

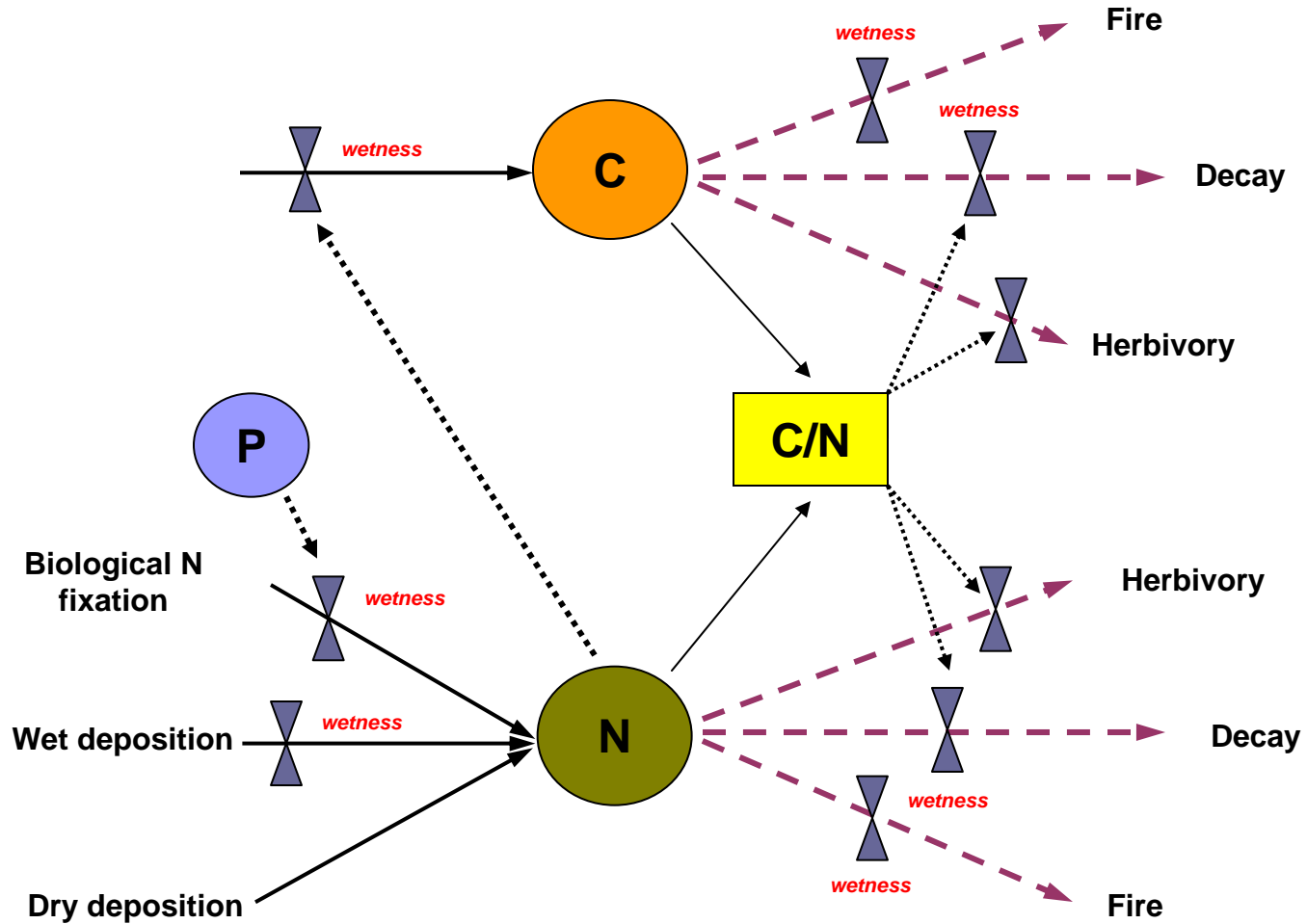


Nitrogen and Phosphorous relationships with productivity, fire and herbivory: insights from a simple model

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An ecosystem model of C, N & P linkages

(Scholes, R. J., Danglmayr, G., Hanan, N. P. & Sankaran, M.)



Model of ecosystem dynamics

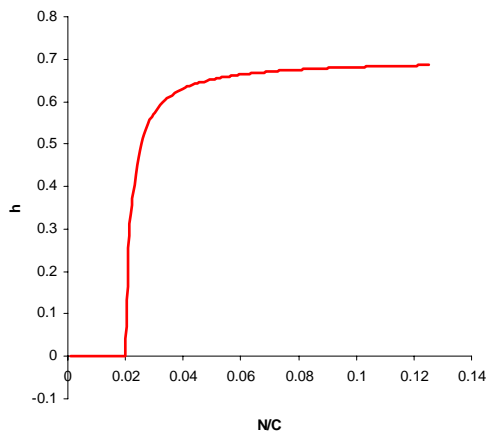
$$\frac{\partial C}{\partial t} = \underbrace{\varepsilon w N}_{\text{assimilation}} (1 - e^{-bC}) - \underbrace{(h(y)C)}_{\text{herbivory}} - \underbrace{(1 - h(y)[k(w, y) + (1 - k(w, y))m_{inv}(C, w)]}_{\text{decay}} \quad \text{Carbon}$$

$$\frac{\partial N}{\partial t} = w(d_w + g) - u(h(y)N) - (1 - h(y)[xk(w, y) + v(1 - k(w, y))m_{inv}(C, w)]) \quad \text{Nitrogen}$$

$$P(t) = P_0 e^{-qwt} \quad \text{Phosphorous}$$

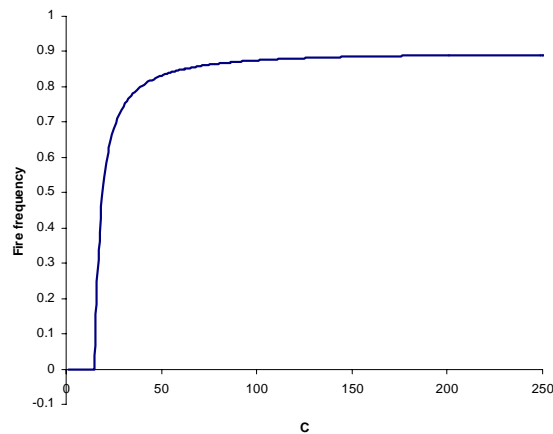
Herbivory

$$h(y) = \begin{cases} h \max\left(\frac{y - y_0}{a_h + y - y_0}\right) \end{cases}$$



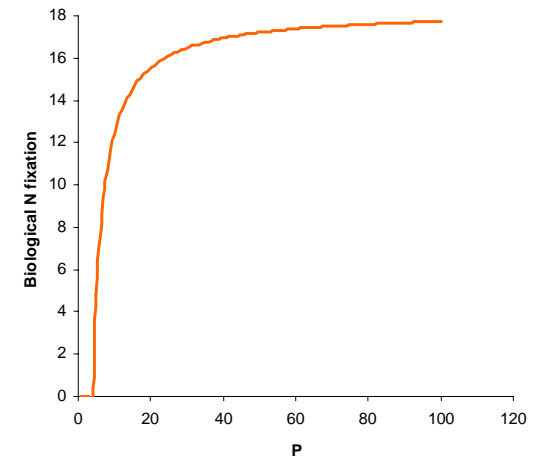
Fire

$$m_{inv}(C) = \begin{cases} m_{\min} \left(\frac{1 - b_m e^{-b(C - C_m)}}{1 - e^{-b(C - C_m)}} \right) \end{cases}$$



Nitrogen fixation

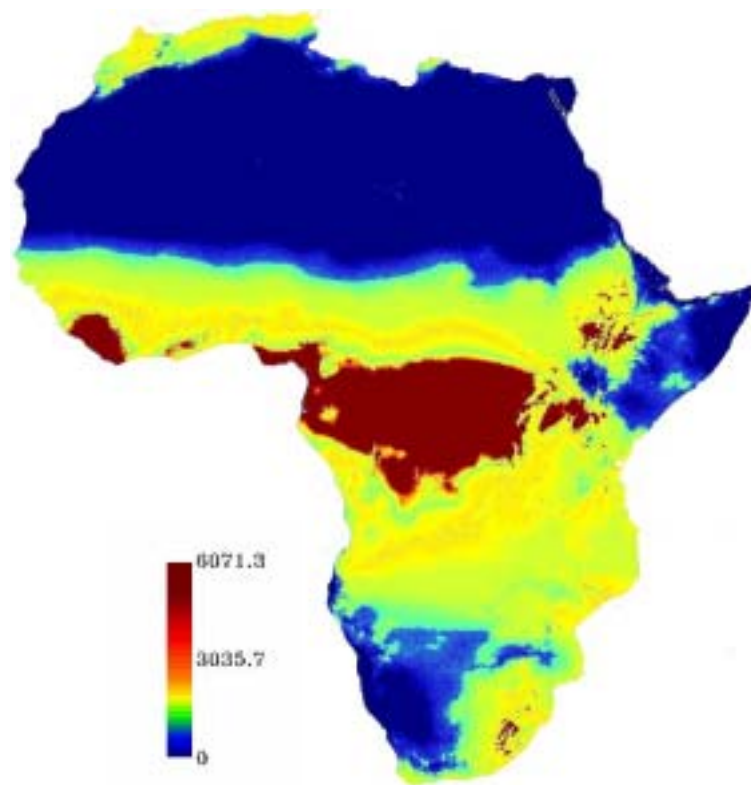
$$g(P) = \begin{cases} g_{\max} \left(\frac{P - P_b}{a + P - P_b} \right) \end{cases}$$



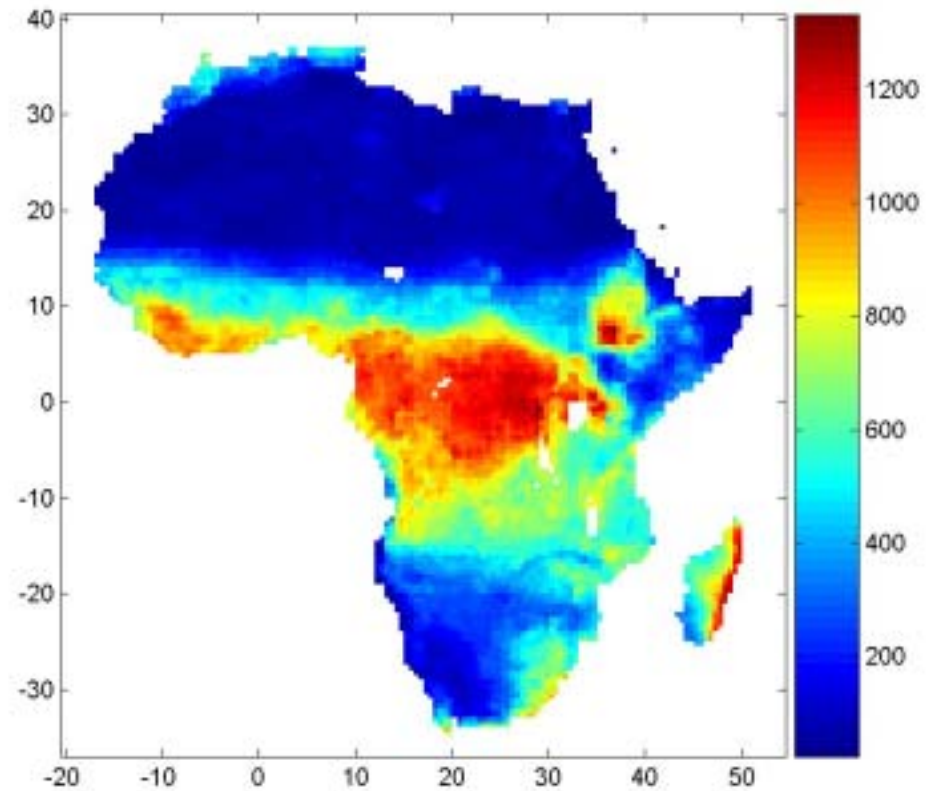
Model of ecosystem dynamics

- **Simulated ecosystem dynamics for the African continent**
- **Wetness estimates for the continent derived from ANU-CRES rainfall & temperature maps based on the ratio of precipitation to potential evapotranspiration**
- **Phosphorus values for the entire continent initialized at 50g/m²**
- **Simulations run for an initial period of 50,000 years**
- **Simulations run for an additional 500 yrs to look at the effects of:**
 - **herbivore extinctions**
 - **fire suppression**

Simulated patterns of continental scale net primary production



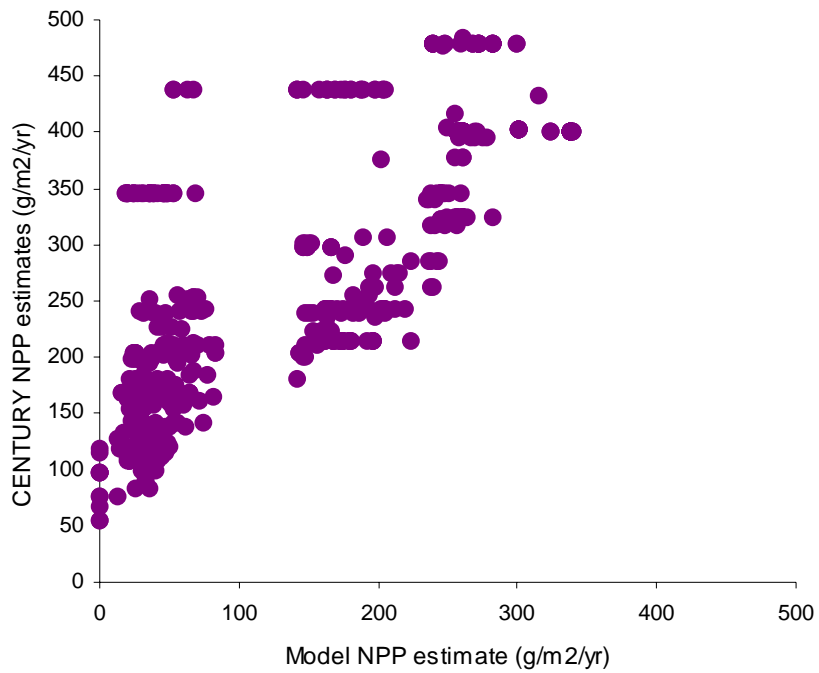
Potsdam95 NPP estimates



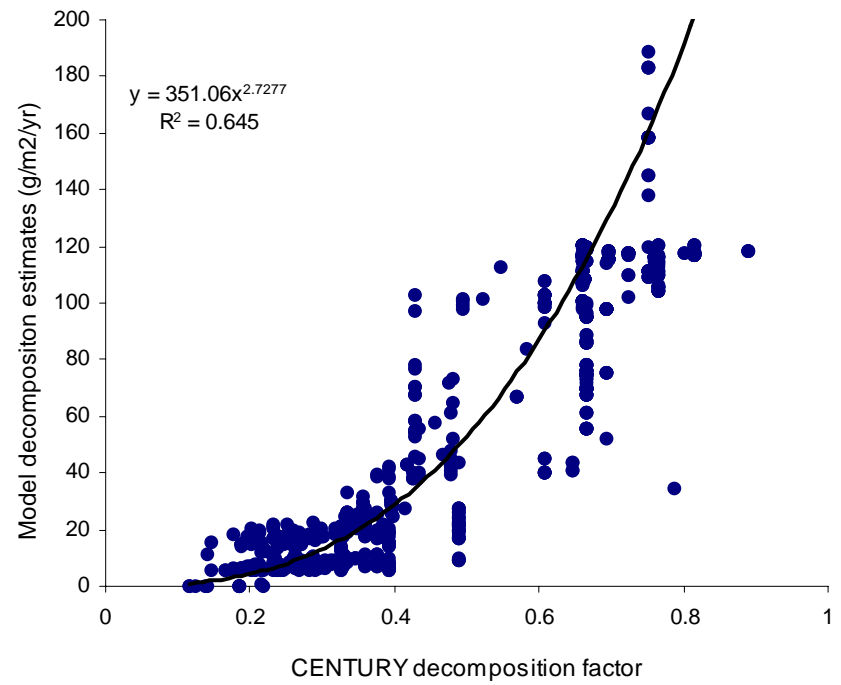
Model overestimates production in Central African wet forests, but appears reasonably adept at estimating NPP for less mesic areas

Comparisons with the CENTURY model

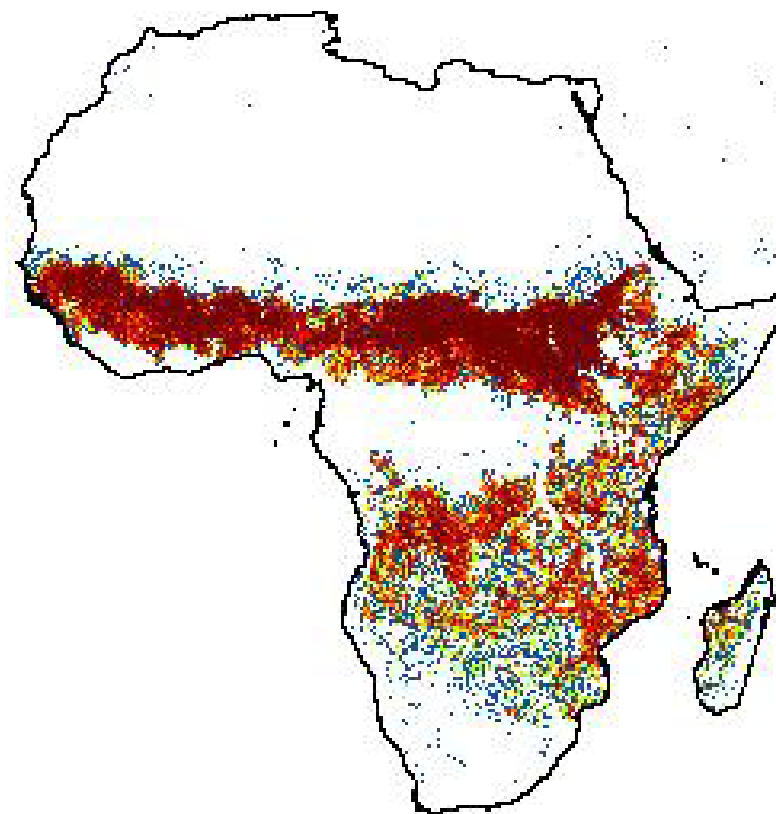
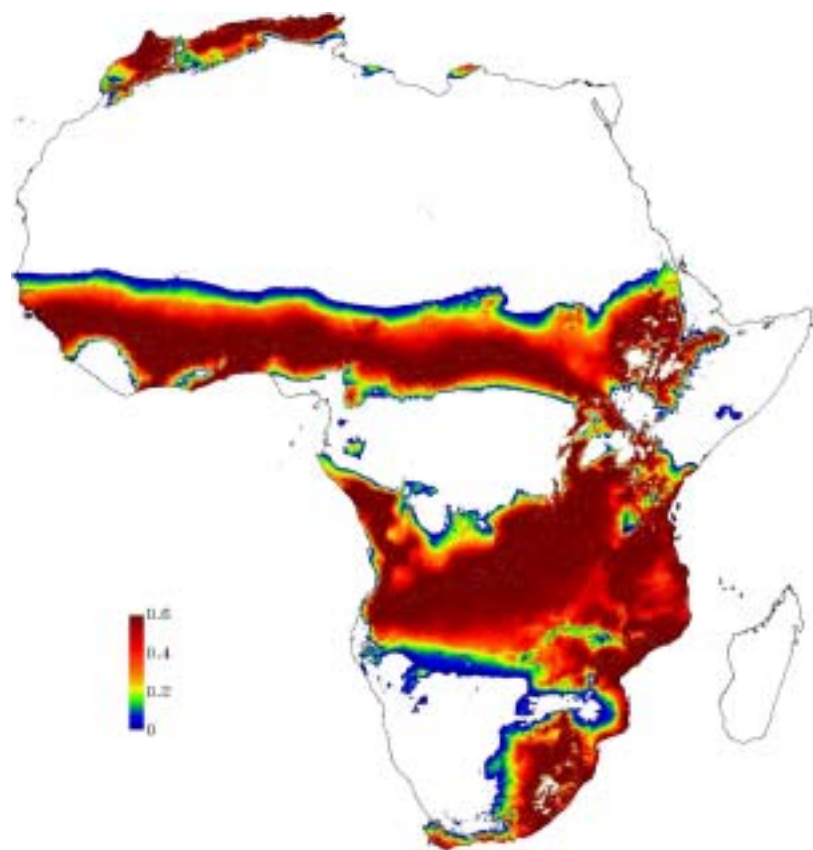
NPP



Decomposition

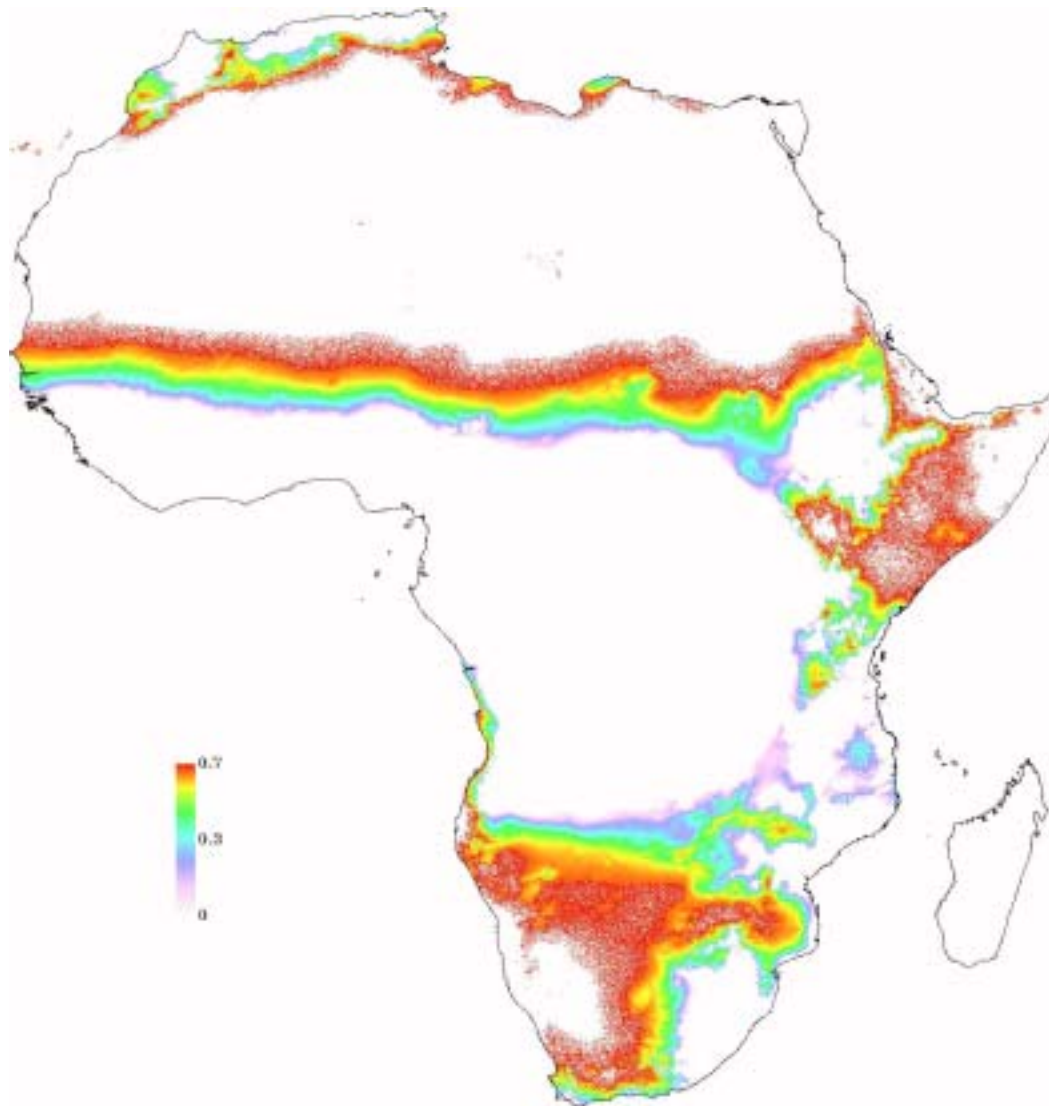


Simulated patterns of continental scale fires



**Satellite derived fire map of Africa
(8km resolution AVHRR fire scar data
Barbosa et al. 1998)**

Simulated patterns of continental scale herbivory



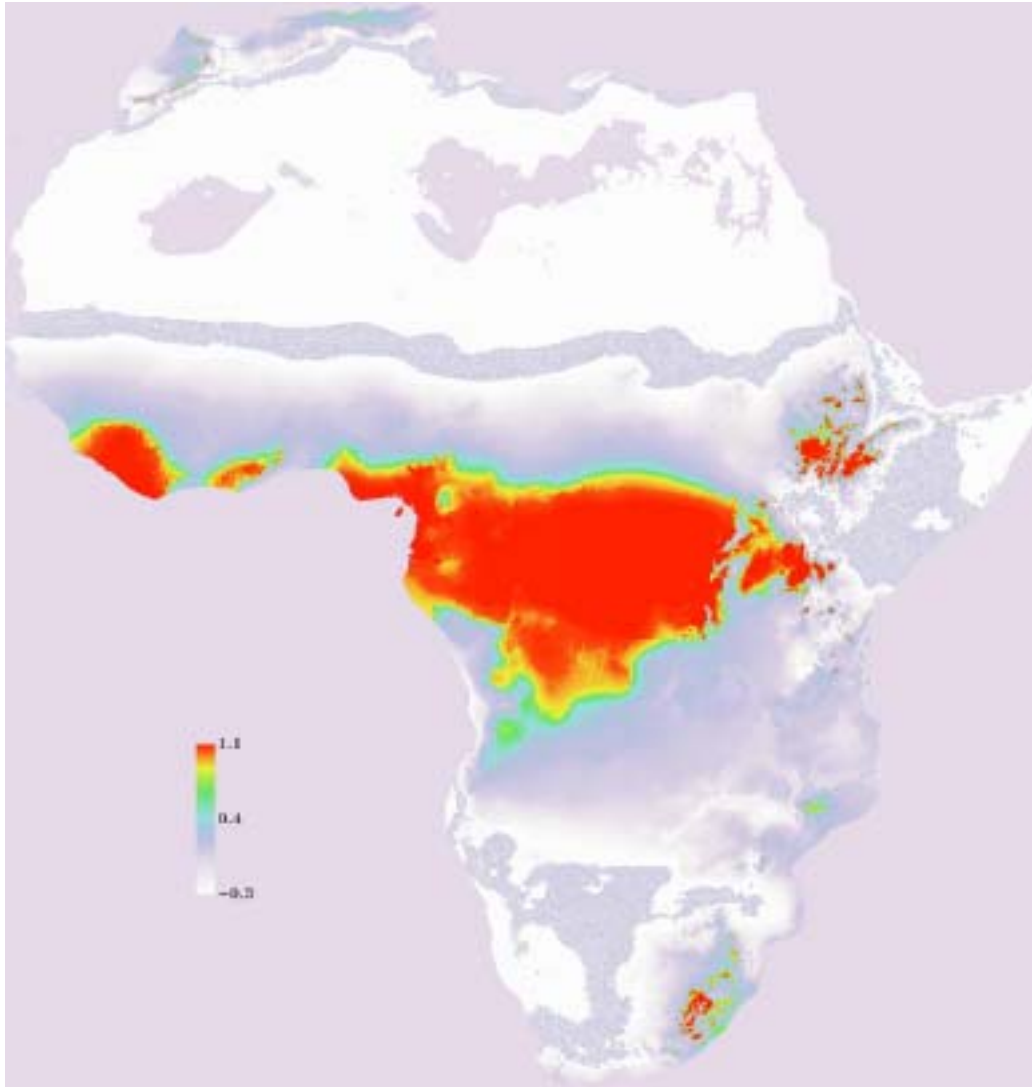
- Model predicts high herbivore consumption in East & Southern Africa and in the Sudano-Sahelian zone

- Results are largely consistent with observed herbivore distributions. However, no continental scale maps exist to provide rigorous tests of model predictions

Summary...

- **This simple model of C, N & P dynamics appears capable of capturing, to a large extent, continental scale patterns of production, herbivory and fire.**
- **The model is currently being validated with independent data sets and predictions are being compared to those of more detailed ecosystem models**
- **In contrast to more complex models where patterns of fire and herbivory have to be specified as input parameters, fire and herbivory are emergent properties in this simple model**
- **The model can therefore be used to derive testable predictions of altered ecosystem dynamics in the face of environmental change (e.g. elevated CO₂)**

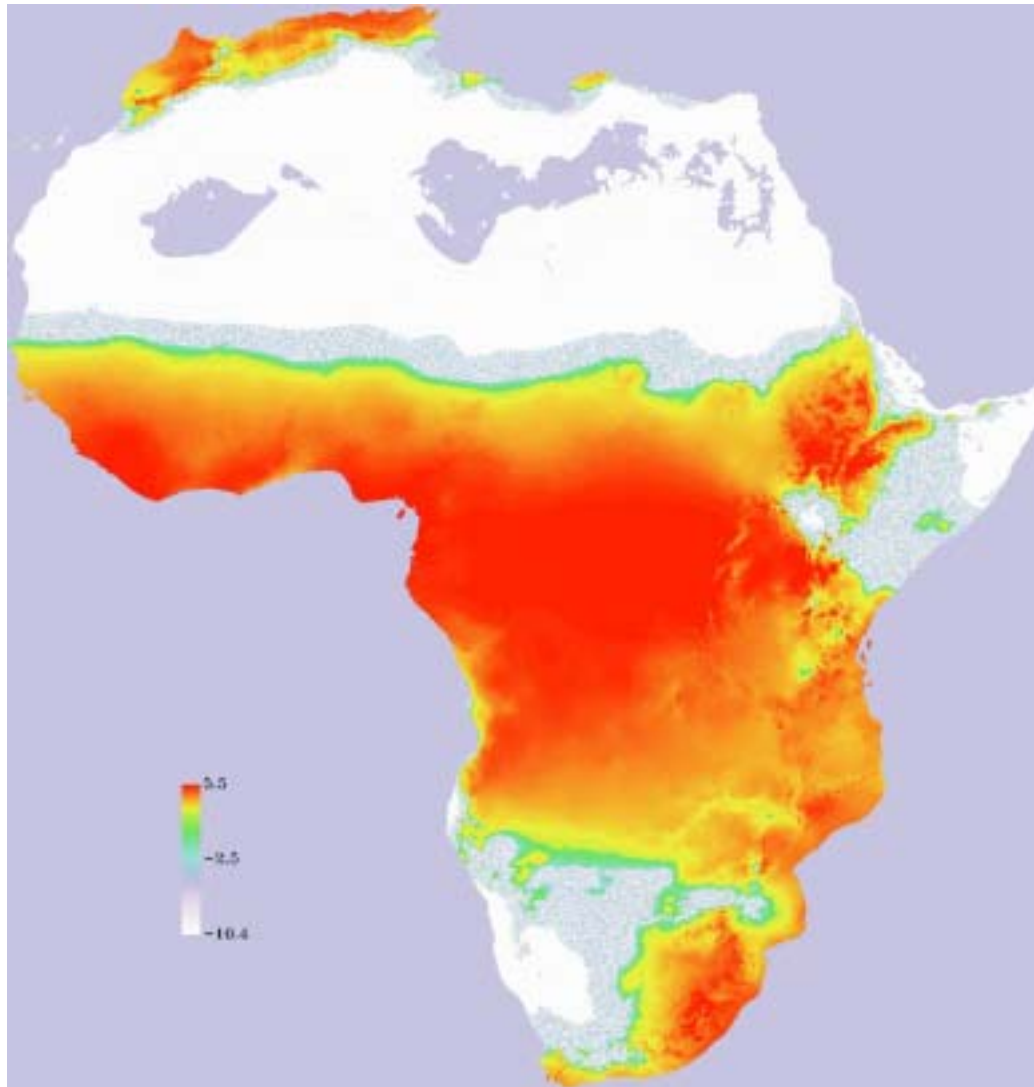
Simulated scenarios: Carbon stocks in a world without herbivores...



- Surprisingly, increases in C stocks greatest in the wet tropics
- In drier areas, fires compensate for the removal of herbivores

Changes in Carbon stocks following herbivore removal

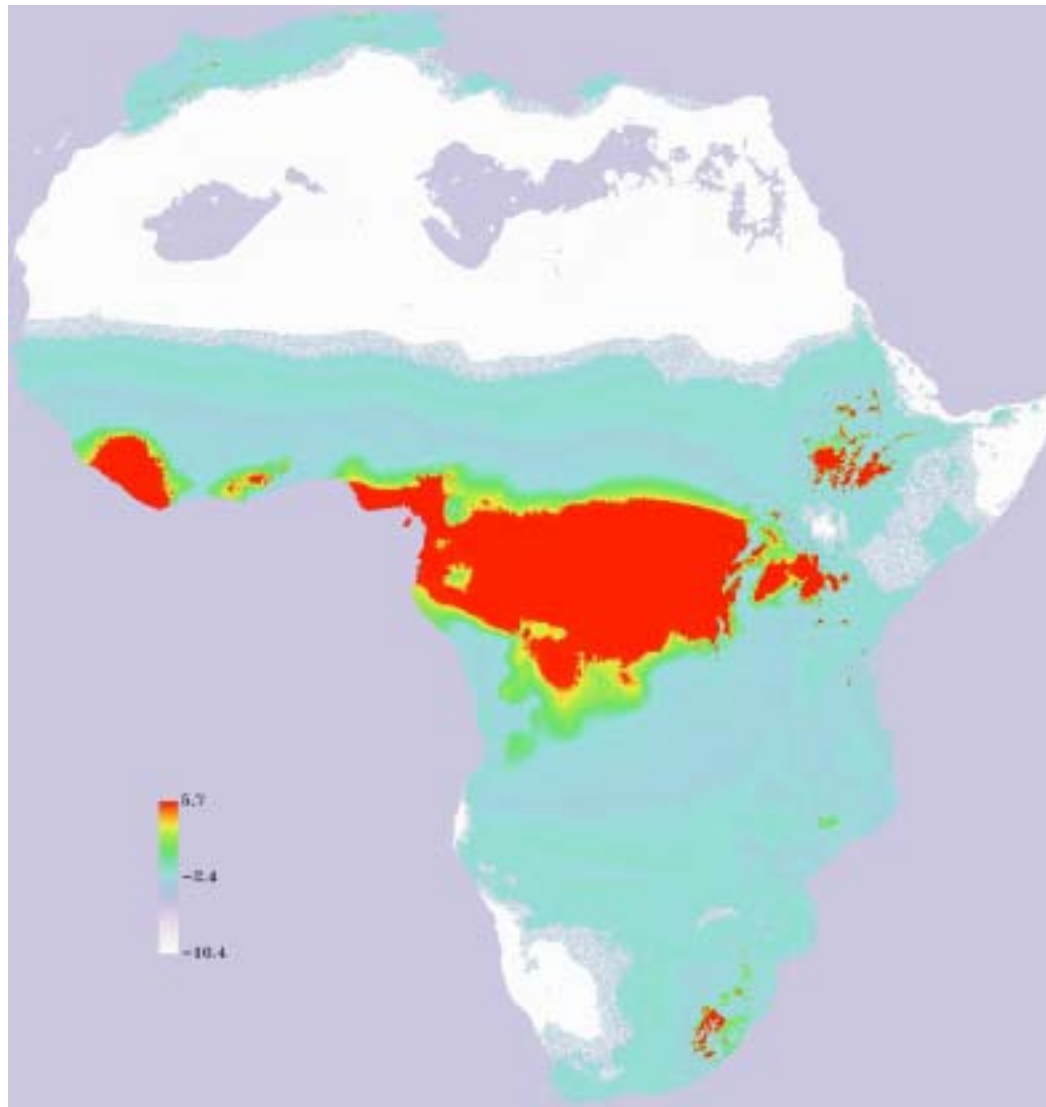
Simulated scenarios: Carbon stocks in a world without fires...



- In the absence of fires, the model predicts significant increases in standing biomass across large sections of Africa
- These results are consistent with predicted distributions of stable and unstable savannas and from more detailed DGVM models (Bond et al. 2005)

Changes in Carbon stocks following herbivore removal

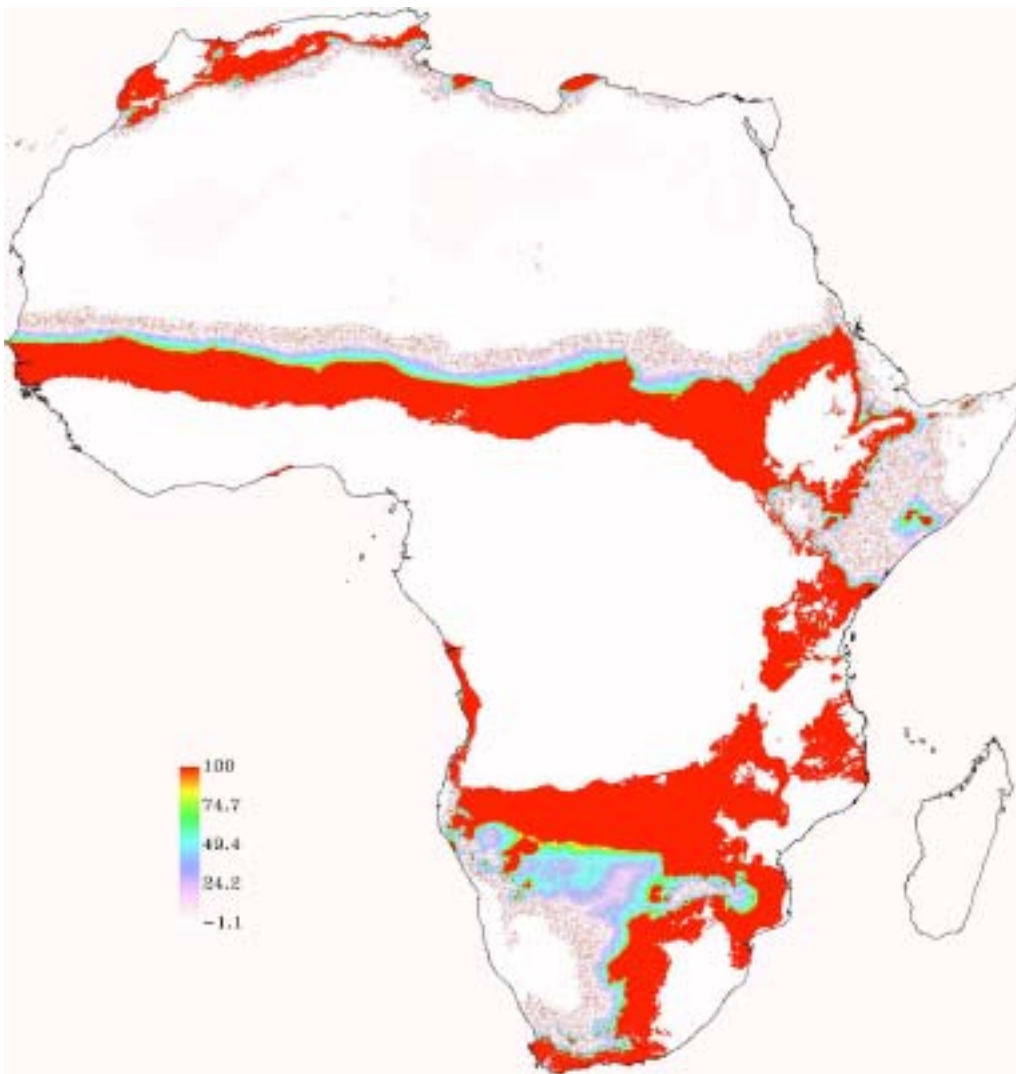
Simulated scenarios: Changes in production following a 50% increase in plant C assimilation efficiency



**Increases in production/
biomass across large sections
of the continent (greatest in wet
tropics)**

Changes in production under elevated CO₂

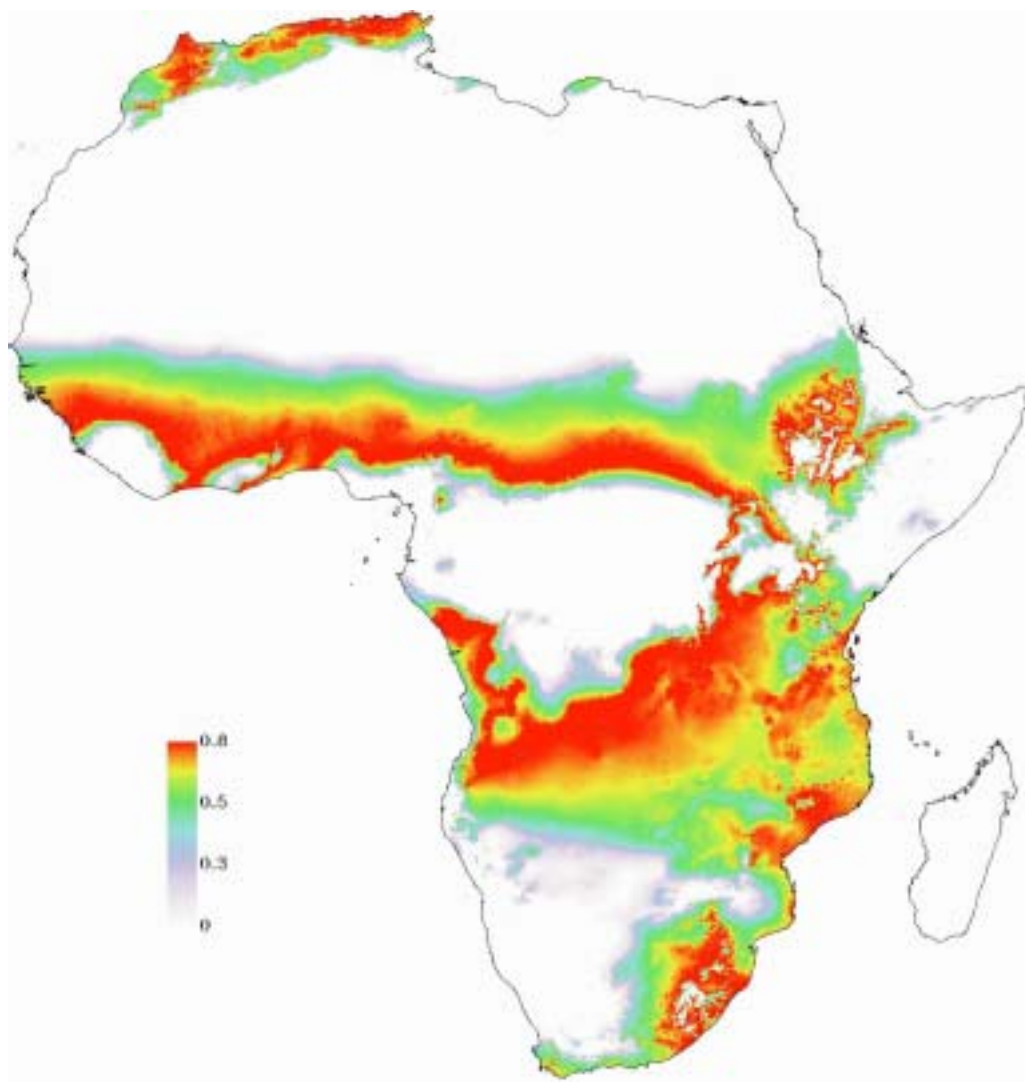
Simulated scenarios: Changes in herbivory following a 50% increase in plant C assimilation efficiency



Large decreases in herbivore consumption across the continent, particularly in the mesic, dystrophic savannas

Changes in herbivory under elevated CO₂

Simulated scenarios: Changes in fire following a 50% increase in plant C assimilation efficiency



Increased fires across large areas of the continent, particularly in the mesic, dystrophic savannas

Changes in fire regimes under elevated CO₂

Summary and future directions

- **Make the model explicitly spatial (currently no interactions between cells)**
- **More explicit considerations of underlying geology**
- **Include climatic variability in models**
- **More detailed considerations of soil processes and vegetation functional groups (C3 vs C4, woody versus herbaceous)**
- **Parameterize the model specifically for KNP**