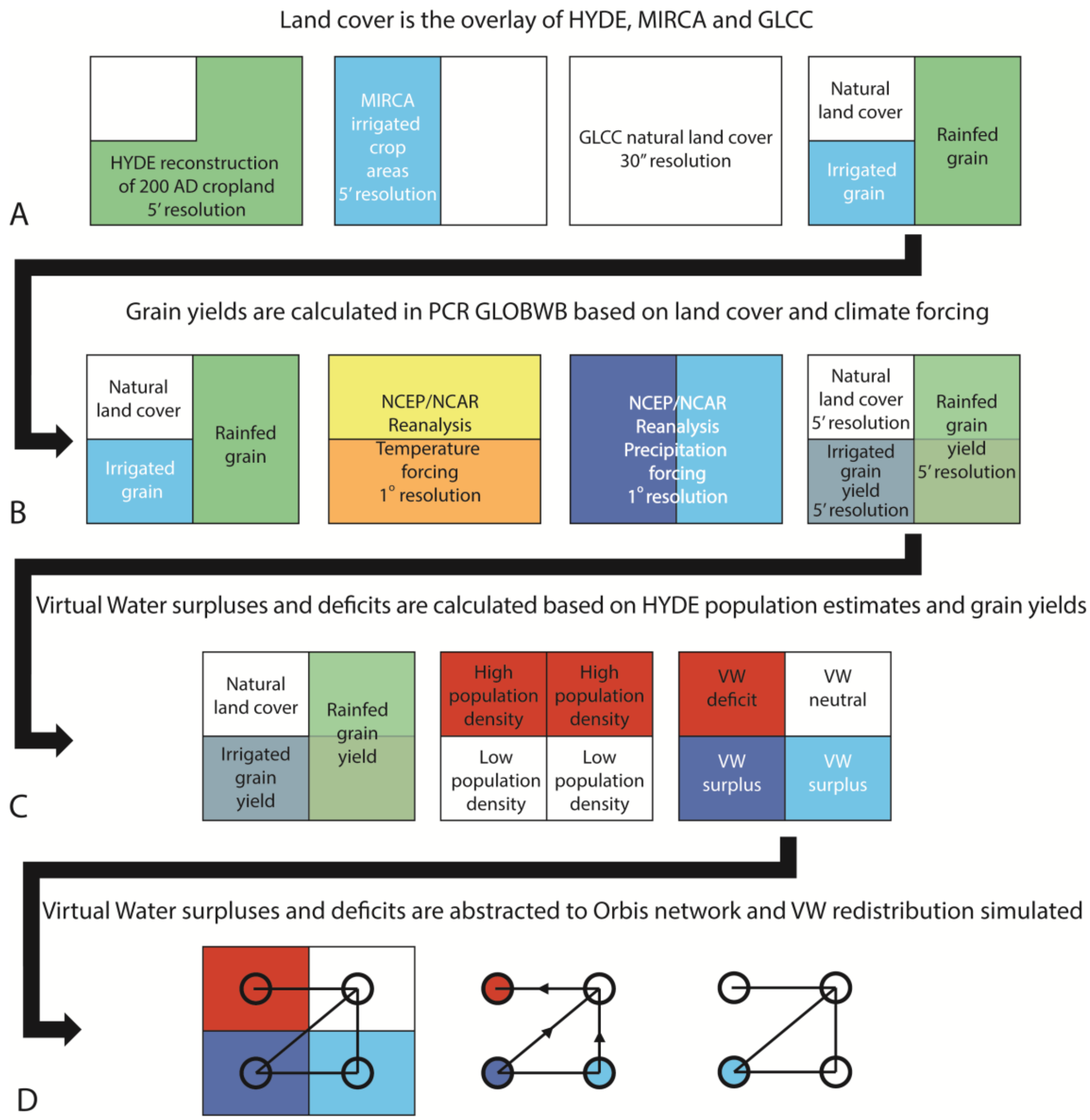
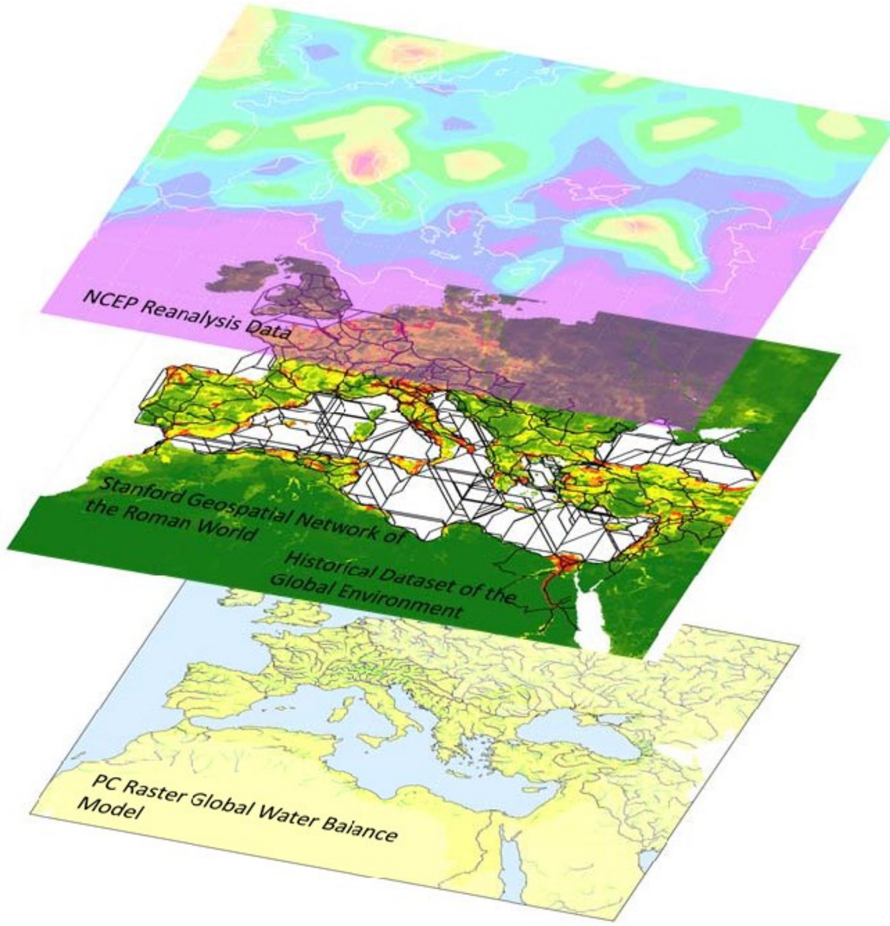
I am pleased to comment favorably on this really interesting discussion paper, which I enjoyed reading. It is indeed an enlightening paper that is focused on "historical sociohydrology" and should be published eventually. However, I have the following detailed comments:

1) I enjoyed reading the paper so much just on the basis of the information presented – then only in the end realized that while the authors presented details of the various components of the model, they did not clearly present how these components came together. In other words, the paper may benefit from a basic, but holistic description of the model, supported by a schematic. It should be of sufficient detail that someone who wants to repeat the work here or elsewhere can easily follow.

We have provided a more intuitive schematic to the one originally presented that it is envisaged will demonstrate how the various components of the model came together (Reviewer 1, Figure 1). We have also included a spatially explicit schematic in the supplement of the revised manuscript (Reviewer 1, Figure 2). In addition we have expanded our explanations of the model in the methods section. In doing so we have outlined in detail how VW trade is simulated and the motivation for simulating it this way based on historical evidence of the grain trade during the Early Third century in the Roman Empire (see reviewer 2, comments 7 and 8).



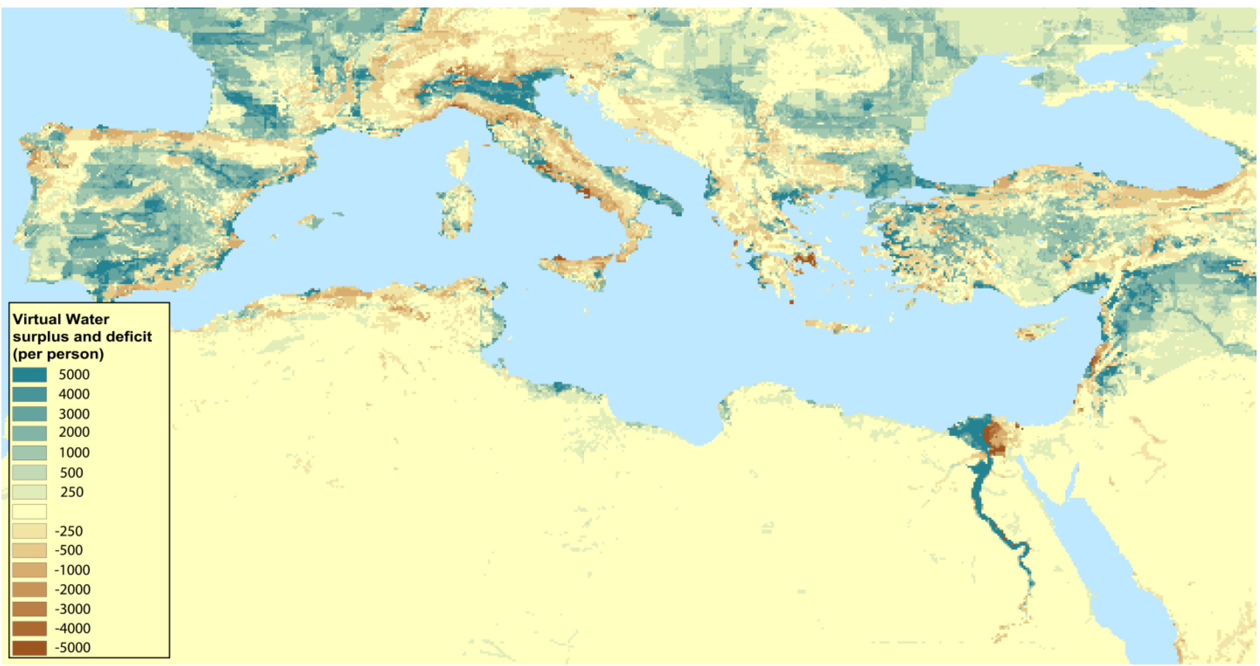
Reviewer 1, Figure 1. Schematic of our virtual water network of the Roman world. (A) The overlay of HYDE cropland reconstructions for 200AD, monthly irrigated and rainfed crop areas (MIRCA) and global land cover characterization (GLCC) forms the land cover attributes in our model. Regions are only assigned irrigated where MIRCA irrigated regions overlap with HYDE 200 AD cropland regions. **(B)** Grain yields in irrigated and rainfed agricultural regions are simulated in PC Raster Global Water Balance model (PCR GLOBWB) based on 52 years of spatially and temporally variable temperature and precipitation forcing. **(C)** Regions are defined based on a Theissen polygon operation between network nodes (see Reviewer 2, figure 1). Virtual water surpluses and deficits are calculated for each region based HYDE reconstructions of Roman Population distribution and grain yields calculated in PCR GLOBWB. We fix the annual grain consumption a 200 kg per person **(D)** The virtual water surpluses and deficits are abstracted to the Orbis network and virtual water redistribution is simulated. Deficit nodes import virtual water from surplus nodes along the minimum cost path. Imports continue until the demand of deficit nodes is met. See Reviewer 1, Figure 2 for a spatially explicit schematic of our virtual water network of the Roman Worl



Reviewer 1, Figure 2. Virtual water network of the Roman World. Grain yields were calculated using the hydrological crop model PC Raster Global Water Balance (PCR GLOBWB) (van Beek and Bierkens, 2009; Bierkens and van Beek, 2009). PCR GLOBWB captures the heterogeneity in the hydrology of the Mediterranean region which has an important impact on the spatial heterogeneity of yields. In addition, PCR GLOBWB facilitates the calculation of crop irrigation demand based on the available surface water for irrigation. Roman agricultural land and population were assigned based on reconstructions from the History Database of the Global Environment (HYDE) (Klein Goldewijk et al., 2011). Grain yields were calculated based on NCEP daily climate forcing which allowed us to simulate the spatial and temporal heterogeneity of grain yields in response to climate. The redistribution of grain through trade was simulated using Orbis, the Stanford Geospatial Network of the Roman World as the network structure.

2) Other details I would have liked to are the distribution of water resource or water availability and the distribution of people (or water demand). After all, in this time period these are the two major factors that drove the virtual water trade. I am sure the authors have these details, but it will be good to include such patterns so the reader gets the sense of drivers of virtual water trade.

Essentially the grain yield maps in the discussion paper display the distribution of the water resource (discussion paper, figure 2) whilst the population maps show the distribution of the water demand (discussion paper, figure S1). However, we have added a VW surplus and VW demand map to the supplement of the revised manuscript, which incorporates both of these aspects by showing the average VW surplus or demand per cell averaged over 52 years of climate forcing (Reviewer 1, Figure 3).



Reviewer 1, Figure 3. Virtual water surplus and deficit. The virtual water surplus and deficit measured in per person VW deficit or VW surplus is shown. The map is generated by subtracting VW demand (based on HYDE population reconstruction for 200 AD and 200 kg grain per person per year) from the average annual grain yield calculated over 52 years of climate forcing.

3) The paper must have been put together quickly, because despite (or because of) the large number of co-authors, there remained a really large number of typos of a grammatical or

presentation type still left in the paper. The authors should go through the paper with a "fine toothcomb" to try and eliminate these typos.

We have endeavoured to eliminate all typos from the paper.

4) Now I come to my final comment. I make this comment to traditional, place based hydrology papers. I always ask what has been learned that is general and transferable places. Here is a paper on the socio-hydrology of a region in the ancient world. There is a lot of virtual water trade work that is presented that is descriptive, but from a broad socio-hydrology perspective, we need these works to graduate to more explanatory type of papers that reveal fundamental concepts or principles or laws.

My question then is, what has been learned from here that is fundamental or general and therefore transferable to another region, 2000 years since, for example China in the present century. I know there is a lot of detail that went into the model, there is a lot of site specific complexity and heterogeneity. In terms of its resilience for a long time and then its eventual collapse, is it possible for the authors to distill the entire thing into a simple, abstract conceptual model that one can mimic in terms of a few coupled differential equations? I am not claiming that this will be easy to do, and I will not object if the authors decide not to do it, but in the final analysis this is the essence of "historical socio-hydrology", learning the lessons from the past. This is already an excellent paper, and it is only this kind of extension that will make it a truly great paper that will stand the test of time. I hope the authors can rise up to this challenge.

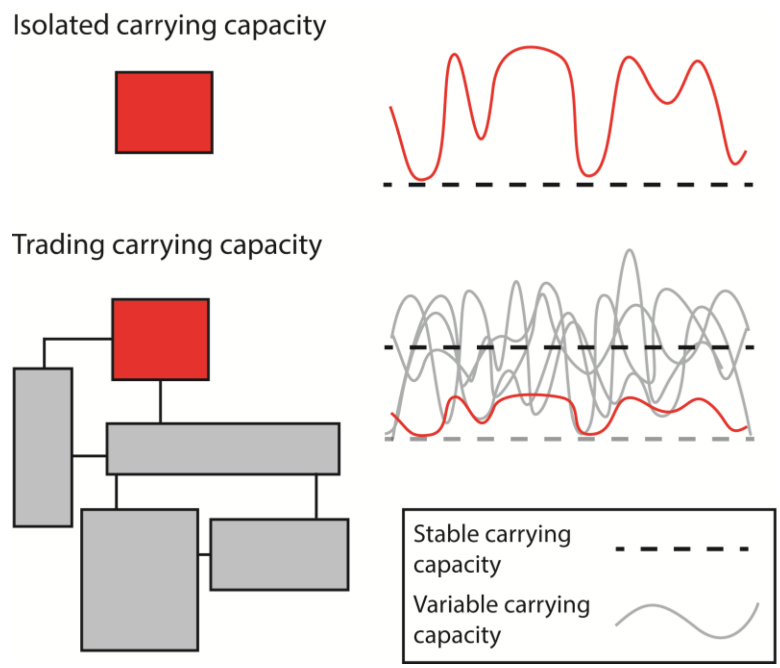
The authors may want to look at three papers recently published in HESS and HESSD where such kinds of conceptual models have been attempted for contemporary situations in Australia and China. In particular, please refer to Figure 1 in Elshafei et al. (2014) Figure 3 in Liu et al. (2014) and Figure 12 in an van Emmerik et al. (2014). Again, I do not claim for sure there is an analogy here, but the authors may want to consider it.

Essentially I am very supportive of eventual publication of this paper in HESS after moderate or major revisions (whatever the authors feel compelled or challenged to do).

We have included the following paragraphs in the discussion section of the revised paper accompanied by a figure outlining the concepts discussed (Reviewer 1, Figure 4).

Our analysis highlighted that the heterogeneity of the Mediterranean environment was important for providing the Romans with resilience to interannual climate variability. For example, areas like the Po Valley and Nile Delta had stable yields compared with rainfed regions because irrigation offered them a certain amount of decoupling from the climate system. In the Eastern Empire grain yields exhibited less year to year variability compared with the West owing to higher average winter temperatures (Lionello, 2012) as well as the reduced influence of the winter storm tracks (Hurrell, 1995; Visbeck et al., 2001). Topographical variations also played an important role with grain yields limited by temperature at higher elevations whereas they were water limited at lower elevations and in more arid environments (Discussion paper, Figure S5). It was the Romans ability to link these environmentally heterogeneous regions through trade that provided them with a stable food supply despite the variable climate of the Mediterranean region. However, virtual water trade also promoted population growth and urbanisation in the Empire. The increased urbanisation during the Late Republican and Early Imperial periods (Scheidel, 2001) likely pushed the Empire closer to the limits of available fresh water resources and reduced resilience to climatic variability (D'Odorico et al., 2010; Garnsey, 1988).

Our analysis, uncovered a number of important features that have general implications for virtual water trade under spatially and temporally variable environmental conditions. For example, provided there are enough trading regions with temporally heterogeneous yields, virtual water trade increases the carrying capacity of trading regions without an increase in water resource use in any of the trading regions (Reviewer 1, Figure 4). Virtual water trade is therefore a highly efficient method of providing resilience to interannual climate variability. However, by increasing the carrying capacity of trading regions as well as allowing VW poor regions to overshoot their local ecohydrological carrying capacities (Reviewer 1, Figure 4), virtual water trade promotes population growth and urbanisation. Therefore, the short term resilience that VW trade provides is eroded in the long term as population growth and urbanisation push trading societies towards a global carrying capacity. The present-day trend of urbanisation (United Nations, 2014) means that the global society is becoming increasingly dependent on trade to ensure food supplies. As population continues to grow there is less space to adapt to yield perturbations that may arise owing to anthropogenic climate change (D'Odorico et al., 2010). The globalised population is therefore in danger of becoming vulnerable to climate perturbations in the same way that an isolated population is. However, unlike an isolated society, globalised societies are also vulnerable to perturbations in the trade network itself (De Benedictis and Tajoli, 2011; Grubesic et al., 2008).



Reviewer 1, Figure 4. Conceptual figure illustrating the impact of trade on carrying capacity in a variable environment. Carrying capacities are variable over time owing to the impact of interannual climate variability on yields. In an isolated society populations must remain below the climate-forced carrying capacity to avoid famine. In societies with trade the carrying capacity becomes the average carrying capacity of all trading regions. Thus carrying capacity is increased without an increase in resource use in any of the trading societies. Trade even allows certain regions to attain carrying capacities well above their local ecohydrological constraints, thus facilitating urbanisation. However, under continued population growth, the interannual resilience to climate variability provided by trade is eroded in the long term as populations approach the new global carrying capacity. Carrying capacities are smoothed to illustrate the dampening effect of food storage.

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