Faculty of Geosciences
Copernicus Institute of Sustainable Development
Environmental Sciences dept.

b.dermody@uu.nl @brianjdermody

Societal resilience to hydroclimatic change in the Roman World

Brian J. Dermody[1], Rens P.H. van Beek[2], Kees Klein Goldewijk[1,3], Walter Scheidel[4], M. F. P. Bierkens[2], M. J. Wassen[1] and S. C. Dekker[1]

1 Utrecht University, Copernicus Institute of Sustainable Development, the Netherlands, **2** Utrecht University, Department of Physical Geography, the Netherlands, **3** Netherlands Environmental Assessment Agency, De Bilt, the Netherlands, **4** Stanford University, Department of Classics, USA

Overview

The Romans developed highly organised irrigation systems and an extensive trade infrastructure in order to maintain stable food supplies to their cities. However, it remains a mystery how resilient the Roman food production and redistribution system was to hydroclimatic changes that occurred at this time. In order to find out, we have developed a socio-hydrological model of the Roman World. The model brings together historical and biophysical data under a unified framework. Our framework provides a next step in understanding the interactions between past societies and environmental change.

Reconstruction of Roman population and agriculture

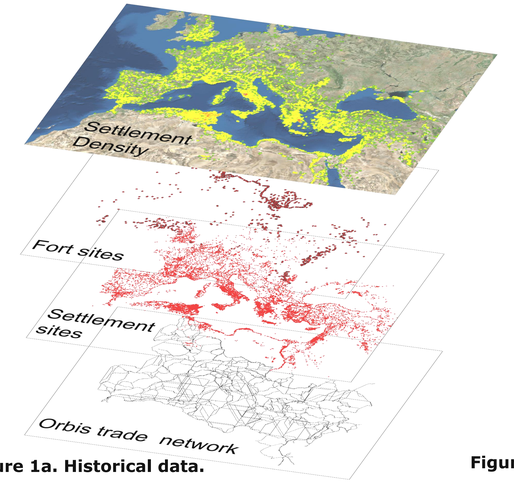

Figure 1a. Historical data.

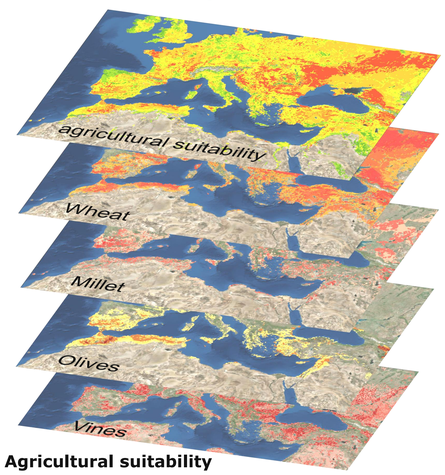

Figure 1b. Agricultural suitability

We applied a novel method to reconstruct Roman population distribution and agricultural practices based on Roman archaeological site distribution and crop suitability maps

- Settlement density was derived from the Pleiades dataset, which contains 14,600 settlement sites dated as active in 200AD (fig.1a)
- Agricultural suitability was derived from FAO crop suitability maps of wheat, millet and olives (fig. 1b). Vine suitability maps were derived based on a regression between current vine distribution and biophysical variables. These 4 crops constituted the majority of Roman calorific intake.
- Population density was reconstructed as the product of settlement density and agricultural suitability (fig. 1c)
- Orbis: the Stanford Geospatial Model of the Roman World was used to represent the Roman trade network. Orbis is an estimate of the cost of transporting goods around the Empire based on cost distance calculations and Diocletian's Edict on Maximum Prices (Scheidel, 2013) (fig. 1c)

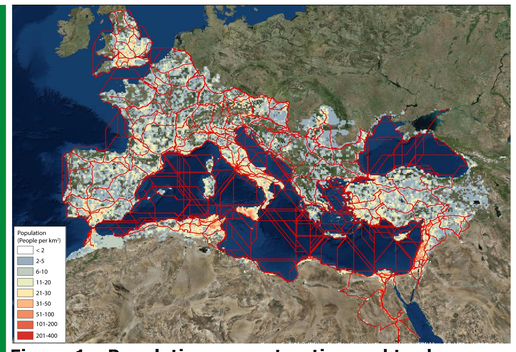

Figure 1c. Population reconstruction and trade network

Calculating the impact of hydroclimatic change on crop yields

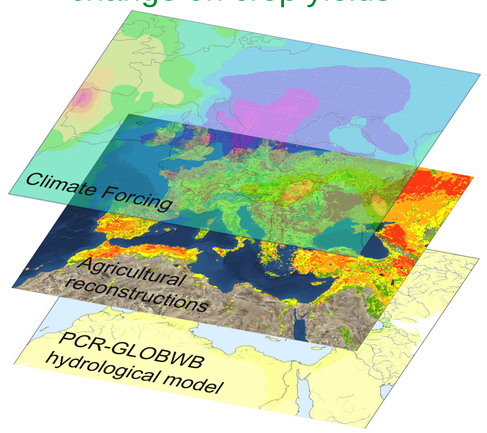

Figure 2. Yield calculation. Yields were calculated in PCR-GLOBWB for reconstructed RWP and DCP climate forcing

In order to estimate the impact of hydroclimatic changes on Roman food supplies, we calculated the yield response to climate forcing using the hydrological model PCR-GLOBWB. With this model we could also estimate available surface and groundwater for irrigation

- Roman Warm Period (RWP) and Dark Ages Cold Period (DCP) climate forcing were derived from proxy reconstructions (Dermody et al. 2012 and Büntgen et al. 2011) and applied using ERA-20CM reanalysis fields (Hersbach et al. 2015)
- Crops were assigned according to the reconstructed crop suitability maps
- Yields were calculated in PC Raster Global Water Balance Model (PCR-GLOBWB) (van Beek et al., 2011) at 5′ horizontal resolution for rainfed and irrigated crops
- Yields were constrained by locally available labour pool for harvesting
- Natural landcover was based on the Olson classification (Olson, 1994)

Preliminary results

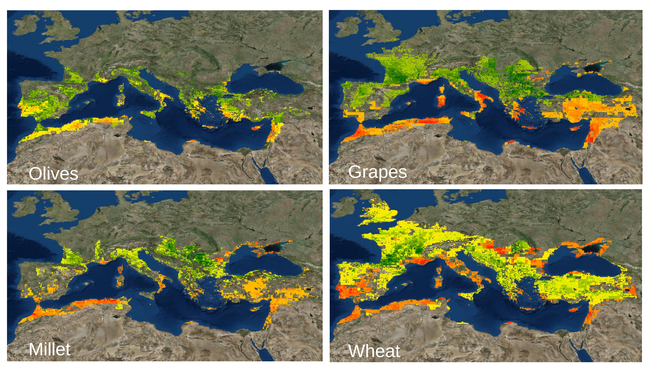

Figure 3. Yield anomaly Dark Ages Cold Period – Roman Warm Period. Cooling in the DCP reduced yields for all crops in the Northern part of the Empire and at higher altitudes. However, our simulations indicate that yields may have increased in the coastal Mediterranean during the DCP

Next steps

- Investigate food trade patterns under changing hydroclimatic conditions
- Examine the resilience of the system to hydroclimatic changes
- Incorporate decision-making agents

The ultimate goal is that our framework will provide a platform for bringing together data on environmental and historical change in the Roman World. In so doing, we can improve understanding of the feedbacks between the society and the environment in the Roman World.

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