ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Cooperation@epfl
EFLUM lab
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Projet de renforcement des capacités des communes urbaines

Application of Soil Moisture Model to Marula and Millet Agro-forestry System

Ceperley, Natalie; Parlange, Marc; Repetti, Alexandre

Technologies for Development Conference

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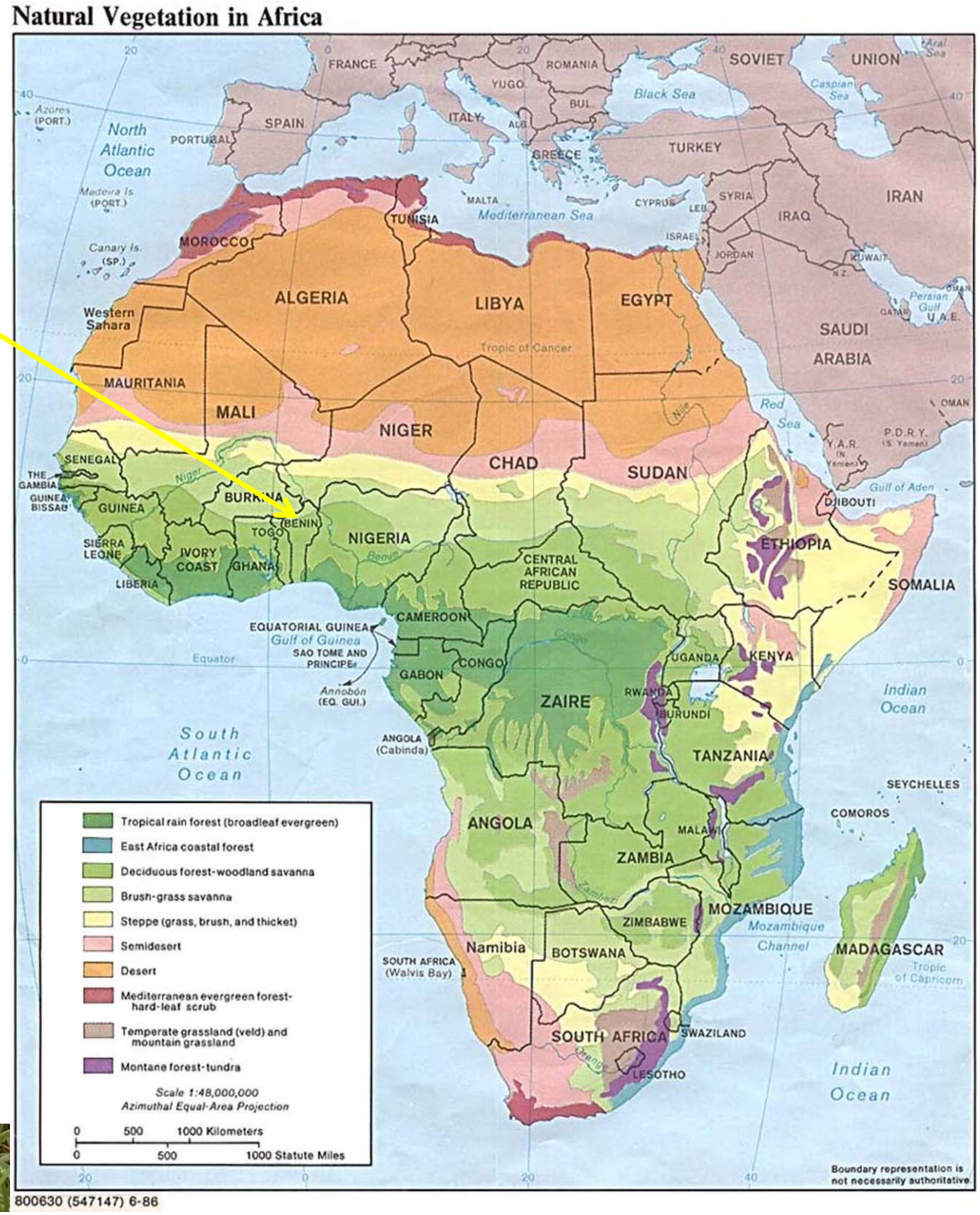
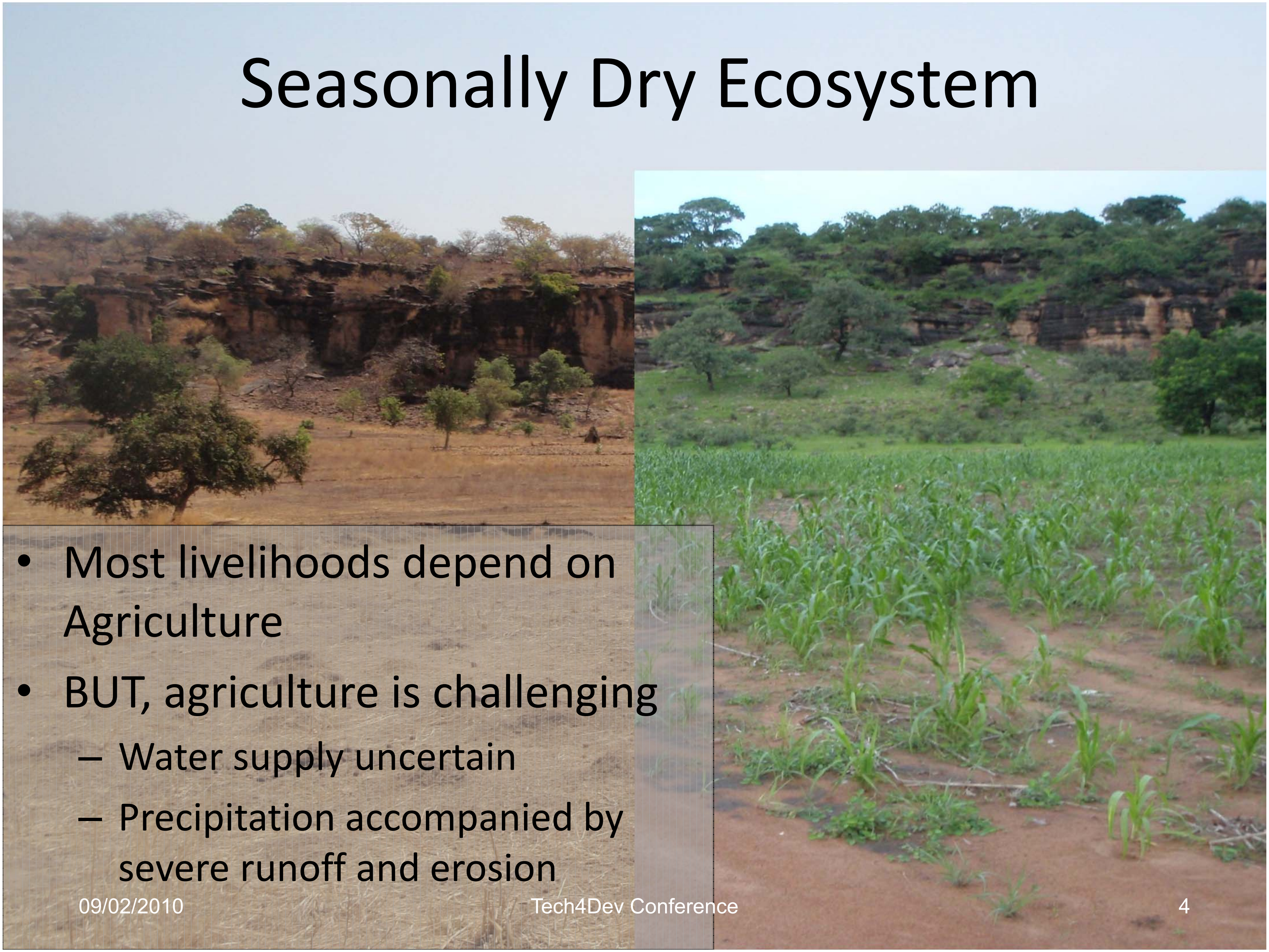
Overview

- Environmental and Cultural Contexts
  - > Current Agricultural Challenges
- Solutions
  - > Agroforestry
  - > Wireless Sensing Networks
- Example of Soil Moisture Modeling
  - > How does a tree alter the water movement
  - > Information to rural farmers
- Conclusions
  - > Example to be improved, expanded and reproduced

Majoari

- Southeastern Burkina Faso
- Sudanian Savanna
- Heavy wet and long dry season
- Ephemeral water courses




Seasonally Dry Ecosystem
• Most livelihoods depend on Agriculture
• BUT, agriculture is challenging
– Water supply uncertain
– Precipitation accompanied by severe runoff and erosion
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Traditional Knowledge

- Relied on signs from the birds, wind, trees, and hills to signal "meteorological data" such as when to plant crops, indicate soil moisture, and predict the rainy season onset, duration and intensity.
- Prior extensive knowledge of benefits of tree species useful for soil and water conservation in farmlands
- Prior systems of crop diversity, rotation and fallows

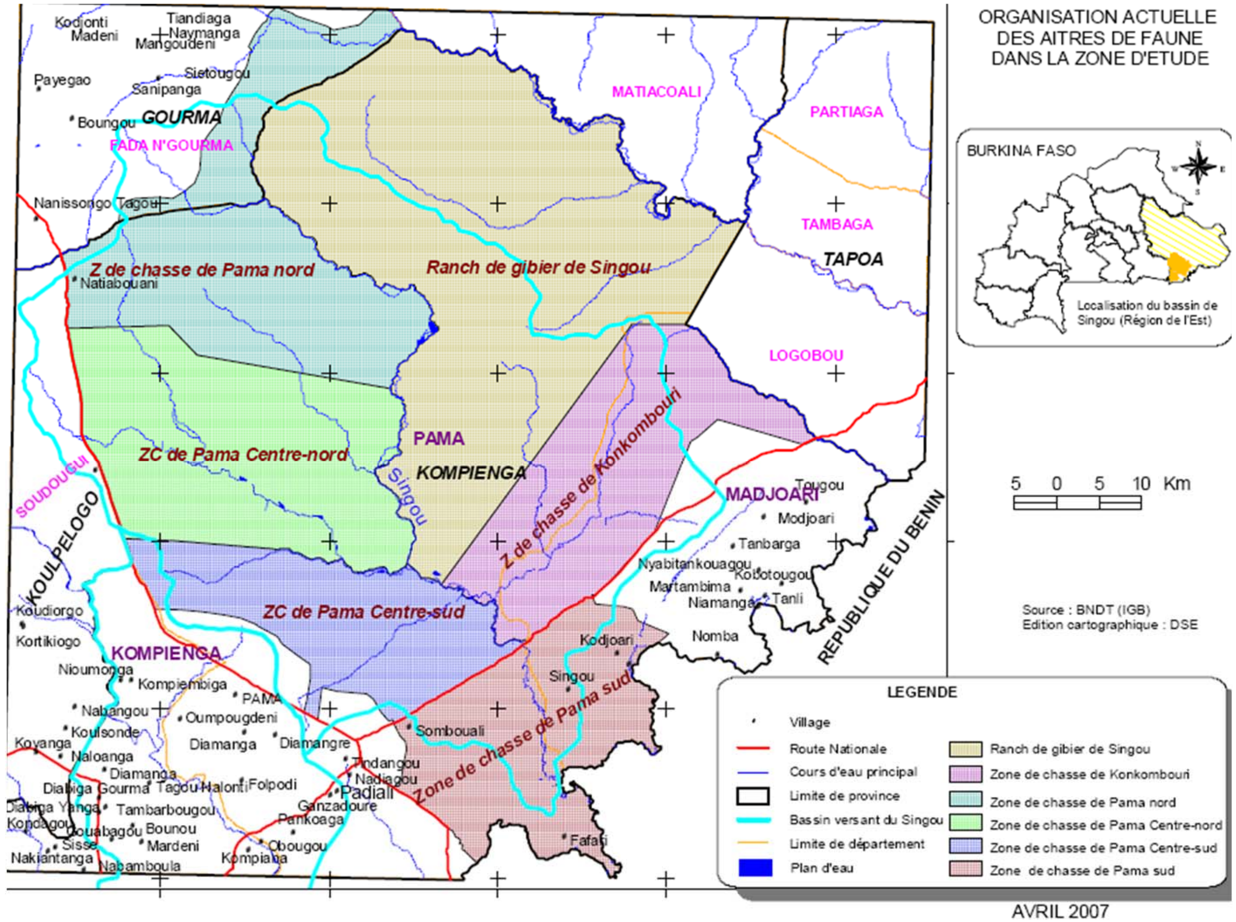
- This knowledge is no longer reliable or used due to
  – Climate and ecologic changes
  – Changing land uses and accessibility
  – Economic pressure to change agriculture
  – Aging elders and uninterested or uninformed youth.

Climate Change

- Reduction in the total quantity of the rain
  - Debatable whether this trend will continue
- However, increase in the variability of the onset, duration, and intensity of the rainy season

Over Population

- Constricting of farmland due to enforcement of protected areas
- Displacement of people to the borders
- Immigrants from other parts of the country seeking the better farmland
- Improvement of infant survival



=> loss of soil fertility
=> failure of livelihood production

Vulnerable Population

- Low capacity to adapt
  - > Is technology a solution?

Solution 1: Agroforestry

- *Planting or maintaining trees in field*
- Diversifies productive base (climate change adaptation)
- Provides food and income security
- Improves soil conservation
  - >But can ‘steal’ water from crops?

Solution 2: Wireless Sensor Networks

- Sensorscope meteorological stations
- Multi hop network
- Easy, quick deployment
- Variations in configurations and sensors
- Real time data available via GSM-internet connection
- Autonomous Solar Panel
- Once installed, little upkeep

Fig 2. Wireless sensing Device, Sensorscope used for observation in agricultural field.

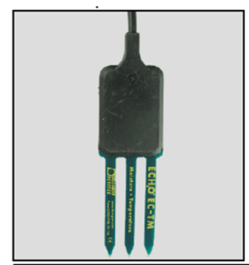


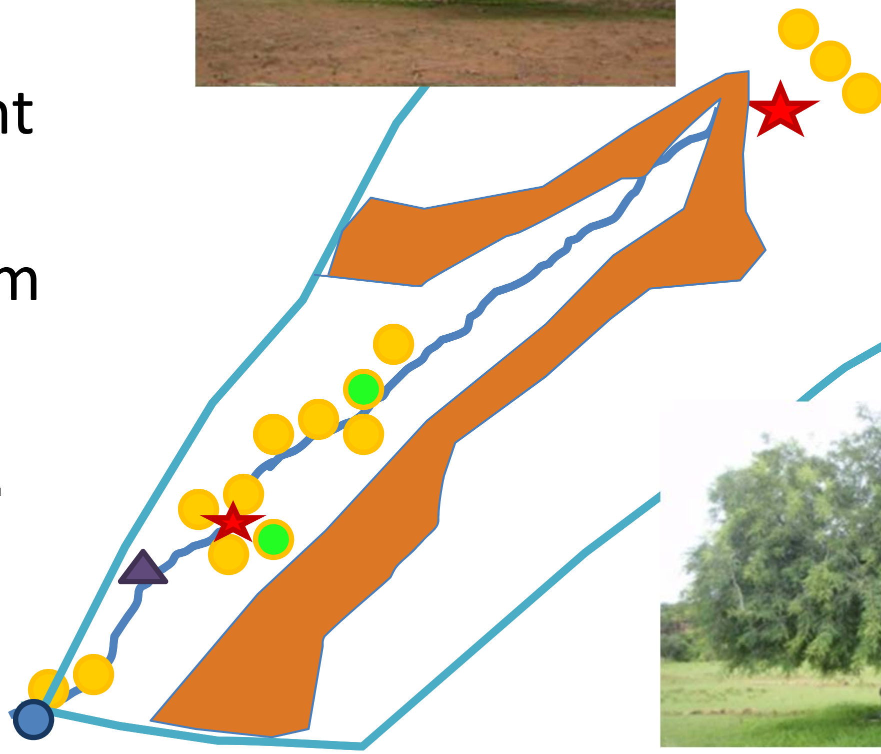
Fig. 5. Decagon Devices EC-TM soil moisture sensor

Experimental Layout

Equipment installed in April 2009 and will remain installed a minimum of a year and a half

- Eddy-Correlation
- Sensorscope Stations
- Equipped Trees
- DTS origin
- Rocky Escarpment
- Watershed Limit
- Ephemeral Stream
- Discharge

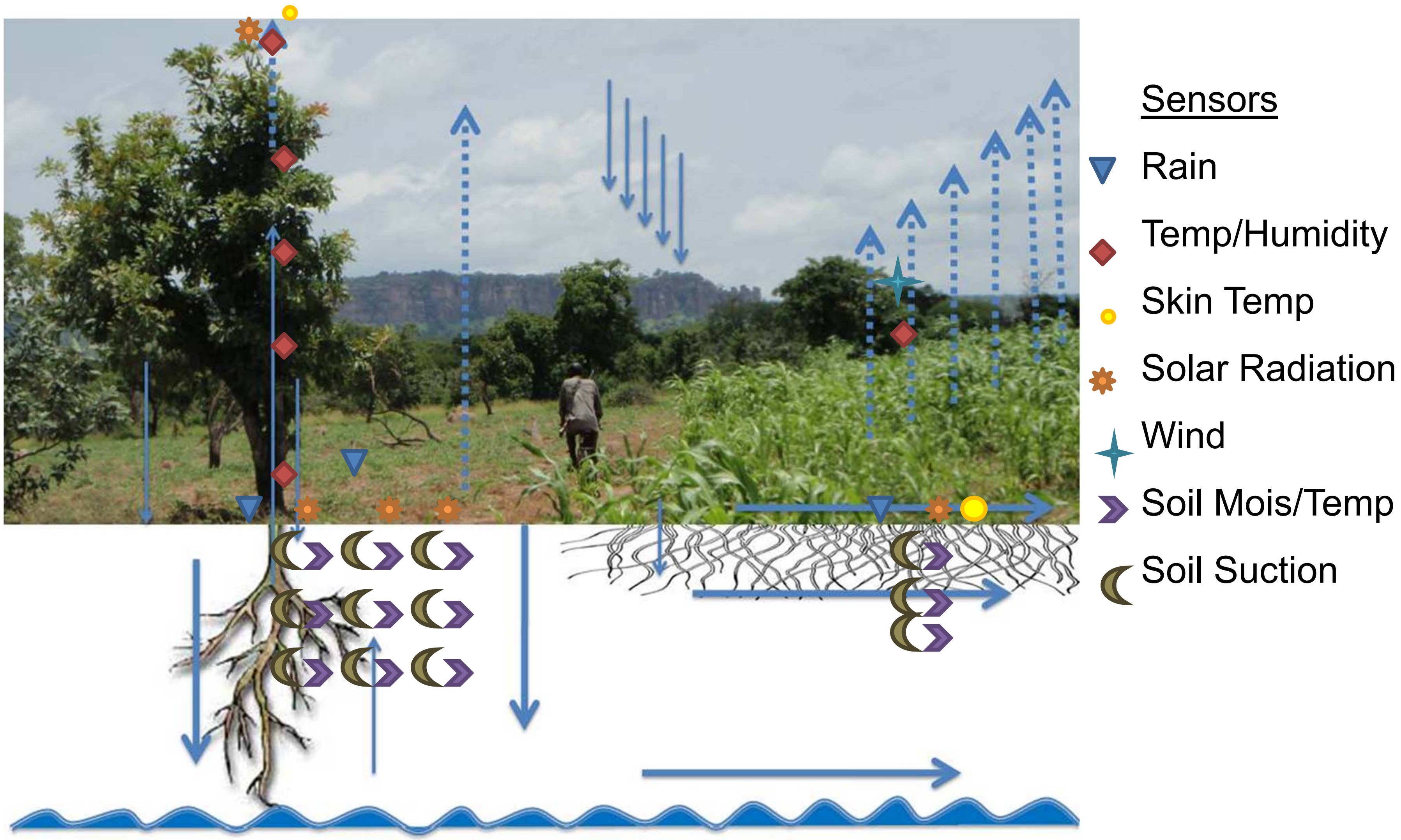
1900 m



Sclerocarya birrea

- 2 individuals
  - 1 large, riparian
  - 1 medium, upfield
  - 6/9 trees in agricultural Ha vs. 2/254 in savanna Ha
    - => Agricultural Valued Species
- Equipped
  - Soil moisture probes along 2 axes & 4 depths
  - Total Solar Radiation Sensors at 3 distances
  - Stemflow/Throughfall Rain gauges
  - Temperature profile along mast of tree at 5 levels
  - Skin Temperature (IR) at leaf surface

Study of Flows around the Tree



Soil Moisture Response to Rain Event

Common simple, one-dimensional ecohydrologic model

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

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

$$R = h = \begin{cases} \lambda < p; h = 0 \\ \lambda > p; p(h) = \frac{1}{\alpha} e^{-h/\alpha} \end{cases}$$

$$I = \begin{cases} h < \Delta; I = h \\ h > \Delta; I = \Delta \end{cases}$$

$$Q = \begin{cases} R - I > (1-s)n \cdot Zr; Q = (1-s)n \cdot Zr \\ R - I < (1-s)n \cdot Zr; Q = 0 \end{cases}$$

$$E = \begin{cases} s < sw; E = \frac{s \cdot E_{max}}{sw} \\ s > sw; E = E_{max} \end{cases}$$

$$L = K \cdot s^{2b+3}$$

- Soil moisture (s) is dependant on
  - Rainfall (R),
  - Interception (I),
  - Runoff (Q),
  - Evaporation (E),
  - Leakage (L)
  - Pore space (n)
  - Rooting depth (Zr)
- Predict each parameter and response given rain event frequency(λ) and depth (α)
- One dimensional model

(Rodriguez-Iturbe and Porporato 2004)

Modeled Rain

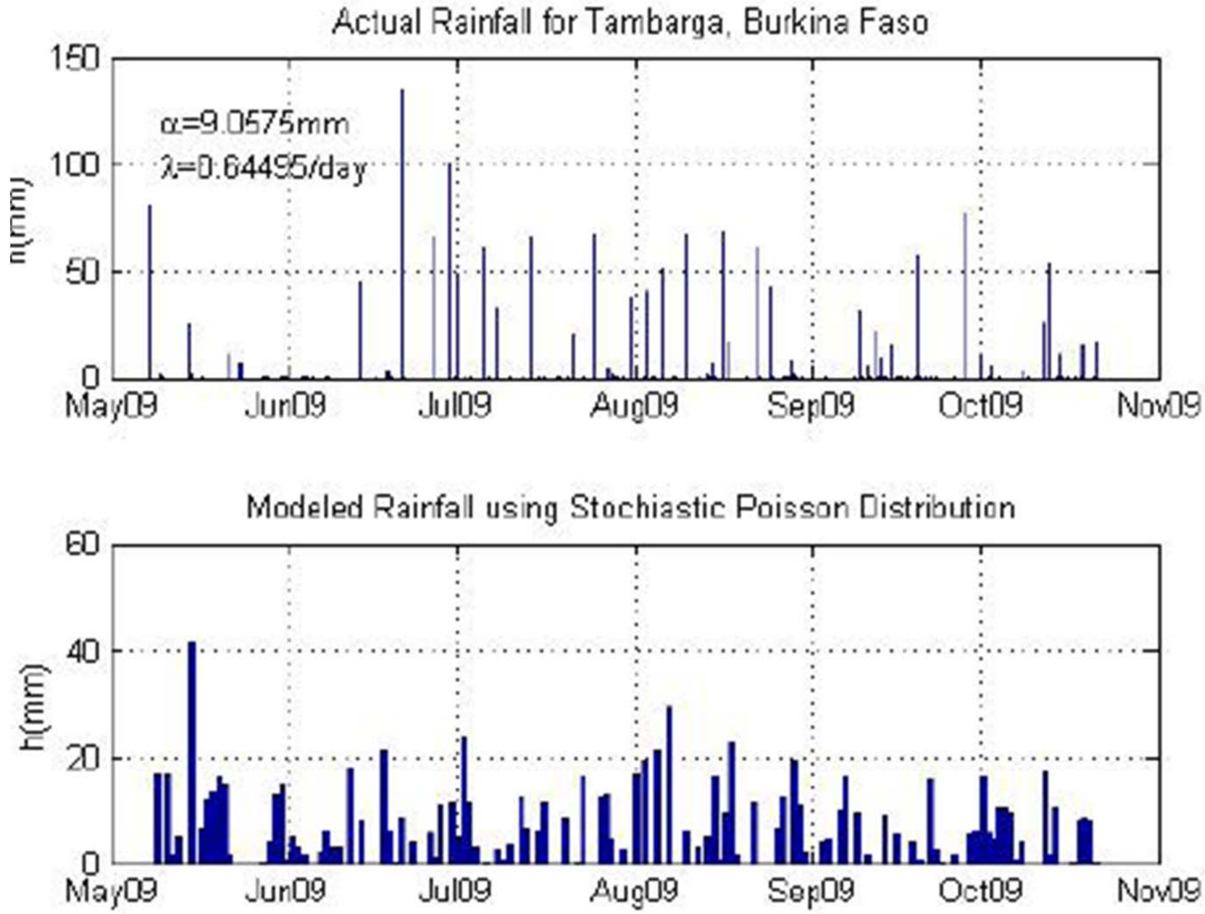


Fig. 6 Actual Rainfall vs. Modeled Rainfall

Conditions

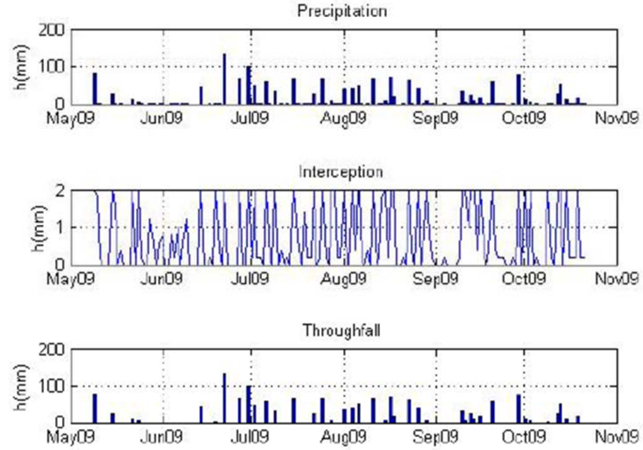
Table 1.1 Vegetation Characteristics Used in 2 Scenarios

Scenario	**Vegetation**	**Infiltration Threshold** Δ (mm)	**Rooting Depth** Zn (mm)	**Wilting Point** sw	**Maximum Evapotranspiration** Emax (mm/day)
1	**Millet (*Pennisetum glaucum*)**	0.55	1400	0.12	3.4752
2	**Marula (*Sclerocarya birrea*)**	2	3000		
Ref:		Laio et al. (2001)	Sivakumar et al. (1994), Smith et al. (1997)	Ong and Leaky (1999)	Measured

Table 1.2 Soil Characteristics Used in 2 Scenarios

Dominant Soil Texture	**Pore Size Distribution Index** b	**Porosity** n	**Hygroscopic Point** s(1)	**Saturated Leakage** K (mm/day)
Silty Loam	4.977	0.39	0.15	622.08
Bunasol (pers. Comm..)	Fernandez-Illescas et al. (2001)	Sampled	Initial measured	Clapp and Hornberger (1978)

Results



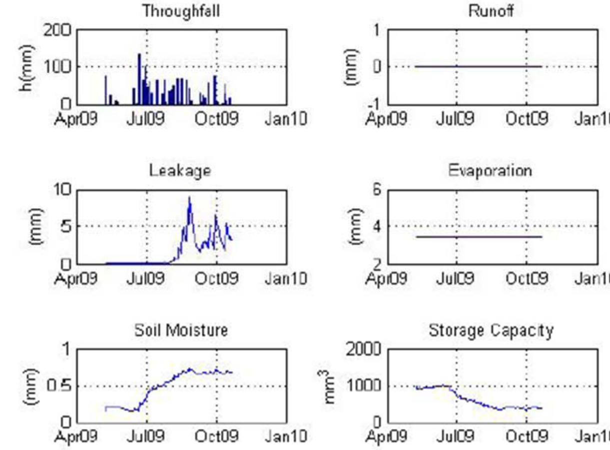
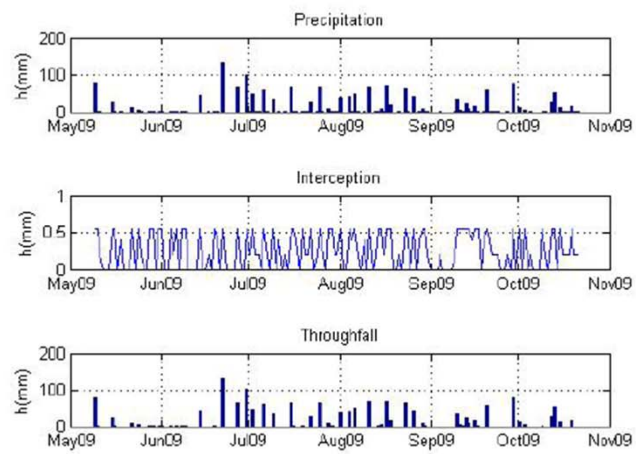


Fig. 7 Comparison of Additions for *Sclerocarya birrea*	**Fig. 8** Comparison of Subtractions for *Sclerocarya birrea*



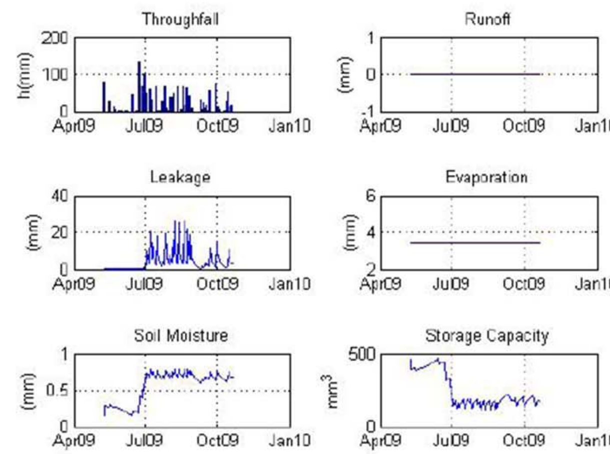
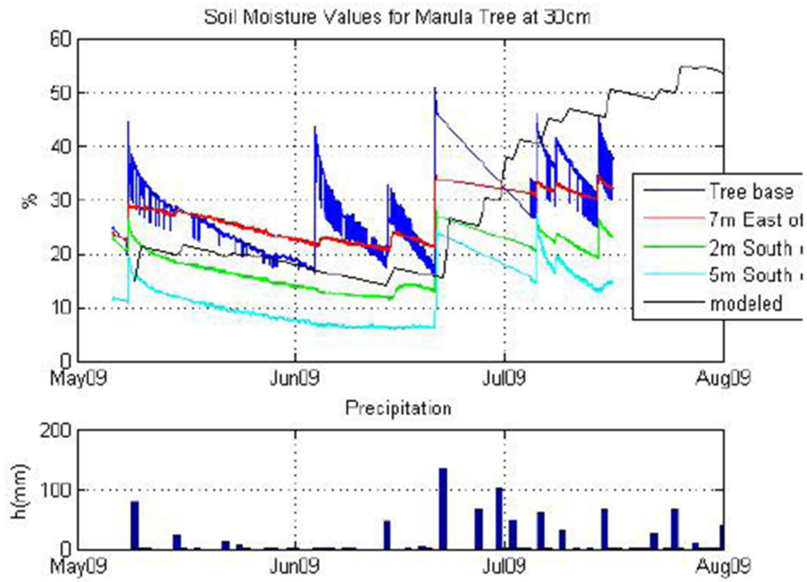


Fig. 9 Comparison of Additions for *Pennisetum glaucum*	**Fig. 10** Comparison of Subtractions for *Pennisetum glaucum*

Comparison



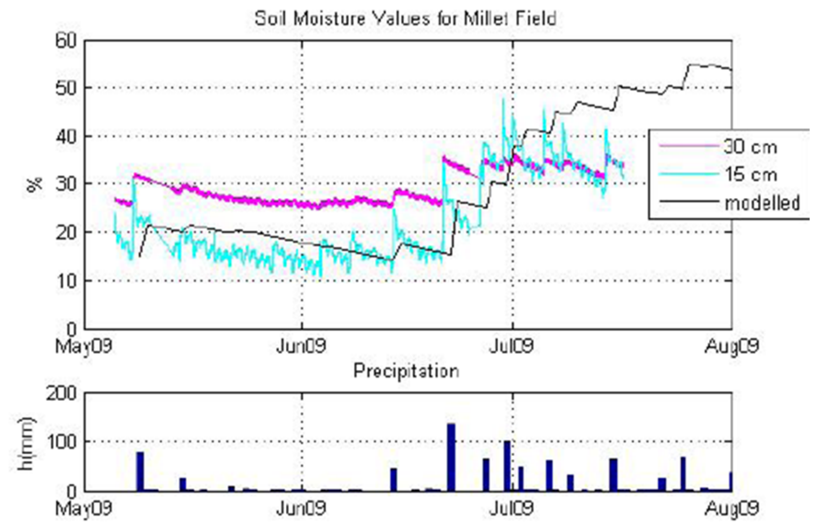


Fig. 11 Comparison of Actual and Modeled Soil Moisture for *Sclerocarya birrea*	**Fig. 12** Comparison of Actual and Modeled Soil Moisture for *Pennisetum glaucum*

⇒ Model ok, but does not show variation in flow
⇒ Under tree water flow important, but less permanent
⇒ Suggests improvements of under canopy flow.

⇒Sensorscope improves research, conclusions useful to farmers.

Information to Farmers

- Center for Environmental Information
- Transformation of data to useful variables
- Continuation of research to answer local concerns and problems
- Education to make research and data more accessible and collaborative (now) and independent (future)
- Collaborate with leaders and technicians to encourage innovation of farming practices

Discussion

- Advantages
  - > Tremendous local support and interest
  - > Successful Local Maintenance
  - > Allows remote research

- Challenges
  - > Dependant on working GSM connection
  - > Livestock
  - > Useful data
- Conclusion
  - > Example to be improved, expanded and reproduced

Comments & Questions

Natalie Ceperley
natalie.ceperley@epfl.ch

Cooperation http://cooperation.epfl.ch
Environmental Fluid Mechanics and Hydrology Lab http://eflum.epfl.ch
Sensorscope http://climaps.epfl.ch