Ecoidrologia, Scienze e Ingegneria: quali connessioni?

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Ecohydrology

"The preservation of the forests and the preservation of the use of water are inseparably connected"

- Theodore Roosevelt, 1903

"Ecohydrology represents the natural evolution of biological sciences and environmental engineering".

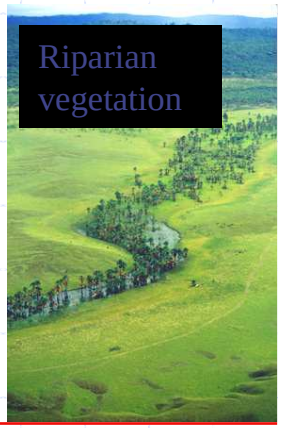
- M.Todd Walter, 2005

Research area: topics

- Climate-soil-vegetation interaction (e.g., Evapotraspiration, Plants & runoff, rivers, aquatic life cycle);
- Dynamics and spatial patterns of vegetation;
- Competition between different species;
- Function and organization of riparian vegetation;
- Effects due to climate change on natural ecosystems;
- Biogeochimestry & physical hydrology;
- Animals and hydrology;
- Microbiology….


Savanna (Bolivia)


Semiarid ecosystem of Northern Australia


Riparian vegetation

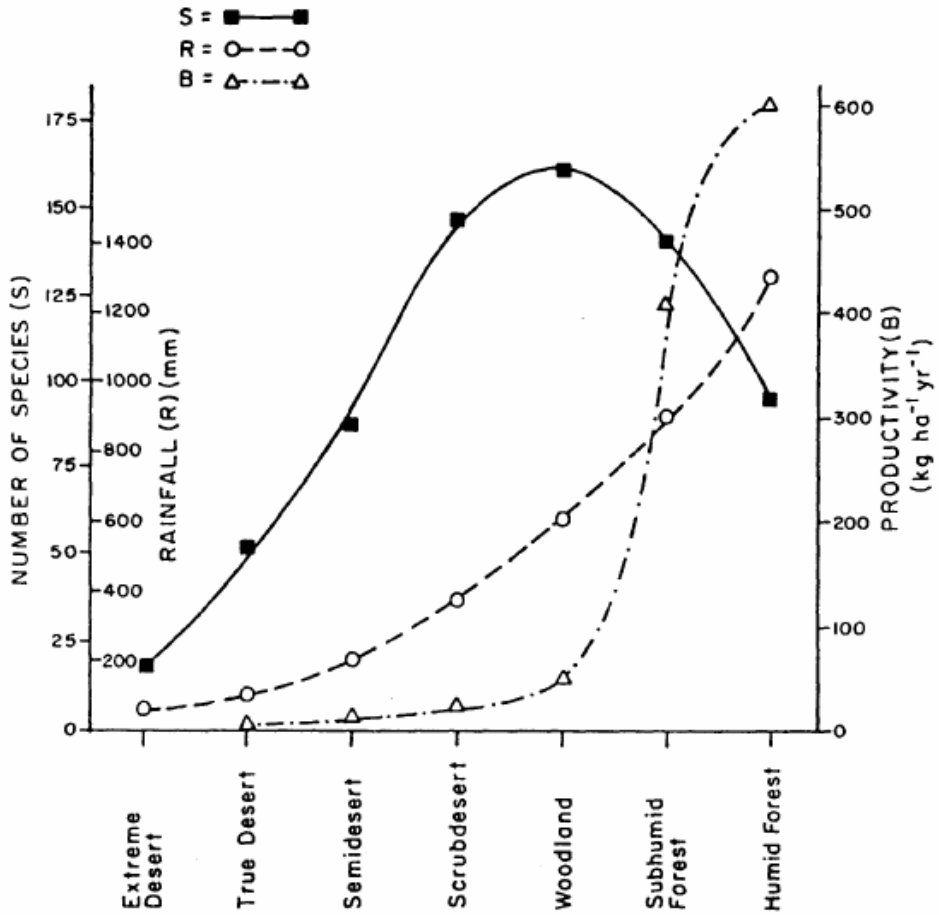
Patterns and Processes

"Two fundamental and interconnected themes in ecology are the development and maintenance of spatial and temporal pattern, and the consequences of that pattern for the dynamics of populations and ecosystems."

– Simon A. Levin, 1992, Robert H. MacArthur Award Lecture

(Photo by Yann Arthus-Bertrand)

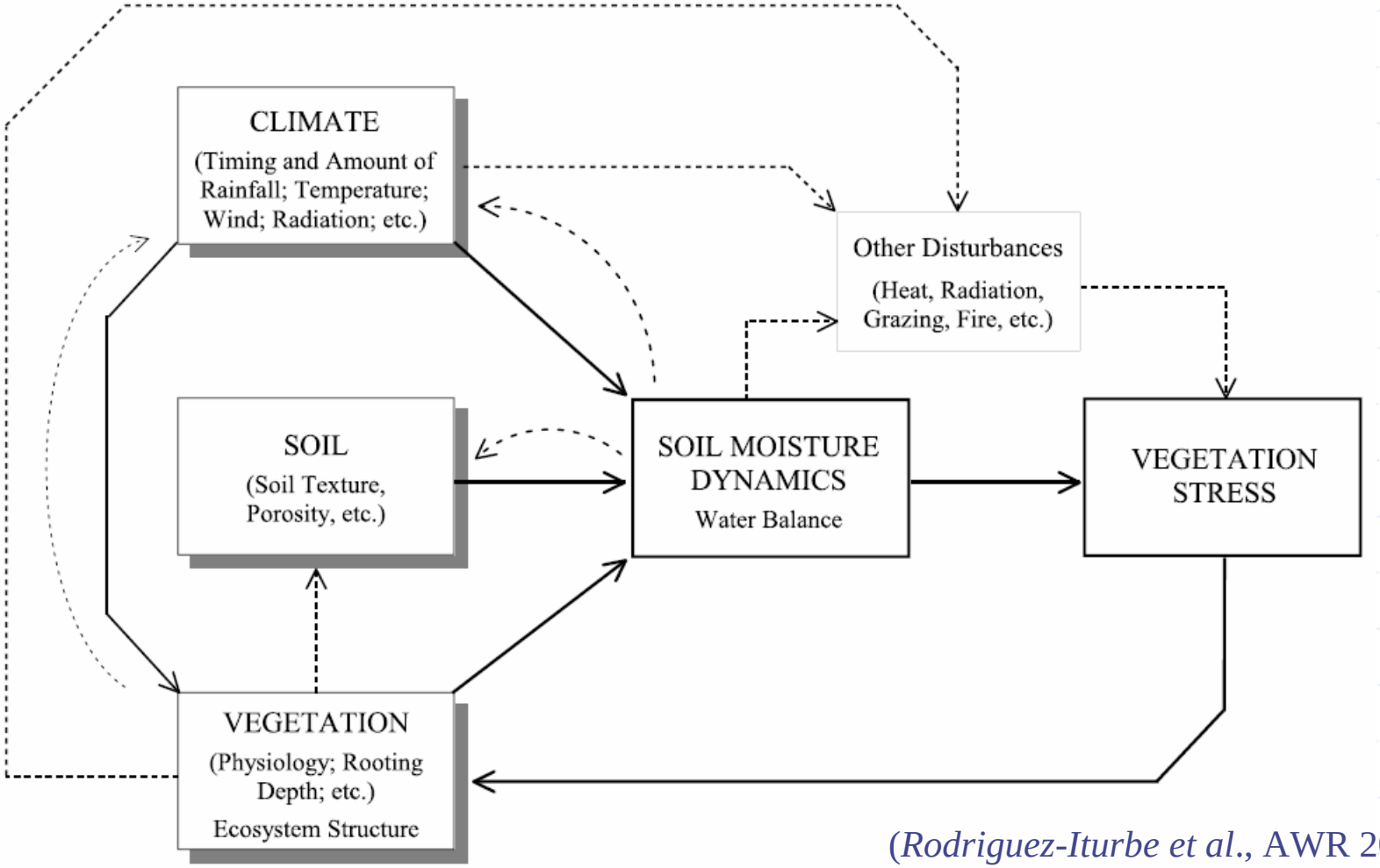
General link between precipitation, biomass, and biodiversity in water-controlled ecosystems



R = precipitation;
B = biomass;
S = biodiversity (number of species).

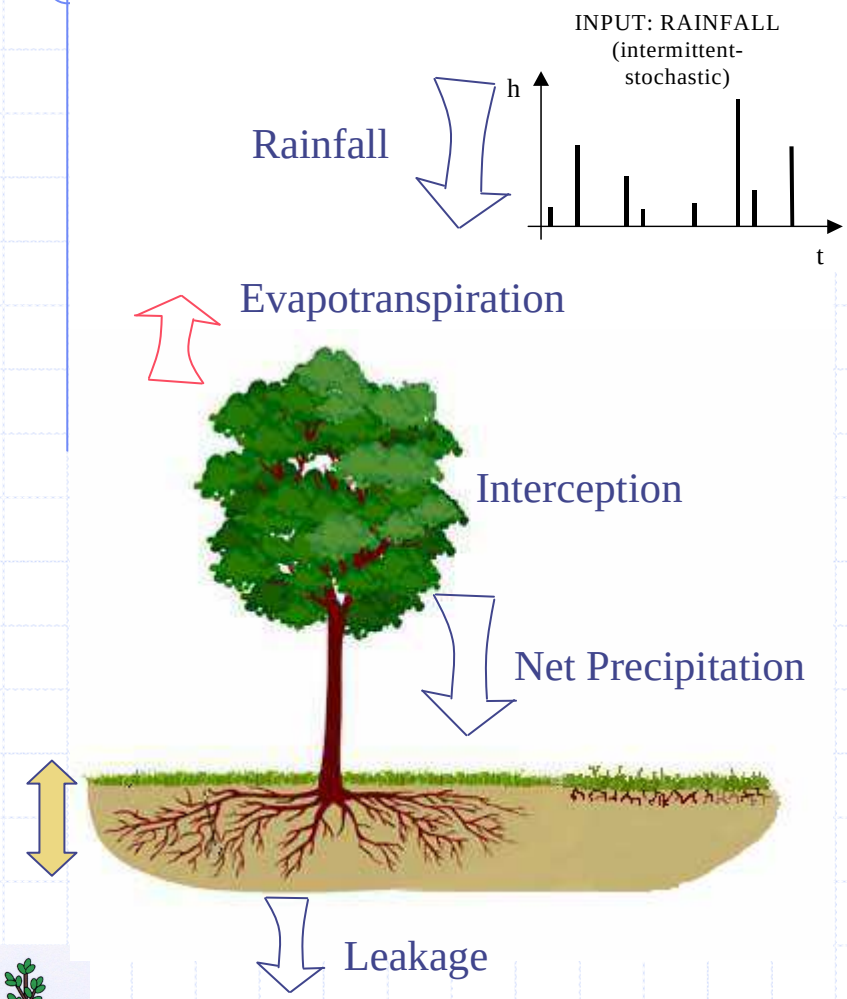
(*Shmida & Burgess*, Plant Form and Vegetation Structure, 1982)

Schematic representation of climate, soil, and vegetation system



(*Rodriguez-Iturbe et al.*, AWR 2001)

Soil water balance at a point



$$nZ_r \frac{ds(t)}{dt} = R(t) - I(t) - Q[s(t),t] - E[s(t)] - L[s(t)]$$

n = soil porosity;

Z_r = root depth;

$s(t)$ = relative saturation;

$R(t)$ = rainfall rate;

$I(t)$ = vegetation interception;

$Q[s(t),t]$ = surface runoff;

$E[s(t),t]$ = evapotraspiration;

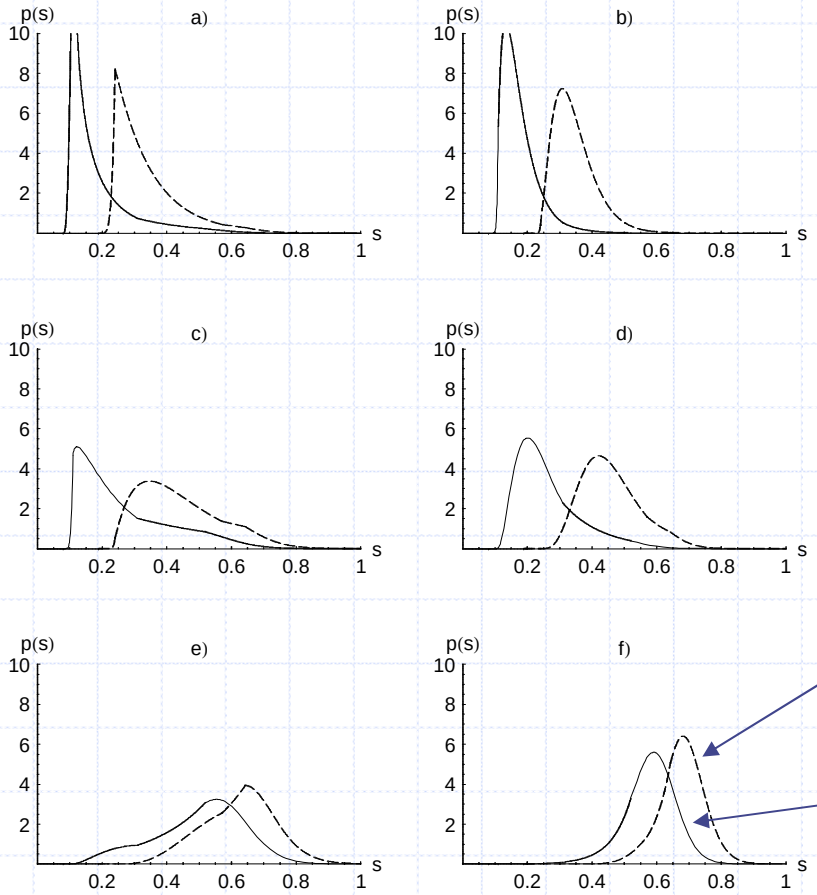
$L[s(t),t]$ = leakage;

(*Rodríguez-Iturbe et al.*, 1999; *Laio et al.*, 2001)

Steady state probability distribution of relative soil saturation

Deeper soils

Drier climates



$$p(s) = \frac{c}{\rho(s)} Exp\left(-\gamma s + \lambda \int_s \frac{du}{\rho(u)} \right)$$

Rodriguez-Iturbe et al., Proc. Royal Soc. A, 455, 3789, 1999.

Loam

Sandy loam

(*Laio et al.*, AWR 2001)

Theoretical covariance function of a soil moisture field

$$cov[S(0,t), S(l,t+h)] = \int_0^\infty \int_0^\infty b_A b_B e^{-a_A\omega - a_B\xi} cov[\tilde{Y}(0,t-\omega), \tilde{Y}(l,t+h-\xi)] d\omega d\xi.$$

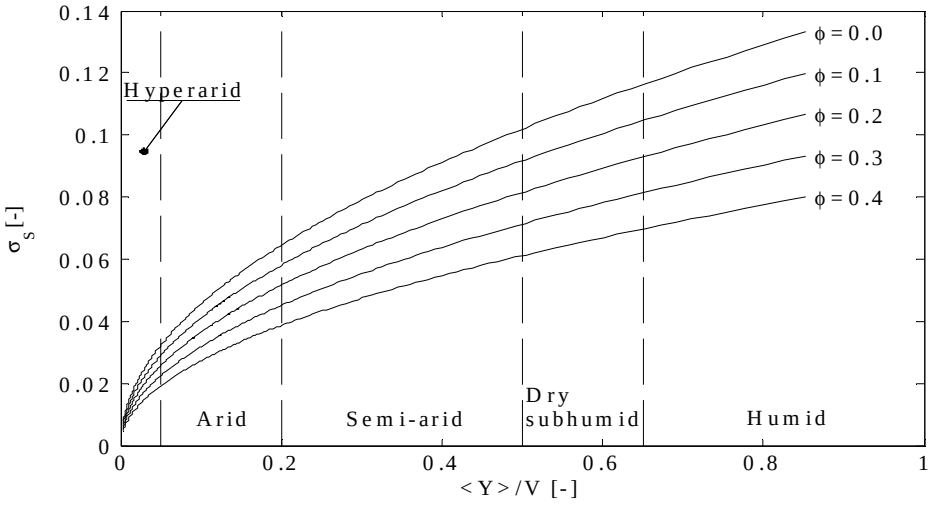
$$C_{AB} := cov[S(0,t), S(l,t+h)] =$$

$$\frac{2\pi\lambda_R}{\eta\beta^2} b_A b_B \left(\frac{2\eta e^{a_B h}}{(a_A + a_B)(\eta^2 - a_B^2)} + \frac{e^{-\eta h}}{(a_B - \eta)(a_A + \eta)} \right) \left(\frac{2}{\rho^2} + \frac{l}{2\rho} \right) e^{-\rho\frac{l}{2}}$$

$$\sigma_S^2 = \frac{4\pi\lambda_R}{\eta\gamma^2\rho^2} \frac{b^2}{a(\eta + a)}$$

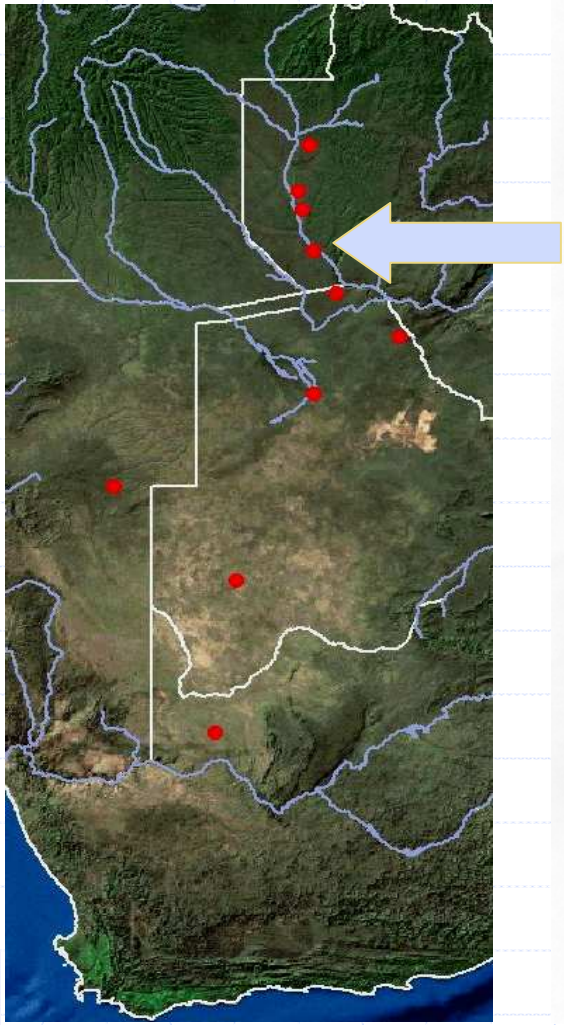
$$\eta >> a,$$

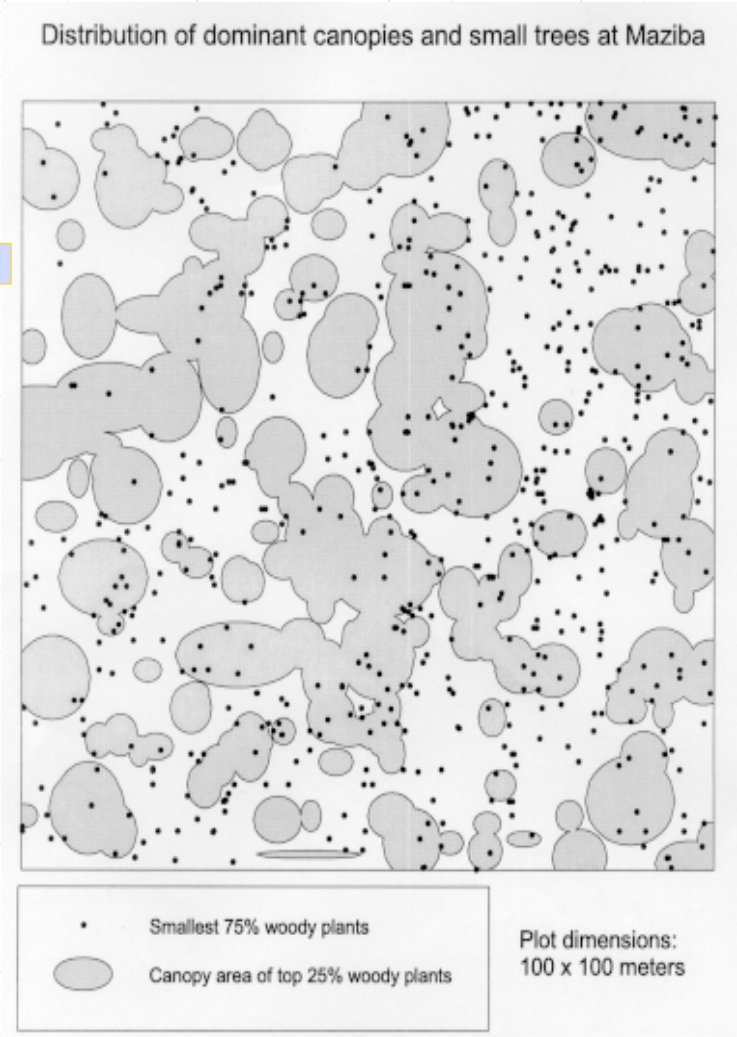
$$b^2/(a\eta) = (1-I)^2/(nZr\ V\ \eta).$$



(*Isham et al.*, PRS 2005)

Plot-scale patterns of vegetation structure along the Kalahari transect





At all sites, large trees are distributed randomly

At all sites, small trees are highly aggregated

(*Caylor et al.*, JAE 2003)

Theoretical correlation function of the relative soil moisture

$\lambda_T = 500\ km^{-2}$
$\rho_T^{-1} = 8\ m$

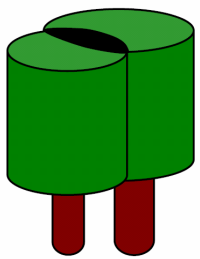
Tree cover = 0.18%

$\lambda_T = 1500\ km^{-2}$
$\rho_T^{-1} = 8\ m$

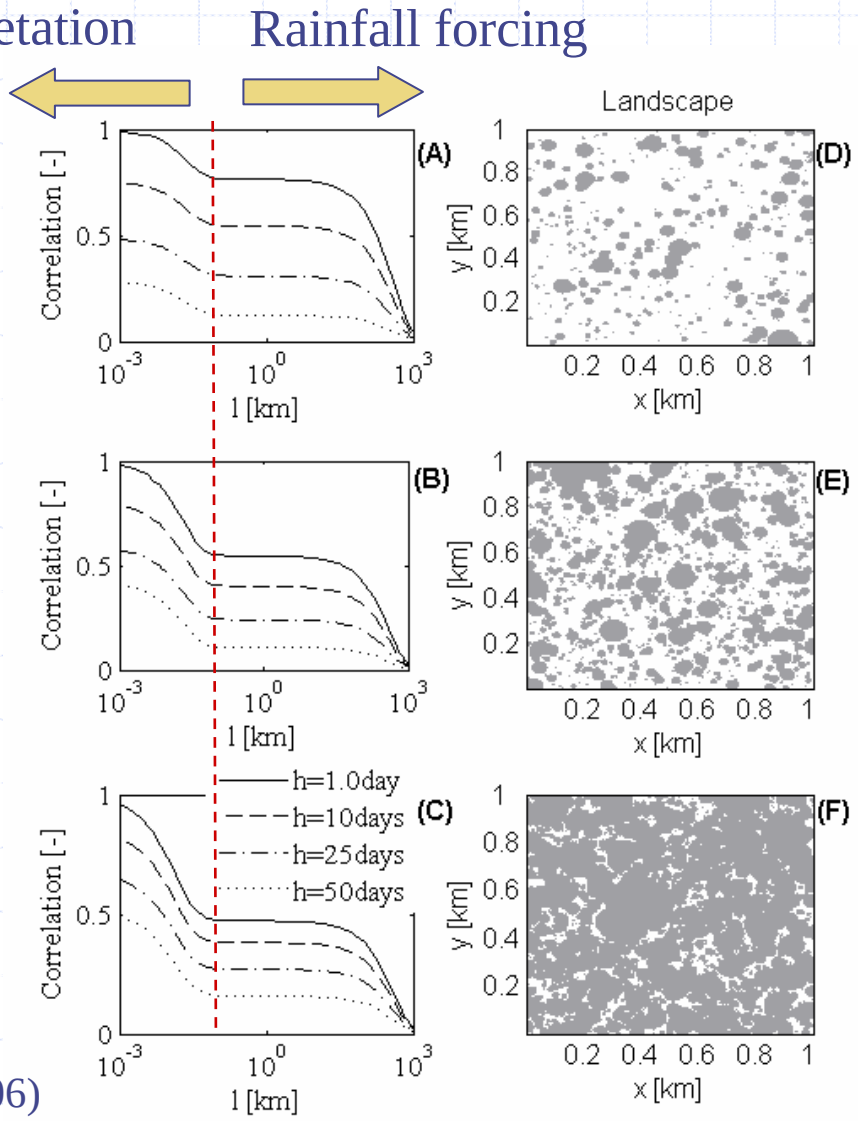
Tree cover = 45%

$\lambda_T = 5000\ km^{-2}$
$\rho_T^{-1} = 8\ m$

Tree cover = 85%

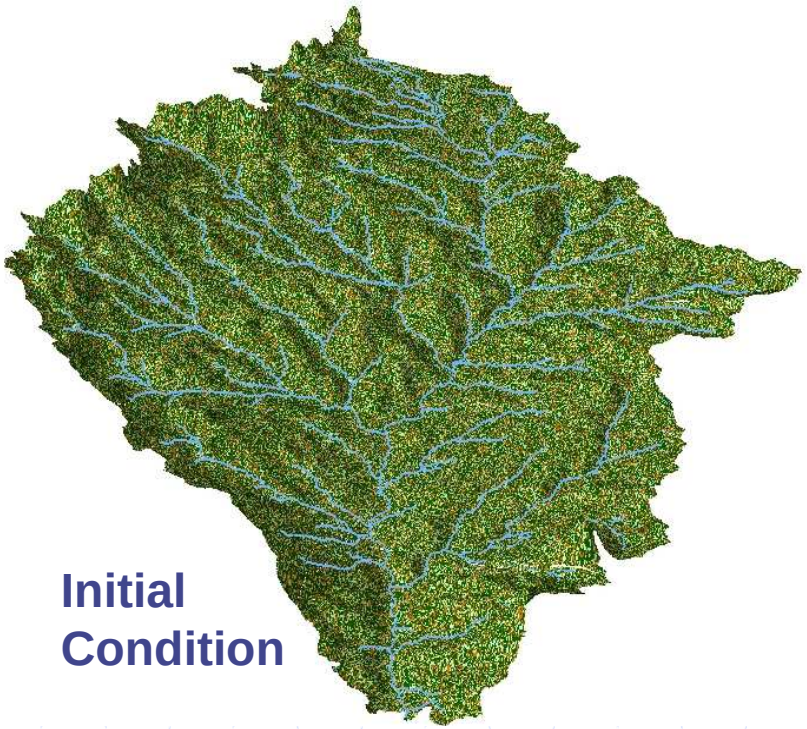


(*Manfreda & Rodriguez-Iturbe*, WRR 2006)



Dynamics of organization within river networks

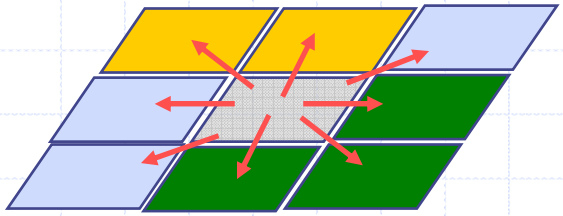
Starting from an initially random distribution, cells probabilistically replace neighbor pixels if it lowers the local amount of water stress



Initial Condition

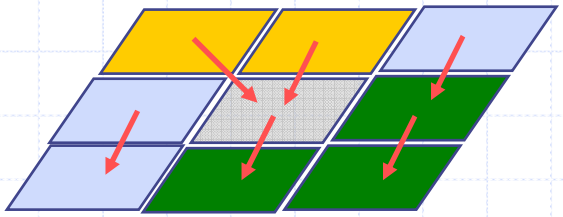
Neighbor model:

Interactions can occur between all 8 neighbors



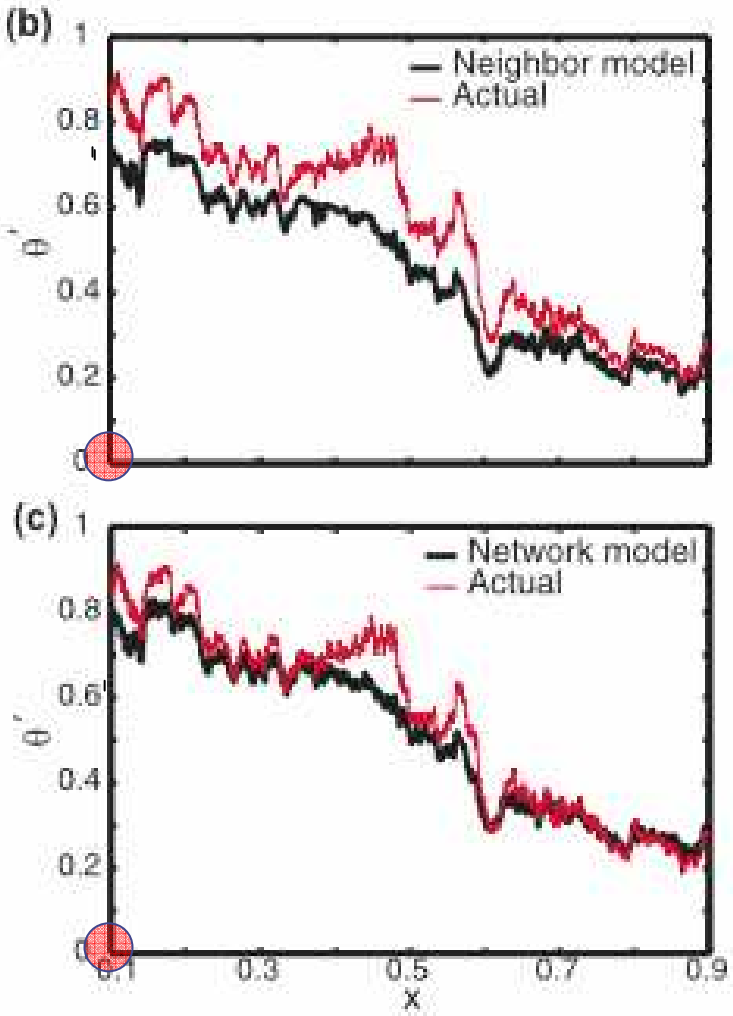
Network model:

Interactions constrained by flow path – only downstream neighbors can be replaced

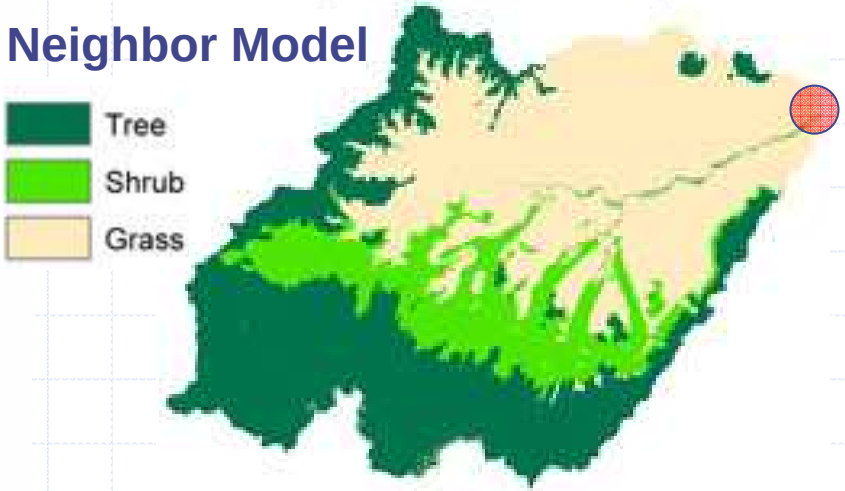


How well do each of these interactions represent the observed water stress?

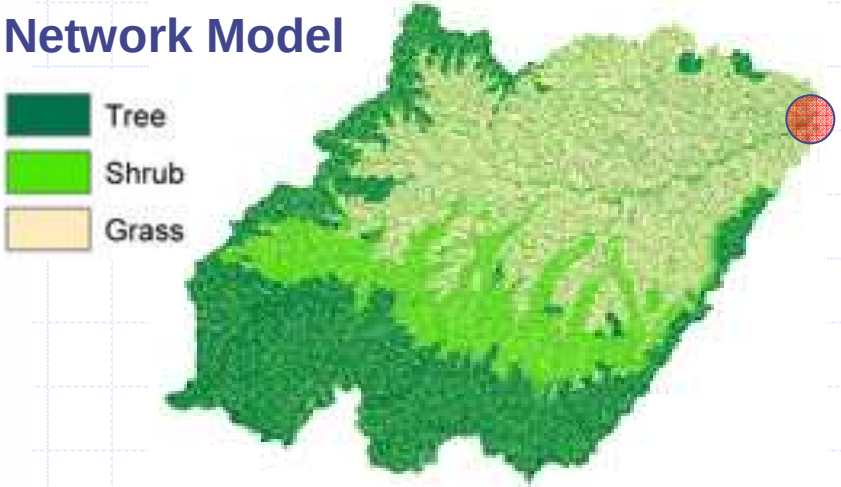
Steady-state condition



Neighbor Model



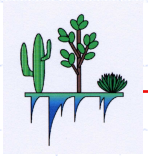
Network Model



(*Caylor et al.*, GRL 2004)

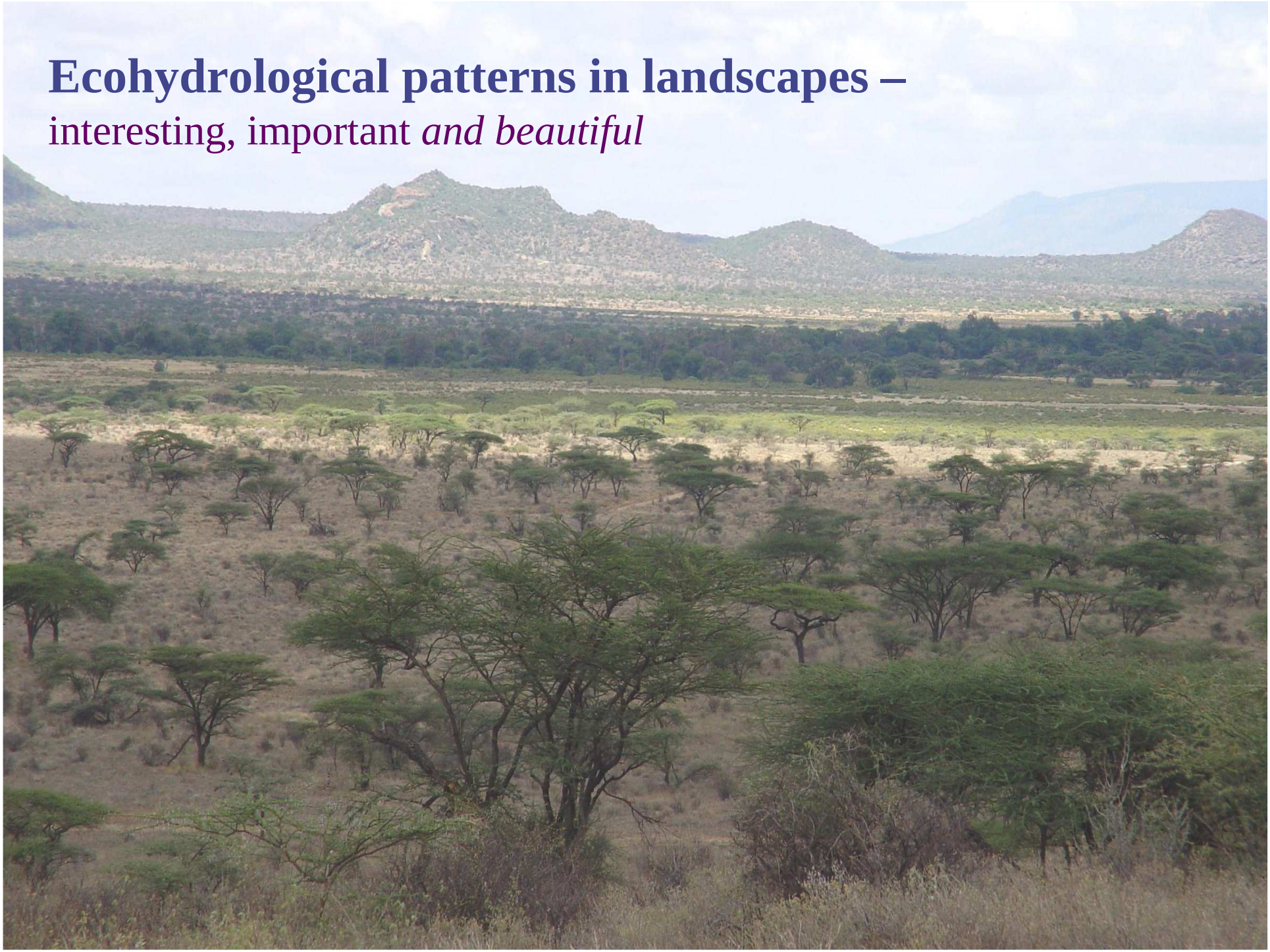
Final Remarks

- Soil water dynamics are intimately related to vegetation evolution and patterns in a way that still needs to be understood;
- Strategies for water use by plants may lead to a preferential state that strongly depends on climatic forcing, soil characteristics and basin morphology;
- Hydrological and ecological variables are mutually dependent and a better understand of ecohydrology should produce benefits for both ecologists and hydrologists;
- Ecohydrology should help scientists and engineers to quantitatively evaluate the actual state of natural ecosystems;
- …



Ecohydrological patterns in landscapes –

interesting, important *and beautiful*



ECOIDROLOGIA, SCIENZA e INGEGNERIA: quali connessioni?

POTENZA, 4 DICEMBRE 2006

GIANLUCA BOTTER e SALVATORE MANFREDA

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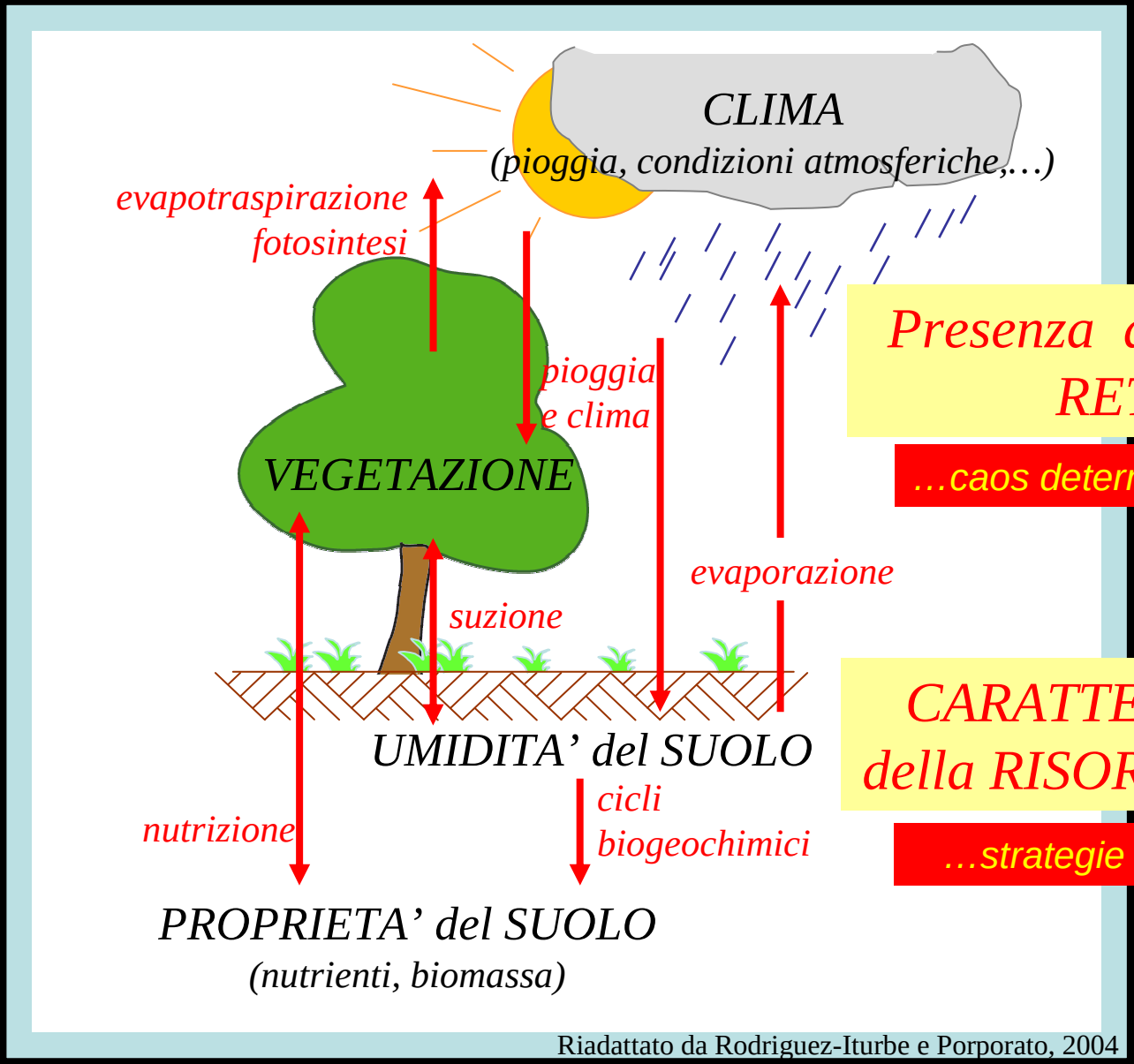
UNIVERSITA' degli STUDI di PADOVA

L'ECOIDROLOGIA

lo studio delle INTERAZIONI tra clima, suolo e vegetazione…



Riadattato da Rodriguez-Iturbe e Porporato, 2004

Presenza di CONNESSIONI e RETROAZIONI

…caos deterministico, anti-riduzionismo

CARATTERE STOCASTICO della RISORSA (precipitazione, luce)

…strategie di gestione della risorsa

OLTRE L'ECOLOGIA TRADIZIONALE…

L'assetto di un ecosistema è espressione di un processo di ottimizzazione volto a migliorare l'efficacia dello sfruttamento delle risorse disponibili

Alaska, USA

Venezia, Laguna Nord

"Quello in cui viviamo è il migliore dei mondi possibili"

Gottfried Wilhelm von Leibniz

LA MULTIDISCIPLINARITA'…

Ecoidrologia: una scienza nuova o un nuovo modo di concepire la scienza?

Venezia, Laguna Nord

QUALE DIREZIONE?

IDEE, PROSPETTIVE E PROBLEMI APERTI

- ✓ *Da dove nasce la complessità? Cosa genera i pattern osservati in natura?*

QUALE DIREZIONE?

IDEE, PROSPETTIVE E PROBLEMI APERTI

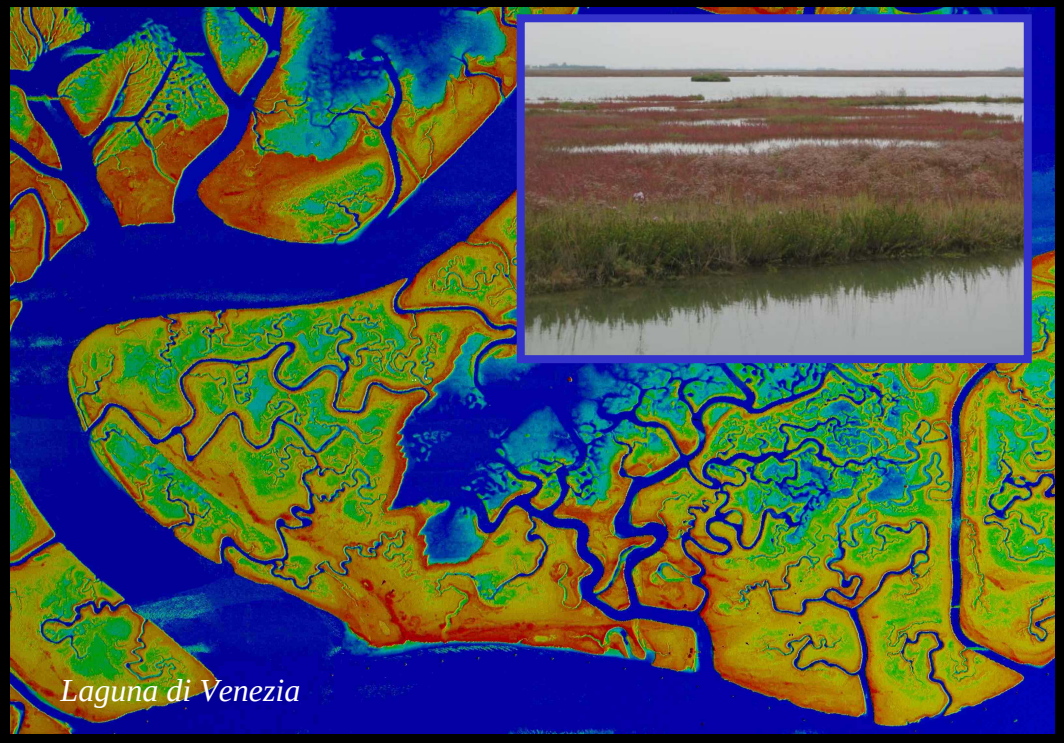
✓ *Il ruolo della topografia nella ridistribuzione delle risorse (e.g., luce, acqua, nutrienti)*

Traful, Argentina

QUALE DIREZIONE?

IDEE, PROSPETTIVE E PROBLEMI APERTI

✓ *La reversibilità delle transizioni (nuovi punti di ottimo)*



Laguna di Venezia

QUALE DIREZIONE?

IDEE, PROSPETTIVE E PROBLEMI APERTI

- ✓ *Stocasticità dei deflussi. Ottimizzazione eco-biologica e ottimizzazione idraulica (salvaguardia del territorio)*

Torrente Boite,
bacino del fiume Piave

QUALE DIREZIONE?

IDEE, PROSPETTIVE E PROBLEMI APERTI

- ✓ *Stress idrico e stress nutrizionale. Ecosistemi limitati dalla disponibilità di acqua e/o di nutrienti…*

PATTERN…

Superficie del pianeta Marte,
immagini rilevate dalla sonda spaziale MGS

…MARZIANI

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