finland, crop yield fluctuations followed the spring and summer temperatures (Huhtamaa et al. 2015, 713–714). Compared to the food systems in continental Europe, the food system in Finland seems to have been relatively simple. The more complex food systems are, the more diverse responses to climatic factors and their impact on populations can be expected. Thus, the case study of pre-industrial Finland appears to be an ideal starting point for exploring the feasibility of proxy evidence in studying past subsistence crises.

Indirect Sources of Subsistence Crises

A subsistence crisis is a crisis of food supply, resulting in increased mortality due to starvation and diseases, whereas famine refers to a catastrophic crisis where the scarcity of food is extremely severe and population loses widespread (Ó Gráda

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[2]Estimations are based on contemporary population and trade statistics published by Statistiska Central-Byrån (1871) and Suomen virallinen tilasto (1868, 1875).

[3]Finland was part of the Swedish Kingdom from the Middle Ages until 1809, when Sweden lost the Finnish War (1808–1809) to the Russian Empire. Thereafter Finland became an autonomous part of the Russian Empire known as the Grand Duchy of Finland up until 1917, when the country declared its independence. In this article, the geographical area that covers modern day Finland is referred to as "Finland" throughout the study period, although no such country existed before 1917. Under Swedish rule Finland was a part of Sweden proper, not dominion or possession of the realm (like, for example the Baltic states in the seventeenth century). During the Russian rule, Finland enjoyed a high degree of autonomy, particularly considering the economy.

Table 3.1 Observed and measured climate, food supply and population statistics and corresponding proxies (i.e. the indirect indicators) from Finland

	Statistical data (continuous series from)	Proxies (first records from)
Population	Population statistics (1749)	Parish registers of baptized and buried (late-17th c.)
		Deserted farms (mid-16th c.)
Food supply		
Production	Harvest statistics: some provinces (1861), the whole country (1871)	Tithes (mid-16th c.)
		Tree-rings (pre-11th century)
Distribution and exchange	Grain import (1738) and export (1810)	–
Affordability and allocation	Food prices: Helsinki (1813), whole country (1920)	Swedish consumer and grain prices (1290) Deserted farms (mid-16th c.)
Climate	Observations (1829)	Tree-rings (pre-11th century)

The year in parenthesis indicates the first year from which the time series are available

2009, 6). Whether food crises and famine events initially result from a production failure or an unequal distribution of food is a matter of debate (see e.g. Sen 1981; Fogel 1992; Pfister 2010). Nevertheless, the key characteristics of the outcome are widely agreed upon: increased mortality due to scarcity of food. Statistics on population and food availability can therefore be used to identify and quantify subsistence crises and famines. However, reliable and comprehensive statistics on population and food supply in Finland are available only for the most recent centuries (see Table 3.1). In order to identify and study pre-industrial subsistence crises, we have to rely on indirect indicators of famine.

Lack of written sources poses a considerable challenge for studying medieval food systems in Finland. Yet, tree-ring data may indicate harvest fluctuations and food availability (Huhtamaa and Helama 2017). The source availability changes for the mid-sixteenth century with the regime of Gustav Vasa, when the emerging state started to keep detailed annual accounts in order to make the taxation system more efficient. Various accountants of the crown kept records on the holdings owned and taxes paid (Retsö and Söderberg 2015, 4). The next shift in data availability occurs in the eighteenth century when the state started to keep official statistics, e.g. on population and trade. Population statistics are available from 1749 onwards, whereas reliable statistics on food production, distribution and trade can be found mainly from the mid-nineteenth century onwards (see Table 3.1).

In this article, first the feasibility of proxy time series to study past crop failures and subsistence crises will be examined by comparing statistical time series of food production, prices and population from the 1860s famine period to the corresponding proxy time series from the 1690s and 1601 crises. Second, new information on the frequency of subsistence crises during the little studied "hunger-ridden" turn of the century will be provided by compiling the proxy time series from the turn of the sixteenth and seventeenth centuries, and by comparing these time series to the better-known famine periods of the 1690s and 1860s. The time series for the two latter famine events are explored over a 10-year period (1689–1698 and 1861–1870), whereas the lesser known turn of the sixteenth and seventeenth centuries is studied over a 30-year period (1590–1619).

Tree-Ring Evidence on Climate and Harvest Fluctuations

Pre-industrial crop cultivation in Finland was exposed to risk caused by cool climate, as the country is situated at the northern limit of successful agriculture. Fluctuations of the onset, length and thermal conditions of the growing season largely dictated harvest success (Mukula and Rantanen 1987, 8; Huhtamaa et al. 2015, 716). However, as continuous meteorological observations are not available before the 19th century (Tuomenvirta 2004, 13), information on past climate fluctuations must be attained from climate proxies—measurable parameters that capture certain climatic signals. Climate proxies can be found, for example, in tree rings, ice cores and sediment varves. In Finland, climate proxies from tree-ring data, and from maximum latewood density (MXD) in particular, have been proven to indicate warm season temperature fluctuations with high accuracy and precision (Briffa et al. 2002, 754–755). Tree-ring data can be dated to exact calendar years, which enables comparisons between tree-ring time series and written sources. Moreover, the relationships between tree-ring and instrumental climate data can be statistically explored and quantified over a calibration period—when the two time series overlap (Fritts 1976, 2–4). Such analyses have shown that reconstructions derived from Scots pine (*Pinus sylvestris*) MXD chronologies can serve to explain approximately 60% of the instrumentally measured thermal growing season[4] variability in Finland (Matskovsky and Helama 2014; Helama et al. 2014). Here, two MXD chronologies have been averaged in order to estimate temperature fluctuations over larger parts of the country (Fig. 3.1). The MXD data originates from Lapland (Matskovsky and Helama 2014) and south-eastern Finland (Helama et al. 2014).

Because the MXD parameter and the crop yield (the ratio of harvest to seed) respond to the same limiting climatic factors, primarily the length and temperature of the thermal growing season, the MXD chronologies may be used as surrogate data to estimate past crop yield fluctuations and to date years of crop failure (Huhtamaa et al. 2015, 718–719). Consequently, MXD data has been successfully used to reconstruct climate-mediated yield ratio fluctuations (Huhtamaa and Helama 2017). Yield ratio is one of the most commonly used indices for long-term

[4]The growing season lasts from May to September in the southern parts and from June to August in the northern parts of the country.

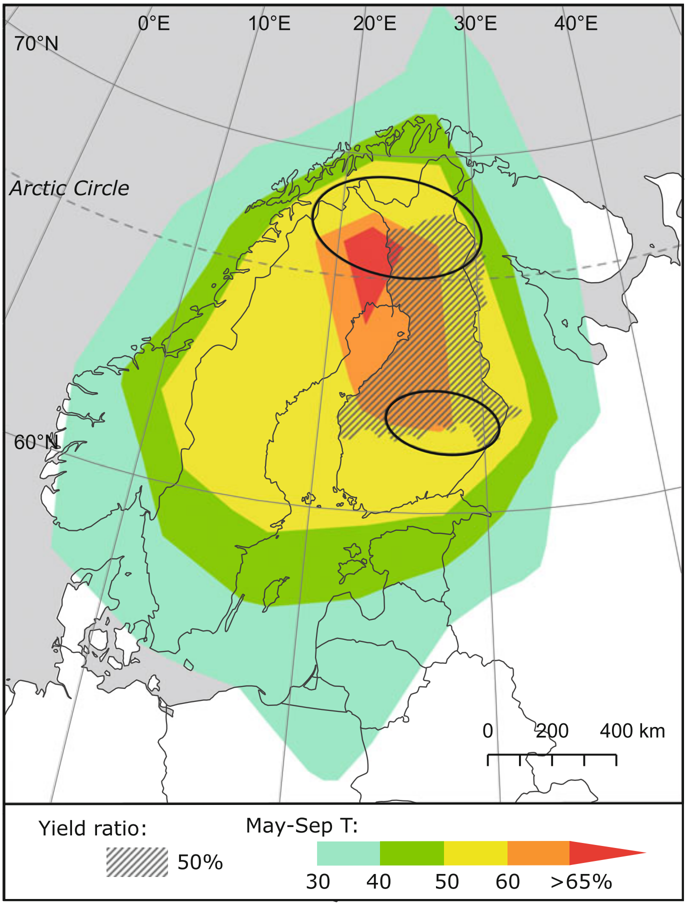

Fig. 3.1 Spatial synchrony between the MXD data and the documented yield ratios (*shaded*) and instrumentally measured May–September mean temperature. The correspondence between the proxy and statistical data is given in percentages, which have been derived by calculating the square of the Pearson correlation coefficient (r^2) between the MXD and yield ratio (over the period from 1866 to 1921) and May–September mean temperature (over the period from 1850 to 2000). The *circles* indicate the approximate sampling sites of the MXD data. *Sources* MXD data—Matskovsky and Helama (2014), and Helama et al. (2014); Yield data—Huhtamaa and Helama (2017); May–September temperature field data—Cowtan and Way (2014)

studies of food production (see e.g. Slicher van Bath 1963; Campbell 2000; Leijonhufvud 2001). Using yield ratio instead of the absolute harvest quantities (volume or mass) reduces the bias caused by variations in the area of cultivation, intensity of planting and population size (Hayward et al. 2012, 4166). Similar to climate reconstructions, when using tree-ring data as a yield ratio proxy, the relationship between tree-ring parameter and yield ratio time series have to be statistically explored over a common period. In doing so, the MXD based yield ratio reconstruction explains approximately 50% of the variance in documented yield in central and northern Finland (c. above 62° N, Huhtamaa and Helama 2017). In order to identify years of possible production failures, however, other evidence on annual harvest fluctuations should be gathered, considering that the reconstruction (see Fig. 3.1) can only explain half of the documented yield ratios and does not cover southern Finland.

Proxies of Population and Food Supply

Similar to natural proxy data, a variety of different indirect man-made sources can be used to explore pre-industrial food supply. Food supply is dictated by the prevailing food system, which consists of the components of food availability (production, distribution and exchange), food access (affordability, allocation, preference) and food utilization (nutritional and social value and food safety) (Gregory et al. 2005, 2141).

With the exception of some sporadic time series found in early modern manorial accounts (Tornberg 1989, 66–78), continuous quantitative series of harvest and sowing in Finland are only available from 1861 onwards (Suomen virallinen tilasto 1868, 1875). When yield ratio series are not available, tithe records can serve as proxy data for harvest fluctuations (see, e.g., Leijonhuvfud 2001; Edvinsson 2009; Campbell 2010). Tithe accounts related to annual harvest fluctuations, however, are available only for some regions and periods. In Finland two tithe systems existed simultaneously. The tithes could be paid either as grain tithes or as “fixed tithes”. In the latter system, fixed amounts of certain grain and other products were to be paid every year. Thus, the collected tithes were not dictated by harvest success (Seppälä 2009, 48, 255–256). The amount of collected grain tithes, on the other hand, could be dependent on the quantity of the sown or harvested grain crops. Grain tithes were collected primarily in western and southern Finland. Whereas the amount of collected tithes was based on harvest everywhere in these areas during the sixteenth century (Seppälä 2009, 48, 102), a century later the collected tithes were based on the quantity of seed in most parts of the grain tithe area (Muroma 1991, 15). The quantity of seed was fixed for each farm, so that the tithes cannot reflect any annual fluctuations. Only in Ostrobothnia in western Finland (see map on Fig. 3.4), the tithes were based on annual harvest fluctuations over the entirety of the early modern period.

Estimating food distribution, exchange, affordability and allocation constitutes the biggest challenge for the study of pre-industrial food systems in Finland. As the majority of the population gained their livelihood from subsistence farming, written sources of food prices, trade and reserves are extremely rare prior to the nineteenth century. Grain and consumer prices as well as import and export quantities are commonly used to indicate variations in food availability and access (see e.g. Campbell 2009; Edvinsson 2009; Seppel 2015). Annual grain and consumer prices are available for Sweden (Edvinsson and Söderberg 2010), which Finland was part of until 1809. Yet, the series may not indicate Finnish price variability accurately, as only a small fraction of the medieval data were derived from Finland and the early modern data originated almost solely form Stockholm (Edvinsson and Söderberg 2010, 11, 421, 425–426). First continuous rye price series (rye was the main component of Finnish peasant diet before the industrialization) are available for Finland from the early nineteenth century onwards (Vattula 1983) and annual import statistics for Sweden and Finland are available from 1732 and 1738 onwards (Statistiska Central-Byrån 1972), respectively.

Information about the nutritional and social value of food as well as dietary preferences and food safety prior to the nineteenth century can be found primarily from narrative sources. In most cases, however, distinguishing and quantifying the short-term variations from the narrative sources and compiling time series with an annual resolution—which is the temporal scope of the analysis here—is impossible. Therefore, neither the nutritional and social value, nor preferences and safety, are examined in this article.

Although the world's longest continuous population statistics are found in Sweden and Finland, these are available only from the 1749 onwards (Uttersröm 2008, 523–525). Prior to the time of official statistics, ecclesiastical registers of baptisms and burials provide additional information on population changes in Finland from the late seventeenth century onwards (Muroma 1991, 31–50). For the medieval and the early modern period, indicators of population crises have been derived from administrative registers of deserted farms (Jutikkala 1981, 117–120), as the crown kept registers of inhabited and deserted farms for tax purposes. Before the modern era, the majority of the farm holdings in Finland were owned by peasants. The peasant lost his ownership and heritance of the holding if he failed to pay taxes for three successive years (Seppälä 2009, 209–210). In such case the holding was marked as "deserted", *öde*, in the cadastres, releasing the farm for sale. Although the number of deserted farms has been shown to correspond to the mortality rates, as they did for example during the 1690s famine (Mäntylä 1988, 25–49), the registers should be used with caution as a population proxy. In the registers the term *öde* was applied irrespective of whether a whole household had perished from starvation or if they "only" had failed to pay taxes.

As nationwide population and food supply data are available only from the eighteenth century onwards, research on food crises dating before the eighteenth century focuses on the southern parts of the province of Ostrobothnia (see map on Fig. 3.4). This was the only province where tithe records were based on annual harvest fluctuations from the sixteenth to the eighteenth century, allowing comparisons between the two early modern famine periods of 1590–1619 and the 1690s).

Due to the data availability and different registration practices and changing units—like collected tithe and deserted farm data—the time series had to be adjusted before analysis. The adjustment procedures for both proxy series are detailed in the appendix. For the purpose of this study, the proxies of food production and affordability (MXD, tithe, yield ratio and price time series) were standardized to enable a rough comparison between the different famine periods.

The deserted farm data for the periods from 1590 to 1619 and 1689 to 1698 are given in percentages of inhabited farms. The demographic data for the periods from 1689 to 98 and 1861 to 1870 are presented as natural population changes, listing the difference between the number of births and deaths. Finally, the statistics of international trade for 1861 until 1870 are given as net import, the difference between import and export. All time series indicate the fluctuations of the harvest year, and not, for example the consumption or taxation year.

Climate, Frost and Crop Failure

The advantage of tree-ring data is that the time series can be calibrated against instrumental temperature measurements and official harvest reports, in order to explore the relationship between the proxy and temperature or crop yield statistically. Such comparisons have shown that in large parts of Finland, pre-industrial rye and barley yields were largely dictated by April through August temperatures (Huhtamaa et al. 2015, 714). However, summer season (especially harvest-time) night-frosts, not spring or summer temperatures, have been named—almost without an exception—as the principal cause for large-scale crop failures and famines in Finland (see, e.g., Manninen 1860, 33; Mukula and Rantanen 1987, 6; Myllyntaus 2009, 77–78). Night-frost is a short-term weather phenomenon, lasting only a couple of hours during the night. If such an acute weather phenomenon was indeed the main cause of large-scale crop failures, what can explain the strong correspondence between the April through August mean temperature, the MXD parameter and the yield ratio (Fig. 3.2)?

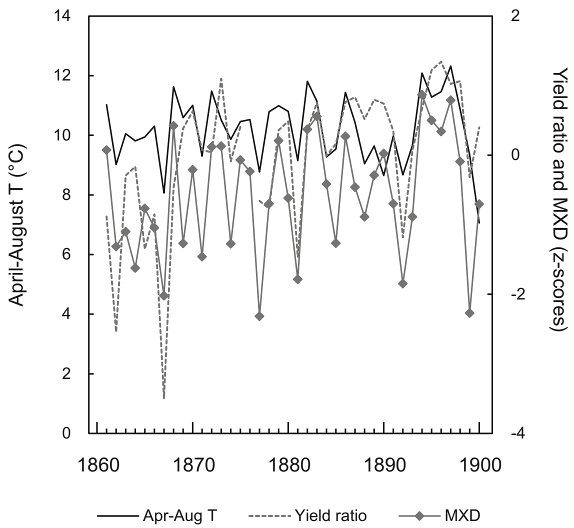

Fig. 3.2 Yield ratio, MXD and April through August mean temperature time series (averaged from three stations: Helsinki, Kuopio, and Oulu) for Finland over the period from 1861 to 1910. *Sources* Yield data—Huhtamaa et al. (2015); MXD data—Matskovsky and Helama (2014), and Helama et al. (2014); April through August temperature data—Tuomenvirta (2004)

During the Little Ice Age, peasants in Finland were well aware of the fact that night-frost could occur every year. They aimed to minimize frost damage by cultivating fields at different locations—as the topography of the land affects their frost prevalence—and by favouring autumn sown rye that ripened earlier than the spring sown varieties. Therefore, frost damage was usually local and did not affect the entirety of the harvest, although night-frosts destroyed crops on some fields almost every year (Lappalainen 2012, 61).

In addition, winter conditions and drought or excessive precipitation caused yield damages almost annually (Manninen 1860, 14–32; Mukula and Rantanen 1987, 4–8, 16).These damages, however, remained mostly local, as in Finland precipitation trends show a lesser degree of spatial synchrony than temperature trends (Holopainen and Helama 2009, 221–222). To put it simply, if the onset of the growing season was delayed and summer remained cold in one part of Finland, the situation was most likely the same all over the country. Yet, if excessive rainfall destroyed the harvest in one location, the precipitation conditions might have been more beneficial for the yields in another region. Cool spring and summer temperature anomalies delayed the ripening of the crops everywhere in the country to a period when the risk of night-frost was increased. In such years, not only frost-exposed fields and later ripening crops were at risk, but every field in every part of the country. If the weather conditions were favourable for night-frost to occur on such years, frost could swipe over the whole country and cause large-scale yield losses during a couple of hours. This explains the strong correspondence between spring and summer temperature, the MXD parameter (indicating both the temperature and harvest fluctuations) and the yield ratio. The examples of the 1695 and 1867 crop failures clearly demonstrate this causal relationship between temperatures and frost damages. On these years the extent and severity of the frost damage on crop yield was dictated by the preceding exceptionally cold spring and/or summer temperatures (Chernavskaya 1996, 1060; Jantunen and Ruosteenoja 2000, 70).

The Little Ice Age and Frequency of Crop Failures

As the length and temperatures of the growing season mediated the crop yields and determined the extent and severity of the annual crop yield loss in Finland, distinct phases can be statistically identified from the MXD data, when climate prevailed favourable or unfavourable for the crop yields (Huhtamaa and Helama 2017; Fig. 3.3). The climate was the most favourable for crop cultivation until the twelfth century and after the 1920s. The yield ratio reconstruction suggests that temperature limitations for crop cultivation were similar during the eleventh century and the latter half of the twentieth century. In the latter half of the twentieth century, severe night-frosts and related crop losses have occurred less frequently than during the early twentieth century (Mukula and Rantanen 1987, 6). Most likely, large-scale crop failures were therefore almost as rare in the eleventh century as they are

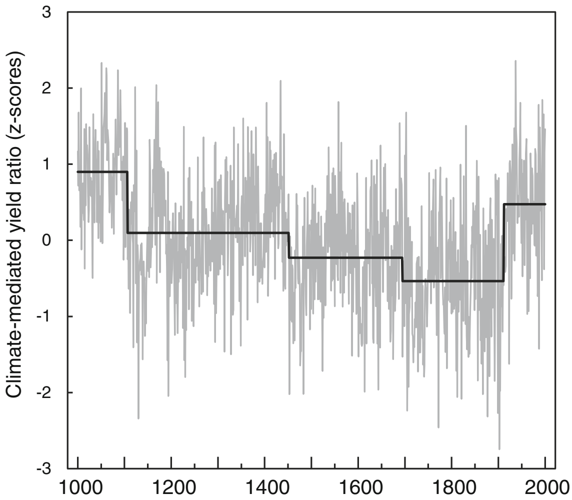

Fig. 3.3 Reconstructed climate meditated yield ratio (z-scores) 1000–2000. The *black line* shows statistically significant shifts in the reconstructed values. *Source* Huhtamaa and Helama 2016

today.[5] With the onset of the LIA (c. 1450 in Finland) yield ratios decreased. Although it is impossible to prove that famines were more frequent in Finland during the LIA than, for example, during the Middle Ages due to the scarcity of older sources, the yield ratio reconstruction suggests that the frequency of climate-driven crop failures was much higher during the LIA than during the previous and following centuries. Over the past millennium, the climatic conditions were the most unfavourable for crop cultivation in Finland from 1695 to 1911 (Fig. 3.2). Nevertheless, the reconstructed yield ratios suggests that large-scale production failures occurred less frequently in early modern Finland than it has been previously anticipated (Gadd 1785; Weckström 1850; Melander and Melander 1924; Keränen 1931; Myllyntaus 2009). The reconstruction does not support the hypothesis of severe crop failure taking place twice in the decade.

In addition to climatic conditions during the harvest year, the quality and quantity of seed grain affected harvest success (Huhtamaa and Helama 2017). In the Finnish subsistence agriculture, the peasant's yield was determined by his previous year's fields. As only a part (if any) of the fields could be sown after a year of crop failure due to lack of seed grain, the next harvest was most likely poor as well (Jutikkala 2003, 293). These back-to-back harvest failures resulting from the lack of seed grain are not visible in the MXD data. In addition, the availability of seed grain in the storages was not only determined by the previous year's yield; human action also greatly affected the amount of grain reserves.

The smaller grain reserves a peasant possessed, the more vulnerable the crop cultivation became to climate and weather. Wartime, for example, and related tax increase, raised the sensitivity of crop cultivation to climate and weather

[5]Over the last thirty years (1986–2015), only one year (1987) has been considered as a year of nation-wide crop failure.

disturbances as well. During times of heavy tax burden, peasants could not save enough for "rainy days". In addition to higher taxes, wartime brought the burden of the *borgläger*.[6] Under the *borgläger*-system, peasants were obligated to provide maintenance and provisions for the troops passing through. On some occasions, soldiers could even levy their wages directly from the peasants' food reserves (Ylikangas 1991, 85). As a result, peasants were left with less grain for seed and consumption. This, in turn, made their crop cultivation more sensitive to climate and weather disturbances. When the sensitivity of crop cultivation was increased, even minor disturbances in climate and weather patterns could entail severe consequences. As climate sensitivity altered due to storage reserves—which were, in turn, partly meditated by administrative practices—no threshold value for crop failure events can be established in the MXD series. To define such values, the impact of possible preceding crop failures and non-climatic factors (e.g. taxation and other burdens) on grain reserves should be evaluated and quantified.

Man-Made Proxies of Food Crises

The key challenge with the sixteenth and seventeenth century proxies of data on population (deserted farms) and food production (grain tithes) is that the time series do not extend to times when statistical data are available. Thus, the proxy series cannot be calibrated and verified against observed and measured population and crop yield statistics. This creates a source of uncertainty in the attempt to quantify the human consequences of early and late seventeenth century food crises. Nevertheless, when compared visually, the proxy (Fig. 3.4a, b) and statistical data (Fig. 3.4c) indicate a rather similar course of events for the years of subsistence crises (onset in 1601, 1695 and 1867). Following a year of cool growing season temperatures the harvest was poor. This is indicated by the low values of the MXD, tithe and yield ratio data. The proxy data (deserted farms and ecclesiastical registers of baptized and buried) and statistical data on population change indicate a population decline taking place one or two years after the crop failure.

Previously, grain prices have been used successfully to identify Nordic famines (Dribe et al. 2015) and Swedish harvest fluctuations (Edvinsson 2009). The grain prices in seventeenth and eighteenth century Finland, too, mostly followed grain availability.

During the first studied period (1590–1619) the highest peak in prices occurred in 1598. As discussed above, the data for this period originates mostly from Stockholm, thus local food availability might have distorted the prices. Coinciding with the price peak of 1598, a civil war troubled the Swedish kingdom, as King Sigismund and Duke Charles fought over the throne (Lappalainen 2009, 207–239). The civil war might have had a decisive impact on grain prices in Stockholm. The

[6]Also known as *burglager* system in English (Ylikangas 1991, 85).

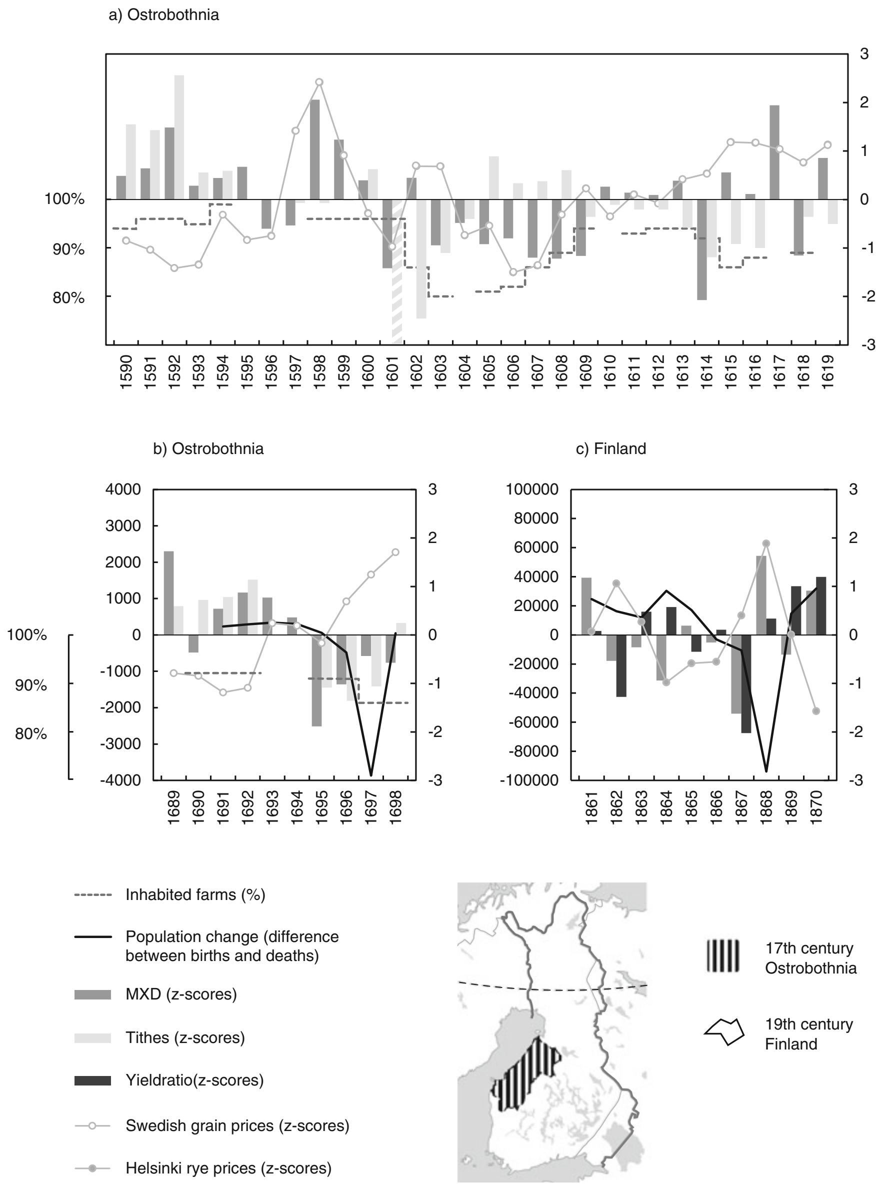

Fig. 3.4 Food supply and population time series over the two "proxy periods" (1590–1619 and 1689–1698) and over the period with corresponding statistical data (1861–1870). For all the time series (except the price series), low values indicate potential food crises. The y-axis on the left side indicates population variations: the percentage of inhabited farms (*dashed grey line*) and the difference between births and deaths (*solid black line*). The y-axis on the right side indicates food production (the MXD, tithe and yield ratio times series, *bars*) and price variability (*lines with markers*), both in z-scores. The year 1601 has been included in the figure (*bar with white shading*), although treated as a missing value when calculating the tithe time series (see Appendix). In the harvest year 1601 the peasants were exempted from paying tithes due to total crop failure (see below). *Source* see Appendix

city was the centre of the kingdom, after all, although the bloodiest battles of the civil war were fought far away. In Ostrobothnia, the paid tithes were somehow low from 1597 through 1599, yet the farm ratio series do not indicate notable hardships in Finland. Although the evidence for Finnish food crises provided by price data is not as unambiguous as the tithe and deserted farm time series, the price time series suggest that rising grain prices were the consequence of—rather than the cause for—subsistence crises, as the price peaks commonly lagged behind the crop failures by one or two years.

Although the tithe series identify the onset of the known subsistence crises over the two "proxy periods" (triggered by large-scale crop failures in 1601 and 1695) accurately, due to the missing tithe registers, dating past crop failure events solely with the tithe series remains problematic. For example, Ostrobothnia tithe records are not available for the years 1595 and 1596. The years 1595–1598 have been considered as crop failure years in previous research (Melander and Melander 1924; Myllyntaus 2009). Therefore, crop failure might explain the missing registers, like they did in 1601 (see below), so that missing data might be interpreted as an indicator of subsistence crises. The years of the missing records, however, coincided with a peasant uprising,[7] which originated in Ostrobothnia and raged in Finland during those years (Katajala 2002, 184–191). In fact, the bailiff's accounts for Ostrobothnia are missing altogether over these years (see Appendix). It is therefore quite likely, that social distress and related difficulties to keep annual accounts, rather than a food crisis, explain the missing registers over these years.

Nevertheless, the tithe time series can provide an insight into the non-climatic factors of food availability. As discussed above, severe crop failure can negatively affect the yields for a couple of succeeding years due to the lack of seed grain. Whereas the effect of poor quantity and quality of seed grain is not visible in the yield ratio reconstruction derived from the MXD data, the tithe records may provide additional information on the quantity of the grain reserves. If the granaries were empty, the peasants could neither pay their tithes nor sow the fields. Early-seventeenth century data supports this assumption, as the amount of paid tithes remained low for some years after the crop failure events in 1601 and 1614, although the MXD data suggest that the climatic conditions would have supported higher yields in 1602 and 1615.[8] On the other hand, the tithe series started to show higher values for 1605, when the MXD values remained low. This might indicate a fast adaptive capacity of the peasants. Although the temperatures remained low, the ascending tithe records suggest that the farmers found a strategy to gain sufficient harvest under deteriorating conditions. In further research, combining evidence from tithe and MXD series may provide insight into signs of storage reserves and coping capacity in a year-to-year resolution.

[7]The Club War (also known as the Cudgel War).

[8]A similar course of events can be seen for 1868, when the MXD data indicates climatic conditions favourable for high yields, but the statistical crop yield data indicates moderate harvest (Fig. 3.4c).

The two population series over the famine period of the 1690s—the farm ratio and the difference between baptisms and burials—indicate a similar course of events. The peak in mortality came two years after the crop failure. Similarly, the percentage of inhabited farms from the early 1600s indicates that the peak in mortality followed two years after the total crop failure of 1601. As discussed earlier, however, the farm ratio should be used with caution as a population proxy. New holdings and resettled farms do not appear in the data, as new farms were exempted from taxes for several years (Jutikkala 1981, 119). As the farm registers were based on tax-paying ability, the registers of deserted farms can still be used as an indicator not just for population variations, but also for fluctuations of wealth and impoverishment and thus food affordability.

The similarity of the trends evidenced in the food supply and population series over the two "proxy periods" (1590–1619 and 1689–1698) and over the period with corresponding statistical data (1861–1870) suggests that proxy time series with annual resolution might provide valuable information on the characteristics of pre-modern subsistence crises in Finland. Moreover, if seventeenth and nineteenth century food crises shared similar trends, the import and export statistics from the 1860s can provide a starting point to reflect on the significance of trade during the food crises of the seventeenth century, as only cursory remarks on the matter are found in written seventeenth century sources.

During the famine of the 1860s, quite surprisingly, the net import did not increase (Fig. 3.5), which raises questions as to the reliability of the import and export statistics as sources for identifying subsistence crises in pre-industrial Finland. However, the main route for grain imports in the 1860s was through Russia, which also suffered from severe crop failure in 1867 (Kahan 1968, 374). Thus, the low net import in 1867 and 1868 might simply result from difficulties at

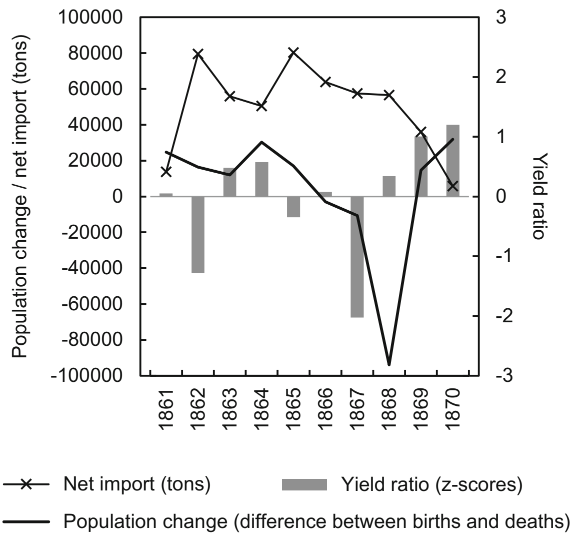

Fig. 3.5 Net import (in tons), population change and yield ratio in Finland 1861–1870 (*Source* see Appendix)

the port of export. Indeed, in 1862, when crop failure had struck Finland but not Russia, the import to Finland increased (Fig. 3.5). Although statistical, or proxy, data on annual import quantities is not available for earlier famine periods, narrative sources provide evidence that the authorities arranged additional grain aid to Finland in 1602 and 1697 (Lappalainen 2012, 215; 2014, 49). Yet, the additional grain shippings were modest (Seppel 2015, 230) and did little to help the rural peasants, who constituted the vast majority of the Finnish population, as poor roads and great need in towns hindered the distribution of the imported grain to rural areas. The country lacked functioning grain distribution systems from the coast to the inland and from the south to the north until the latter half of the nineteenth century (Ikonen 1991, 85). From the early sixteenth century onwards, the peasant's duty was to cultivate land and *provide* grain to the crown (Lappalainen 2012, 57–59). Establishing a grain import and distribution system across Finland might have therefore been an alien idea for the authorities. It can be argued that the early modern Finnish subsistence crises were not crises of failed import or distribution, as there was simply no working system in place—perhaps not even in the 1860s (Ikonen 1991, 85)—that could have failed.

Identifying and Quantifying Famines from Proxy Data?

The proxy time series of climate, food production and population, derived from tree-ring data and registers of tithes and deserted farms, appear to be promising material for identifying subsistence crises in pre-industrial Finland. The MXD and the tithe series supplement each other as harvest proxies, as tree-ring data captures the climatic signal, whereas the tithe series include the human component (like storage reserves), both important factors dictating harvest fluctuations. Over more steady periods, like in the early 1590s and 1690s, the MXD data and tithe series indicate rather similar evidence of annual harvest fluctuations (Fig. 3.4). Yet, when social distress affected the food system, the reliability and comparability of these series are weaker. Although the climatic conditions supported high yields in 1598 and 1599, for example, the paid tithes indicate that the harvest remained rather poor during these years. This was most likely due to internal distress like the repercussions of the unsuccessful peasant uprising and the power struggle between King Sigmund and Duke Charles. Overall, Finland was in turmoil for a couple of decades after the onset of the peasant uprising in 1596. Plundering soldiers, increased taxes, additional payments and arbitrary bailiffs, among others, could take a greater toll on the harvest than the unsettled weather (Lappalainen 2014, 51). Over these periods, the ability of MXD data to estimate past harvest fluctuations is weaker than during peaceful times, whereas the tithe time series can indicate the "hidden" component of the effects of human actions.

The tithe and deserted farm records suggest that the little known food crisis of 1601 could have been as severe as the 1690s famine. In fact, tithes were not collected at all in1602, as frost had killed the crops all over the country in the previous year.[9] The consequences of the 1601 crop failure are evident in the proxy time series at least until the year 1603. After the crisis of 1601–1603, the proxy data suggest the years 1614–1615 as being the most severe over the period from 1590 to 1619. The MXD data indicates the year 1614 as being the coldest one over a 30-year period. In addition, the amount of tithes collected in Ostrobothnia was the lowest in 1614 since the 1601–1603 crisis and the number of inhabited farms decreased notably in 1615. Additionally, rising grain prices followed the year 1614, quite similar to 1601–1603. As the years 1614/1615 have previously not been considered as years of crop failure or hunger, it can be argued that proxy time series may provide an insight on past food crises that are, for one reason or another, not mentioned in other sources and therefore overlooked by historians.

Considering the period of "chronic crop failure" of the late 1590s, the proxy time series of climate, food production and population quite interestingly do not indicate a single year of crisis. Yet, the tithe and deserted farm data has been gathered solely from Ostrobothnia. Therefore the situation may have been different in other parts of the county. The highest grain price peak over a 30-year period was in 1598, although this might have resulted from the civil war, as discussed above. Nevertheless, it is striking that the proxy time series barely agree with the existing chronologies of Finnish crop failures and famines. Over a 30-year period, the proxy data suggests food crisis occurring in Ostrobothnia from 1601 to 1603 and in 1614/1615, whereas previous research has dated major crop failures taking place from 1595 to 1598, in 1600/1601 and 1609 (Myllyntaus 2009, 83).

The period between the 1590s and the early 1600s was a time of constant power struggle between King Sigismund and Duke Charles. The peasant uprising in 1596/1597 and the civil war in 1598/1599 were interwoven in this battle. Hunger was one of the reasons (or excuses) for the contemporaries—and later an explanation for historians—for the peasants taking up arms (Ylikangas 2005, 15), which is why narratives of hunger and agony during these years were written down and preserved. Whether the scarcity of food resulted from a crop failure or heavy taxes, and whether the misery was real or exaggerated, might not be possible to discern from the narrative sources. Nevertheless, these descriptions have found their way into the existing crop failure chronologies. Where and when food crises may not have been considered worth writing down, proxy time series of climate, food production and population might provide new material for identifying crop failure and food crisis events in Finland.

[9]National Archives of Finland (NAF), Bailiff's accounts of Ostrobothnia 4827 (1602). Here, the tithe time series have been calibrated to correspond to the harvest year. The remark in the 1602 tithe registers indicates the harvest year of 1601.

Summary

During the Little Ice Age, harvest success in Finland was largely mediated by climate. Crop cultivation was limited to a couple of grain crops tolerating the shortness of the growing season at the northern margin of crop cultivation. Due to the rather simple food system, pre-industrial Finland is an optimal case study for exploring whether past subsistence crises can be identified from proxy evidence. Time series derived from tree-ring data as well as tithe and farm registers are promising material for identifying large-scale crop failures and subsistence crises. On the other hand, data on prices and import quantities, which have been successfully used in many other European regions for studying past subsistence crises, may not indicate accurately crises of food supply in a society, where the majority of the population gained its livelihood from subsistence agriculture, where taxes were largely paid in kind and grain trade and distribution was marginal.

Due to the availability of data, different registration practices and changing units—all of which varied both temporally and spatially—adjustment and standardization of the time series prior to the analysis was necessary. This enabled a coarse comparison between the three famine periods under examination.

Although harvest fluctuations were largely mediated by climate, subsistence crises were never solely “natural disasters”. Therefore, by compiling and comparing proxy evidence from natural and written sources, subsistence crises can successfully be identified. However, whether a crisis may have been “just” a severe crop failure or a catastrophic famine is difficult to distinguish without accurate population data. Here, for periods when population data are not available, the inhabited farm ratio time series were used as an indirect indicator for population fluctuations. Farm ratio proxies, however, might more accurately indicate tax paying ability than population variations.

The MXD and tithe records supplement each other as harvest proxies. MXD data provides new material for identifying climate-induced crop failures. The tithe series, on the other hand, suggest that storage reserves were a decisive factor determining the consequences of climate and weather on the crop yields. Taxes and other burdens of the state, in turn, affected the storage capacity. To better understand how—and with what limitations—climate proxy data could be used in historical research, the impact of human actions on food production sensitivity to climate and weather should be carefully identified and quantified in further research.

Natural and man-made proxy data provide useful material for historians to explore past subsistence crises. These data can even challenge established histories and chronologies, like the example of late-sixteenth century Ostrobothnia demonstrates. Consequently, proxy data can help us to contemplate why we know of some subsistence crises while others have been forgotten.

Table 3.2 Missing data by harvest year

Study period	1590–1619	1689–1698
Tithes	1594, 1595, 1601, 1617	1693, 1694
Deserted and inhabited farms	1594, 1595, 1597, 1604, 1610, 1617, 1619	1689, 1693, 1694

Note No explanation was given for the missing accounts, except for the harvest year 1601 when the tithes were not paid due to severe crop failure (NAF 4827)

Appendix

Annual registers for tithes and deserted farms in Finland can be found in bailiff's accounts up until 1634 and provincial accounts from 1635 onwards (National Archives of Finland, NAF). The accounts hold, inter alia, annual tax, land and tithe registers. The smallest unit in the accounts is the individual farm, which is grouped by villages and further by parishes. Some data were missing from the accounts, which are detailed in Table 3.2. With the exception of the deserted farm data for 1689–1698, which was derived from literature (Mäntylä 1988), the data for tithe and deserted farms time series was collected from the primary sources.

The parish tithes in Ostrobothnia were recorded by a measure of volume, which was commonly a barrel (146.35 L). Registers that marked the tithes in another measure of volume (mainly the 16th century registers), have been converted into barrels. In addition to the missing annual registers (Table 3.2), some sporadic parish accounts were missing from the registers over the period from 1590 to 1619, without any explanation given. The missing records might have resulted from crop failure, changes in local administrations (parishes could have been divided or joined together) or simply the result of a clerk's mistake. These matters pose a challenge for calculating the tithe time series. The parish series could not be summed up due to missing records. Moreover, the series could not be averaged due to the varying numbers and sizes of the parishes.[10] Thus, the annual tithe time series (T_i) was calculated as the weighted sum of the paid tithes (in barrels B) per parish (B_P) as:

$$T_i = \sum_{P \in Parish} B_P \cdot w_P, \tag{3.1}$$

where the weights (w_P) are the ratio between the parish tithes and all the recorded paid tithes in this year, $w_P = B_P \big/ \sum_P B_P$. To enable interproxy comparisons and coarse comparison between the different study periods, the tithe time series (T_i) was standardized (z-scores) as:

$$z_i = (T_i - \mu)/\sigma, \tag{3.2}$$

[10]Although the studied land area is constant over the 16th and 17th centuries, the number of parishes rose from 12 to 18 between 1590 and 1614.

where μ is the sample mean of the tithe time series and σ is the sample standard deviation of the series during the study period.

The recorded units in the deserted farm registers varied over the 16th and 17th centuries. On some years the number of the deserted farms were given as *mantals* (a taxation unit), on some years as number of peasant farms. The relation between *mantal* and peasant farm varied over time. In the mid-16th century one *mantal* more or less equaled one peasant farm, but in the early 17th century ½ and ¼ *mantal* farms were common in the land registers (Seppälä 2009, 63–68). Thus, to avoid bias due to changes in the recorded units, the deserted farm ratio for year i (F_i) between the number of deserted farms (F_D) and the total number of farms (F_T) of the same unit (*mantal* or peasant farm) was determined as

$$F_i = F_D / F_T. \tag{3.3}$$

To enable visual comparison between the deserted farm time series and population change data (see below), the deserted farm time series are presented in inhabited farm ratios in the illustrations (see Fig. 3.4). The ratio of inhabited farms for a year i is given by $1 - F_i$. The farm ratios are given in percentages.

Provincial population data form Ostrobothnia for the period 1689–1698 was derived from literature (Muroma 1991) and national data for the period 1869–1870 from the Official Statistics of Finland database. From these time series, an annual series of the natural population change (the difference between the number of live births and deaths) was calculated.

Provincial data on seed and harvest for both grains—rye and barley—were derived from the official statistical reports (Suomen virallinen tilasto 1868, 1875). The yield ratio time series were calculated as a weighted average of rye and barley yield ratios for each year as

$$Y_i = w_R \cdot Y_R + w_B \cdot Y_B, \tag{3.4}$$

where the weights are the fractions of harvested rye and barley, respectively. The grain specific yield ratios Y_R and Y_B were themselves calculated as weighted averages of the provincial yield ratios (the weights being the fractions of harvested rye and barley from a province compared to the total rye or barley harvest from all provinces). To enable comparison with the tithe series, yield ratio series were transformed into z-scores (cf. Eq. 3.2).

The data on Swedish nominal grain prices and Helsinki rye prices was derived from literature (Edvinsson and Söderberg 2010; Vattula 1983, respectively). The adjustment procedures of these series are presented in the original publications. Also the price series were transformed into z-scores (cf. Eq. 3.2).

The statistics for import and export for the period from 1869 to 1870 were derived from literature (Vattula 1983). Here, the net import, the difference between import and export, was calculated. The annual net import is given in tons.

And last, the tree-ring (MXD) data originated from Lapland and northern Finland (Matskovsky and Helama 2014) and southern Finland (Helama et al. 2014).

For the purpose of indicating annual temperature and yield ratio fluctuations over a larger part of Finland, the two time series were combined by normalizing the records into z-scores (cf. Eq. 3.2) and by averaging the normalized data into a mean MXD record.

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