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Coupling Eco-hydrologic Components in the Landlab Modeling Framework

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CSDMS COMMUNITY SURFACE DYNAMICS MODELING SYSTEM
CIRES
NSF

ABSTRACT

In arid and semi-arid regions, geomorphic response of a catchment is tightly coupled with Eco-hydrologic dynamics. Climate-driven biotic and abiotic processes strongly influence land-surface-atmosphere interactions and thus play an important role in landscape evolution. Landscape Evolution Models (LEMs) provide a platform for scientists to quantitatively understand these complex interactions by exploring testable hypotheses. Hydrology and vegetation dynamics are thus critical components of these LEMs. This work illustrates the development of such components and model-building by coupling fluvial and ecohydrologic components in the Landlab modeling environment. The Landlab is a component based framework for 2D numerical modeling, coded in Python. It provides a gridding module and allows users to either configure a model from scratch or use existing components. We present a coupled vegetation dynamics model where vegetation is simulated based on inputs from stochastic precipitation generator, radiation component, potential evapotranspiration component and soil moisture component. This work demonstrates the flexibility of the Landlab and also highlights the advantages of component-based approach.

THE LANDLAB

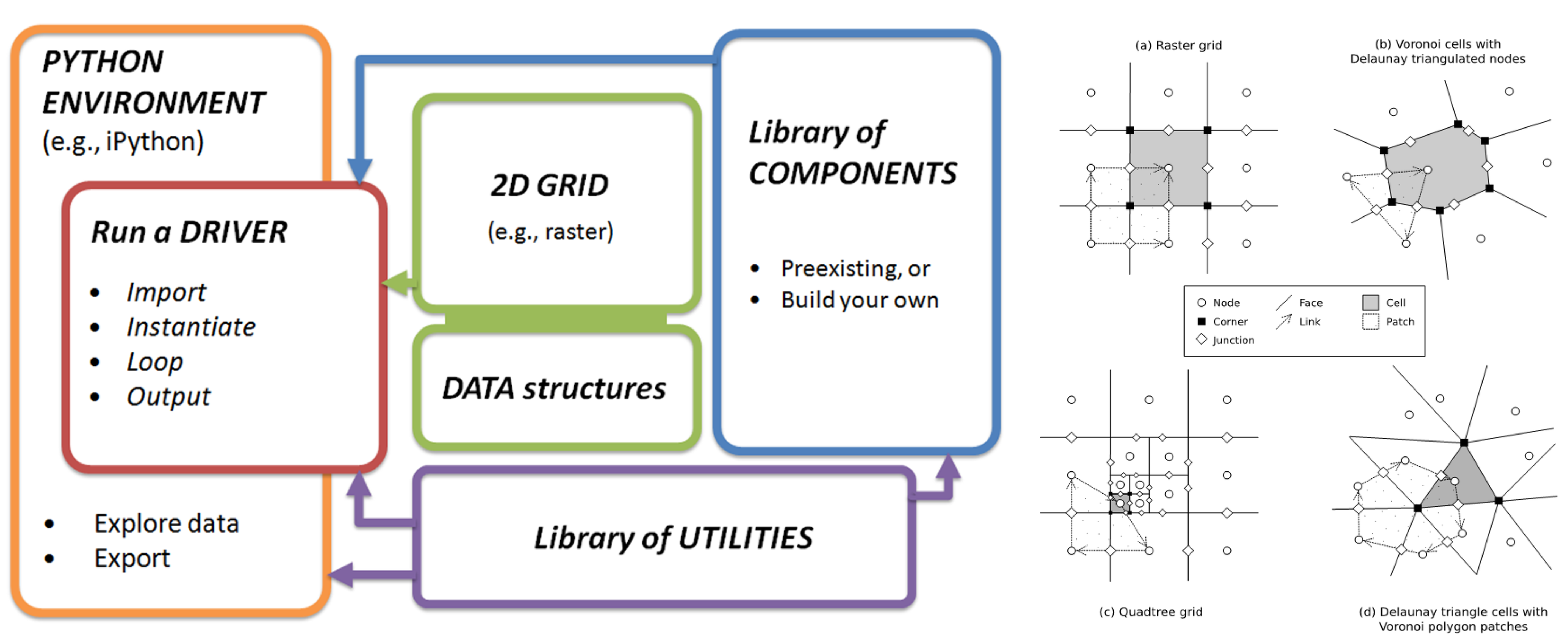
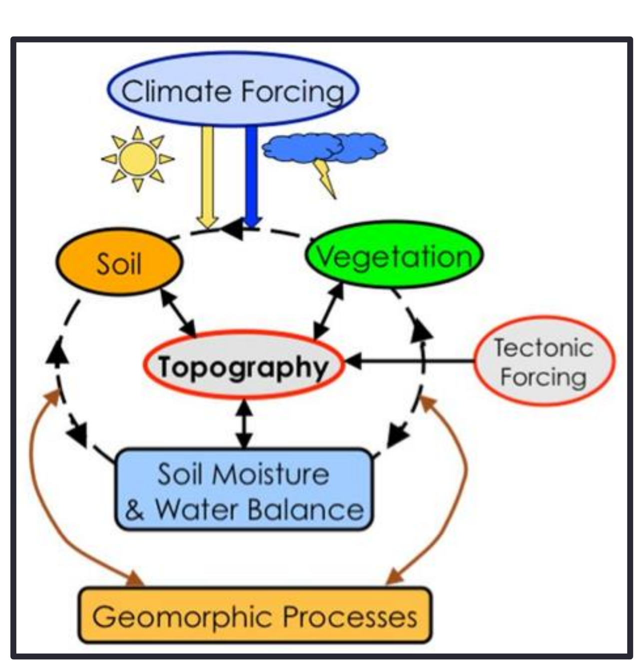


Fig. 1: *Landlab Architecture*

ECOHYDROLOGY & GEOMORPHOLOGY



Radiation balance: $R_n = (1-\alpha) R_{SW} + (\downarrow R_{LW} - \uparrow R_{LW})$

Energy balance: $\frac{dS_h}{dt} = R_n - H - \lambda ET(s)$

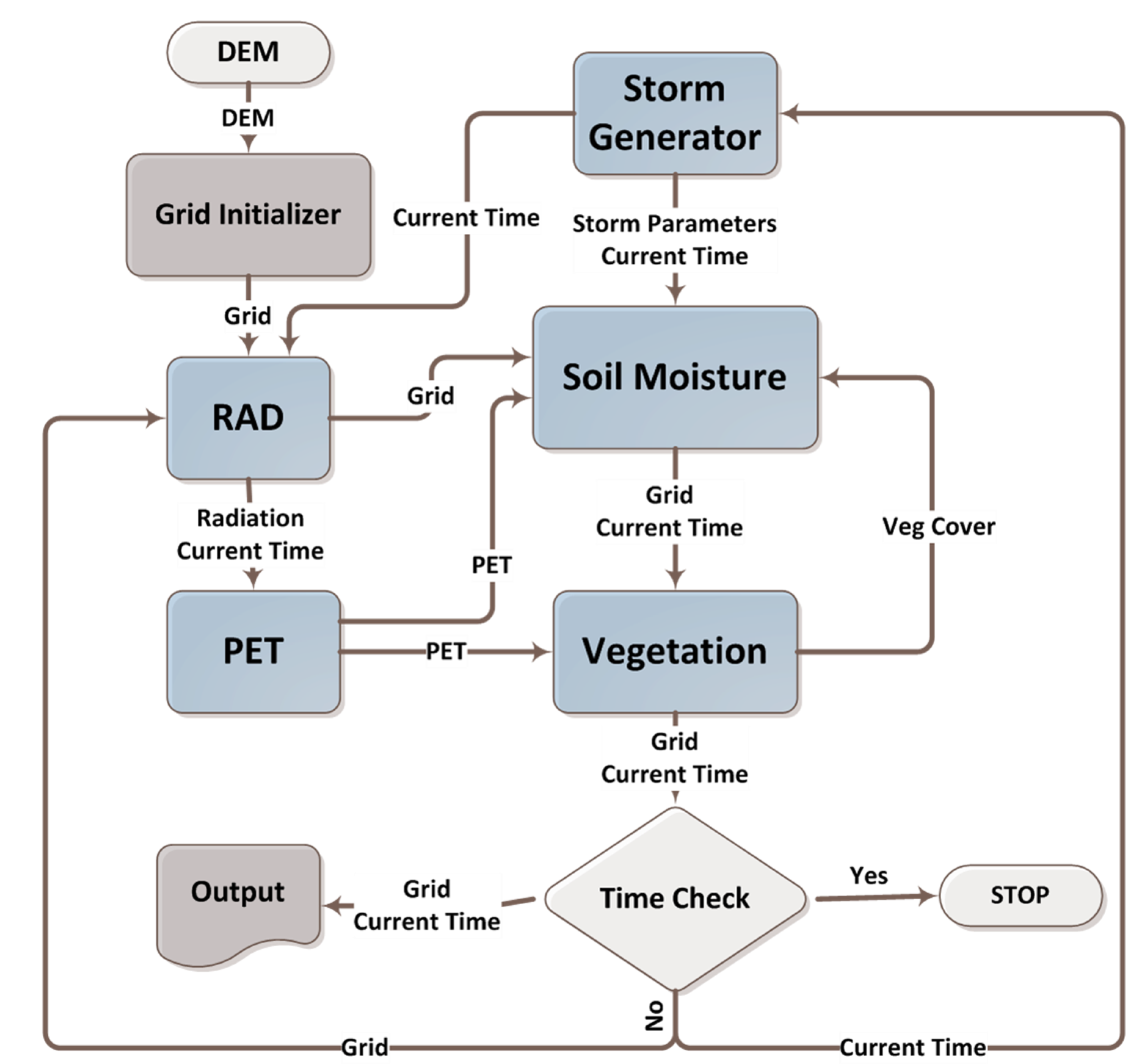
Water balance: $nZ_r \frac{ds}{dt} = I(s) - ET(s) - D(s)$

Vegetation dynamics: $\frac{dB}{dt} = k_g ET(s, V, T) - k_d B$

Elevation: $\frac{\partial z}{\partial t} = U - \nabla q_{sd} - \nabla q_{sf}(q_w(V))$

Fig. 2: *Connection between Ecohydrology and Geomorphology*

COUPLED ECOHYDROLOGY MODEL



Storm Generator: generates rectangular Poisson distributed storms

Radiation (RAD): calculates daily spatially distributed solar radiation

Potential Evapotranspiration (PET): uses solar radiation fields and weather variables to calculate PET at each model element

Soil Moisture: solves root zone water balance between two storms given PET and rainfall fields and returns actual evapotranspiration and soil moisture at the end of the inter storm duration

Single Vegetation: *computes net primary productivity based on actual evapotranspiration and calculates leaf area index and biomass*

PSEUDO CODE

```
Precipitation_Generator = PrecipitationDistribution()
Precipitation_Generator.initialize()
Precipitation = Precipitation_Generator.get_storm_time_series()
RMG, Elevation = RasterModelGrid( 'DEM' )
Radiation_ = Radiation()
Radiation_.initialize( RMG, Elevation )
PET_ = PET()
PET_.initialize()
Soil_Moisture = SoilMoisture()
Soil_Moisture.initialize( RMG )
Vegetation_ = Vegetation()
Vegetation_.initialize( RMG )
for i in range( 0, Number_of_Storms ):
    current_time = Soil_Moisture.get_current_time()
    Radiation_.update( RMG, current_time )
    Radiation_Factor = Radiation_.get_RadFactor()
    PET_.update( Radiation_Factor, current_time )
    PET = PET_.get_PET()
    Soil_Moisture.update( RMG, Precipitation[i], Radiation_Factor, PET )
    Vegetation_.update( RMG, PET )
```

MODEL CONFIRMATION

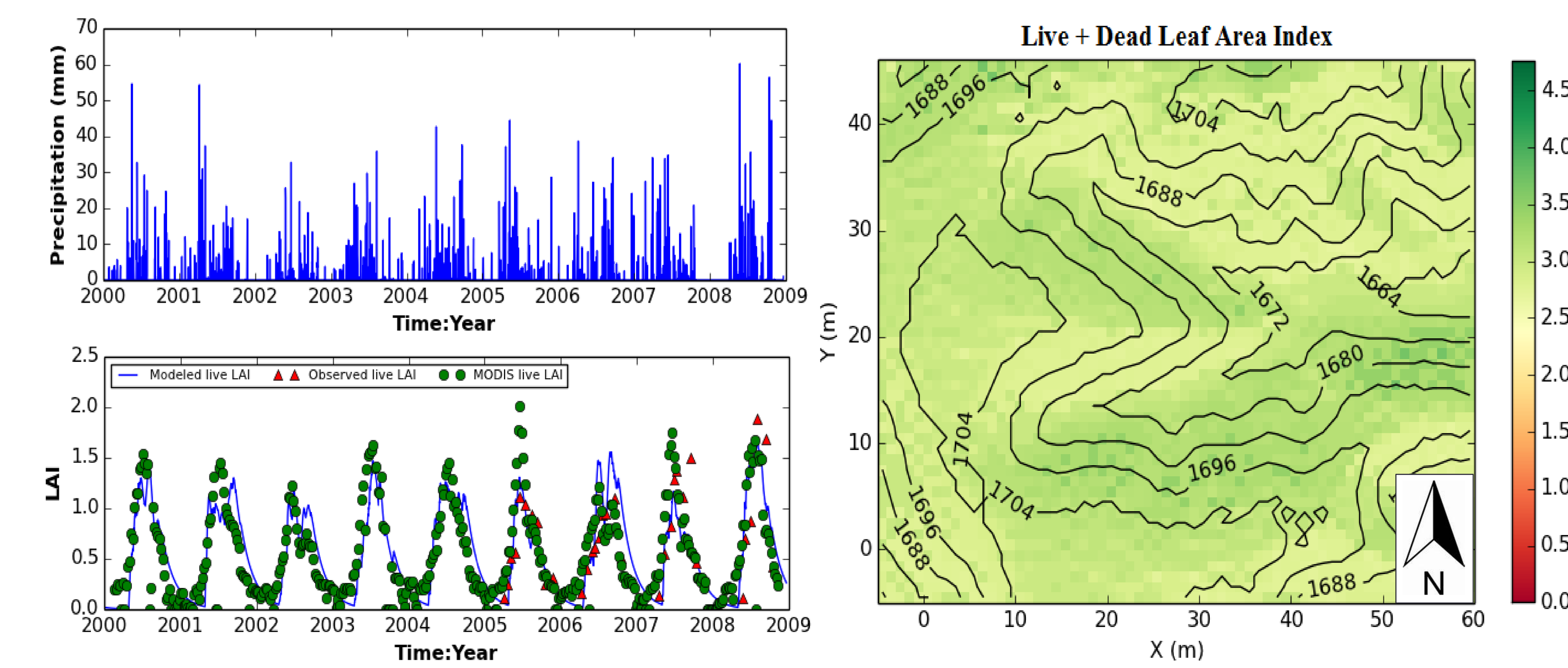
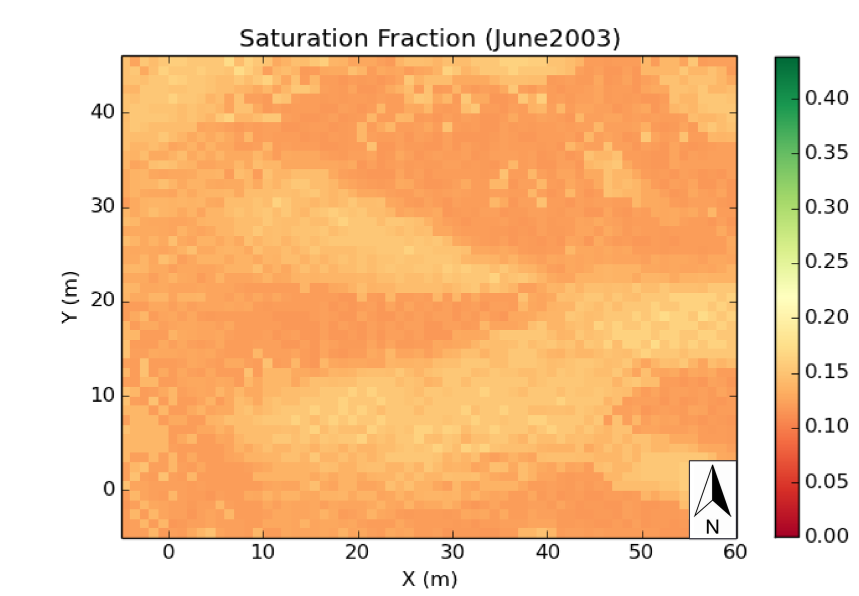


Fig. 3: *Point Model Validation of Leaf Area Index at Nebraska Sand Hills*



Model was driven by observed daily storms at the Sand Hills of Nebraska where grass is the dominant vegetation type. Model confirmation was done against observed soil moisture and leaf area index from observations and satellite data.

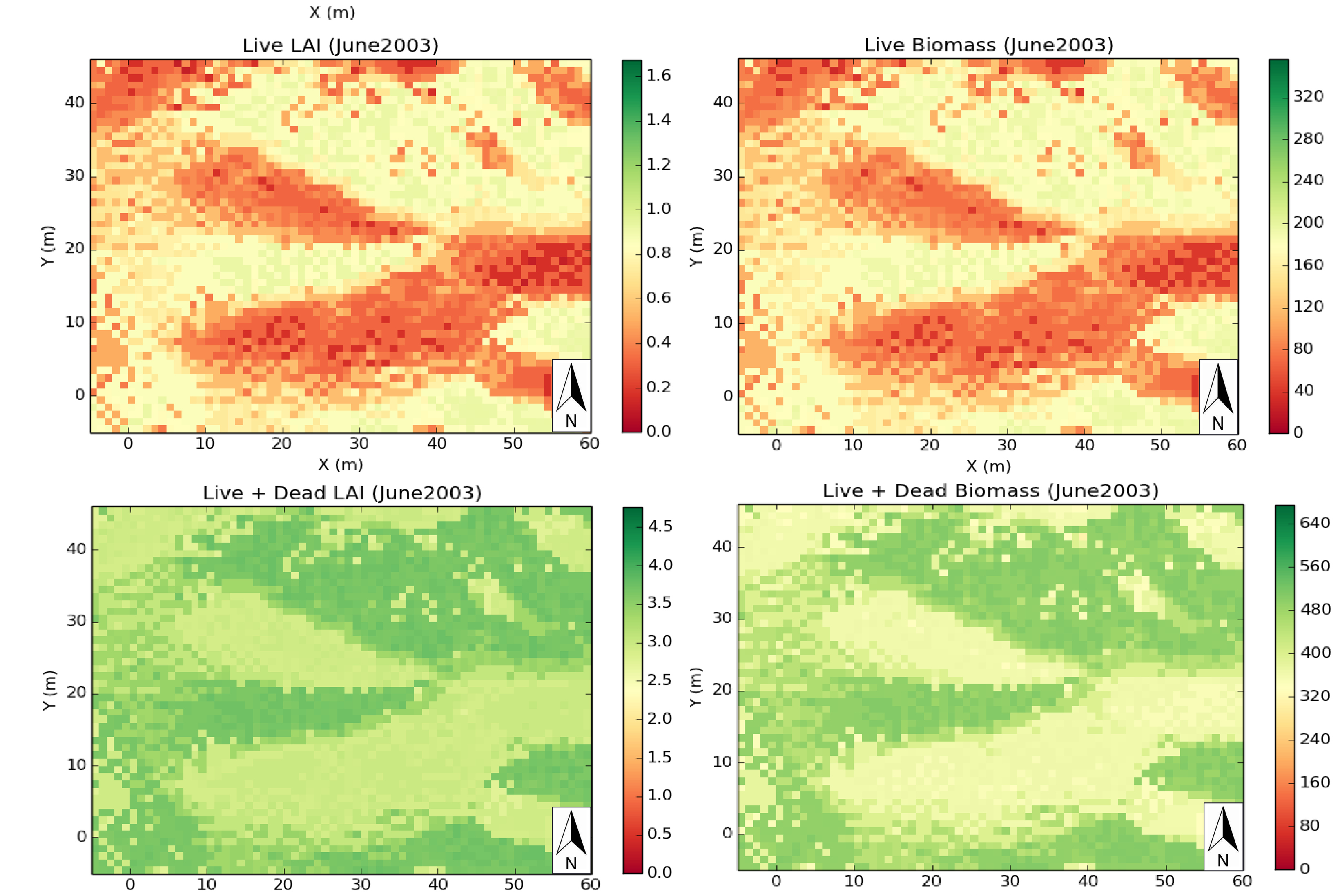


Fig. 4: *Spatial Distribution of Leaf Area Index and Biomass Production*

REFERENCES

1. Tucker, Gregory E., et al. "An object-oriented framework for distributed hydrologic and geomorphic modeling using triangulated irregular networks." "Computers & *Geosciences* 27.8 (2001): 959-973.

2. Istanbulluoglu, Erkan., et al. "Evaluation of ecohydrologic model parsimony at local and regional scales in a semiarid grassland ecosystem." *Ecohydrology* 5.1 (2012): 121-142.

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Know More About The Landlab here: http://the-landlab.readthedocs.org/en/latest/index.html#