Food exchange and the robustness of agrarian societies in the Eastern Mediterranean

Introduction

Over the past 10,000 years, farmers in the Eastern Mediterranean basin have developed sophisticated risk-minimizing strategies to maintain stable food supplies given uncertain rainfall. The core package of Mediterranean rainfed agriculture - fruits and lentils grown near houses, wheat and barley in outfields, herds of sheep and goat beyond - has remained constant for millennia (Butzer 1997). Relying on a mix of food types with orthogonal climate tolerances is an efficient way to maintain a robust food supply (Anderies 2006). Mediterranean farmers also tend to produce more food than is needed in a given year in order to save for the next year (Halstead 1989), an effective adaptation shared by many Mediterranean crops (Abbo et al. 2009).

Farmers using these storage and diversification strategies must consistently monitor crop yields and make resource-allocation decisions in response to perceived social and environmental risks. They are vulnerable to the same things as all managers social-ecological systems with regulatory feedbacks: poorly-specified performance measures, imperfect monitoring, and biased decision making.

These vulnerabilities can lead to food crises in times of drought, but (at least in classical antiquity) while droughts and food crises were common, major famines were rare (Garnsey 1989). This is because food-exchange networks act as social safety nets in times of major drought. These networks and the institutions that maintained them are often overlooked in long-term studies of Mediterranean agriculture because they have changed so markedly over time, from Neolithic “big men” to Bronze Age god-kings and Roman *patroni*. But there is a tradeoff between robustness and performance at the core of each of these institutions.

In this paper, I argue that social dilemmas make it difficult to maintain the kinds of food-exchange networks best-suited to absorbing the shocks of a major Mediterranean-style drought. I first explore the spatiotemporal pattern of drought in the Eastern Mediterranean during the recent past, and discuss how these patterns may have shaped past exchange networks. I then discuss the social dilemmas that arise from the use of exchange networks as public, social infrastructure, and their significance in the long-term social history of the Eastern Mediterranean.

Rainfall patterns and "the strength of weak ties"

Water availability, particularly during the growing season from October to May, is the primary constraint on agricultural productivity in the Eastern Mediterranean. Only a handful of winter storms deliver the majority of annual precipitation, and as a result water availability and crop yields are extremely variable. Food-exchange networks generate robustness to this variability by connecting areas where rainfall patterns do not covary. To better understand the forces structuring these networks, a more precise view of this covariance structure is needed.

The observational record of drought from the past century is complex (Vicente-Serrano et al. 2010), but can be decomposed calculation of empirical orthogonal functions (EOFs) (see Appendix). Maps of the resulting of EOF loadings represent key modes of spatiotemporal variability in water stress (Figure 1). The leading two EOF modes together explain nearly 30% of the

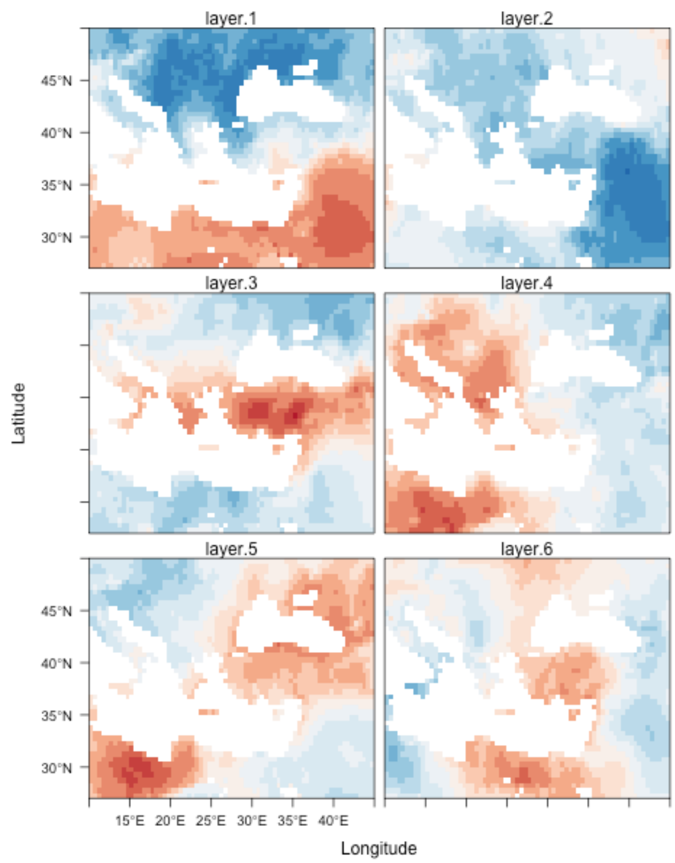

Figure 1: The leading six empirical orthogonal functions over the Eastern Mediterranean from a century-long drought dataset. In a given mode of variability, regions with the same color tend to experience dry (wet) conditions similarly as regions with a different color experience wet (dry) conditions (eigenvectors). Color intensity corresponds to the magnitude of the correlation (eigenvalues).

variance in the of the variance in monthly water stress for the past century, and the leading six EOFs explain nearly 50% of this variance.

Although a precise comparison of these EOFs with known atmospheric circulation patterns and is beyond the scope of this paper, the EOFs suggest that drought patterns in the Eastern Mediterranean are often extensive and spatially-autocorrelated. Assuming that similar modes characterize drought variability in the past, we would expect that ancient exchange networks needed to span great distances to connect farmers unaffected resource systems. This suggestion is consistent with Granovetter's (1973) argument for "the strength of weak ties", which states that the weakest social ties between distant actors are vital for facilitating flows of information and energy through a network. But food-exchange networks are social infrastructure, and as network distance increases so too does the cost of monitoring and sanctioning free-riders.

Food-exchange networks as social infrastructure

Food-exchange networks are sets of institutions that employ social relationships to distribute food in periods of food crisis. They are a form of public, social infrastructure that provides affordances for the transfer of energy (calories) within and between resource systems (farming communities) (Anderies et al. 2004; Anderies 2015). These social networks are both intangible and irregularly mobilized, and thus difficult to maintain and monitor.

The link between those who provide and maintain public food-exchange infrastructure and the the average farmer is a key vulnerability. The nature of this link mediates the degree of under-provisioning and free-riding, and thus the robustness of food exchange networks. Increasing social distance between resource users and exchange-network providers has been a major axis of social change in the Eastern Mediterranean. In small-scale kinship networks the resource users and infrastructure providers are one in the same, and reciprocity drives egalitarian exchange. As scales of time and space increase, the public infrastructure providers become more socially distinct from the resource users in any particular system. They can take the form of local elites or "big men" who dominated village exchange through feasting, regional elites dominating redistributive palatial economies, market economies in which the public infrastructure providers are resource users in a distinct, yet coupled, system from the one in question (Halstead 1989; Wilkinson et al. 2007; Freeman et al. 2014).

As is often true of public infrastructure, social dilemmas arise from the incentive for individuals to maximize personal benefits from food-exchange networks at the cost of group benefits (Anderies 2015). Both the infrastructure providers and resource users can free-ride on such systems. Rent-seeking, speculation, and price fixing were rampant among wealthy Romans tasked with the management of grain resources (Garnsey 1989). For resource users, knowledge that unexpected food shortfalls can be mitigated through a social safety interferes with agricultural feedback mechanisms, creating a perverse incentive for farmers to sacrifice robustness in favor of performance by trying to maximize yields rather than minimize yield variance. Because exchange networks pool risks, too many free-riders can lead to system-wide failure. This social dilemma is directly analogous to that underlying recent US banking crises in which particular firms that the federal government could neither monitor nor allow to fail were incentivized to make high risk/high reward capital allocation decisions.

Conclusion

Weak ties may be necessary for food-exchange networks to absorb drought-related shocks, but these ties are by definition difficult to maintain. This tradeoff is a general feature of exchange networks in the Eastern Mediterranean, but it has become more salient over time as these networks and the institutions that maintain them have grown in scale and complexity.

Appendix: Drought data and EOF calculation

To examine the patterning of spatiotemporal variability in water stress I analyzed a dataset of nearly a century of a monthly drought index over the Eastern Mediterranean. The dataset uses an index known as the Standardized Precipitation Evapotranspiration Index (SPEI) (Vicente-Serrano et al. 2010). SPEI is a normalized measure of water stress (precipitation - potential evapotranspiration) in which positive values represent unusually wet months and negative values unusually dry months. Importantly, SPEI is calculated for each location independently, meaning that variability in water availability is presented *relative* to the mean availability for each location. This shifts the focus of analysis to patterns of *variability* in rainfall over space, rather than patterns in the average value. Thus during a given month two locations that receive very different amounts of rainfall, such as the windward and lee slopes of a coastal mountain range, can both be experiencing "unusually dry" conditions.

Not only does the normalization process in SPEI makes it easier to visualize patterns of drought, but it also facilitates analyses that generally perform poorly on non-normal climate variables such as precipitation. Empirical orthogonal functions were used to decompose the complex space-time signal in the SPEI database into modes of variability. EOFs were calculated by applying a principal component analysis to the correlation matrix of a latitudinally-weighted sample of points from all SPEI raster layers. The leading six EOFs were graphically selected as representative using a scree plot. All analyses were conducted using the **raster** package in R (Hijmans 2015).

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