

Answers to the referees:

Climate of migration? How climate triggered migration from Southwest Germany into North America during the 19th century” by Rüdiger Glaser et al.

We thank the reviewers for their inspiring comments which helped improving the article a lot.

We largely followed their comments and recommendations:

- *General remarks on spelling, grammar and figures were largely accepted.*
- *Following the suggestions of reviewer_2, we inserted a lot of additional references, we restructured the whole article, the introduction has been enriched with the requested paragraphs on climate and climate-variability in the beginning, also with definitions of the often used keywords in this context. We reorganized and restructured the methodological parts and merged it in the relevant paragraph. The chapter of the study area was complemented adding land use and vegetation aspects, and the discussion-and conclusion section was restructured.*

In general:

Neither climate determination nor an old-style Malthusian theory was intended in this article and we now made this clearer. We had no fixed expectations regarding the results. This is shown by our results for some of the peak years (and we mentioned them now in our discussion). Our results of an indirect climate influence on migration via the chain of effects (climate-harvests-pricing) and the absolute quantification (of up to 22% of the total variation explained by climate) underline this point.

To Referee_1:

P10, L22 “The almost complete failure of the potato harvests between 1845 and 1847 additionally increased the pressure on grain markets. This shows that the emigration of those times was mainly triggered by climatic conditions via their effects on harvest yields and pricing.” **I’m not sure that your assumption is right.**

Answer: We think that we are right, because of the structure of the farming in Württemberg in those times, which we have explained. In some way it was like in Ireland regarding the subsistence character of the farming people, who farmed not full-time and had only a little piece of land – where they cultivate potatoes. The potato disease destroyed their subsistence harvests, so they had to buy compensation food on the market, which brought the prices under extra pressure. Nevertheless, we changed the sentence into: “This represents a further indication that the migration of these times has mainly been triggered by unfavorable climatic conditions via their effects on harvests and prices.”

P11, L12: “The aim of getting control over the ‘overpopulation’ was apparently achieved, as a comparison of the censuses of 1852 and 1855 points out: in 1852, 1357208 people lived in Baden; until 1855, despite an excess of births of 14347 people, the population decreased by 3.12 %.” **It has been proven that the concept of overpopulation doesn’t work out. Please make it clear that a Malthusian view is "old fashion" and there are newer theories to explain those situations.**

Answer: As said above, this was not our intention. We changed this sentence and clarified this issue in the discussion.

P14, L6: Translation “Kernen”

*Answer: „Kernen“ is out-dated for “Spealtwheat” (*Triticum spelta*). Other German terms are “Spelt” or “Fesen”. Up to the 19th century it was the most common breed of crop. In the literature it is also called “hulled spelt”, what we use in our figures.*

P1, L35: “Recently, increasing discussions emerged on the influence of climatic conditions and natural hazards, which are now considered as an independent group within the push-factors.” **1. “Hazards”, influence on what? 2. “now”: considered by the authors or in the literature in general?**

Answer: We clarified this in the text.

p. 2 “The effect of climatic conditions on population dynamics and societal success and/or failure at different scales during ancient and prehistoric times, including settlement patterns and migration processes”. **Can you explain how this influenced settlement patterns? Can you explain which climatic conditions you are considering? Storms? Droughts? Floods?** p. 2 **Here you mention climatic change for the first time, before you only mention climate variability. Both terms should be introduced at the beginning of the introduction and their differences explained. Please justify why you chose the given term.**

Answer: We tried to clarify this in the text.

p. 2 the hypothesis formulated is rather general and logical. “The underlying hypothesis was that emigration in the 19th century was a function of climate and other environmental, as well as economic and socio-political factors.” **Would it be possible to weight or differentiate these somewhat?**

Answer: We changed the whole paragraph; the approach of linear modelling (see section 6), moreover, aims at identifying the variation in the variables explained by the predictors (e.g. the climatic parameters ‘average temperature’ and ‘precipitation’ to explain the response variable ‘harvests’ which represents one method of weighing influence. A qualitative description and assessment of important influencing factors is given in each subsection with reference to the single migration waves.

P2, L36: “The main drivers were considered to be population development itself as well as changes in harvests yields and subsequent price developments” **what kind of development?**

Answer: We changed the whole paragraph and clarified the multifold stressors.

P3, L6: “As temperature, precipitation, crop yields and cereal prices were considered as the main climatically influenced drivers of the effect variable *emigration*, these variables were used for an event-specific, statistical analysis.” **all these factors should be explained in more detail. How exactly were they used? Intervals? Resolution?**

Answer: A more detailed ‘material and methods’ section is included now (section 3). We explained the used data, calculations and further assessments it in terms of long-term trends on the one hand, and waves, respectively peak years of migration, on the other hand in detail. The used stats should be clarified now.

p. 6 It would be useful to outline in more details what exactly was considered in order to standardize the precipitation variable and how the results would have varied if other indicators for temperature and precipitation would have been used.

Answer: For all factors taken into account for the quantitative analysis, a standardization approach was used (calculation of z-scores respectively the well-known SPI and STI for precipitation and temperatures – this was necessary due to the non-normal distribution of these parameters), as explained in section 3, we cannot evaluate quantitatively approaches other than we used.

p. 6 “The positive z-scores in Fig. 7 indicate ‘warmer temperatures’, ‘higher precipitation’, ‘higher crop yields’ and ‘higher prices’ whereas negative values by analogy indicate ‘lower temperatures’, ‘less precipitation’, ‘lower crop yields’ and ‘lower prices’.” **How do you cope with the discrepancy between warmer temperatures and higher precipitation as opposed to lower precipitation in the same season in view of heat waves and droughts?**

Answer: We are not sure whether we could understand the question, in any way, Fig. 7 is a good example for the broad range of different scenarios of (partly) adverse weather conditions during a few seasons which led to varying losses in harvests; it also illustrates that the climatic effects are rarely as evident as concerning the “year without summer”, 1816.

p. 6 **Why was the time period from 1804 -1886 chosen? Solely because of emigration?**

Answer: This time period covers the most outstanding migration waves during the 19th century.

p. 6 **Did you consider the threshold temperature for the growth of certain cereal crops?**

Answer: We introduced a larger paragraph on phenology as well as growth condition, in which we take these aspects into account.

P6, L15: “Hereby, the 3-monthly SPI or STI of May and August indicated the degree of precipitation or temperature during the spring (March–May) and summer (June–August) season, while the 6-15 monthly SPI and STI of August were used to attain indicators for the spring and summer half-year (March–August).” **what exactly was considered for the variable precipitation, which thresholds?**

Answer: the SPI was used, without introducing any thresholds (as explained in section 3); it represents a standardized index, showing in how far the precipitation sum of a certain period deviated from the mean of the reference period. We considered this index to be useful for our study, especially as the monthly resolution of the raw data needed for this index has an appropriate magnitude with regards to further data (yearly).

P6, L28 “The positive z-scores in Fig. 7 indicate ‘warmer temperatures’, ‘higher precipitation’, ‘higher crop yields’ and ‘higher prices’ whereas negative values by analogy indicate ‘lower temperatures’, ‘less precipitation’, ‘lower crop yields’ and ‘lower prices’.” **does this not exclude the possibility of droughts and heatwaves?**

Answer: the newly designed figure makes this clearer – also the paragraph in which we explain the concept of SPI and STI; droughts and heat waves can as well be expressed in the SPI and STI (very low respectively high values, a good example is the summer of 1846, Fig. 7).

P6, L36: “For example, in the case of August 1816, the average temperature (14.6 °C) was subtracted from the mean of the whole time period of 1804 to 1886 (18.5 °C) and divided through the standard deviation of this period, which was in this case 1.5 (see Fig. 8).” **why was this time period chosen?**

Answer: Because this is our research period (and concerning the index calculation, as far as data is available, also the ‘reference period’) – and climate needs per definition a longer period of 30 years and more. Using the whole period also reflects the lifetime and climatic experience of the people.

p. 8 First paragraph. **Did you try correlating debts and migration?**

Answer: we did not use data on this.

Apart from Fig. 7 with the case studies, it would have been interesting to show a graph with the long-term variability of the PSI and STI, distinguishing cold and wet against dry and hot and how the peak emigration years are correlated (or not).

Answer: we analyzed the peak years with the preceding year using SPI and STI, and deliberately focused on these years – also with regards to visualization of data. We also analyzed the long term correlations of the different parameters in a specific paragraph.

p. 8 line 21 **Please indicate what the “additional stressors” were in 1816.**

Answer: The overall post war situation of the Napoleon era, f.e. food storage was not enough infrastructure had been hindered by frozen canals and rivers.

p.10 **In general, in how far were famines influential on emigration as compared to grain prices and regulations or financial incentives for emigration?**

Answer: we did not follow these specific parameters – but took pricing into consideration as outlined as working hypothesis.

p. 12 **It would be useful to illustrate the above and below average fluctuations for each of the periods analysed in a chronological, annual sequence. As mentioned earlier, Fig. 7 is rather confusing when it comes to combined events (hot and dry), (cold and wet).**

Answer: Fig.7 had been redesigned completely to be read and understood more easier now.

Special comments

p.1: The introduction is rather short and missing a balanced overview of climatic and migration issues. A discussion of climate issues, in particular what you understand by “Climate and climate variability” should be introduced in the first sentence, then taken up in detail later on. Not all climate variability is negative, from which threshold onwards do you consider them to be negative? Climatic conditions are mentioned only in the last sentence of the introduction without explaining their context. It is essential that the reader learns more about which extremes you are dealing with and whether there is an expected difference between “dry, hot” and “wet, cold” (drought, heatwave, frost, excess humidity?). Can you distinguish between climatological and hydrological phenomena e.g. severe winters, as opposed to frozen or flooded rivers?

Answer: we added relevant text passages.

p. 2 Study Area: The description of the study area lacks a list of dominant vegetation types and land-use, in particular that related to agriculture.

Answer: we added relevant text passages.

p. 2 Section 3. It would be advisable to separate the “Working hypothesis” from the “methodological concept”, place the working hypothesis in the introduction and enlarge the scope of the methodological concept dedicated only to section 3, mentioning the type of analyses to be undertaken and problems of data availability encountered. Many parts of the methodology are dispersed throughout the paper (in particular section 4) but there are major methodological descriptions as late as section 6 on the second last page of the paper. All of these should be included under section 3.

Answer: we followed these recommendations.

p. 3 I recommend restructuring sections 4.1 – 4.3. The descriptions of methodology and data sources (migration sources, newspapers etc) in sections 4.1 -4.3 should be placed in section 3. “Methodological Concept”. Even parts of section 5 are methodological (description of data analysis and sources) and should be transferred to section 3. All sentences that should appear earlier in the methodology have been underlined in the pdf.

Answer: we followed these recommendations.

p. 3 4. The long-term development of population, migration, harvest yields, pricing and climate. This is a purely methodological section and could be placed into Section 3 Methodological Concept as a subsection.

Answer: we followed these recommendations.

p. 3. Section 4.1 should be re-organised, bringing the methodology and data sources first, then the results.

Answer: we followed these recommendations.

p. 5 Section 5.1 The first few sentences in this section are methodological and should be transferred to section 3 methodology.

Answer: we followed these recommendations.

p. 7 In the very interesting discussion in the second last paragraph on harvest yields in 1816 please **add citations and indicate whether the interpretation is derived from Stieffel and Dürr, or the result of your own research.**

Answer: we followed these recommendations.

P8, L20/21: “This clearly demonstrates that the 1816/17 migration peak was triggered by the climatic consequences of the Tambora eruption in 1815, enforced by a number of additional stressors (Heünisch, 1857; WJB 1818.1).” **please indicate which**

Answer: we added relevant text passages.

P9, L21: “Recent research concerning the origin of this disease shows that it was first observed in Belgium in June 1845 and spread out from there throughout Central Europe and its southern parts until September”. **please include citations**

Answer: see answer to Ref.1 Answer: The source is already mentioned in brackets at the end of this paragraph (Hermann, 2011).

p. 13-14, section 6. This section is dedicated primarily to the methodology of statistical analysis and modelling and should be put into the section 3 on methodology. Section 6 can then concentrate on the results and discussion. At the moment the results and discussion of results are very short compared to the methodology.

Answer: we restructured the methodological paragraph, following these suggestions.

Take care with your figure numbering. It does not correspond to the figure numbers in the text: Fig. 12 instead of Fig. 1, Fig. 13 instead of 2 etc.

Answer: the numbering is now in clear order.

P1, L29 “rent system” (Pachtsystem) ; suggestion “rentability?”

Answer: The system of agricultural leasing was meant, and we changed it.

P2, L5: “Even though the decision processes leading to migration can also be governed by various other factors aside from climate-related circumstances (McLeman & Smit, 2006), current discussions consider climate and climatic change to play a key role within 5 trends in population dynamics (McLeman, 2011).” **here you mention climatic change, before you always speak about climatic variability. Both terms should be introduced at the beginning of the introduction and their differences explained.**

Answer: we added relevant text passages.

P2, L29: “These regional climatic and soil variations explain the differentiated ecological conditions, which have had a significant influence onto harvest results and their regional variations.” **list the dominant vegetation types and land-use, in particular the type of agriculture**

Answer: we added relevant text passages.

P7, L31: “For both territories, harvest yields for 1816 were described as “bad failure” (Stieffel, 1842; Dürr, 1895). To assess and understand the general societal and environmental conditions during this year, the preceding years have to be taken into account. No one was prepared to deal with such an extreme year: the last full harvest dated back to 1812, since then granaries had not been filled completely due to the Napoleonic Wars and marauding troops. It seemed that, due to the turmoil of war, large parts of the agrarian country were not cultivated in these times, which reduced the total harvest yields 30 even more. As a consequence, large portions of the population were highly vulnerable with respect to food security. In addition, responsible politicians reacted with a substantial and disastrous time lag: it was not until November 1816 that tariff measures regulating import and export of grain were implemented, which was definitely too late.” **please add citations. Is this from Stieffel and Dürr, or the result of your own research?**

Answer: Here we quote Gehlinger, 1897 and complement it.

P7, L35: “In Württemberg, several thousand bushels of grain - worth 1.4 million guilders - had been exported instead of supplying domestic population. In October it was already too late for a government-initiated additional purchase of grain on foreign 35 markets. It was not possible to deliver the urgently required goods to Württemberg or Baden before wintertime.” **again, please add citations. Is this from Stieffel and Dürr, or the result of your own research?**

Answer: Here we quote Gehlinger, 1897 again and further Memminger, 1818 who represents the “official site” and complement it.

P10, L3: "Only a ban on the export of potatoes could be implemented (Landwirtschaftliches Wochenblatt für das Grh. Baden, Issue July/August 1845)." **is it indicated by whom?**

Answer: A ban of export could only be indicated by the ministry.

P11, L34: "In a climatologically broader context, the emigration between 1863 and 1869 fell into a phase of warmer temperatures (see),"

Answer: In the original text the reference to Fig 7 is present. the numbering is now in clear order.

P12, L14: "Neckar floods" show this and other major Rivers on your study area map

Answer: we changed the relevant figure and included the relevant names.

Fig. 12: Legend illegible. Increase font size and resolution considerably. Increase font size of major agglomerations such as Stuttgart.

Answer: Done.

Fig. 13: socio-economic and agricultural

Answer: Done.

Fig. 19 u. 20: please use other colour to distinguish between 1804-1886 and 1961-1990. The pink becomes invisible against the orange. Same for precipitation 1961-1990, use a stronger blue.

Answer: We changed the colors.

Referee_1:

P1 mentioning the project in the title

Answer: We mention the project-title in the abstract and acknowledgement section.

P1, L24: You should refer to newer theories Twyrdy (2010), Marschalk 1973...

Answer: we referred to these authors

P1, L34: source for pioneer and chain migration?

Answer: we added relevant ref.

P2, L5: climate is only one factor; an important one, however there are much more. You should refer to those as well to avoid climate determinism. See for example (Engler et al. 2013)

Answer: we added much more ref. and pointed out, that our concept is not a relapse to natural or climate determinism.

P8, L21: please mention those a bit more, otherwise it is too simplistic.

Answer: we changed it into: "This clearly demonstrates that the 1816/17 migration peak was triggered by the climatic consequences of the Tambora eruption in 1815, amplified by a number of the specific circumstances, like a lack of preparedness, harvest failures in the preceding years, the situation after the Napoleonic Area and a poor crisis management (Behringer 2016, Heünisch, 1857; WJB, 1818.1)."

P9, L25: "In Ireland, this illness caused an extreme famine and in consequence an exceptionally high emigration peak because of the one-sided dependence on the potato plant and crop failures of up to 90 %." **Source?**

Answer: The source is already mentioned in brackets at the end of this paragraph (Hermann, 2011).

P12, L37: “Looking for a major reason for this emigration wave, current research stemming from a more societal point of view concludes that the ‘attraction of the New World’ as a whole and the ‘reunification’ of successfully emigrated family members were the main drivers (Fies, 2010).” **That is a very good point. I think it is a useful way to explain emigration.**

Answer: thank you!

Fig. 4 „migrated“ instead of „has migrated“.

Answer: we changed it.

Fig. 7: “influencing” instead of “influence”.

Answer: we changed it.