# Preferential States Driven by Feedbacks from Soil Moisture to Rainfall Frequency and to Potential Evapotranspiration


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## Introduction

Persistent drought or wet climate was often explained by local water recycling. Feedback from soil moisture to rainfall frequency (Feedback I) may lead to bimodality in frequency distribution of soil moisture.

Generally, when soil moisture increases at certain range, evapo-transpiration increases. On the other hand, the soil moisture controls the sensible and latent heat fluxes partitioning, and consequently influences the atmosphere temperature. Potential evapo-transpiration (PET) is associated with temperature. So, there could be a possible feedback from soil moisture to PET (Feedback II) which may have some influence on the soil system.

Based on a stochastic soil moisture model, this research aimed at analyzing the influences of Feedback I and II (Fig.1) and their combining effects on PDF of soil moisture, and on PDF of rainfall interval.

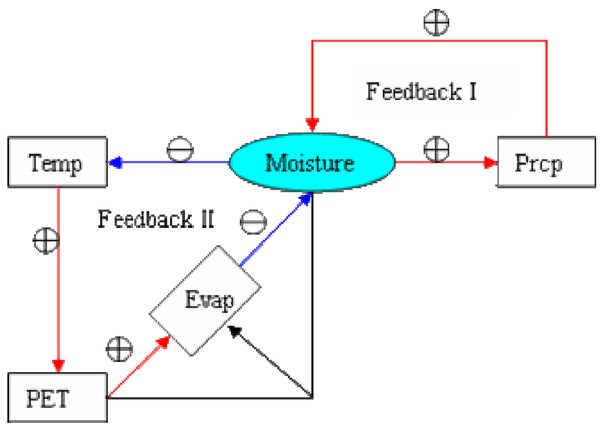



*Fig.1 .Feedback I and II discussed in this research*

## Methodology

The stochastic soil moisture model is a simple water balance model (Rodriguez-Iturbe, Porporato et al. 1999)

$$nZ\frac{ds}{dt} = R(t) - L(s) \quad (1)$$

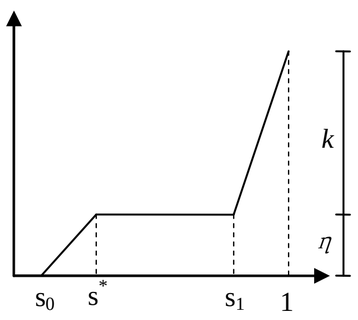



*Fig.2 Normalized loss function. It is similar to the expressions in (Rodriguez-Iturbe, Porporato et al. 1999). The value $s_0$ and $s_1$ should not be strictly interpreted as hydroscopic and field capacity of the soil.*

Porporato, A. and P. D'Odorico (2004) derived a PDF of soil moisture for steady-state condition from the stochastic soil moisture model (Eqn. (1)).

$$p(s) = \frac{c}{\rho(s)} e^{-\gamma s + \int_s [\lambda(u)/\rho(u)]du} \quad (2)$$

When rainfall frequency depends on soil moisture which is a random variable, probability of time interval is not exponentially distributed but becomes a superstatistical problem

$$f(t) = \int \lambda e^{-\lambda t} g(\lambda) d\lambda \quad (3)$$

## Preliminary Results

Data from state of Illinois were tested where local recycling was often discussed. Parameters were chosen from (D'Odorico and Porporato 2004)

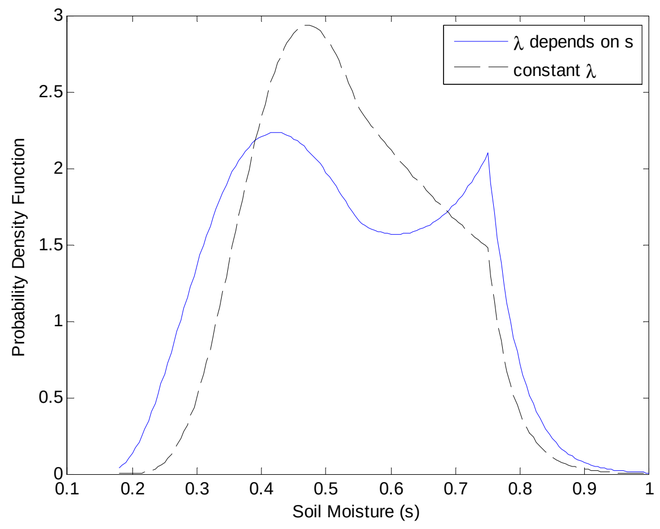
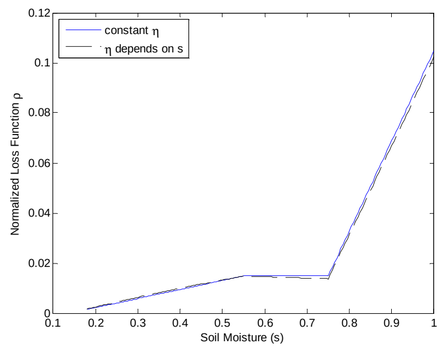



*Fig.3. PDF of Soil Moisture Calculated by Different Rainfall Frequencies. Feedback I trends to generate bimodality in PDF of soil moisture*

*Fig.4 Loss functions with and with out Feedback II (soil moisture - PET $\eta = c+ds$) in Peoria, IL. It has subtle change.*



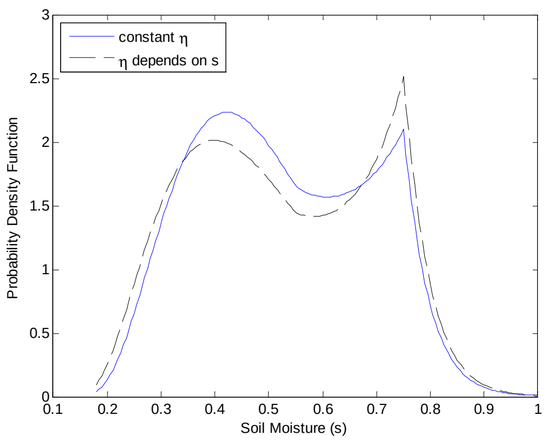




*Fig. 5 PDF of Soil Moisture from Different PET (with and without Feedback II) both under Feedback I*

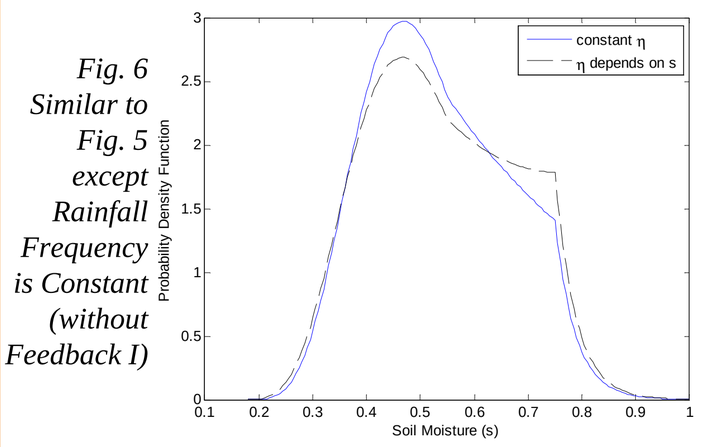



*Fig. 6 Similar to Fig. 5 except Rainfall Frequency is Constant (without Feedback I)*

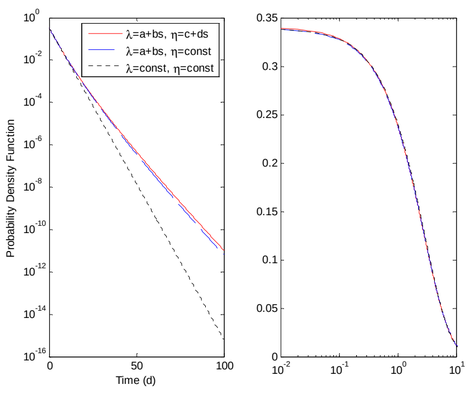



*Fig. 7 PDF of inter-arrival Rainfall Interval with or without Feedback I or II (The left graph has logarithmic scale on the y axis; the right one has logarithmic scale on the x axis)*

Monte Carlo simulation was conducted to analyze the influence of calibrated noise term in Feedback I and II on PDF of soil moisture.

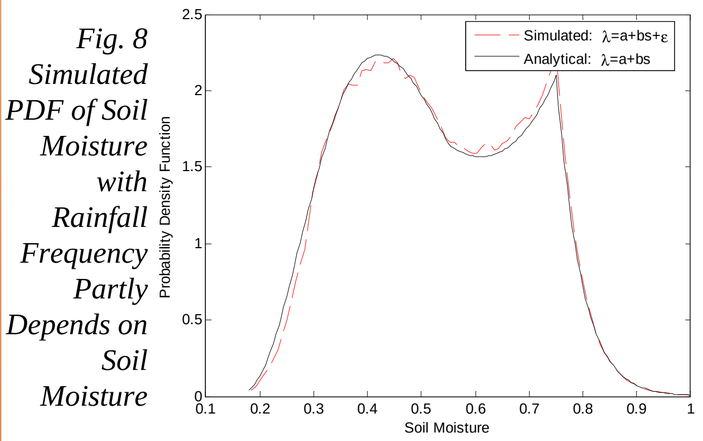



*Fig. 8 Simulated PDF of Soil Moisture with Rainfall Frequency Partly Depends on Soil Moisture*

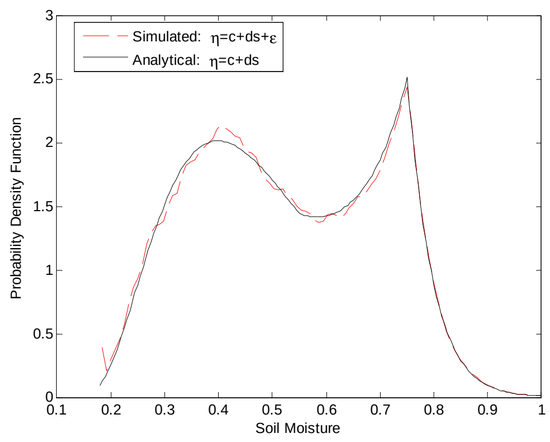



*Fig. 9 Simulated PDF of Soil Moisture with PET Partly Depends on Soil Moisture*

## Conclusion

1. Feedback I and II both tend to generate bimodality, and together they magnify the individual effects.
2. Feedback I tends to induce a longer inter-arrival rainfall interval.
3. Feedback II does not influence the inter-arrival rainfall interval, but when combined with feedback I, it can amplify the persistent drought state.
4. The noise terms in Feedback I and II have little impact on the PDF.