Introduction

- Climatic conditions have largely influenced agricultural practices and crop failures.
- Short growing season, and related spring and summer temperatures, were the main limiting factors for the old agriculture.
- The aim is to examine written primary sources and tree-ring studies in order to:
  1. construct a chronology of large-scale crop failures,
  2. investigate on what frequency extreme climate events contributed to crop failures in 1300–1900 Finland.

An analogue from the 19th century

Quantifying the past effects of climate and weather on agricultural production is challenging, as evidence for past crop failures in Finland is scant, especially prior to the 19th century. This could partially result from both temporally and spatially fragmented (Table 1). However, reliable crop yield statistics, meteorological observations and other socio-environmental data with high accuracy and precision are available from the mid-19th century onwards. Therefore, the example of 19th century crop yield responses to climate and weather fluctuations is used as an analogue for the earlier times.

The contemporaries named early autumn night frost as the main reason for large-scale crop failures. Yet, the consequences of night frost on crop yields were partly dictated by preceding spring and early summer temperatures.

Low spring temperature delayed the onset of the growing season, sowings and flowering. Hence, the ripening extended to late summer or early autumn, when the risk of crop failure due to night frost was increased. Therefore, expectedly, the 19th century data of crop yields correlated positively with warm season (April–August) monthly-mean temperatures. On years of countrywide poor harvest and crop failure due to night frost (1862, 1867, 1877, 1892 and 1902), the April–August mean temperature was 1.5°C lower (or more) than the average (Figure 3).

Continuous meteorological observations started in Finland 1829. Where and when instrumental observations are not available, climate proxies provide evidence of past-climatic fluctuations. In Finland, the highest paleoclimatic correlations are typically derived from latewood maximum density (MXD) series (Figure 3). The MXD is used to reconstruct warm season temperatures. In addition, the MXD data can offer a promising, new paleo-climatic proxy (z scores) to study climate and weather fluctuations from past years. In Finland, the highest paleoclimatic correlations are typically derived from latewood maximum density (MXD) series (Figure 3). The MXD is used to reconstruct warm season temperatures. In addition, the MXD data can offer a promising, new paleo-climatic proxy (z scores) to study climate and weather fluctuations from past years.

The lack of correspondence between the MXD series and the historical crop failure chronology might be due to:

1. Nature of the crop failure data prior the 19th century
   a. Inaccurate dating of the crop failure events (especially prior the 17th century)
   b. Errors concerning the extent of the crop failure. Local poor harvest might have been marked as countrywide crop failure due to lack of information or economic interests, such as tax relief.

2. Nature of the MXD series. For example, the sample size of the southern Finland MXD series is smaller than 15 prior the 1200s.

3. Human component
   a. Agro-ecosystem. The agricultural productivity was much lower in the medieval and early modern times. For example, the yield in-seed rate was in the 17th century 4% whereas in the 19th century it was 6% (and today between 30 and 60%, depending on the crop species).
   b. Wars and social distress. Military recruiting took labour off the fields, and during wartime taxes tend to increase. In addition, the peasants were obligated to feed the armies passing by.
   c. Taxation. Taxes and other payments were partly paid in grain till the late 19th century. Fixed tax products, prices and practices burdened the cycle of crop cultivation.
   d. Opportunities and regulations. Were peasants and institutions able to cope with climate extremes? For example, could peasants clear new fields for cultivation? Or, did the state offer taxes for seed grain and ease the tax burden on years of poor harvest?

Conclusions

- Constructing reliable chronology of crop failures prior 16th century is impossible due to lack of written sources.
- Tree-ring data help to identify when crop failure was caused by climatic factors.
- In the later half of the 19th century cold April–August anomalies always contributed to the crop failures.

Prior the 19th century man made factors increased the crop production sensitivity.
- Cold summer anomalies caused only minority of the crop failures.
- Yet, in further research, “climate extreme” should be defined time-specifically, considering the changing socio-environmental factors.

The comparison between the written records and tree-ring material suggests that the historical records hold many dating errors and false events.

Table 1. Historical sources on harvest and weather fluctuations

| Source | Temporal precision | Spatial coverage | Fragmentary information (e.g. letters, manorial accounts) | Decadal to annual | Annual to monthly | National statistics | Non-systematic harvest reports, diaries, etc. | Tree-ring data
|--------|-------------------|------------------|--------------------------------------------------------|------------------|-----------------|-------------------|------------------------------------------|------------------|
| Archaeology | Centennial (archaeology) | Couple towns | Some towns | Decadal to annual | Annual to monthly | National statistics | Non-systematic harvest reports, diaries, etc. | Tree-ring data

Fig. 5. Finland in the 1539 Carta marina.

Combining written sources and tree-ring data

All of the late-19th century crop failures coincided with years when the MXD series holds extremely low values (below the 2nd percentile of the period 1200–2000). Thus, the historical yield statistics, early meteorological observations and the MXD data suggests that crop failures were connected to cold climate extremes. However, historical records of large-scale crop failures prior the mid-19th century can be found on years, when the MXD series do not hold extremely low values (Figure 7). The sampling sites of the MXD series, the MXD based growing season temperature reconstruction and field correlations with observed April–August temperatures 1800–2000.

Fig. 1.3 (from top left clockwise). The sampling sites of the MXD series, the MXD based growing season temperature reconstruction and field correlations with observed April–August temperatures 1800–2000.


Fig. 2.

Fig. 3. Annual to monthly.

Fig. 4. Averaged northern and southern Finland MXD series, observed growing season temperature and crop yield statistics from 18th–Finland Source: Huhtamaa (2015) Crop yield responses to temperature fluctuations in 19th century Finland. Boreal Environmental Research 40.

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Fig. 6. Parish records of the crop failure in 1831, saw-year 2163 barrels, harvested rye: 170 barrels, 25 coppers. (Postal Illustrations from Carta Marina (1539) and Litho de gentilis exsurbanus (1555) by Olasca Magnus)

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Fig. 7. Crop failure (orange bar), and MXD proxy (grey line)

The chronology of past large-scale (1/3 of the provinces or more) crop failures have been gathered from medieval chronicles and letters prior 16th C,ewise records (16th–17th C), peasant complaints (from 17th C) and national yield statistics (from 18th C).