

AMEDEES – DB: **A**daptation of **MED**iterranean **E**conomies to **E**nvironment **S**tresses: building a database for archeological and paleoenvironmental data

Participants.

These were drawn from 4 research groups.

GREQAM

Alan Kirman, Professor Emeritus Aix Marseille University Economist and Complex Systems specialist

D. Contreras, archaeologist post doc OTMed and ABM modeller,

Nobuyuki Hanaki, economist Professor Aix Marseille University Economist and ABM modeller. (Now professor at the UCA Nice)

Sylvie Thoron, professor at Paris-Est Créteil University, Economist specialized in game theory, environmental economics and experimental economics. She is an associate member of GREQAM.

CEREGE.

Joel Guiot DR CNRS, Paleoclimatologist and Specialist in Climate Change

C. Morhange, geoarcheologist, Romain Suarez, OT-Med GIS engineer

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Alberte Bondeau, CR1 CNRS, Agricultural System Modeler,

M. Djamali, palynologist,

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M. Leydet, pollen database manager,

F. Guibal, dendrochronologist.

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Delphine Isoardi, CR1, CNRS

Loup Bernard is lecturer at the University of Strasbourg, in the UMR 7044 Archimede. He is an associate member of the CCJ. Specialist in Archaeological Data-bases.

Eneko Hiriart

Other participants MB Carre, F. Mocci, JL Edouard, D. Garcia, S. Bouffier.

This project started from the premise that natural ecosystem, agropastoral and socio-economic models give us some insights into the future path of the feedback cycles between societies and their environments. These feedback cycles are known to have contributed to the evolution of socio-economic systems in both the distant and the recent past. It has been argued that the effects of recent regional droughts on the crops were quite similar to what happened earlier in the past with non-industrialised societies. The past is then an important source of information in terms of its wide repertoire of adaptive patterns and risk-minimizing measures and we may use it to develop some questions, such as *why did some past societies show better socio-economic adaptation than others?* We do not suggest that these events can be considered simply as direct analogues for our current highly technological societies. Nevertheless, they can be used to contextualize the concurrent socio-economic adaptations, which then can be used to develop a framework for adaptive responses in the future. The problem is complex and we need to integrate basic science with the analysis of the evolution of society and that is what was the aim of the work achieved so far.

Results

We have started to develop an integrated data based model as the first step towards achieving an overall model. Our project incorporates the following steps:

- (1) a regional documentation of climatic changes and socio-economic transformations in the Mediterranean during the last millennia,
- (2) a climate model with downscaling tools to work at the appropriate scale,
- (3) proxy models able to simulate the main characteristics of the ecosystems studied,
- (4) an agropastoral model to simulate the main food resources used by the past societies,
- (5) a socio-economic model able to simulate various modes of socio-economic behaviour that replicate the real-life decision making parameters of societies in sub-regions of the Mediterranean,
- (6) various statistical methods to merge data and models and to validate the results.

With the limited resources and time available we could not hope to complete the entire project but we have made considerable progress on each of the steps.

Specific Results

In particular we have analysed the relationship between past climate and prehistoric Mediterranean agriculture by adapting a process-based dynamic vegetation model to estimate past agricultural productivity under climate scenarios that characterize the extremes of Mediterranean climate (warm/wet, cool/wet, warm/dry, and cool/dry) in the Holocene. We have adapted LPJmL (the Lund-Potsdam-Jena-managed-landscape model, (cf.

Bondeau et al. 2007)) to the modeling of past agricultural productivity. Calibrating this model for past crops and agricultural practices and using a combined downscaling and simulation approach to produce high spatiotemporal resolution paleoclimate data from a Mediterranean-wide Holocene climate reconstruction (Guiot & Kaniewski 2015), we have simulated realistic potential agricultural yields under past climatic conditions derived from the Holocene climatic extremes for a study area in Provence. We have focused on comparing the range of variability induced by climatic shifts with that achievable through changes in agricultural practices.

For a case-study area in Provence we have drawn together data from a Mediterranean-wide Holocene climate reconstruction (Guiot & Kaniewski 2015), the Patriarche archaeological atlas (<http://www.culturecommunication.gouv.fr/Politiques-ministerielles/Archeologie/Etude-recherche/Carte-archeologique-nationale>), and ArkeoGIS (<http://arkeogis.org/>). We have developed a series of methodological tools to downscale the paleoclimate data and enable use of the LPJmL agroecosystem model results as a means of analysing archaeological settlement patterns over time. These advances make possible the continued development of the agent-based model with some reasonable parameters relating changes in potential agricultural productivity to human behaviour.

The socio-economic agent-based model is still in a rather simple form and this needs now to be generalised to allow us to model and calibrate to data from more recent periods. In particular, we need to model the way in which the individuals learn from their experience and change the rules that they use to adapt to changes in the climate.

Interdisciplinarity: This project required active collaboration between specialists of present and past societies (sociologists, economists, anthropologists, historians, archaeologists, geographers...) and specialists in the environment ((palaeo)-ecologists, (palaeo)-climatologists, geoscientists, hydrologists, agronomists...). Almost all these disciplines are present in this consortium. The project is based on field data, and existing digital tools (relational databases, geographical information systems) have been used to interconnect the data. Where necessary we have also developed new analytical tools in R for analysing the relationships between these data.

AMEDEES-DB is an important contribution to the international program MISTRALS (2010-2020) launched by the CNRS, which intends to devote considerable resources to obtaining a better understanding of the Mediterranean Basin, its vulnerabilities and potential for the future. In particular, it is an important contribution to the component PALEOMEX (<https://paleomex.lsce.ipsl.fr/>), which aims to understand interactions between climate and water, food, fibre resources during the events when past civilisations have declined during the Holocene.

AMEDEES-DB is a contribution to ECCOREV Axis 1 and more particularly the impact of climatic change on ecosystems and human societies. The objective has been to collect information about past relationships between climate and man.

Publications and Presentations

Papers

Submitted. Contreras, Daniel A., Alberte Bondeau, Joël Guiot, Alan Kirman, Eneko Hiriart, Loup Bernard, Romain Suarez, and Marianela Fader. "From Paleoclimate Variables to Prehistoric Agriculture: Using a Process-Based Agroecosystem Model to Simulate the Impacts of Holocene Climate Change on Potential Prehistoric Agricultural Productivity in Provence, France." In Kluiving, Sjoerd, ed. *Geoarchaeology Approaches and Methods: Special Issue of Quaternary International*.

Submitted. Contreras, Daniel A., Joël Guiot, Romain Suarez, and Alan Kirman. "Reaching The Human Scale: A Spatial and Temporal Downscaling Approach To The Archaeological Implications Of Paleoclimate Data." *Journal of Archaeological Science*.

In preparation. Contreras, Daniel A., Eneko Hiriart, Alberte Bondeau, Alan Kirman, Joël Guiot, Loup Bernard, Romain Suarez, and Sander Van Der Leeuw. "Regional Paleoclimates And Local Consequences: Integrating Gis Analysis Of Diachronic Settlement Patterns And Process-Based Agroecosystem Modeling Of Potential Agricultural Productivity In Provence (France)". To be submitted to *PLOS One*, Feb 2017.

Presentations

2016

- EGU "From Paleoclimate Variables to Prehistoric Agriculture: Using a Process-Based Agroecosystem Model to Simulate Prehistoric Agricultural Productivity" Daniel Contreras, Alberte Bondeau, Joël Guiot, Alan Kirman, Eneko Hiriart, Loup Bernard, Marianela Fader, and Romain Suarez
- Troisième journée scientifique de l'OSU Pythéas - La modélisation : de l'infiniment petit à l'infiniment grand "From Paleoclimate Variables to Prehistoric Agriculture: Using a Process-Based Agroecosystem Model to Simulate Prehistoric Agricultural Productivity" Daniel Contreras, Alberte Bondeau, Joël Guiot, Alan Kirman, Eneko Hiriart, Loup Bernard, Marianela Fader, and Romain Suarez [poster]
- SimulPast, Barcelona "Simulating Known Unknowns: Integrating GIS Modeling Modeling of Settlement Patterns and Process-Based Agroecosystem Modeling of Past Agricultural Productivity in Provence (France)" Daniel A Contreras, Eneko Hiriart, Sander Van Der Leeuw, Alberte Bondeau, Alan Kirman, Joël Guiot, Loup Bernard, Romain Suarez
- Anthropology, Weather, and Climate Change (RAI/BM) "Using Dynamic Socioecological System Modeling to Explore the Footprint of Prehistoric Agriculture in the western Mediterranean" Daniel A. Contreras, Alan Kirman, Alberte Bondeau, Joël Guiot, Eneko Hiriart, Loup Bernard, Nobuyuki Hanaki, Sylvie Thoron, and Romain Suarez
- Nouvelles directions dans l'archéologie du paysage, IMéRA, Marseille "How Significant Were Past Climate Changes in Provence? Examining Paleoclimates at Landscape Scales Using GIS and Agroecosystem Modeling" Daniel A. Contreras
- Modeling Challenges for Sustainability, Research Institute For Humanity And Nature, Kyoto (Japan). "What can archaeology contribute to modeling sustainability". September 28-30, 2016. Daniel A Contreras
- "Archaeology, Climate Change, and Agent-Based Models: Necessary Ingredients and Viable Questions in a Case Study from Provence." Invited talk in the 7th Workshop on Complex Evolving System Approach in Economics: "On Agent-Based Modeling", Université Nice Sophia Antipolis, November 2016. Daniel A Contreras
- "From Paleoclimate Variables to Prehistoric Agriculture: Settlement Patterns, Human Environments, and Process-Based Agroecosystem Modeling in Holocene Provence". Invited talk in the Capita Selecta Research Seminar, Groningen Institute of Archaeology, December 2016. Daniel A Contreras

2015

- Our Common Future Under Climate Change - The Mediterranean Basin in a warmer and drier world: challenges and opportunities. "Lessons from the Past: Modeling past human adaptation to climatic change in the Mediterranean Basin - AMENOPHYS (an OTMed Project)." Paris, July 2015. A. Kirman, A. Bondeau, D. Contreras, J. Guiot, N. Hanaki, S. Thoron, L. Bernard, E. Hiriart.