

A first step toward a model coupling the climate and
resources variability with socio-economical
dynamics and legal norms

Cournil C. (1,3) **Amigues J.P.** (2) **Mazzege P.** (1,2)

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(1) **LMTG**

Observatoire Midi-Pyrénées, CNRS / IRD / Univ. Toulouse III

(2) **LERNA**

*Laboratoire d' Economie des Ressources Naturelles Renouvelables
INRA / Univ. Sciences Sociales Toulouse I*

(3) **TACIP / CERDH**

Univ. Sciences Sociales Toulouse I

Objective

- **The objective** is to explore the possibility to draw, in a diversity of contexts simulating co-evolutions of societies and environments, some « rules » favouring the sustainability of the resources and environmental services as well as the reproduction of social groups and of their cultures.
- **L'objectif** est d'explorer la possibilité de dégager, dans une diversité de contextes simulés de co-évolutions entre sociétés et environnements, des « règles » favorisant la durabilité des ressources et services environnementaux ainsi que la reproduction des groupes sociaux et de leurs cultures.

Climate & Resource Dynamics I

Spatial stochastic agent based
model

to

Nonlinear coupled ODE

- **Aggregation to an « *intermediate scale of non trivial determinism* »**
- **Not well mixed system**
- **Stabilizing effect of space**
- **Interaction with the demographic noise**

Pascual, Levine, Mazzega 2001

Pascual, Mazzega 2003

Dependent variables:

- W: surface waters
- V: vegetation density
- R: ruminant density
- P: « predator » density

Functional processes

- Grazing
- Predation
- Growth

Climate & Resource Dynamics II

$$W(i+1) = [1 + \sin(\omega i)]/2$$

$$V(i+1) = W(i-j) - p_g * R(i) * \Gamma(i)$$

$$R(i+1) = R(i) + \beta_1(i) * R(i) * K(i) - P(i) * X(i)$$

$$P(i+1) = P(i) + \beta_2(i) * P(i) * X(i) - \delta * P(i) * [1 - X(i)]$$

Processes:

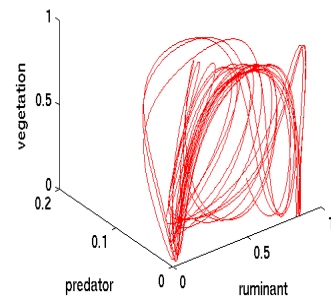
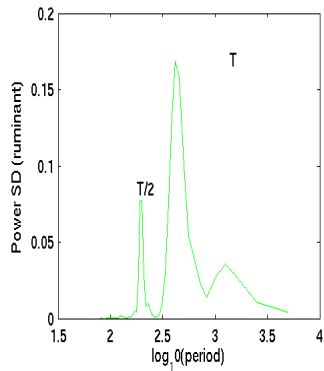
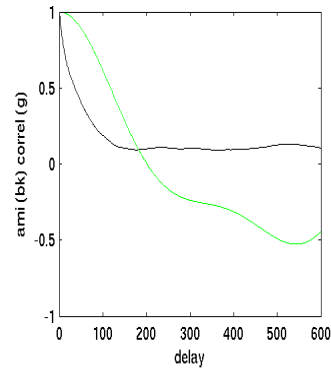
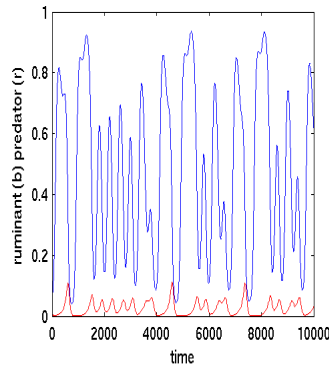
- Per capita grazing rate
 $\Gamma(i) = 1 - [1 - v(i)]^{**} \gamma$
- Per capita predation rate
 $X(i) = 1 - [1 - R(i)]^{**} \chi$
- Per capita rate of growth of R
 $K(i) = 1 - [R(i) + P(i)]^{**} \kappa$
- Powers γ , χ and κ accounts for spatial unresolved patterns

« physiological dependency »

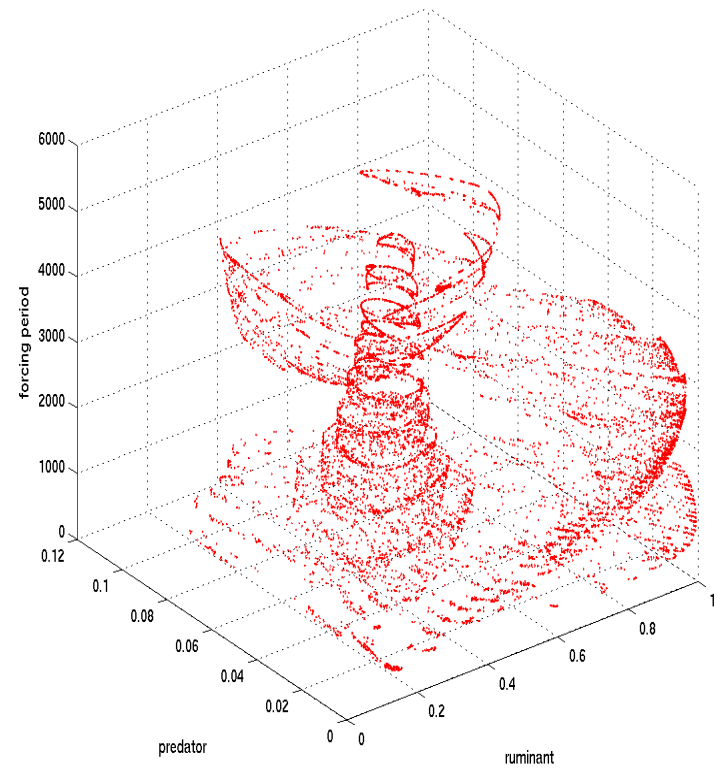
- $\beta_1(i) = \beta_1 * [W(i) + V(i)] / 2$
- $\beta_2(i) = \beta_2 * [3 + W(i)] / 4$

Climate & Resource Dynamics III

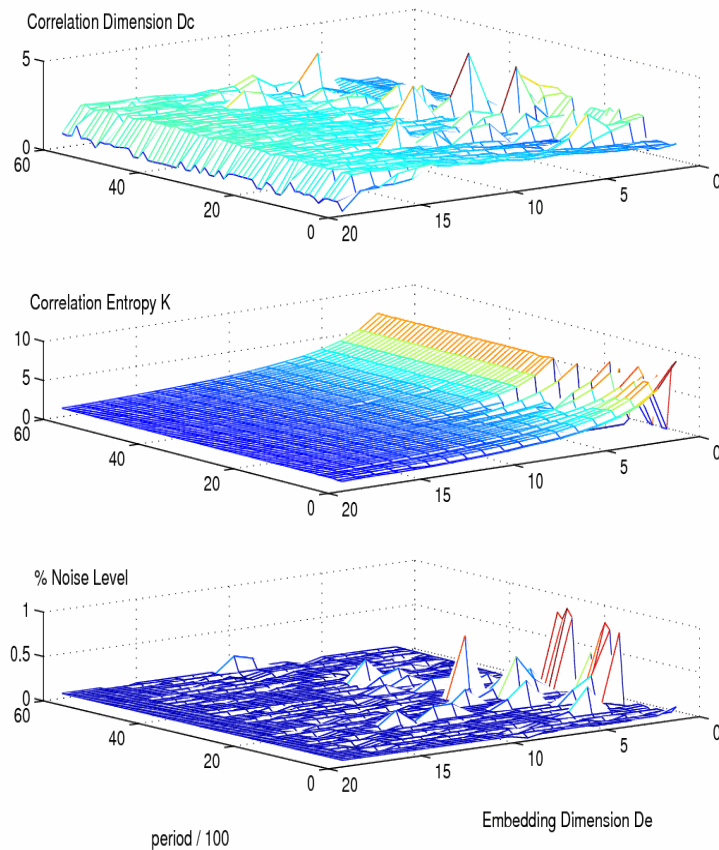
[$D_c \sim 2.6 \pm 0.2$; $K_c \sim 2.4 \pm 0.2$; $s_{\text{noise}} \sim 1\%$]



Poincaré Section (vegetation=1/2)



Tackling with complexity



- DS Ergodic Theory
- Nonlinear invariants
 - *AMI function*
 - *Embedding*
 - Correlation dimension
 - Kolmogorov entropy
 - *Noise level (N-hyp.)*
 - PDFs

Economical Dynamics

- Generalized Lotka-Volterra
- Power-law probability distributions
Pareto 1897, Zipt 1949, etc.

- Multi-scale fluctuations
- Non-stationarity
- Multi-agent simulation

Solomon 1998 et sq.

Dependent Variables

- $n=1..N$ traders (agents)
- $w_n(i)$: abstract individual traders
« wealth »
- $\bar{w}(i)$ Average social wealth
(groups)

Processes

- $\Pi[\lambda(i)]$: stochastic success factor
- $a(i)$: auto-catalytic process *wrt* environment (social wealth,...)
- $c(i)$: individual & social competition
- Asynchronous trading

Economical Dynamics

For $n=1..N$

$$\begin{aligned}w_n(i+1) = & \\ & + \lambda(i) * w_n(i) \\ & + a(i) * \bar{w}(i) \\ & - c(i) * \bar{w}(i) * w_n(i)\end{aligned}$$

Coupling:

via $\bar{w}(i)$

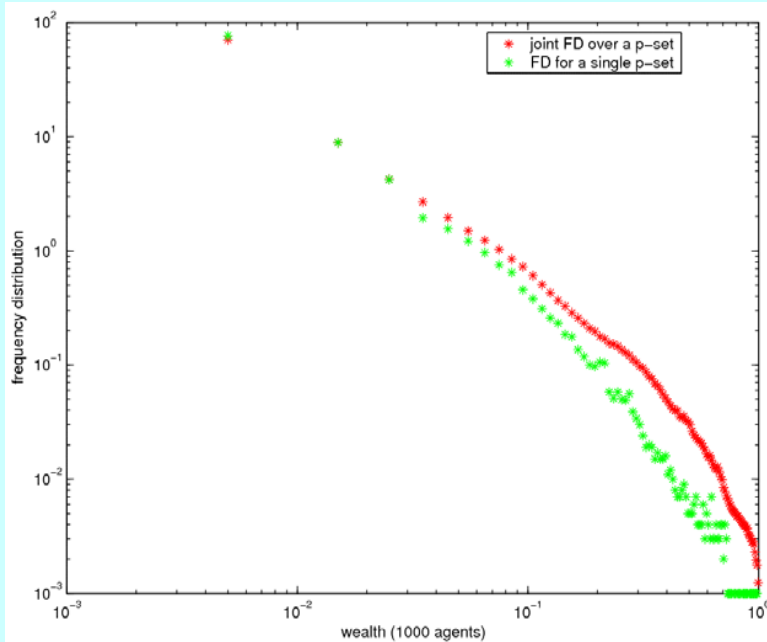
via the auto-catalytic and competition factors

- $\text{PDF}(w) \sim w^{-1-\alpha}$
- $\langle [1 + \lambda(i) - \langle \lambda(i) \rangle - a(i)]^\alpha \rangle = 1$
- $c(i)$: ecologic/economic conditions:
 - No impact over $\text{PDF}(w)$
 - Scales population/wealth ratio
- k Sub-groups lumping via
$$\bar{w}(i) \xrightarrow{\text{partition}} \bar{w}_k(i)$$

Economical Dynamics

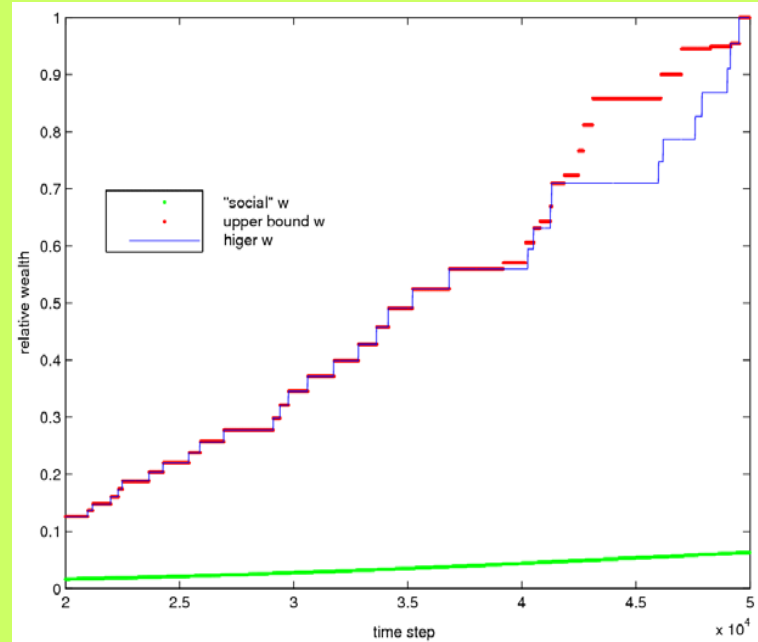
power laws

- Invariant Measure
 $U \rightarrow \text{Log}N \rightarrow P(w) \sim w^{-1-\alpha}$
- wrt the GLV parameters ?



wealth trajectories

- Inflating/shrinking economy
- « w-social » trajectories
- Sub-groups of traders ?



Thinking & Observing Norms

- ? : as inducing several partitions over the population
- ? : rights and obligations as behavioural norms
« *ought to* » as « *do* »
- ? : rational agents and traders
 - Perfect information: resource state, legal and customary system, etc.
 - No anticipation

Field surveys (Mali, ...)

Laws, municipal by-law, custom:

*Surface waters, Pastures, Forestry,
Land legislation & tenure, ...*

Property right regimes:

*Access, Substraction, (Management),
exclusion, alienation*

Agent & Trader Partitions

*Unauthorized user, user, claimant,
...owner*

Co-Management

Public, « common », collective, private

Coupling « C ⊗ R ⊗ E ⊗ N » dynamics...

- Questions

- Impact of climate variability ?
- Incidences of the social and institutional organisation ?
- Effectivity & efficiency of norms ?
- Build prospective scenarii
- Etc.

« from
resources to
agents via
norms ? »

- **E. Ostrom** works on « common pools resources »
- **Le Roy** works on the theory of Land tenure (« maîtrises foncières »)
- **Kirat et alii** works on « Law & economics » (Commons, Coase)
- References / critics of some (inter-)national orientations ?
 - Agenda 21, Johannesburg etc.
 - Transferring State prerogatives to Local/Public authorities