Biodiversity and food security:
Learning from smallholder farmers



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NETSEED
FRB-CESAB

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Biodiversity and Food Security – From Trade-offs to Synergies

3rd International Conference on Biodiversity and the UN Millennium Development Goals

Aix-en-Provence, France, 29-31 October 2014

Smallholder agriculture is a topic at the heart of many themes treated in this conference

- The often neglected importance of agricultural biodiversity
- *In situ* conservation of genetic resources, to complement *ex situ* gene banks
- New paradigms of agroecology, integrating natural mechanisms and imitating nature
- Regulatory systems that restrict varietal diversity vs. participatory approaches to varietal innovation
- Contested conceptual frameworks: food sovereignty, sustainable intensification, land-sharing vs. land-sparing

Seen and heard at a symposium on biotechnology and plant breeding, about 10 years ago

Seen: an illustration of slash-and-burn agriculture as conducted by Amerindian manioc farmers

Bahuchet & Betsch (2012), *Revue d'Ethnoécologie* (http://ethnoecologie.revues.org/768)

Heard: « This is what we are trying to get away from. »

'Traditional' smallholder agriculture has often been maligned and misunderstood

But these systems are increasingly seen as systems from which we can learn, in designing new models of agriculture

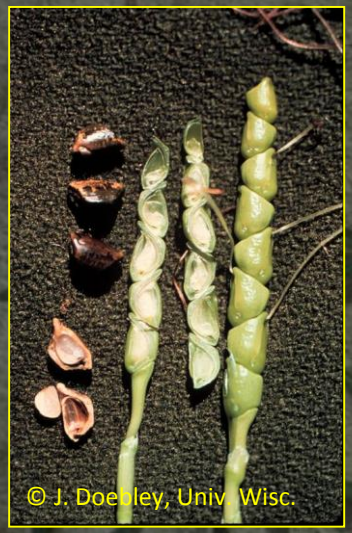
I will focus on how these systems function, and what we can learn from them to achieve food security and well-being in a changing world

Focus on three aspects of 'traditional' agriculture

- How farmers generate and maintain the diversity they need
- The social exchange of seeds by farmers and the resilience of agriculture
- Novel ways in which 'traditional' farmers imitate nature in their design of agroecosystems

How farmers generate and maintain the diversity they need

Crops sexually propagated by seed:



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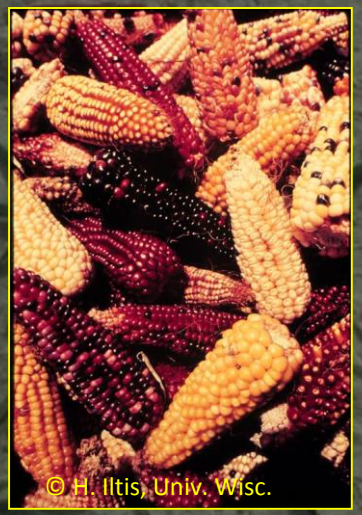


Maize

Vegetatively propagated crops: clones—exact genetic copies of the preceding generation

Many root and tuber crops, and bananas, are clonally propagated

Not only does clonal propagation fail to generate diversity…

It can also lead to the evolutionary loss of sexual fertility

Loss of the very mechanism that generates diversity

But despite selective pressures favoring reduced sexual fertility, most clonally propagated domesticated plants are still fertile

Multiple advantages. Foremost:

Maintain evolutionary potential

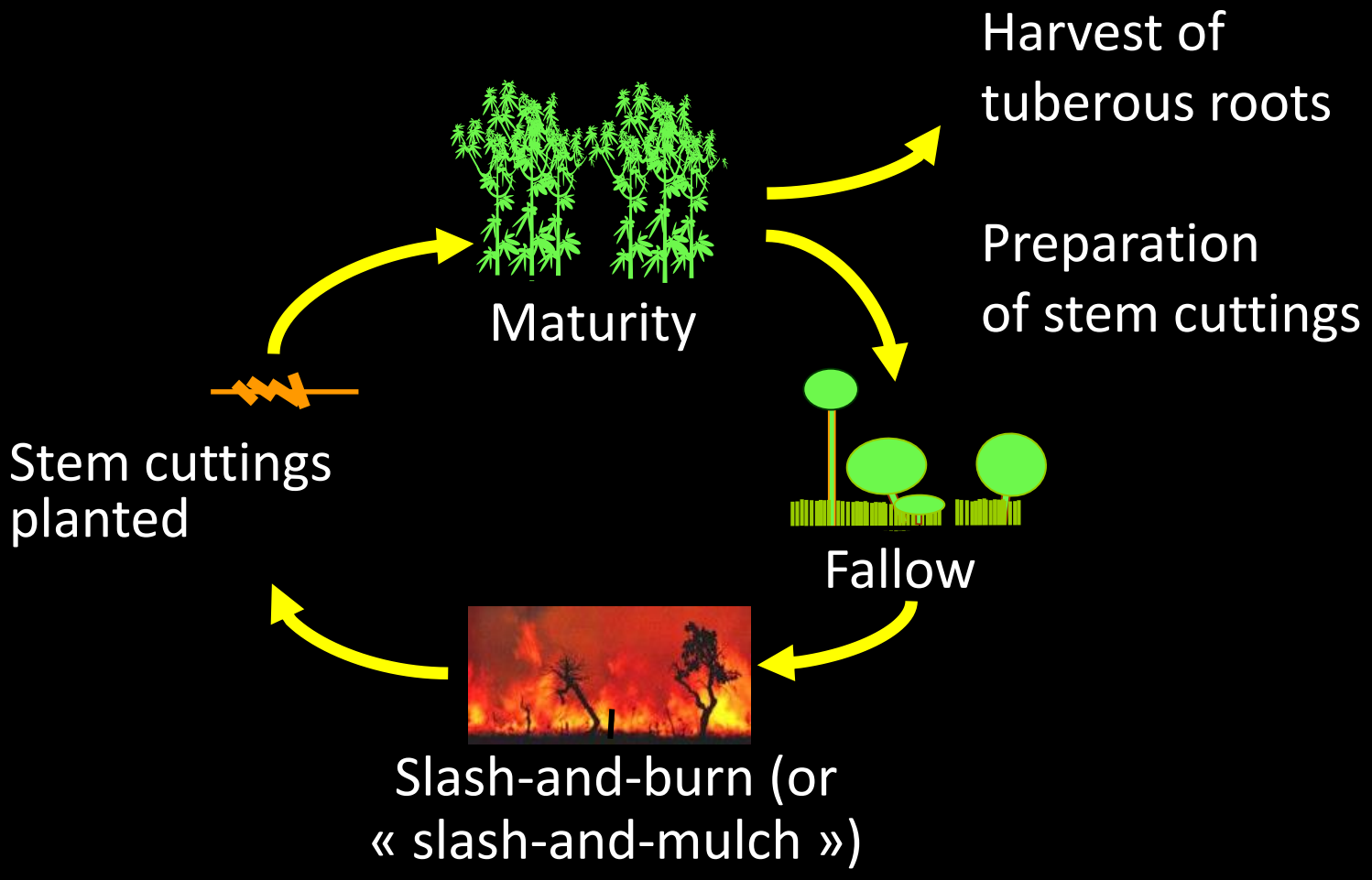
How do farmers maintain sex in their clonally propagated crops?

We have studied this question
with Amerindian farmers of manioc

What is the origin of this diversity,
in this clonally propagated plant?

The functioning of manioc populations in traditional agricultural systems

Life cycle of manioc:




© mongabay.com

But this schema leaves out sexual reproduction

Which continues to play a very important role!

Life cycle of manioc:

Harvest of tuberous roots

Preparation of stem cuttings

Sexual reproduction

Maturity

Volunteer seedlings

Stem cuttings planted

Fallow

Dispersal of seeds

Slash-and-burn

Germination

Soil seed bank

How does the soil seed bank get there?

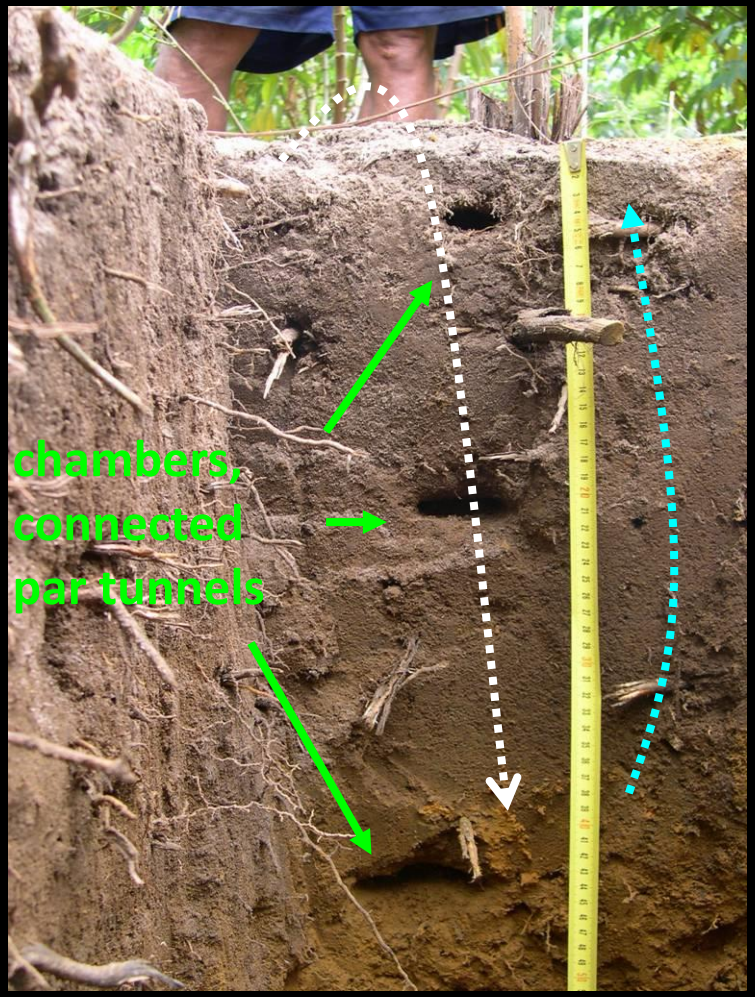
Dispersal, dormancy and germination

First step: the capsule explodes, releasing three seeds…

Dispersal, dormancy and germination

…each seed bears an oil body that attracts ants

Dispersal, dormancy and germination



Travels inside a nest of *Ectatomma brunneum*, principal dispersal agent

Refuse pile of a nest of *Ectatomma brunneum*

Seedlings germinating from an old refuse pile

Dispersal, dormancy and germination

Physiological dormancy controlled by thermal signals

Shade (plant cover)

Soil surface

25°C → Seeds remain dormant

Sun (no plant cover)

Soil surface

> 35°C → Seeds germinate

In incorporating volunteer seedlings into stocks of clones, farmers *experiment*

Seedlings are unpromising material. Two handicaps:

Start small and grow slowly (fewer reserves in a seed than in a cutting)

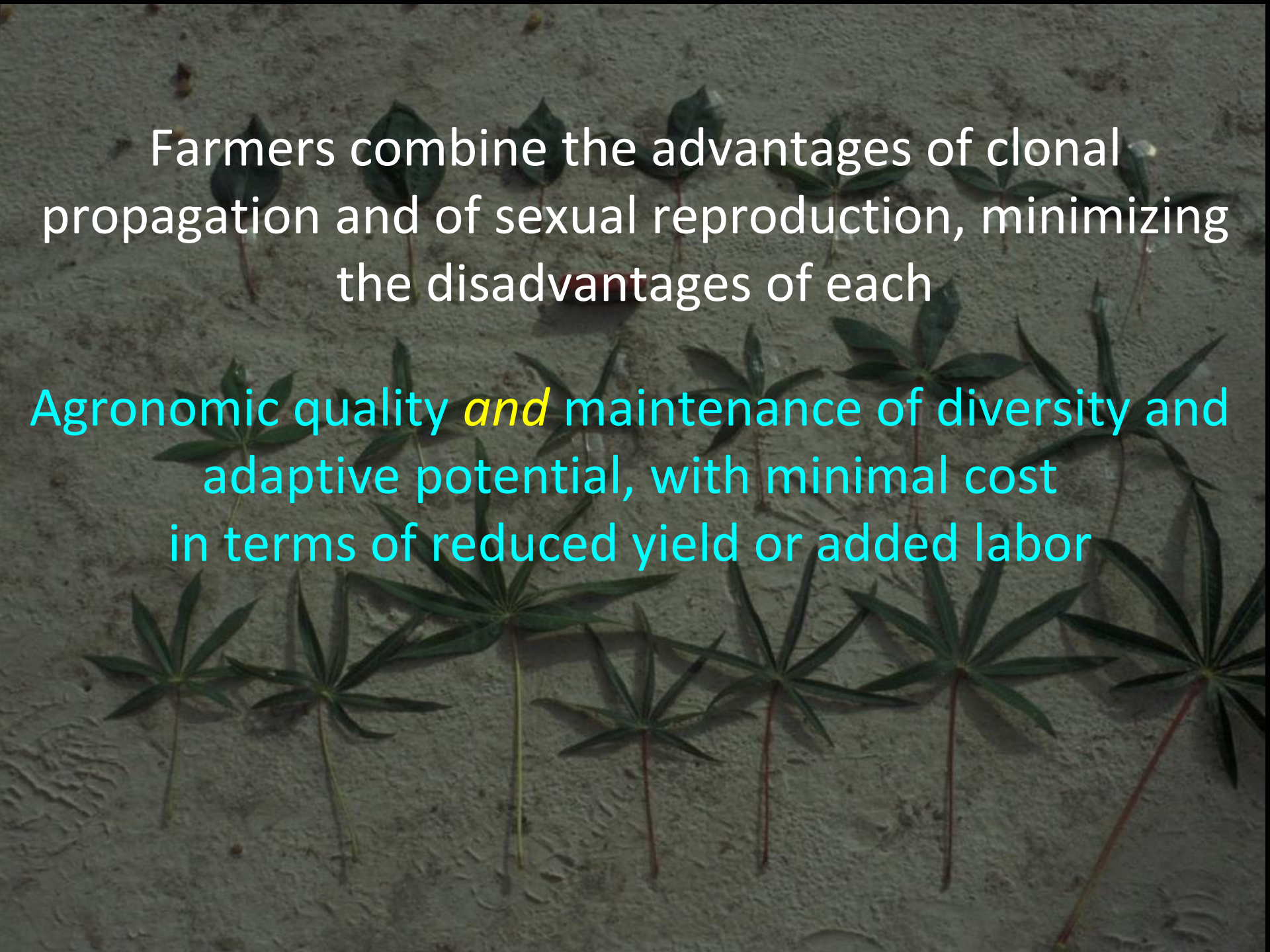
Only one tuberous root, the taproot

Cuttings can form several roots at each node

Farmers evaluate seedlings by their vigor and root quality, evaluate CLONES of seedlings by their root yield

New genotypes undergo a trial period of several years.

Duputié et al. (2009), *Journal of Evolutionary Biology*



Farmers combine the advantages of clonal propagation and of sexual reproduction, minimizing the disadvantages of each

Agronomic quality *and* maintenance of diversity and adaptive potential, with minimal cost in terms of reduced yield or added labor

What features are worth imitating in modern breeding programs?

Maintenance of diversity

Different landraces for different uses, different environments, different persons (root dry matter content…)

Mutualisms with wild components of biodiversity

Pollinating insects

Seed-dispersing ants

Mycorrhizae-forming fungi

What features are worth imitating in modern breeding programs?

Resilience

Diversity contributes to resilience

Other sources of resilience

Loss of crop genetic diversity following disasters? (drought, warfare)

Is emergency seed aid required?

How manioc farmers respond to loss of their clones (El Niño years):

Slash and burn fallow patches, regenerating a new set of clones from volunteer seedlings

→ *Genetic diversity is even greater than before the disaster!*

Farmers' seed systems have unexpected sources of resilience

Pujol et al. (2007), *Biological Conservation*

The social exchange of seeds by farmers and the resilience of agriculture

The NETSEED project, funded by the CESAB (Centre de Synthèse et d'Analyse sur la Biodiversité) - FRB

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Strengthening management of agrobiodiversity through social networks

An interdisciplinary method for analyzing how local seed systems impact the diversity of domesticated plants

Farmers' 'informal' seed systems: much maligned and misunderstood

Common misconceptions:

Inefficient for seed dissemination, low quality seed

Closed, conservative systems

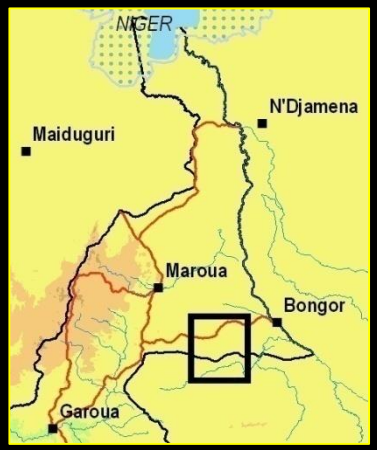
Provide ready, egalitarian access to seed

Coomes, McGuire, *et al*., *submitted*


Farmers’ seed systems are dynamic, adapting to stress

Chloé Violon (Laboratoire d'Ethnologie et de Sociologie Comparative, Université Paris Ouest-Nanterre)

Fieldwork among Tupuri farmers, northern Cameroon



Great inter-annual variation in rainfall

Late rains → First planting fails → Shortage of seeds

How does climatic variation affect modalities of seed exchange?

Violon, Garine, Thomas, *in prep*

What happens in a bad year?

	Number of events	Number of givers	Number of giving households	Quantities (in cups)
2010 (good year)	128	82	62	280
2011 (bad year)	177	92	74	411

More frequent exchanges, larger quantities exchanged

Geographic extension of the exchange network

Crucial contribution of relatives by marriage: *wives and their networks play an expanded role*

Violon, Garine, Thomas, *in prep*


To study farmers' seed systems correctly,
we first have to understand them
Sampling strategies matter

Jean Wencélius (Laboratoire d'Ethnologie et de Sociologie Comparative, Université Paris Ouest-Nanterre)

Sorghum farmers in northern Cameroon

Whom should we interview to understand seed exchange?

The household head?

('most knowledgeable actors', 'key informants'…)

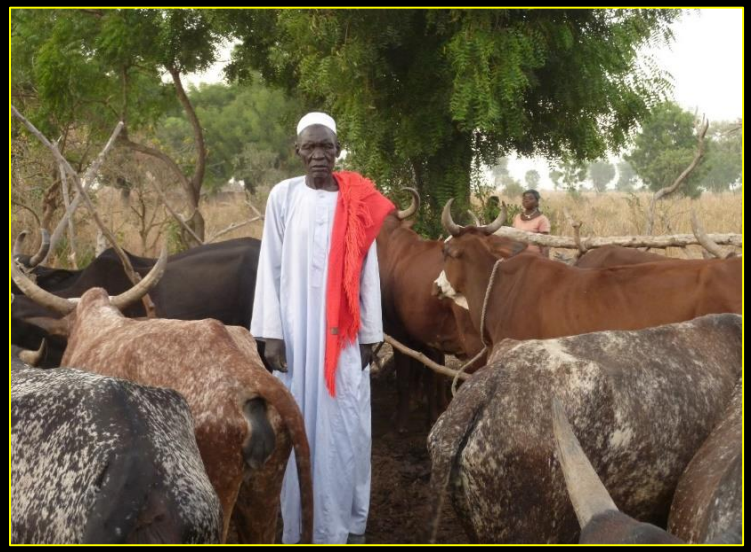
All members of the household?

(reduces the number of households that can be sampled)

Which sampling strategy is preferable?

Wencélius, Garine, Thomas, *in prep*

Wealth is strongly correlated with household size (multiple marriages, brideprice is delivered in cattle)



Great inter-household heterogeneity

Different colors = different villages of birth

Upon marriage, women move from their father's village to their husband's

Through women, members of rich households may benefit from a larger geographical area and a greater social pool from which to acquire seeds

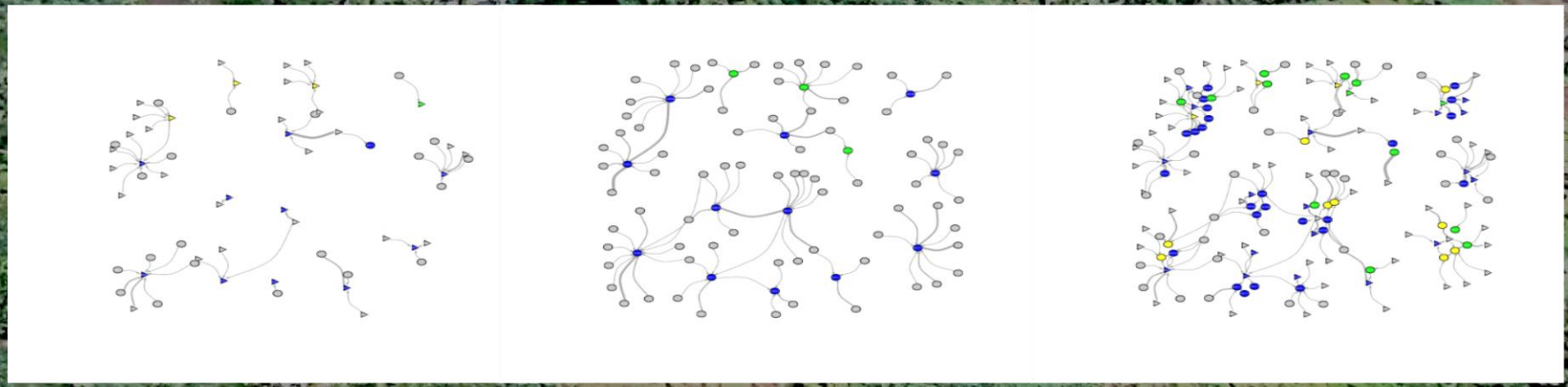
Wencélius, Garine, Thomas, *in prep*

Wealth is strongly correlated with household size (multiple marriages, brideprice is delivered in cattle)

Household-heads (nodes = individuals)

All events (nodes = HH)

All events (nodes = individuals)



Most frequent type of source
- Within-village
- Other villages
- Both
- Not surveyed

Gender
- Women
- Men

Choice of units of analysis → Different pictures of the structure and dynamics of exchange

Wencélius, Garine, Thomas, *in prep*

Farmers' seed systems are vibrant, dynamic and constantly changing; they provide seed for over 80 % of smallholder farmers today: they are structured by social and cultural norms

Like other components of 'traditional' agriculture, farmers' seed systems hold lessons for shaping an agriculture that is resilient in the face of change.

Coomes, McGuire, *et al.*, *submitted*


Novel ways in which ‘traditional’ farmers
imitate nature in their design
of agroecosystems

Agriculture should imitate nature:

Integrate natural mechanisms of population regulation and of the functioning of biogeochemical cycles

NEWS & COMMENT

Agriculture in Nature's image

Todd Dawson Rae Fry *TREE vol. 13, no. 2 February 1998*

Designing cropping systems from nature

Eric Malézieux

Agron. Sustain. Dev. (2012) 32:15–29

Have 'traditional' agricultural systems long imitated nature?

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Biomimicry at the ecosystem level

Designing cropping systems from nature

Eric Malézieux

Agron. Sustain. Dev. (2012) 32:15–29

« One of the main concepts at the basis of ecological engineering is the self-designing capacity of ecosystems… Self-organisation, a property of natural ecosystems, is generally opposite to the imposed organisation of agriculture… »

« …Would it be possible to take inspiration from self-organisation in natural ecosystems to define an imposed organisation? »

An example:

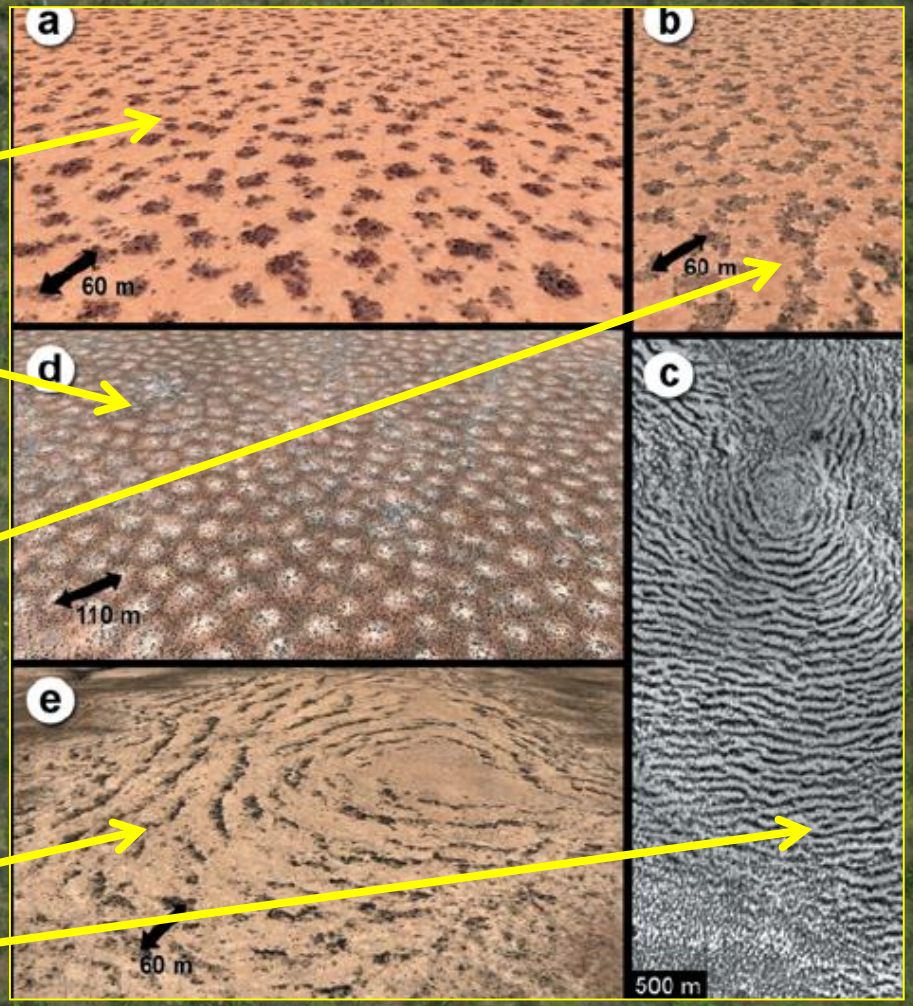
Spatial self-organization in natural systems and in agroecosystems

Spatially regular structures of natural origin, built by organisms, occur in a diversity of environments

Leopard bush
(spotted bush)

Labyrinth pattern

Tiger bush
(striped bush)



Deblauwe et al. (2008),
Global Ecol. and Biogeogr.

Such spatially self-organized landscapes are frequent in semi-arid regions

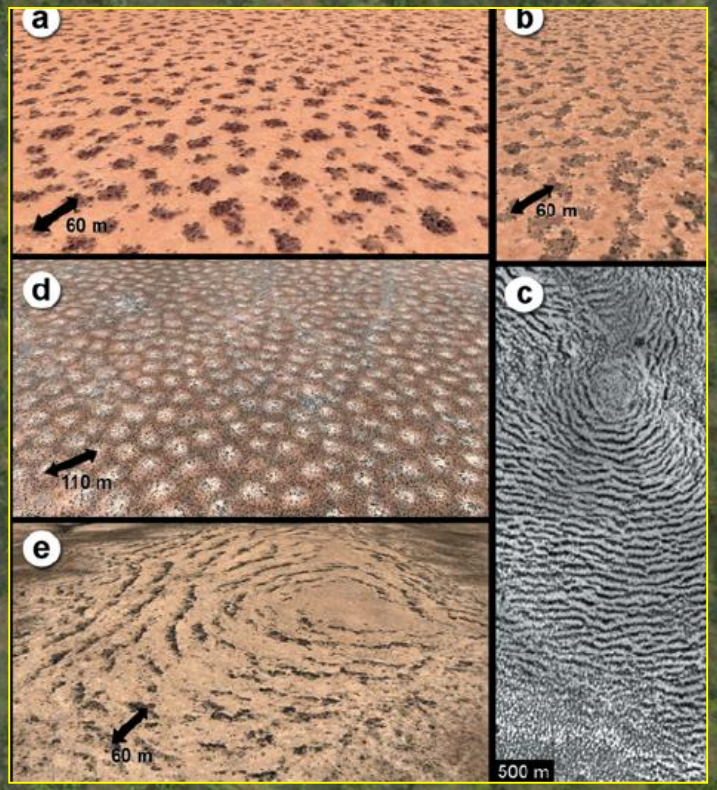
Theory on spatial self-organization in ecosystems

Principle:

Some critical resource or factor constrains the distribution of organisms

« Engineer » organisms modify the distribution of this resource, concentrating it in patches, with resource-poor spaces in between

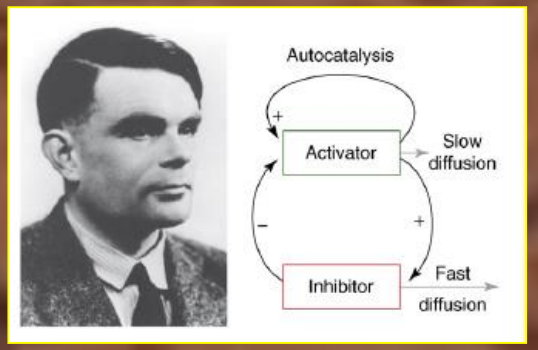
In semi-arid ecosystems, the critical resource is water



Deblauwe et al. (2008), *Global Ecol. and Biogeogr.*

How do such mechanisms produce patterning in semi-arid ecosystems?

Alan Turing:
activator-inhibitor principle
and scale-dependent feedbacks



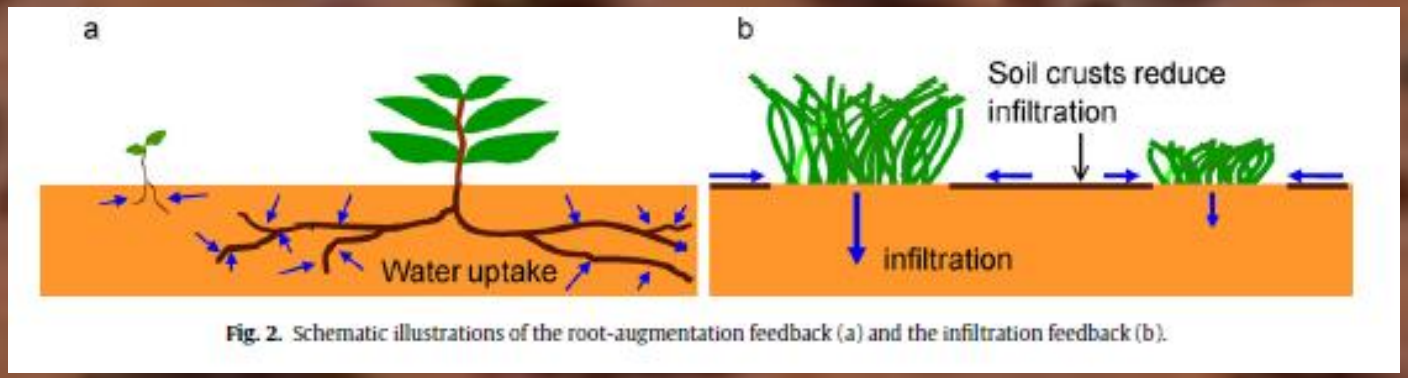


Fig. 2. Schematic illustrations of the root-augmentation feedback (a) and the infiltration feedback (b).

Meron (2012), *Ecol. Modelling*

Near a plant, soil is porous and water **infiltrates**. Moist soil favors establishment of other plants

Farther from a plant, water **runs off over crusted soil, or is taken up by roots**. Dry soil prevents establishment of plants

Plants can only establish beyond a threshold minimum distance from other plants

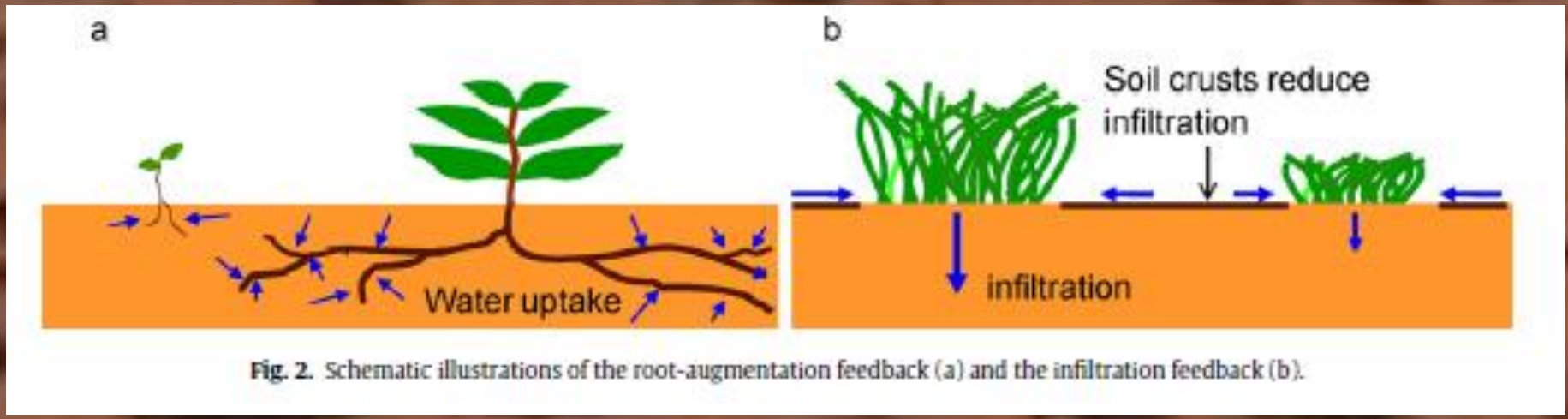


Fig. 2. Schematic illustrations of the root-augmentation feedback (a) and the infiltration feedback (b).

Regular spacing, with distance between patches determined by scales of the processes driven by ecosystem engineers

The encrusted soil between plants collects water that flows to plants, which store it in the porous soil created by their roots

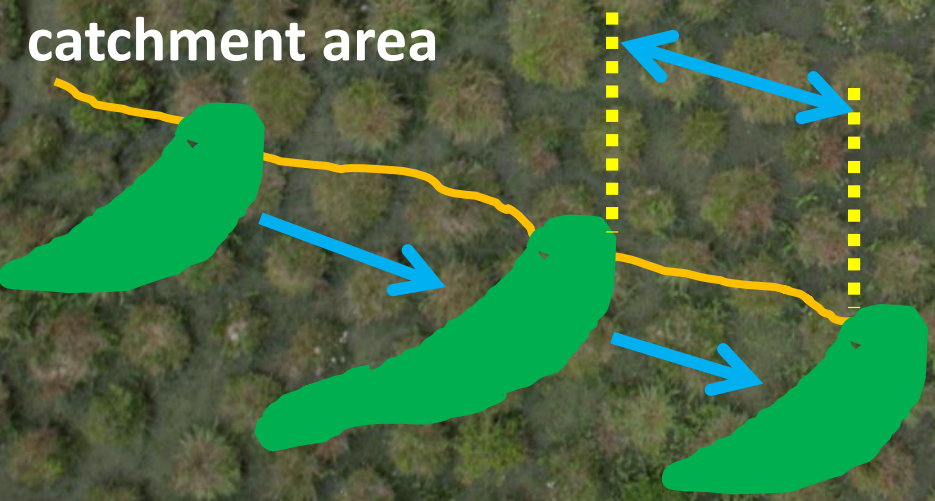
The patterns formed depend on topography

Flat landscapes → Isotropy of water flow → No favoured orientation

Spotted bush

Sloping landscapes → Anisotropy of water flow → Stripes following contours

Distance between stripes set by runoff catchment area



Tiger bush

Resource concentration enables plants to grow where this would be impossible if rain were distributed evenly over the surface

Farmers in the sahel have devised a system, called *zaï*, that *integrates the same resource-concentration mechanism*

Objective: rehabilitate degraded, devegetated sites

Frequent recommendation of agronomists: destroy the soil crust to permit water infiltration

Zaï system: dig holes 20-40 cm diameter, fill them with organic matter

http://en.howtopedia.org/wiki/How_to_Start_Culture_in_Zai_Holes

Preserve the encrusted soil between the plants, use this surface to harvest rainfall that flows to the plants, where it infiltrates

Spotted zaï on flat ground, striped zaï on slopes

Agronomists have described the feedback mechanisms behind functioning of the zaï system

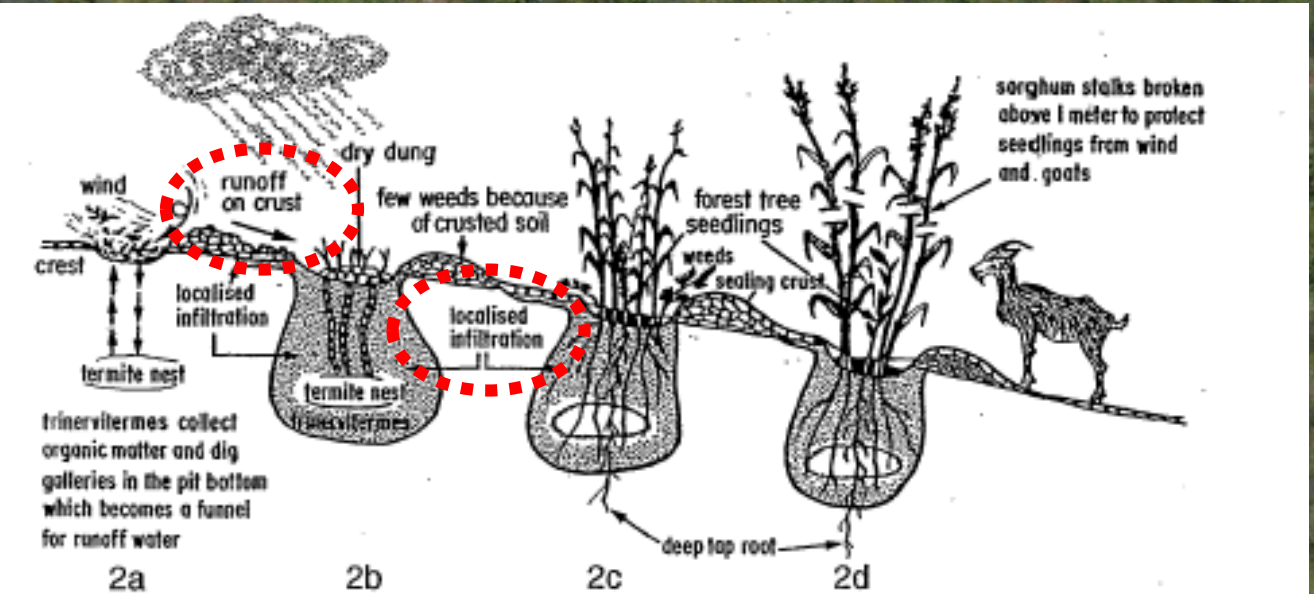


FIGURE 2 Zaï practice for soil and green cover rehabilitation.

Roose et al. (1999), *Arid Soil Research and Rehabilitation*

But seem to be unaware of the parallels with the functioning of natural tiger bush and leopard bush in the same region

What could we learn if ecologists, agronomists and farmers did more talking together?

Systems devised by 'traditional' farmers contribute to food security and well-being at several different levels

Manipulation of biological / evolutionary mechanisms of crop plants and other components of agrobiodiversity (individual persons interacting with individual plants and populations)

Diffusion of seeds within and among populations and across landscapes (farmer communities interacting with plant metapopulations)

Shaping the nature of the landscape itself

Exploration of other aspects of 'traditional' agriculture will no doubt turn up other kinds of interactions

Thanks to my collaborators:

All the members of the NetSeed consortium

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The ‘Earthmovers’ consortium working on seasonally flooded savannas

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Mission pour le Parc Amazonien, Guyane


Thanks to the organizers of the conference for the invitation to speak
And thank you
for your attention!
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