CP-2021-52
**Climate variability and grain production in Scania, c. 1702–1911**
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Special Issue: International methods and comparisons in climate reconstruction and impacts from archives of societies
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**Author's response**

In the following, I have divided the RC3 (comments from referee #3) into distinct and answerable parts. Author's comments are denoted AC3. RC3 and AC3 are followed by a reference list. In the end of the document there is a list where all changes made to the manuscript are summarized.

**Comments and responses (RC3 and AC3)**

**RC3 part 1:**

"I liked this paper! It is interesting and I could only find minor flaws.
If I can understand Figure 9 and 10 (correlations for the earlier period until 1865) and figure 11, correlations for the later period (1865-1911), climate sensitivity INCREASED. It is possible that this is an effect of the "enclosure" movement in Scania during the first ½ of 19th century.
In my opinion, something of that kind is hinted at on p. 20, where Cluster 3 (peasant-farmers on freehold land) dominated. It is expected from theory that private ownership will generate greater risk-taking (= more sensitivity to weather conditions) than tenant farming. It is quite possible that Cluster 1 and 2 reflect inflexible leaseholds where tenants were encouraged NOT to experiment, but rather deliver a fixed - or as close to fixed as possible - amount of lease to the landowner."

**AC3 part 1:**

Fig. 11 shows higher correlation coefficients than those in Fig. 9 and Fig. 10, and I agree that this might be interpreted as climate sensitivity increasing, at least for the spring-crops and in the face of summer droughts, such as those occurring in the years 1868, 1870 and 1899 (see lines 90-92). However, an important caveat here is the smaller number of years; therefore, I would be careful to make a direct comparison based on the magnitude of the correlation coefficients alone.

Several authors have argued that the Swedish enclosures increase incentives for long-term investments, for example in land improving investments such as diking and other types of draining of lands. Such land improvements increased the share of high-yielding cultivated soils, while at the same time increasing the risk of drought (see the first two paragraphs in Section 4.1). Nyström (2018) found that enclosed farms in Scania did experience slightly increased risks in agricultural production compared to non-enclosed farms in the period 1750-1850. The results obtained here are in line with those results. I have added a few lines in the discussion Section 4.1 where I highlight the institutional difference as well as the differences in soil qualities between Cluster 3 and the other clusters in order to further emphasize this point raised by the referee.

**RC3 part 2:**

"Minor corrections and thoughts (as they occur):

Line 6 &7: I don't understand why a low share of temperature-sensitive proxy-variable (wheat) is a good thing if you want to study climate variability."

**AC3 part 2:**

Previous research on this subject has often been focused on temperature-sensitive grains like wheat or alternatively in marginal areas where temperature was clearly the most important agro-meteorological constraint. However, Scania is a case where farmers was largely cultivating a mix of grains not as sensitive to temperature as wheat while at the same time Scania was far from a marginal grain-producing region (see lines 55-58). These are conditions similar to those pointed out by Michaelowa (2001) as making English grain production more resilient than French grain production during cold periods in the 18th century (see lines 195-198). In the Swedish-language historiography, Utterström (1957) and later Edvinsson et al (2009) argued that grain production in southern Sweden was mainly limited by precipitation rather than temperature (as in northern Sweden). A study of the relationship between grain production and climate variability in the 18th and 19th centuries offers a possibility to further explore these arguments.

**RC3 part 3:**

"Line 30-31: An admirable ambition to provide an understanding of phenology of historical grain varieties -when this ambition is presented later in the article (p 5), it is rather thin. E.g. the different rye varieties, Larsmässoråg, Svedjeråg etc, is not shown to have different phenology/being of different races. I've always understood these "varieties" as being harvested at Lars mässa or grown on slash-and-burn land."

**AC3 part 3:**
I agree that based on the available (to my knowledge) historical source material any possible understanding on the characteristics and extent of different grain varieties is necessarily thin, evident for example on page 5 as suggested by the reviewer. Larsmässoråg (roughly translated as *St Laurentius Day-rye*) was sown around the 10th of August, however actual sowing and harvesting dates varied by village and by year, according to local conditions (see lines 137-142). Furthermore, while St Laurentius Day-rye did appear in some instances in Scania, Carl von Linné (1751) points out that it was mostly found on manors in the middle of the 18th century. In the parish descriptions cited in Section 1.3, no St Laurentius Day-rye is mentioned and the earliest general sowing date mentioned for autumn-rye is in the middle of August (Bringéus, 2013). Regarding whether St Laurentius Day-rye was a variety with a distinct phenology, the sources do seem to indicate that it did (for example Linné, 1751, Leino, 2017). In the manuscript, Larsmässoråg was incorrectly translated as autumn-rye, this has been changed to *St Laurentius Day-rye.*

In relation to rye varieties, there are two points I would highlight. The first is that the available rye varieties offered in the early study period offered a broad range of possible sowing and harvesting dates (see Section 1.3). The second point I would highlight is the shift to new and more temperature-sensitive autumn-grain varieties in the late 19th century (see lines 614-620).

The implications of different grain varieties in terms of the overall relationship between grain production and climate variability is discussed in Section 4.2.

**RC3 part 4:**

"Line 44: "early study period (1702-1911) and the late study period (1865-1911)".
Ought to be? "early study period (1702-1864) and the late study period (1865-1911)"."

**AC3 part 4:**
Corrected.

**RC3 part 5:**
"Line 45: "conceptualized neither in a simplistic or deterministic"
Should be: "conceptualized neither in a simplistic nor deterministic"."

**AC3 part 5:**
Corrected.

**RC3 part 6:**
"page 3, line 77-86: I get the impression that cold periods in 1740s and 1780s were associated with sand drift etc. But soil erosion was not a problem in the 1694-1698, when it was really cold. I got an impression of inconsistency in argument."

**AC3 part 5:**
Increasing sand drift and soil erosion was associated by Mattson (1987) to colder temperatures *as well as* intensified land use practices *and* an increase in heavy winds and storms, particularly easterlies (see lines 79-86). Presumably, these other factors in addition to colder temperature were absent in the cold period in the late 17th century. However, there is much less data on wind patterns from the 17th century compared to latter centuries. Regarding land use, it has been established that an intensification took place during the 18th century and this factor can therefore explain the different results for the latter periods as compared to the 1694-98 period (Bohman, 2010).

**RC3 part 6:**
"Line 89: the great transformation of agriculture during the period makes it difficult to identify climate signal. True. So why did you choose the period? (=maybe a few lines about sources etc)."

**AC3 part 6:**
The statement on line 89 refers mainly to the 19th century, constituting roughly half of the total study period. While the annually resolved climate and grain production data is available from the 18th century, in the 19th century there is even more data, making it feasible to conduct a study of the relationship between grain production and climate variability, despite potential difficulties in easily identifying detrimental or beneficial climatic periods for agriculture (except those years of summer droughts discussed on lines 90-95). Annually resolved data allows for detrending and controlling for the expansion of agricultural expansion during the period.

**RC3 part 7:**
"Line 158-159: "selection of barley seed a long-term adaptation process"…. Hm? Wasn't the most common way that peasants took some of their harvest as seed for next year? Also, seed grain was not so "pure", if I remember correctly Maths Isacsson and Täpp Peterson (both in Dalecaria) have shown that the grain seed could be so mixed that a farmer THOUGHT he sowed barley but it was so mixed with oats that "the barley turned to oats" (cos of the rainy weather)."

**AC3 part 7:**
The sentence on lines 158-159 refers to a suggestion made by Cockram *et al*, 2007 who discusses the increasing divergence found in genetic markers of barley seed across northern and southern Europe over the very long term (i.e. in the last 7000-9000 years after the introduction of domesticized grains in Europe), and propose that the mechanism underlying this divergence was adaptation of farming to local natural conditions.

I would agree with the reviewer that the most common way farmers obtained their seed during the period was from the previous years harvest. In the framework of Cockram *et al* (2007), this would have led to adaptation over the very long term. This type of adaptation process can be both "passive" or "active" (see lines 188-194).

To my knowledge, the grains cultivated in Scania and subsequently paid in tithes would have been mostly pure categorizes of grain. Note that there was a distinct category for mixed-grains, which in the context of Scania was mainly a mix between barley and oats, similar to the reviewers example from Dalecarlia. Distinctions between barley and other grains would have been quite important due to the use of barley of brewing beer. Rye was importantly used for yeast bread and was mostly grown as an autumn-crop, distinguishing it from the other spring-crops of barley, oats and mixed-grains.

Furthermore, barley and rye was generally seen as more qualitative grains in terms of nutrition for humans, whereas oats was generally seen as a lower quality grain and often used as fodder for cattle (Dahl, 1942). Finally, each type of grain was priced and valued differently, including mixed-grains, implying that there was an incentive and interest in making sure grains were categorized accurately.

**RC3 part 8**
"Line 181-185: "a flexible farming system", check out Ronny Peterson "Ett reformverk under omprövning" where he discusses the problems with falling production in the late 18th century as a driving force for the "enclosure" movement. (Also, be careful with that concept since the connotation in English is different to Swedish conditions prevailing.)"

**AC3 part 8:**
The sentence in the mentioned lines mainly refers to sowing and harvesting dates. However, as the referee indicates there was a debate at the time (which in some ways is still ongoing) whether the traditional farming systems of *tegskifte* (Swedish variant of open-fields) was inefficient and inflexible. Farming in *tegskifte* could be done in a myriad of ways. Dahl (1989) lists no less than 62 different types of crop-fallow rotations in Scania during the 18th century.

It should be mentioned that in Scania, grain production was increasing throughout most of the latter part of the 18th century, as well in the following century, i.e. before and after the Swedish enclosure reforms. Studies on the effects of enclosure in Scania have found that farms that underwent enclosure experienced a greater increase in production, compared to those that did not (Olsson & Svensson, 2010). Eventually, pretty much all farms and villages underwent enclosure. The Swedish enclosure reforms (*storskifte, enskifte* and *laga skifte*) are briefly discussed on lines 112-118, where I also discuss the farming systems of the early study period.

**RC3 part 9:**
"Line 201: "If such adaptations were took place…" = "If such adaptations took place…"."

**AC3 part 9:**
Corrected.

**RC3 part 10:**
"Line 524: "Practically no /-/ correlation /-/autumn wheat /-/ 0.46)": this sentence indicate no, or low, correlation for autumn wheat. But on line 521, the same correlation of 0.46 is regarded as a good result. (I agree – it is not bad. But it has to be equally good (or bad)."

**AC3 part 10:**
The mentioned sentence has been rephrased.

**RC3 part 11:**
"Line 602: "not only precipitation but rather the combination of precipitation and precipitation during the summer…" I don't understand."

**AC3 part 11:**
Should be **temperature** and precipitation and has been duly corrected.

**RC3 part 12:**
"Line 649-654: I found this rather an ad hoc argument. Why should the "trade deficit" between Scania and Sweden proper result in more northerly grain varieties? As before (and prior to Monsanto™), farmers took part of their harvest and used for seed the next year. I think you might just delete those rows."

**AC3 part 12:**

Farmers did indeed take part of their harvest for seed for the next year. The vast majority of seed was most likely obtained in this way. However, there was also trade in seeds across Sweden, even though its extent is not known. Seed was traded within villages as well as over broader regions. Most known here is the import of rye seed from Finland or the imports of barley varieties like Bråkorn from northernmost Sweden to Bergslagen, the Mälaren valley and as far south as Östergötland (Leino, 2017).

The argument being made on line 649-654 is that such trade across the Sound with the Danish provinces would have reduced after 1658, and conversely that trade in the northwards direction would have increased. Of course, trade in grain for consumption and trade in grain seeds should be considered as two separate phenomena. (Note the example above were barley seed was imported from grain deficit regions like Lappland to grain surplus regions in the South.) While the new political and administrative reality in Scania after 1658 had an effect on trade and possibly on lateral seed exchange with the Danish provinces, the sources are extremely sparse of the latter type of exchange and thus the argument on lines 649-654 is in the end purely speculative. Furthermore, they are only indirectly related to the results presented in the manuscript. Hence, after due consideration of the referee comment in the matter, I have removed the lines as suggested.

**RC3 part 13:**
"Figure 12 & Figure 13 and Table B1, B2, B3 & B4 are really good! Keep at all cost!"

**AC3 part 13:**

No changes made.

**References**


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**List of changes to the manuscript**

- Slight changes in the text in line with RC3 part 4, 5, 9, 10, 11, 12
- Added a few lines to Section 4.1 in line with RC3 part 1.
- Removed all footnotes in line with request from the review file validation. Footnotes judged superfluous were completly removed while the rest were incorporated into the text. Footnotes 1, 2, 5 and 6 were removed. Footnotes 3, 4, 7, 8, 9, 10 and 11 were incorporated into the text in a slightly revised form.
- Added a missing reference to the reference list, Bringéus (2013).
- Removed superfluous reference, i.e. Jones *et al* (2005).
- Larsmässoråg was incorrectly translated as autumn-rye, this has been changed to *St Laurentius Day-rye.*