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SAA 2016: Human-Environmental Interactions in the Mediterranean Basin

Agricultural risk management in Mediterranean environments: a computational modeling approach

Abstract

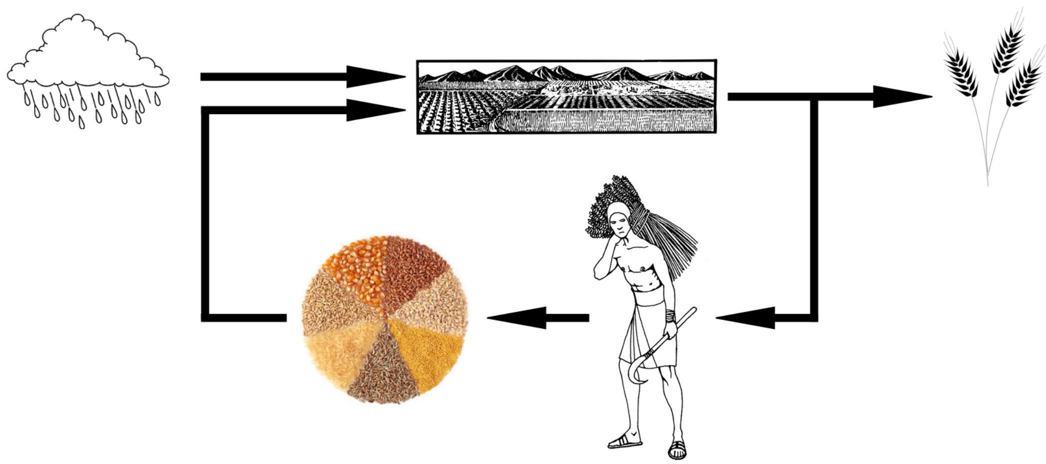
Small-scale agriculturalists in the Mediterranean Basin rely on multiple strategies including diversification, intensification, and storage to maintain a stable food supply in the face of environmental uncertainty. Each of these strategies requires farmers to make specific resource allocation decisions in response to environmental risks and is thus sensitive to variability in both the spatiotemporal pattern of risk and the ability of farmers to perceive that pattern.

In this talk, I present an agent-based model of a Mediterranean agroecosystem. By driving the model with realistic environmental dynamics derived from simulations of mid-Holocene Mediterranean climate, and by allowing the psychology of risk perception to vary among individual farmers, I explore the hidden vulnerabilities of traditional risk-management strategies to periods of rapid climate change. I show that even when farmers are able to manage risk "optimally" in light of past experience, *unanticipated* changes in the spatiotemporal pattern of rainfall can still lead to major food shortfalls.

Outline

Introduction

- Over the past 10,000 years, farmers in the Mediterranean basin have developed sophisticated strategies to maintain stable food supplies given uncertain rainfall.
  - Rainfall highly variable in space and time (seasonal, annual, decadal).
  - Water limiting factor for crop yields $\therefore$ uncertain rainfall = uncertain food supplies.
- Crop diversification is a particularly common strategy — relying on a mix of food types with different climatic tolerances is an efficient way to maintain a robust food supply (Anderies 2006).
  - Wheat and barley a common combination.
  - wheat has higher yields but barley is drought tolerant
  - farmers adjust the ratio of wheat to barley to adapt to changing drought risks.
- But farmers using crop-diversification strategies must consistently monitor crop yields and make resource-allocation decisions in response to perceived social and environmental risks. Are these systems vulnerable to the same dynamics as other social-ecological systems with similar regulatory feedbacks mechanisms? One way to address this is to model the influence of imperfect monitoring and biased decision making in uncertain environments.



- An agent-based modeling framework is needed
  - population level responses of agricultural communities are an emergent property of the imperfect risk-management of individual farmers

Methods

Land-use ratios

- Given known risk of drought and the yields of wheat and barley in normal and drought years, the optimal wheat-barley ratio that maximizes *expected* yields can be calculated.

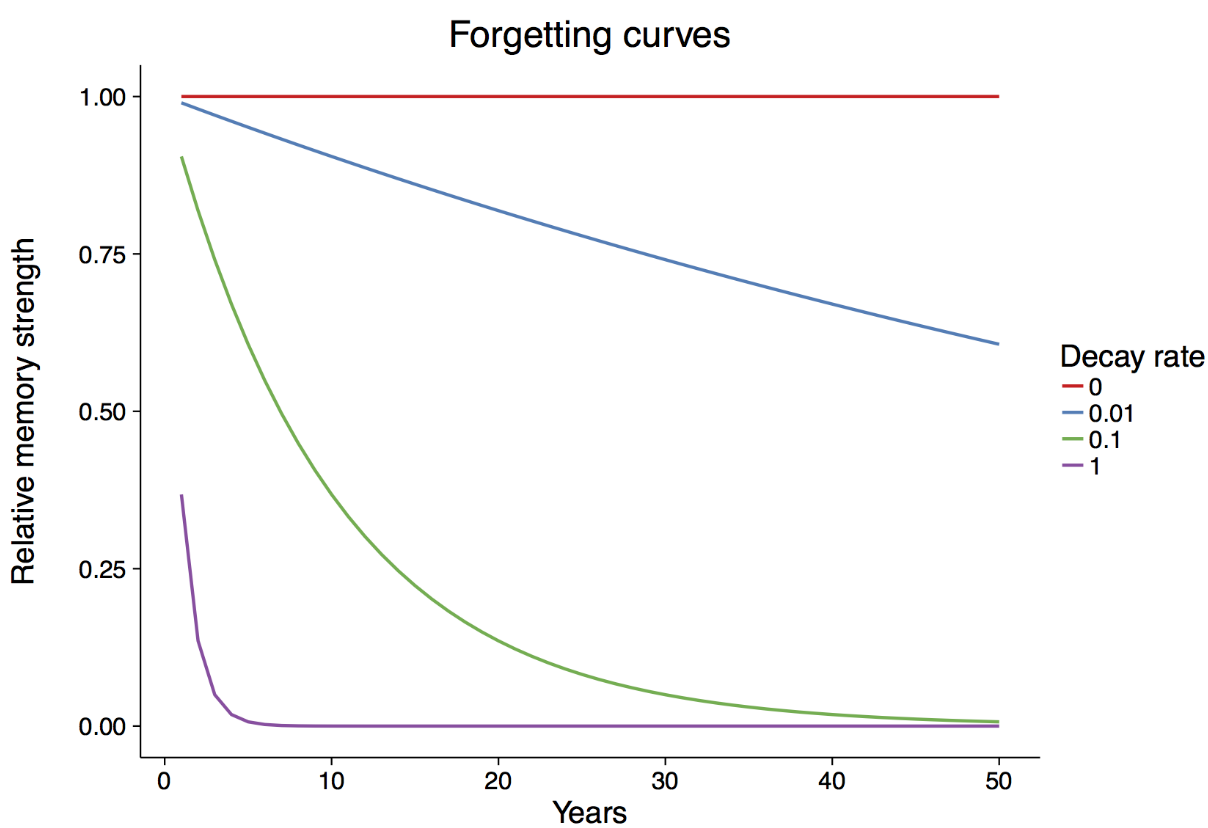
Risk:	***25%***	***75%***
	Drought Year	*Normal Year*
Barley Yield	*0.93*	*1.18*
Wheat Yield	*0*	*1.6*

Best land-use ratio: 52% barley, 48% wheat

  - simple optimization problem
  - yield values taken from estimates of ancient wheat and barley varieties

Risk perception

- Calculate drought risks by determining the proportion of the past 50 years where $< 300mm$ of rain fell during the growing season.
  - wheat crops fail in years below this rainfall threshold.
- Wheat-barley ratios only "optimal" if drought risks are accurate.
  - farmers calculate risks based on past experience, but perceptions of risk can vary among individuals.
- Examine the sensitvity of crop diversification strategies to variations in risk-perception psychology.
  - represent psychological variability using "forgetting curves" that capture the exponential decay of memories over time.
    * drought events in previous years are less salient than droughts in recent years for the calculation of drought risks.
  - allow the decay rate to vary
    * e.g. a decay rate of 0 corresponds to perfect recall over the past 50 years, decay rate of 1 means everything more than 5 years old is forgotten.

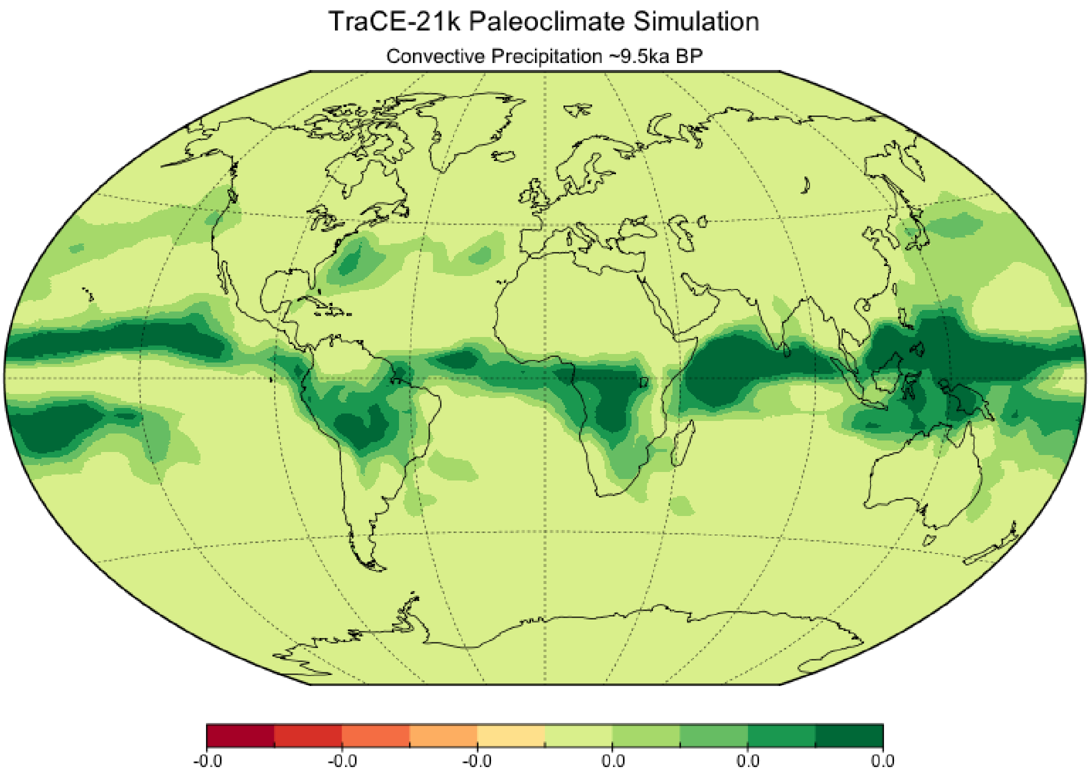


- the result is that farmers calculate the optimal land-use strategy that, *to the best of their knowledge*, uses information from the past.

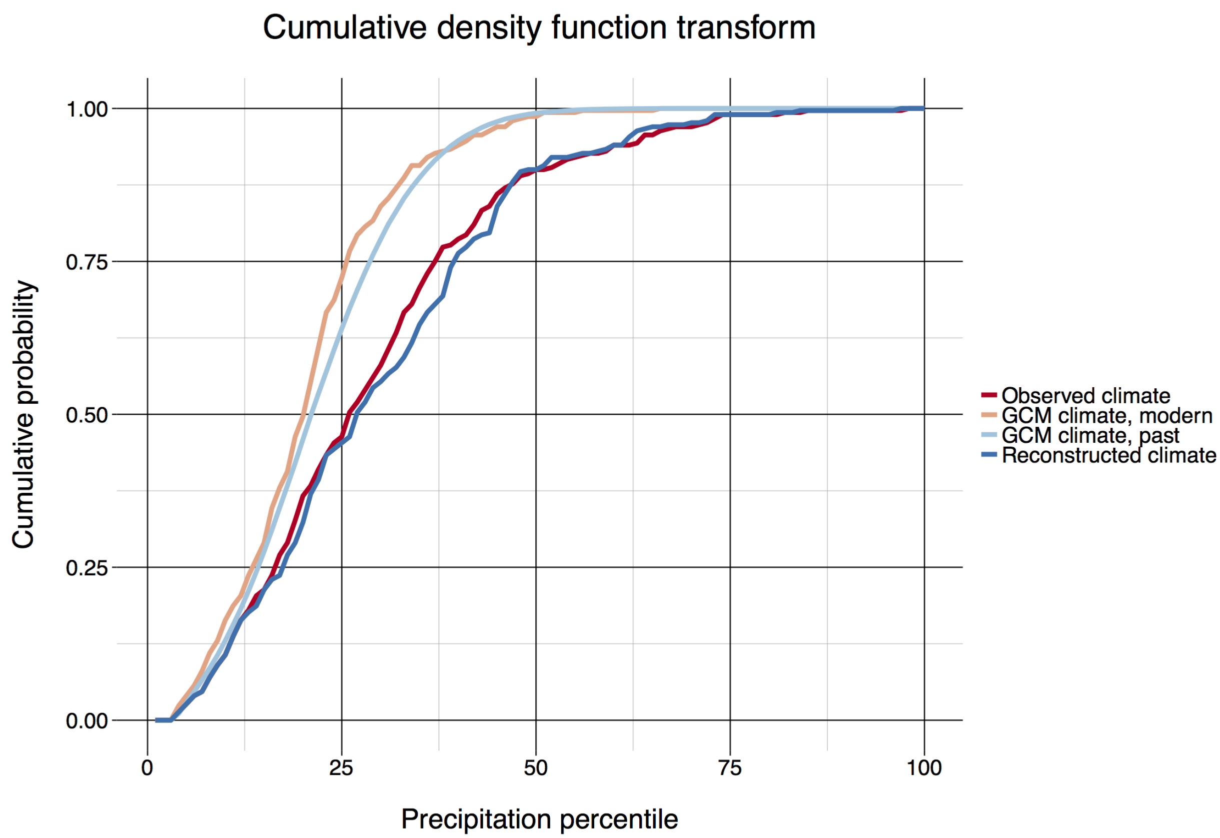
Climate model

- Estimate patterns of drought risk in the past using paleoclimate models

- TraCE21k, transient simulation of global climate during the last deglaciation.
  - physically consistent spatiotemporal dynamics, driven by current best estimates of climate forcings (e.g. orbit, GHGs, meltwater flux).
- Extract and bias-correct climate model for a region in western Turkey representative of the typical Mediterranean rainfall regime.

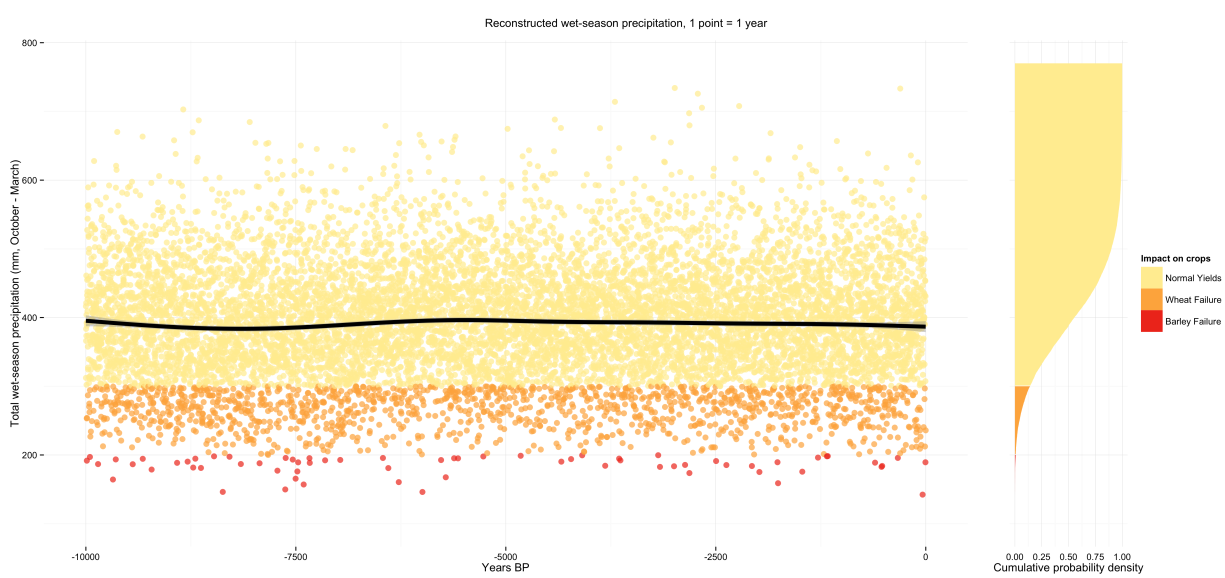


- Correct biases from scale mismatches, parameterizations, etc., using CDFt approach.



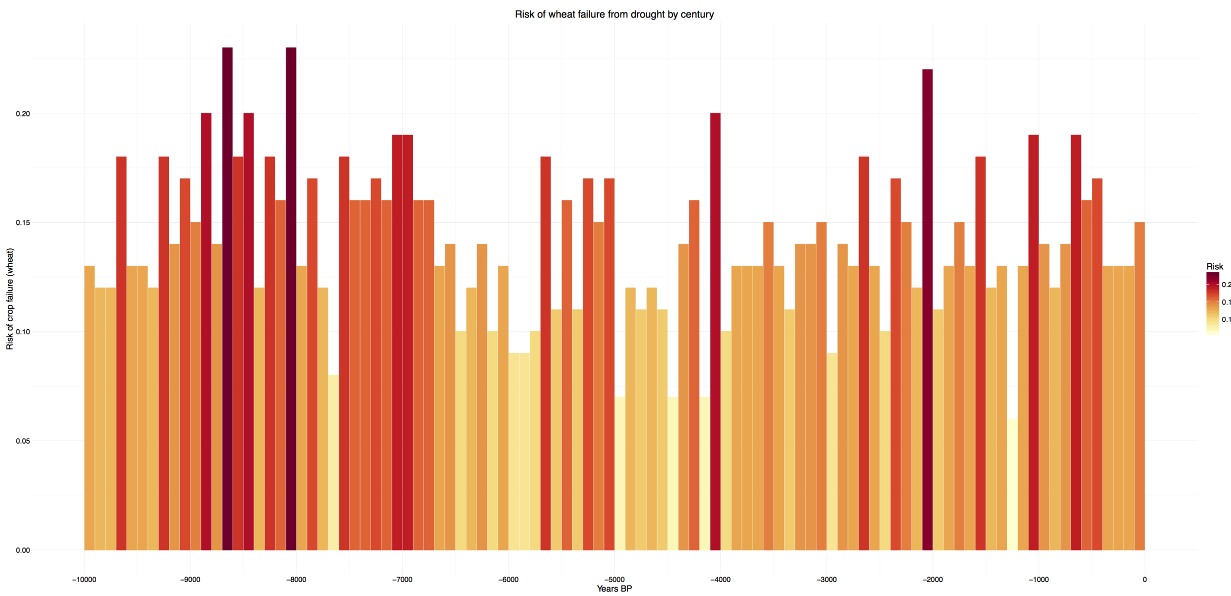
Risk calculation

- Calculate temporal drought patterns from bias-corrected climate model outputs using the 300mm wet-season rainfall threshold.

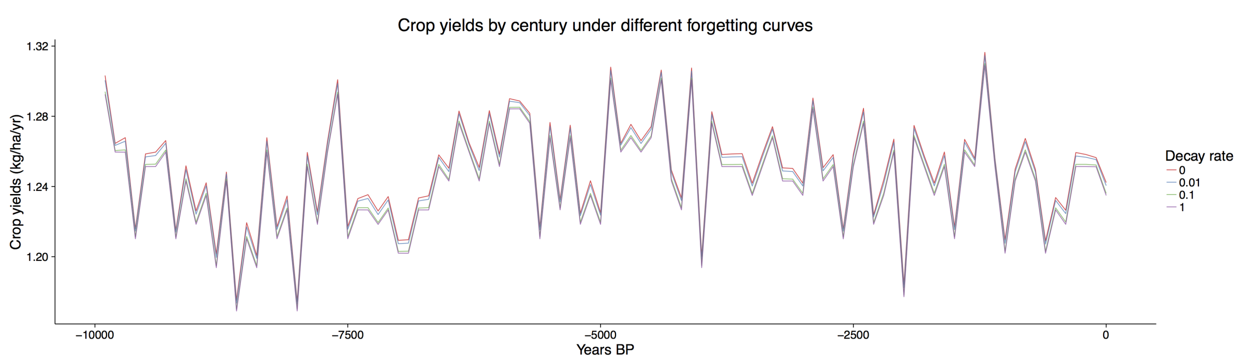


Results and Discussion

- Visualize temporal patterns of drought using bias-corrected climate model outputs, calculating risks for each century of the simulation.
  - Risk of drought in a given year varies between ~10% and ~20%.



- During periods of climatic stability, allowing past experiences to influence decision making helps farmers minimize the impacts of *predictable* drought. But past experiences are less informative during periods of rapid climate change, and even farmers who manage risk "optimally" experience major food shortfalls. Climatically-induced variability in food supplies far surpasses that from differences in risk-management strategies.
  - This finding suggests that the efficacy of risk managing strategies that rely on regulatory feedbacks is limited to periods of relative climatic stability.
  - This is consistent with the observation from the Roman Period Mediterranean that while minor food crises were common in the ancient world, extreme famines were rare (Garnsey 1989).



- Future work should incorporate:
  - Yield information derived from crop models
  - Food sharing between farmers
  - Spatially-structured climate change