

IHOPE: the role of the very long term in reconstructing socio-environmental interactions

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What is the Earth System Modeling community good at?

- It is good at global climate modeling
- It is good at global modeling of aspects of the dynamics of the terrestrial environment
- It is getting better at multiscalar modeling of dynamic interactions between climate and aspects of the terrestrial environment (Ingram)
- It is beginning to use a complex systems perspective (Finnegan)
- It is beginning to include societal dynamics (both)

What is it not so good at?

- Interactions between societal and environmental dynamics (including atmosphere, hydrosphere and biosphere)
 - In the anthropocene, there is no ‘environmental subsystem, nor a ‘human’ one, there are only socio-environmental dynamics (McGlade)
 - Trans-disciplinary, not inter- or multi-disciplinary work:
 - Definition of different kinds of questions
 - Reflection on epistemologies of different disciplines
- Regional scale necessary to fully contribute to adaptation (downscaling of climate and upscaling of societal dynamics)
- Dealing with complexity (see John Dearing’s talk)
- Modeling of the very long term dynamics
 - Why is it important?
 - What does it require?

Why a Complex Systems approach?

- Our interventions in the environment are based on simplifications, but cause new complexities on unknown time-scales
- Current science is an extension of the hypothesis testing, problem solving and learning strategies that have served humans successfully for long.
 - They are based on trial and error methods lacking sufficient understanding of underlying rule sets.
- This reductionist, mechanistic and empirical approach seemed adequate for many centuries
- It is increasingly inadequate to deal with the dynamics of highly inter-connected and rapid changes in global society.

Why very long-term research?

- Increasingly, we dependent on models and scenario's based on the last 50-200 years
 - That is a very high risk strategy to attain long-term sustainability
- If you don't take the longer term into account:
 - you miss the long time-scales (millennia) both natural and cultural
 - you overlook many dynamic system states
 - your sample is biased towards the present
 - you overlook the change of change
 - you overlook the role of legacies
- Archaeology and history can provide the data
 - They collect very different kinds of data that are less easy to integrate

IHOPE goals

- *Map the integrated record of biophysical and human system change on the Earth over the last ten to hundred millennia, with higher temporal and spatial resolution in the last 2000 and the last 100 years.*
- *Understand the socio-ecological dynamics of human history by testing human–environment system models against the integrated history.*
- *Project with more confidence and skill options for the future of humanity and Earth system dynamics, based on models and understanding that has been tested against history.*

Questions

- What are the key socio-ecological interactions from an integrated history that provide insight into future options?
- What are the complex and multiple interacting processes and scales that steer the emergence, resilience, sustainability or collapse of coupled socio-ecological systems?
- What is needed to evaluate alternative explanatory frameworks, specific explanations and models (including complex systems models) against observations of highly variable quality and coverage?

Core research issues

- What role does society play?
 - It defines the environment and environmental problems
 - It is at the core of all environmental challenges and solutions
- How do different social structures behave under similar circumstances?
- How to translate lessons from the past into the future?
 - Major epistemological problem
 - Models and scenario's only partial solution
- Can we avoid a crisis?
 - We seem now to be more in control - how real is that?

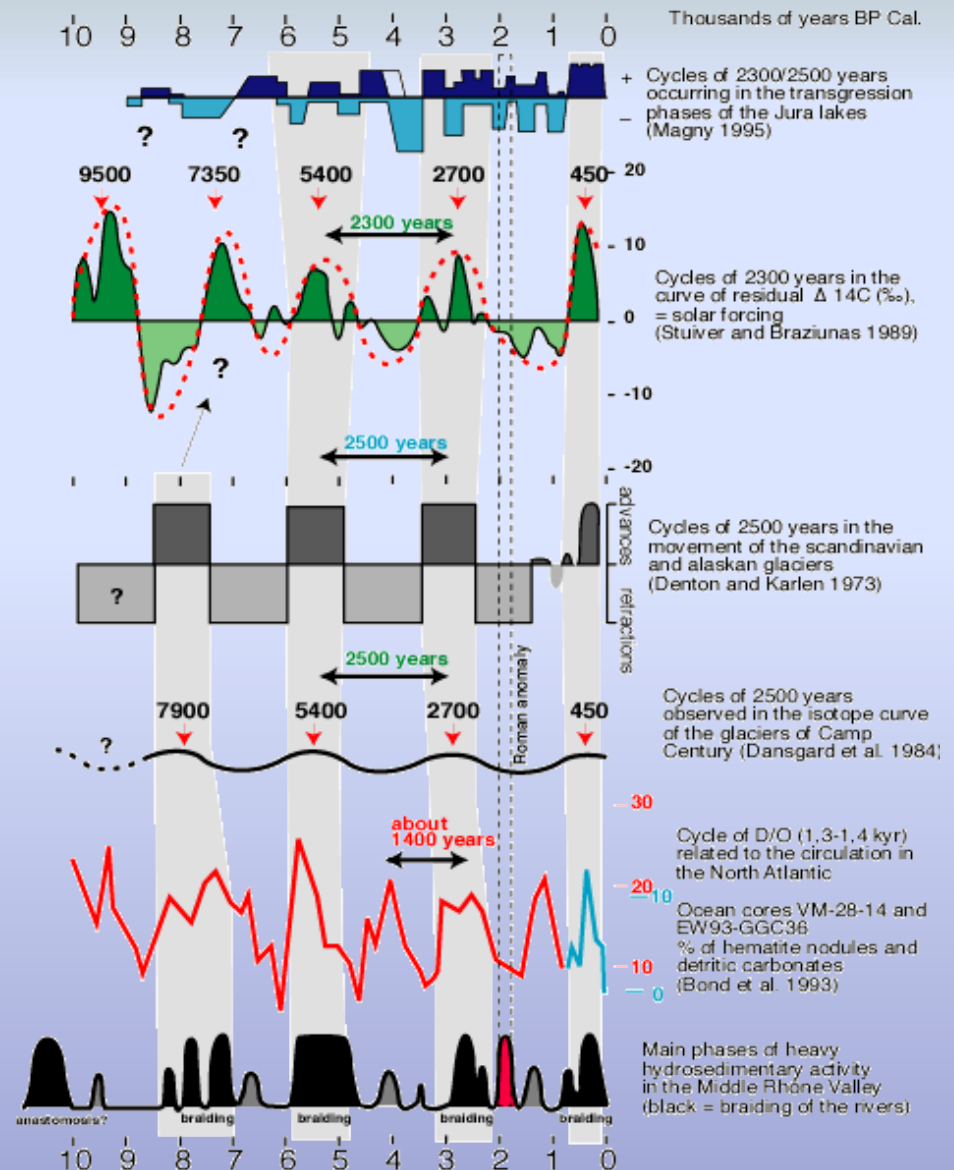
The increasing role of humans in the environment

- **Early Holocene**: diffuse erosion under expanding vegetation cover, dominated by bio-climatic parameters (10300-7500 bp)
- **The Atlantic and the “climatic optimum”** (7.500-4.500 bp): biostasis and the first anthropogenic impact on the landscape (Neolithic and Chalcolithic)
- **Later prehistory** (4.400-2.200 bp): strong contrasts between the human and the climatological dynamics.
- **The end of the Iron Age and the Roman period** (2.200-1.500 bp): extensive fragilisation of the geosystem with different morphogenetic consequences.
- **The Middle Ages** (1500 - 500 bp): Relative stability of the landscape, followed by delayed morphogenetic activity due to earlier human pressure.
- **The modern and contemporary periods** (500-0 bp): the conjunction of a multisecular climatic deterioration and the holocene maximum in human pressure on the environment.

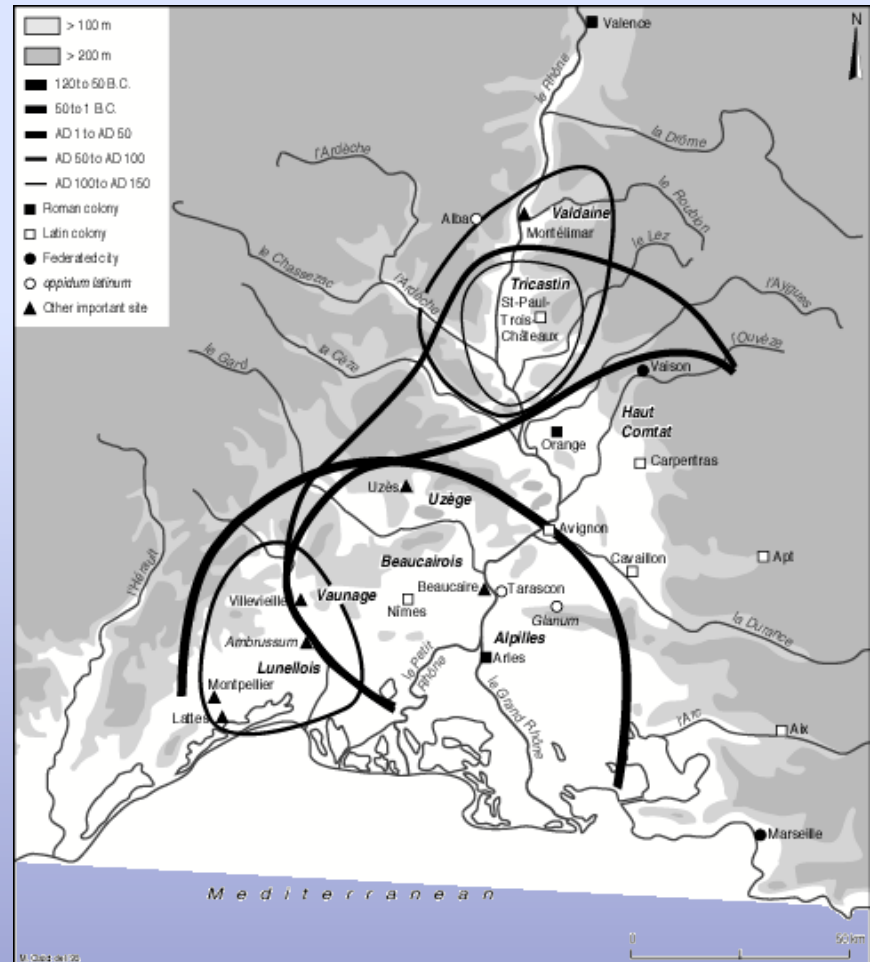
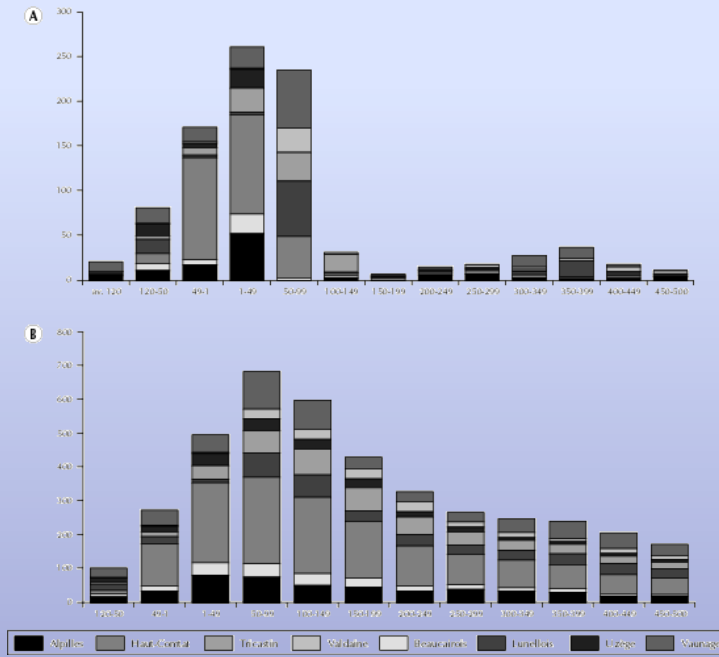
Why study the Roman period?

- We chose to study the Roman period
 - It was experienced as a crisis
 - We have good data
 - We can study a complete cycle
- Urban perception of the landscape
 - *Centuriations* (land registers)
 - Irrigation agro-industry
 - Rectangular road systems
 - Drainage works
 - Land re-allotments
 - Aqueducts
- Very similar to our own

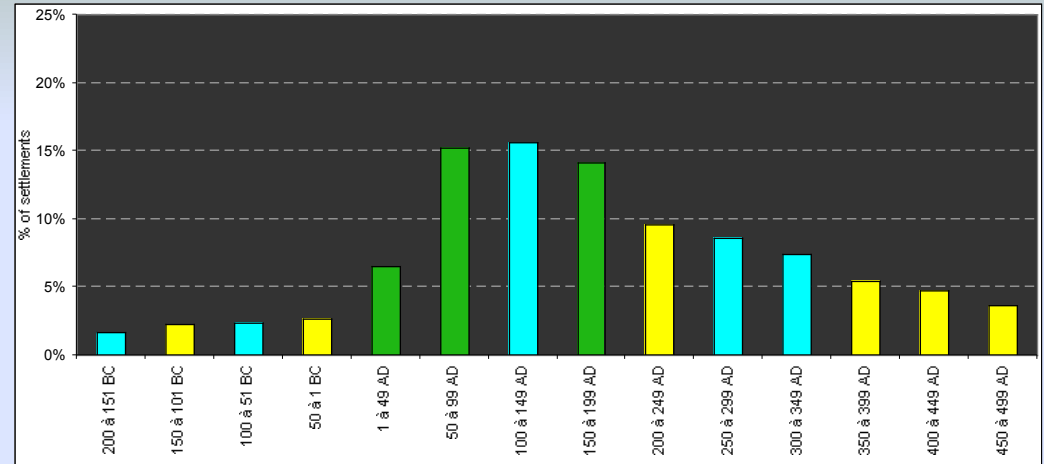
Global climate change ... and a regional anomaly!



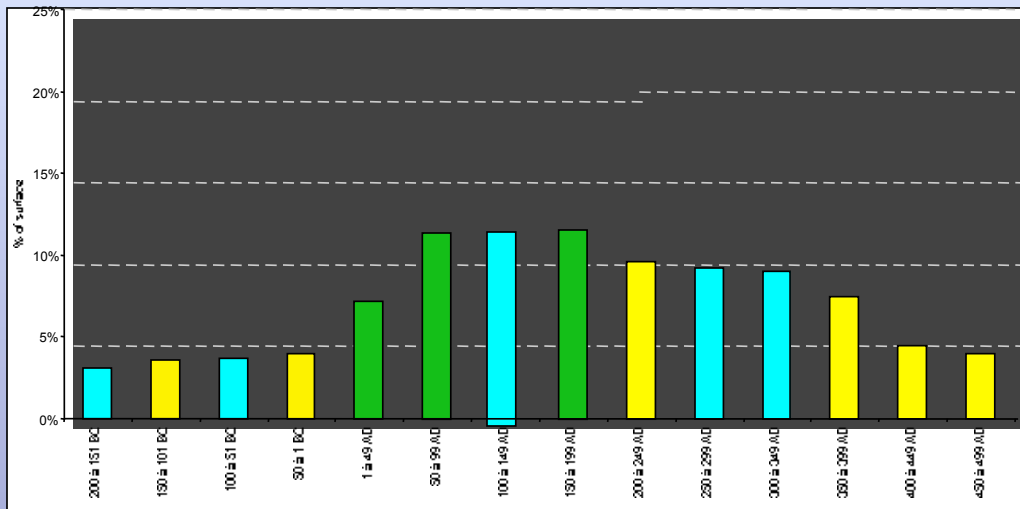
The Roman settlement of Southern France



Green: Mixed
Blue: Unstable
Yellow: Stable



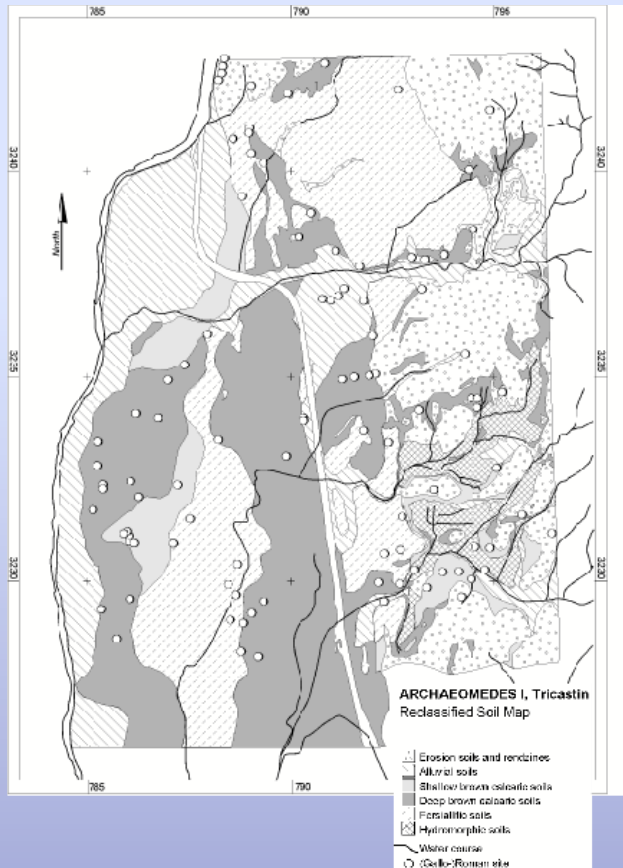
Number of sites per period of 50 years



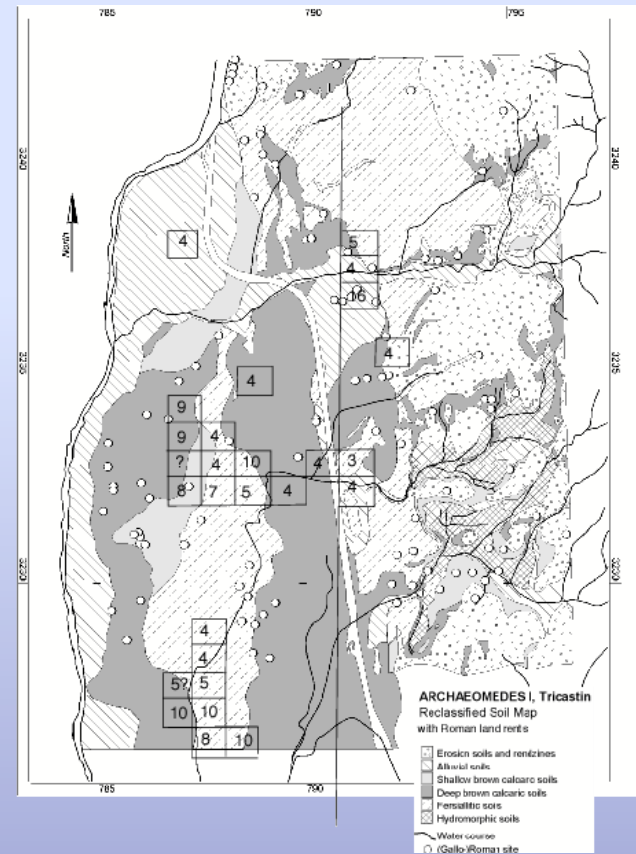
Total surface settled per period of 50 years

Settlement and
climatic
stability are
independent!

Roman perception of soils: Ease of handling over mineral content

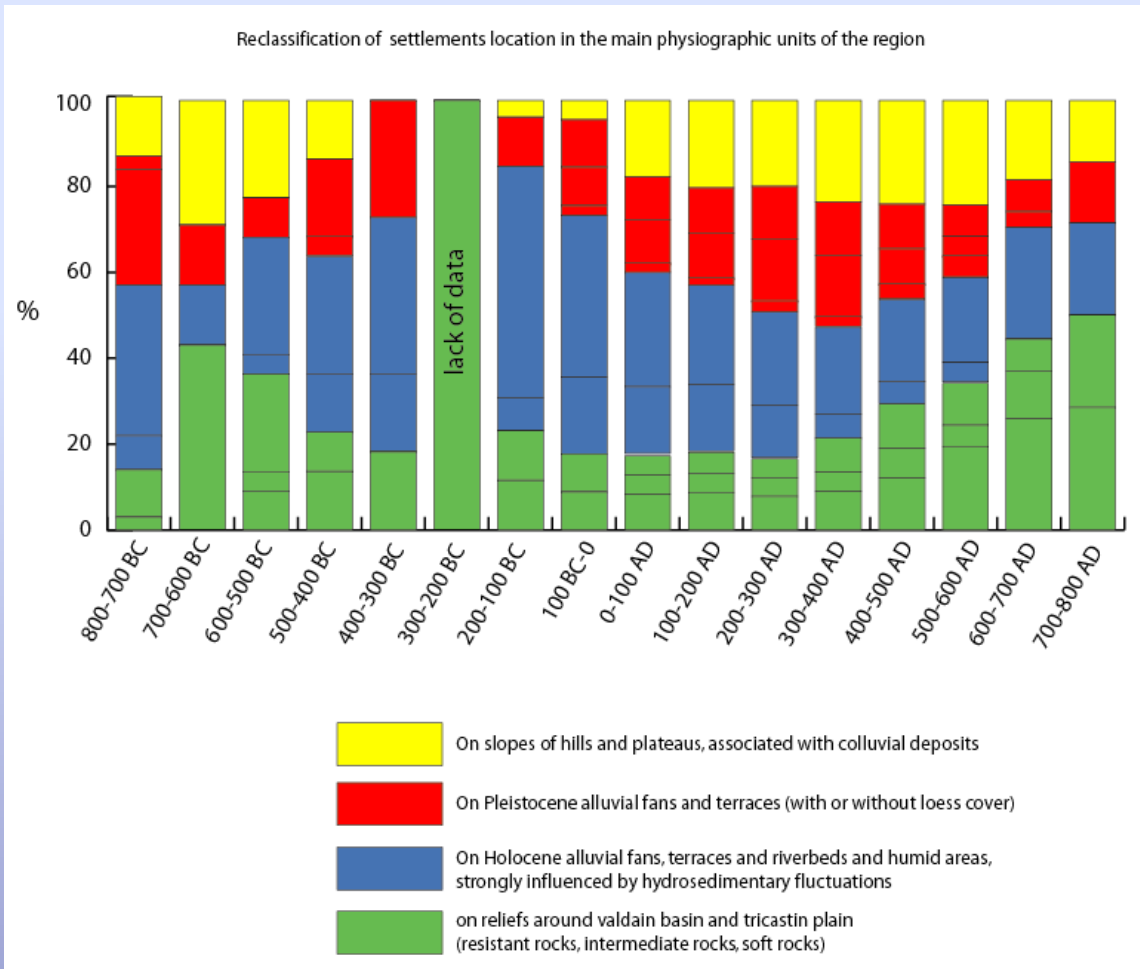


Light soils on low slopes preferred
over very rich, but heavy, valley
bottoms

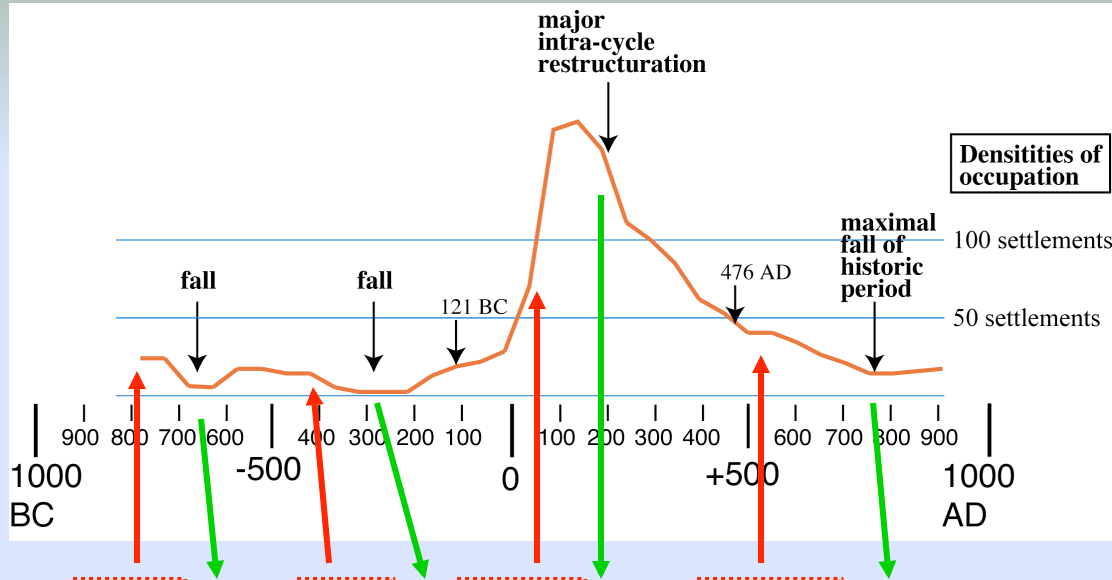


Taxation records confirm the
quality assessment

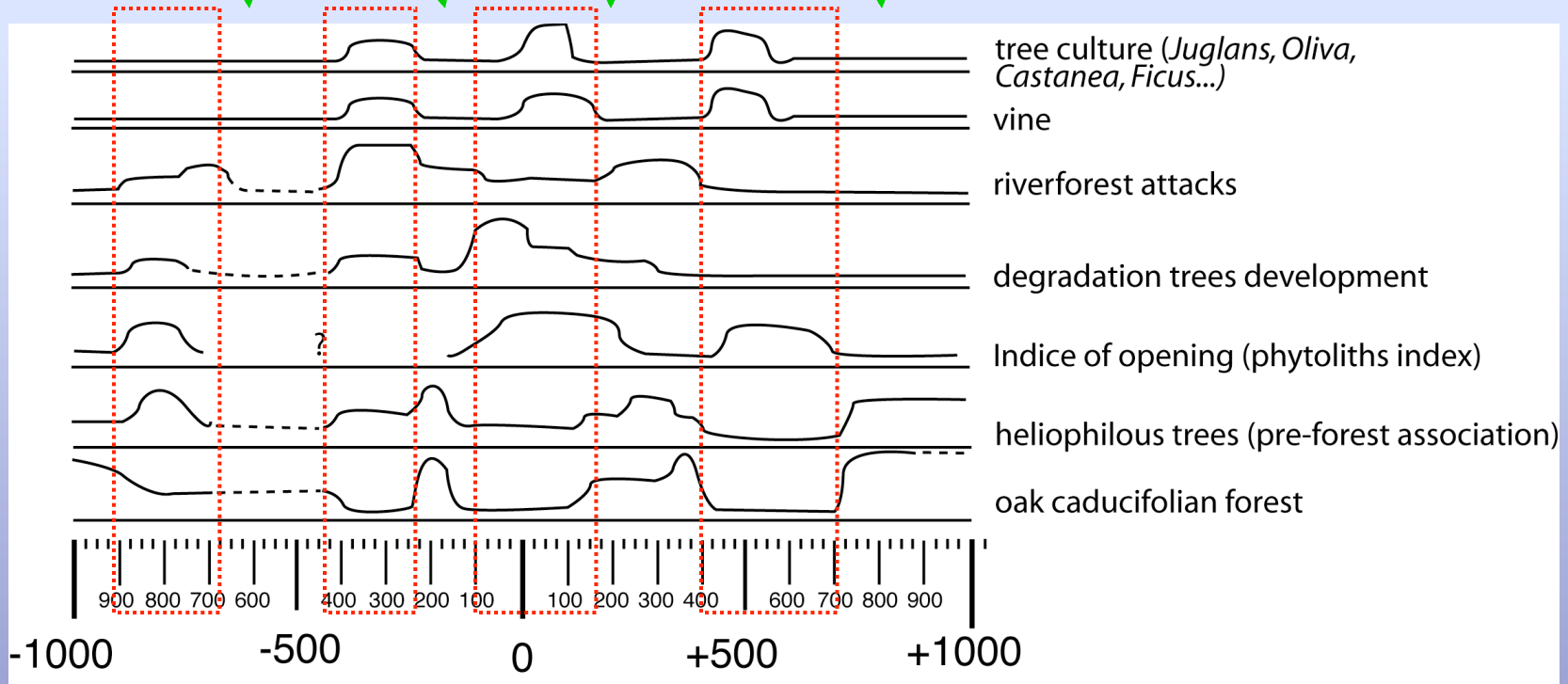
Settlement choice changes, but not with climate!



Vegetation cycles & settlement dynamics

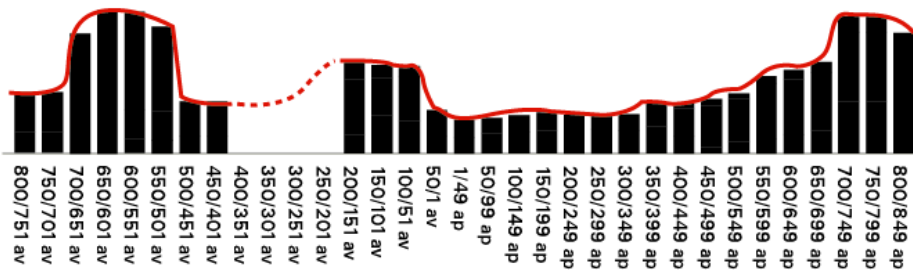


red arrows : agropastoral expansion
green arrows : agropastoral retrenchment / transformation)



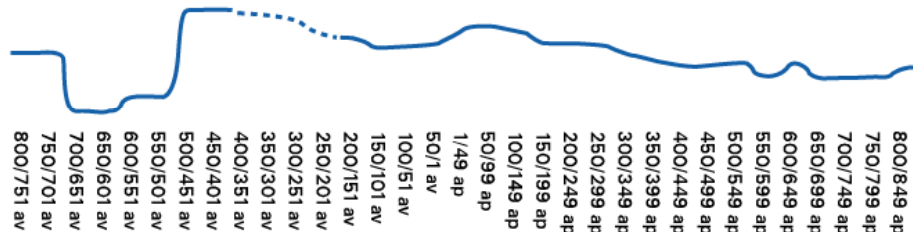
a.

Agrarian territories : dominant erosion soils around settlements between 800 BC and 800 AD (location in reliefs around the Valdain and Tricastin)



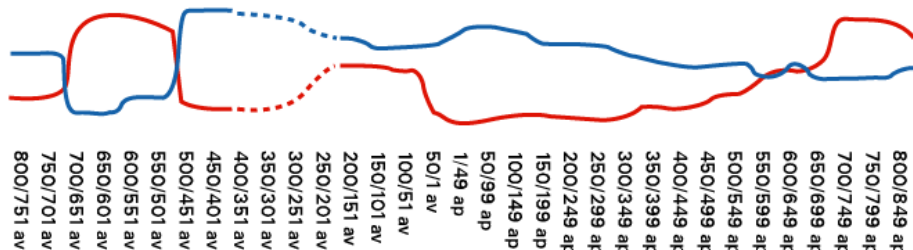
b.

Agrarian territories : dominant fluvial soils around settlements between 800 BC and 800 AD (location in lower plains of the Valdain and Tricastin)



c.

Typological study of the settlement organization
Comparison of curves of erosion soils association and dominant fluvial soils of agrarian territories between 800 BC and 800 AD (anti-correlation)



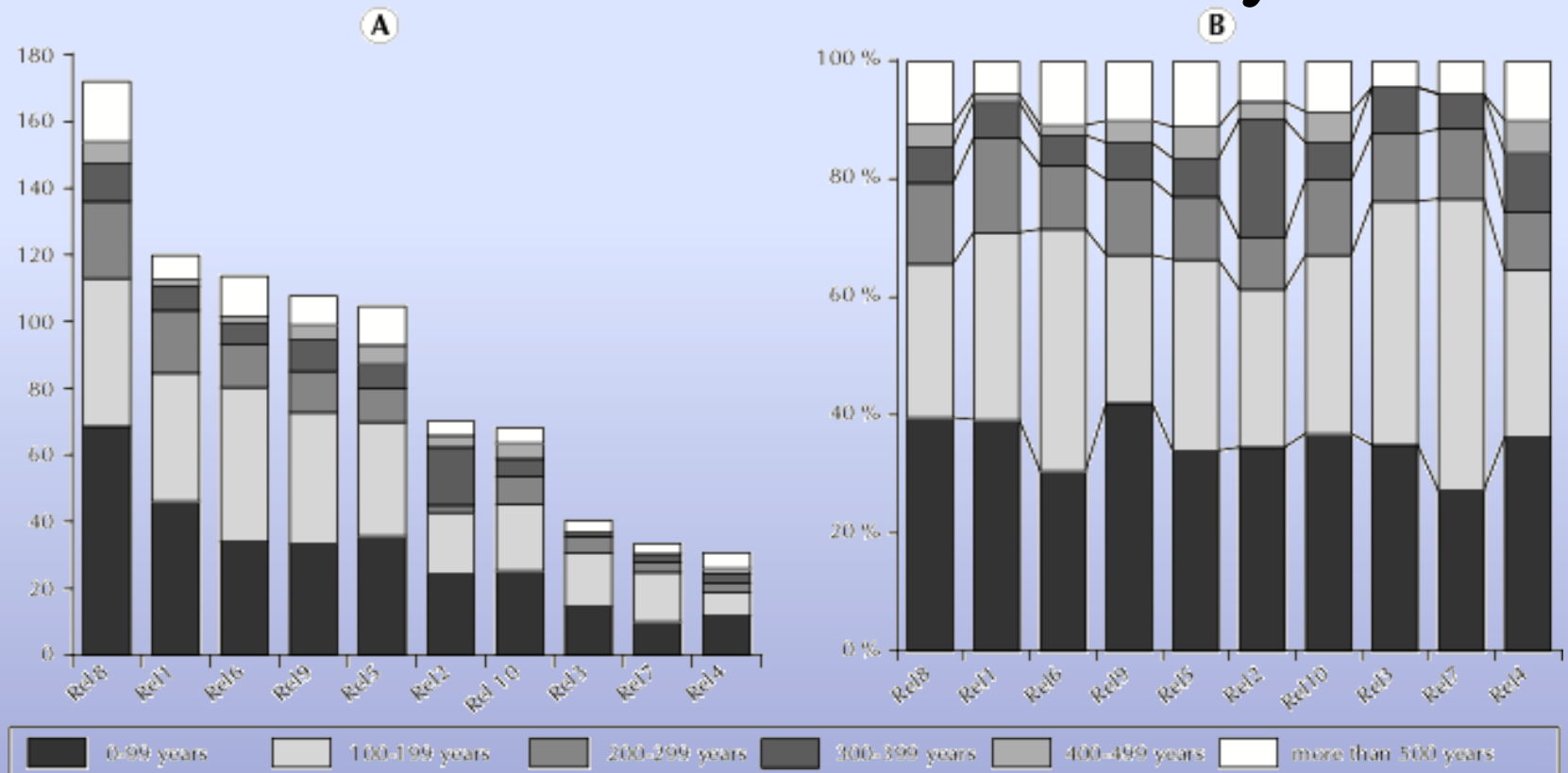
Eroded soils in the highlands and agricultural lands around settlements in the lowlands

a. Eroded surfaces in the highlands

b. Agricultural lands in the lowlands

c. Comparing the two curves

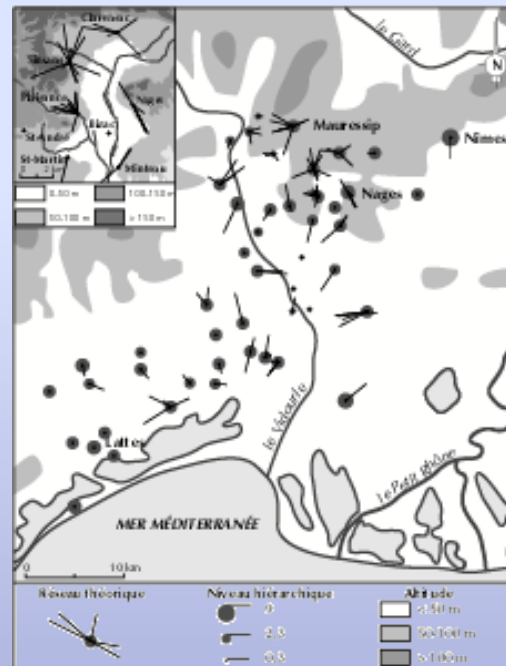
The 'environmental crisis' is a reorganization driven by the economy



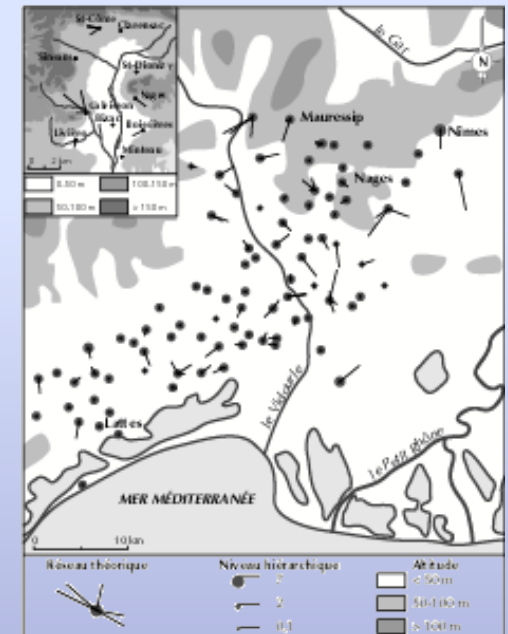
Internal dynamics of the settlement system



1st Cty. AD

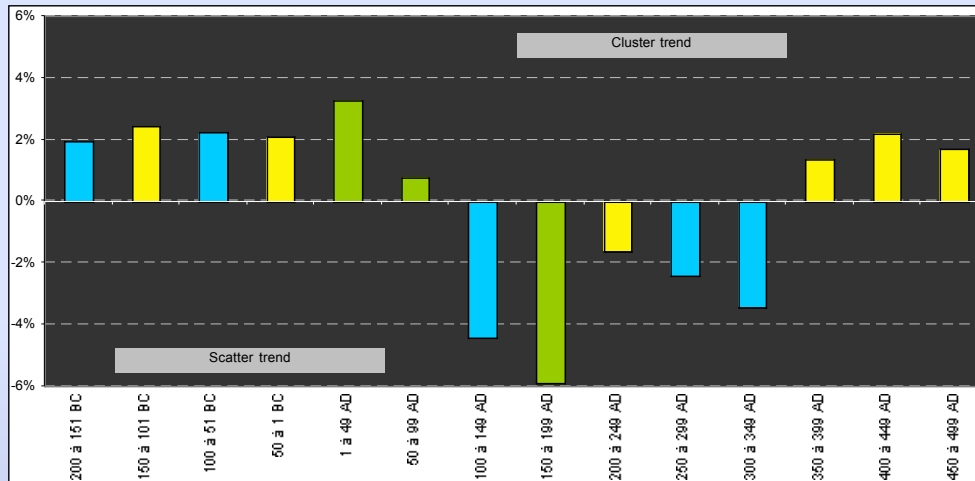


5th Cty. AD



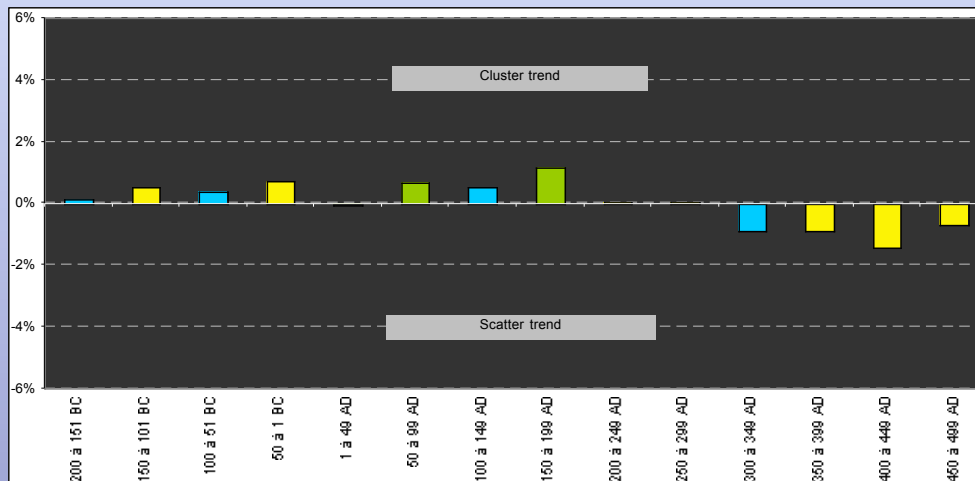
11th Cty. AD

Each region reacts differently



A: Tricastin
(densely settled plain)

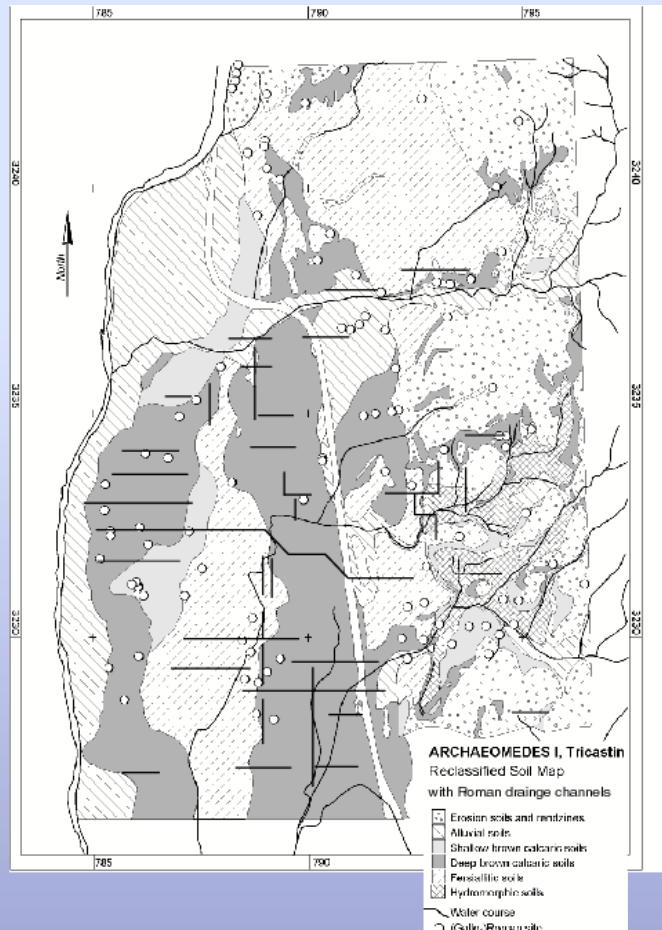
B: Valdaine
(mountainous area)



Green: Mixed
Blue: Unstable
Yellow: Stable

In the Tricastin, the 'crisis' is a 'peace dividend'

1st Century BC administrative
drainage scheme runs into
trouble in 1st Century AD
when it runs out of soldiers to
retire -
natural drainage takes over
again!



Comparing two crises

- 2–3rd century crisis is overcome, 6th century is not!
- Difference in degree of integration:
 - Before 3rd C. much looser
 - Lower overheads
 - Romans collect accumulated wealth
- 3rd C. transformations cause different structure, increase vulnerability
 - No easy pickings left - system depends on annual production
 - Huge administrative structure
 - It is no longer interesting for people to support the Empire
- Continued value creation essential to keep society together!

The appropriation of Nature

- Over the long term, the landscape becomes disturbance-dependent
 - In the early Holocene, crises occur only when climate and human occupation weigh in together
 - If they are out of phase, delays build up
 - At the end of the period, the slightest oscillation in either climate or anthropogenic pressure creates an immediate crisis
- The system has become hyper-coherent (an accident waiting to happen)
- Society keeps the environment stable
- *This seems a long-term trend*

Disturbance- dependency

- Complex ecological systems consist of hierarchies of dynamics on multiple spatio-temporal scales
- Faster dynamics easily take control of slower dynamics, *but not vice-versa*
- In the long term, “human” dynamics (rapid, but initially without much impact) take the upper hand, controlling the (slower) “natural” dynamics, that are more encompassing
- Landscapes become dependent on human activity to continue as they are (“*disturbance-dependent*”).
- *This seems to be another irreversible tendency!*

Risk spectrum shifts

- Any society's risk spectrum shifts over time with respect to its environment.
 - The perception of risk over-emphasizes frequent risks, and societies tend to do something about these
 - Human action involved introduces new risks, which include both short and long-term frequencies.
 - Long-term socio-environmental interaction tends to shift the risk spectrum towards the long-term.
 - Eventually, the society will meet what one could call a “risk barrier” by analogy to a “sound-barrier”. That may just be a bit too much ...
- *Another irreversibility!*

Societal dynamics are negentropic

Problem-solving structures knowledge → more knowledge increases the information processing capacity → that in turn allows the cognition of new problems → creates new knowledge → knowledge creation involves more and more people in processing information → increases the size of the group involved and its degree of aggregation → creates more problems → increases need for problem-solving → more problem-solving structures more knowledge, etc.

- That process brings people together in societies, transforms the environment, builds temples and cities, creates world views, innovations and technologies
- Societies are kept together by information flows, rather than flows of energy and matter

Two ways to perceive a relationship...

Milieu ...

- Humanity is compared to nature
- The cohesion of nature, its unknown aspects, its strangeness and force are amplified,
- The confusion and the handicaps of humanity are accentuated;
- Humanity is *passive* in a natural environment which is *active* and *agressive*
- Change is attributed to nature, and people have no other choice but to adapt to nature;
- Natural changes tend to be viewed as dangerous, because they are beyond the control of humanity.

Environnement

- Nature is compared to humanity
- The cohesion and strength of nature is diminished
- The same properties are accentuated in humanity
- The known aspects of nature seem to be more important
- Nature seems more controllable and loses its dangerous appearance
- Humanity tends to be viewed as the source of all change, people as creating their environment

The interaction between two perceptions

- The “*milieu*” and “*environnement*” perspectives are complementary
- By their interaction, the natural dangers are exaggerated and those of human intervention systematically undervalued.
 - This encourages society to increasingly intervene in its natural environment
 - It gives the impression that society’s actions reduce the risks it runs
 - In reality, society reduces by its actions the predictability of natural phenomena.
 - Society loses control: the more it transforms its surroundings, the less it understands them.
- *This seems to be an irreversible tendency!*

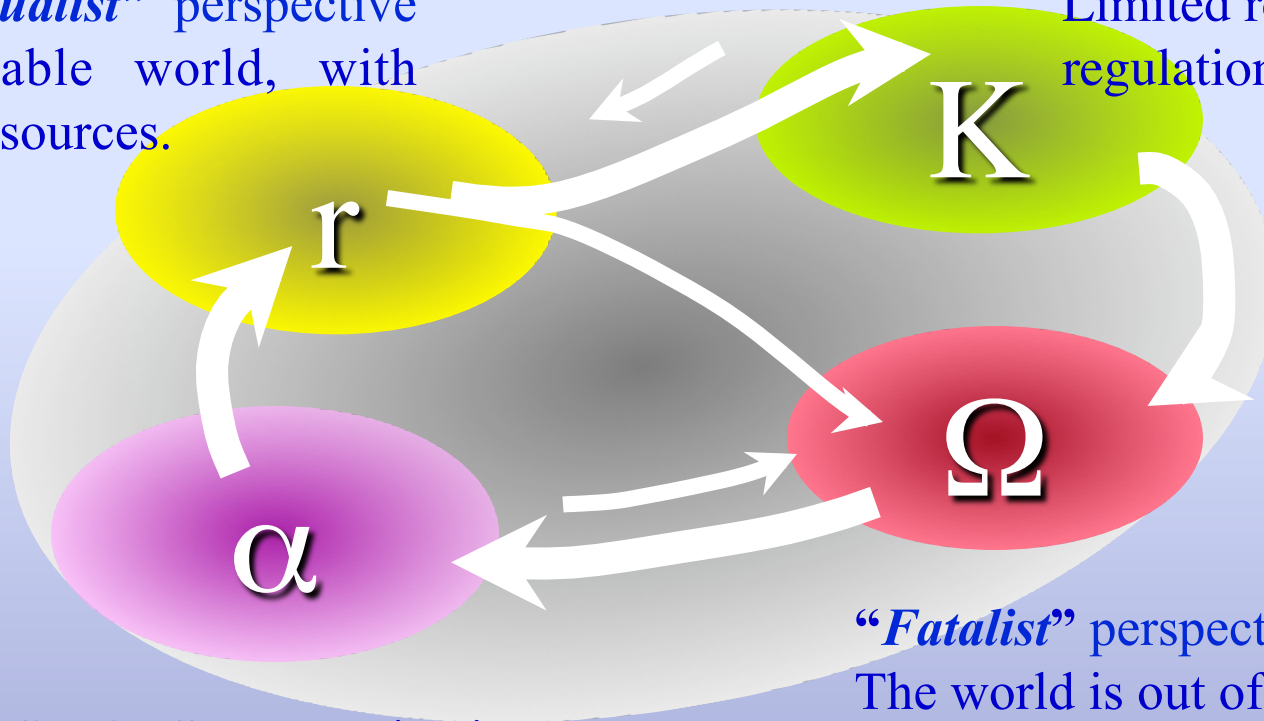
Crises

- Temporary incapacities of society to process the information needed to deal with change
 - Short-term solutions create long-term problems
 - Reduction of flexibility
 - Increasing overheads
 - Risks and ‘time-bombs ’
 - Initial structuring also structures the form of the demise?
- The dynamics are irreversible
 - The appropriation of nature point in this direction
 - So does the human perception of the relationship between people and their environment
 - So does human risk perception
 - And so does the relation between cognition and action
- *Unless frequent, drastic and encompassing change!*

People's attitudes change

“Individualist” perspective
in a stable world, with
ample resources.

“Hierarchist” perspective:
Limited resources, impose
regulation and control



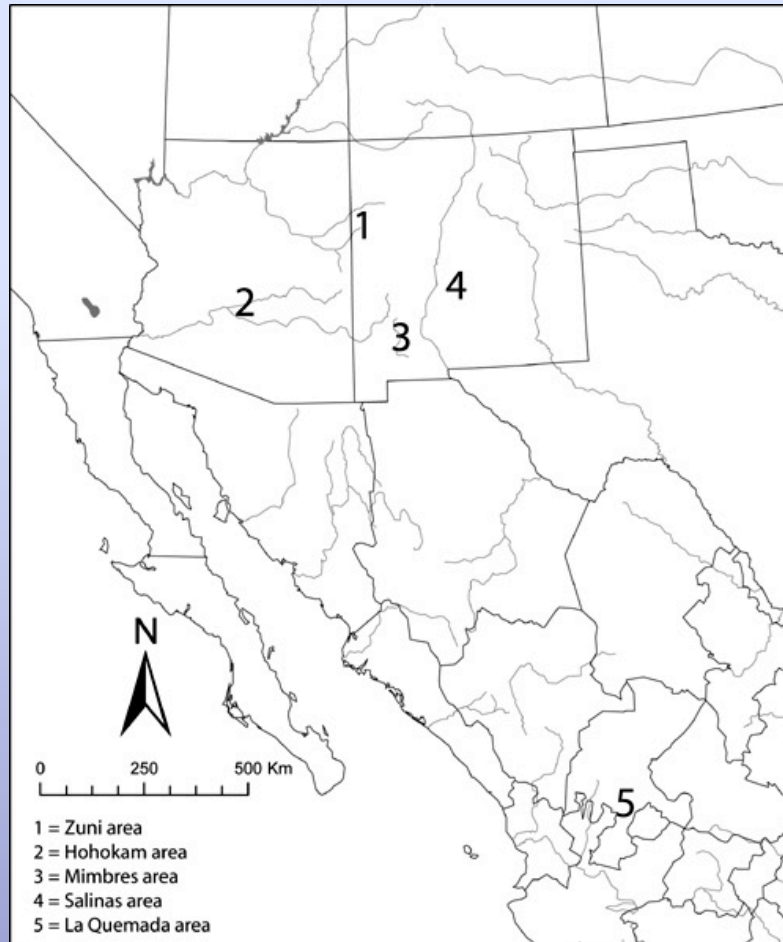
“Egalitarian” perspective in
unstable, precarious
circumstances of reorganization,

“Fatalist” perspective:
The world is out of control,
and life as a game of chance.

Conclusions

- The long term is important, archaeology can help
- A multi-scalar approach is essential
- Crises are societal rather than environmental
- Striving for sustainability externalizes change, and enhances vulnerability
- Society's impact is strongest in domains where it is most dependent on environment
- Ultimately, every exploitation system exhausts its resources, making fundamental change imperative
- Whether such change comes in time depends on the creativity and coherence of the society

Comparing 5 societies of the US SW

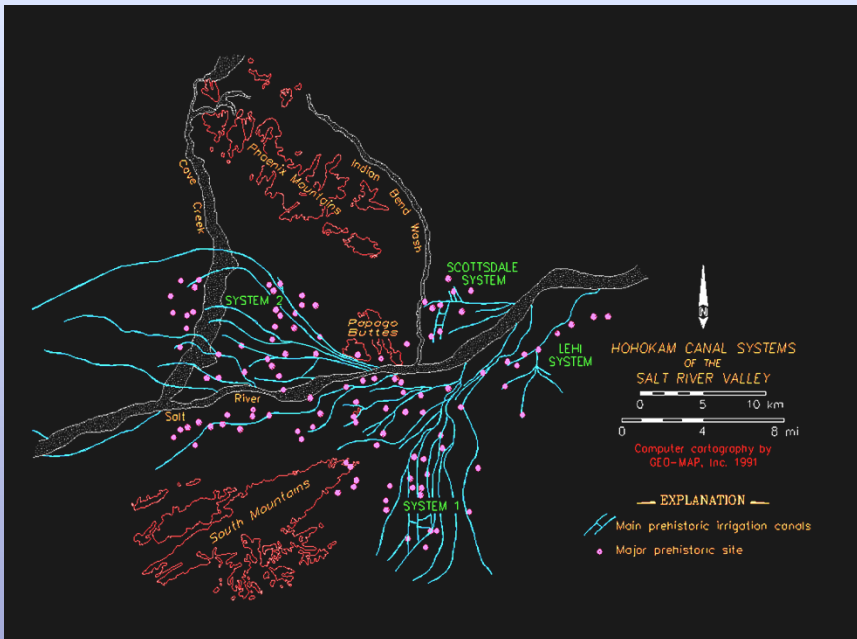


- The societies span 1000+ years (450-1600 AD)
- They are broadly similar
 - Agriculturalists
 - Arid environments
 - Not state-level
 - No draft animals or metal tools or wheel

Contrasts: Water control



Small water diversions in the Mimbres



Huge irrigation systems in Hohokam region

Contrasts: Social Complexity



Massive public architecture at La Quemada
Nothing approaching this scale elsewhere

Contrasts: Transformations

Hohokam

- Collapse of regional exchange system ca. 1070
- End of irrigation system and major population decline ca. 1450

Salinas and Zuni

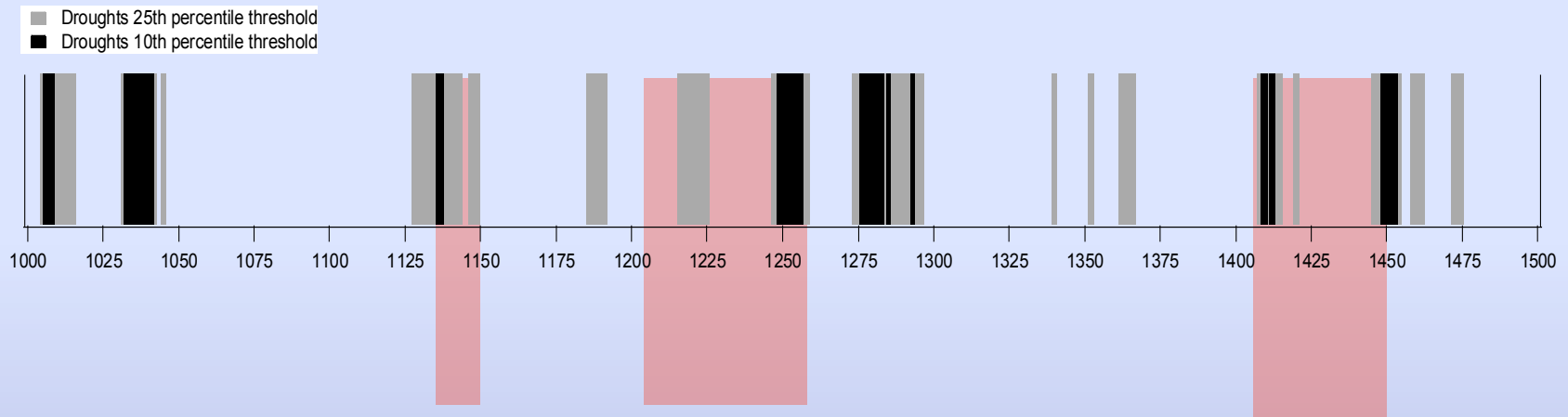
- Continuity from prehistoric to historic
- Settlement shifts, but no major declines

Research Questions

- Under what conditions does diversifying crops enhance resilience?
- Analysis re. addition of agave to corn-based economy
- Anderies, Nelson & Kinzig 2008
- Why are some transformations so much more difficult than others
- Role of the rigidity trap
- Hegmon et al. 2008



Mimbres climate and settlement data integration



**Reorganization from
large villages to
dispersed hamlets**

**Re-
aggregation**

Regional depopulation

Length and severity, and distribution of droughts. Grey bars are less severe than black bars. Bar width indicates the number of years of continuous drought. Pink bars mark periods of social transformation. While droughts occur during all of these periods, they also occur before and after each. **Droughts are not singularly causal.**



The Maya Hotspots

| Dates | Periods |
|-------|--------------------|
| 1530 | Late Post-Classic |
| 1200 | |
| 900 | Early Post-Classic |
| 600 | Late Classic |
| 250 | |
| AD BC | Early Classic |
| 300 | Late Preclassic |
| | |
| | Middle Preclassic |
| 800 | |
| 2000 | Early Preclassic |
| | (Archaic) |



Environmental Setting



highly karstic
and drought
prone

riverine deficient
and high
biophysical
diversity

riverine deficient
and high
biodiversity

saline marsh
and sea level
intrusions

riverine and
coastal

granitic hills and
topographically
complex

Social Organization



large sites but
populated late

large sites and
great complexity

huge sites and
great complexity

small sites and
limited
complexity

large sites with
complex inter-
dependencies

large sites and
great complexity

Research Questions

1. What are/were the biophysical and social costs to the ancient Maya during their evolutionary trajectory?
2. To which extent are social developments and the degree of stability and/or upheaval correlated with environmental forcing?
3. Does climate change/influence societal decision-making?
4. How is the bio–geographical diversity within the six hotspots affecting population dynamics?
5. Are there significant differences in the rate and processes of biophysical change within and between hotspots?