The modeling way-back machine

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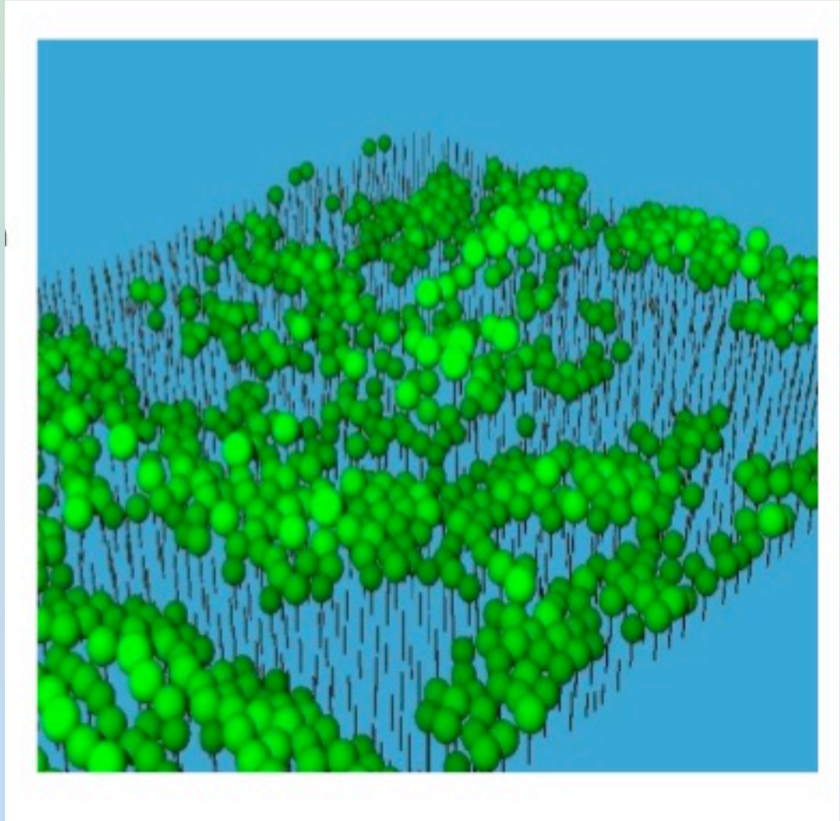
Scaling

Remember what it was like back them!
This is what my computer looked like:

And this!

I was at NASA Ames…

And, we all knew you couldn't scale from leaf to canopy!



State of the art ca 1985: Growth curves simulating annual biomass accumulation and NPP, no fluxes

Partly, because this guy told us so…

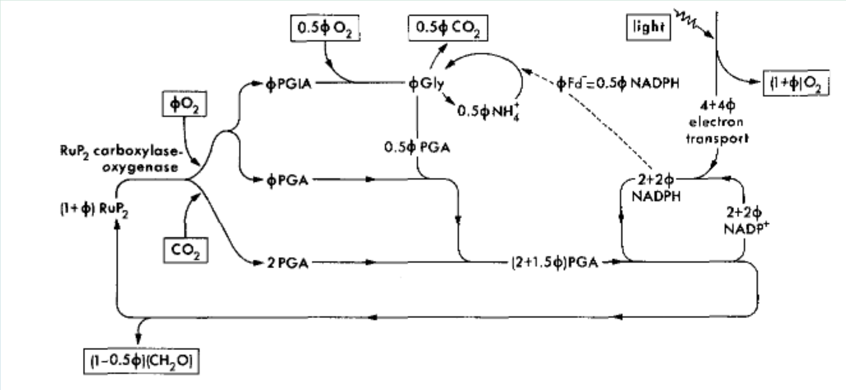
There were at least two big reasons:

1. Canopies were t complex to model without scaling rules (brute force didn't work very well, the data to describe a canopy was laborious to collect and didn't generalize).

2. We didn't know the answer (we could model fluxes but there was no way to tell if the simulation got the right answer)

These were heady times for modeling, though, the key parameterizations we still use were new then:

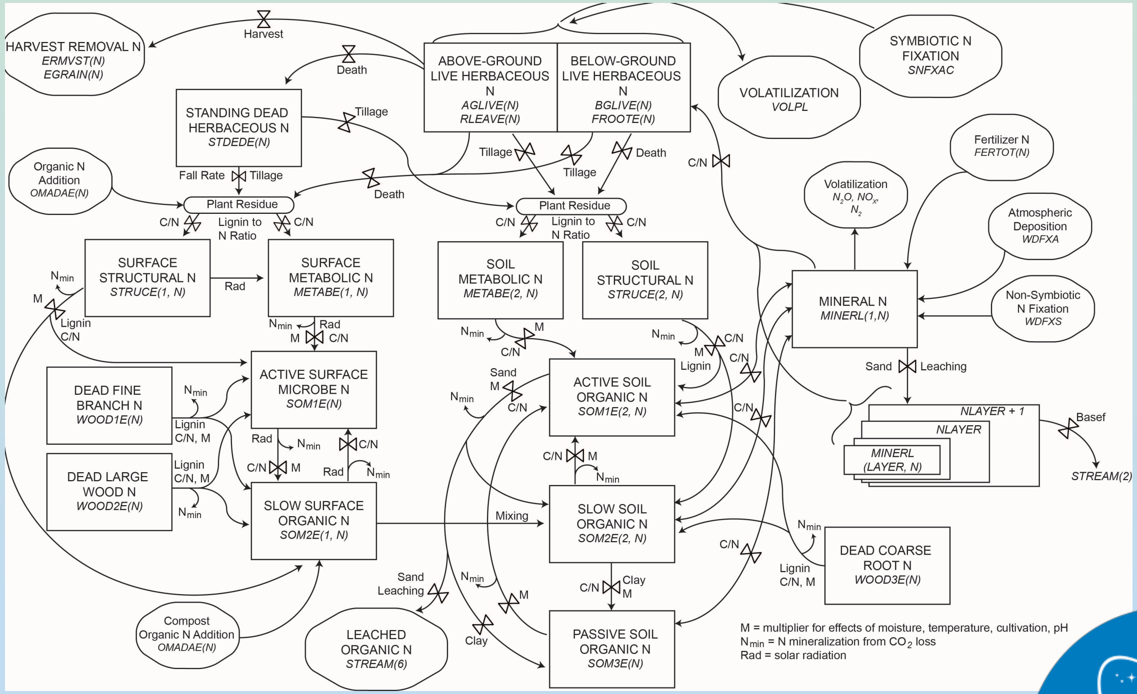
Growing plants



$$V_c = V_{c\max}\frac{C}{C+K_c(1+O/K_o)}\cdot\frac{R}{R+K'_r} = V_{c\max}\frac{C/K_c}{1+C/K_c+O/K_o}\cdot\frac{R/K'_r}{1+R/K'_r}$$

Farquhar-Berry photosynthesis

Decomposing plants



Parton soil organic matter

Seminal… an overused word but right on here!

A biochemical model of photosynthetic CO_2 assimilation in leaves of C3 species
GD Farquhar, S von Caemmerer, JA Berry - Planta, 1980 - Springer
Abstract Various aspects of the biochemistry of photosynthetic carbon assimilation in C 3 plants are integrated into a form compatible with studies of gas exchange in leaves. These aspects include the kinetic properties of ribulose bisphosphate carboxylase-oxygenase; ...

5494 citations

Analysis of factors controlling soil organic matter levels in Great Plains grasslands

WJ Parton, DS Schimel, CV Cole… - Soil Science Society of …, 1987 - dl.sciencesocieties.org

Abstract We analyzed climatic and textural controls of soil organic C and N for soils of the US Great Plains. We used a model of soil organic matter (SOM) quantity and composition to simulate steady-state organic matter levels for 24 grassland locations in the Great Plains. **...**

3320 Citations

Empirical evaluation at the Konza and environs!

Tim

Mark

Using the landscape

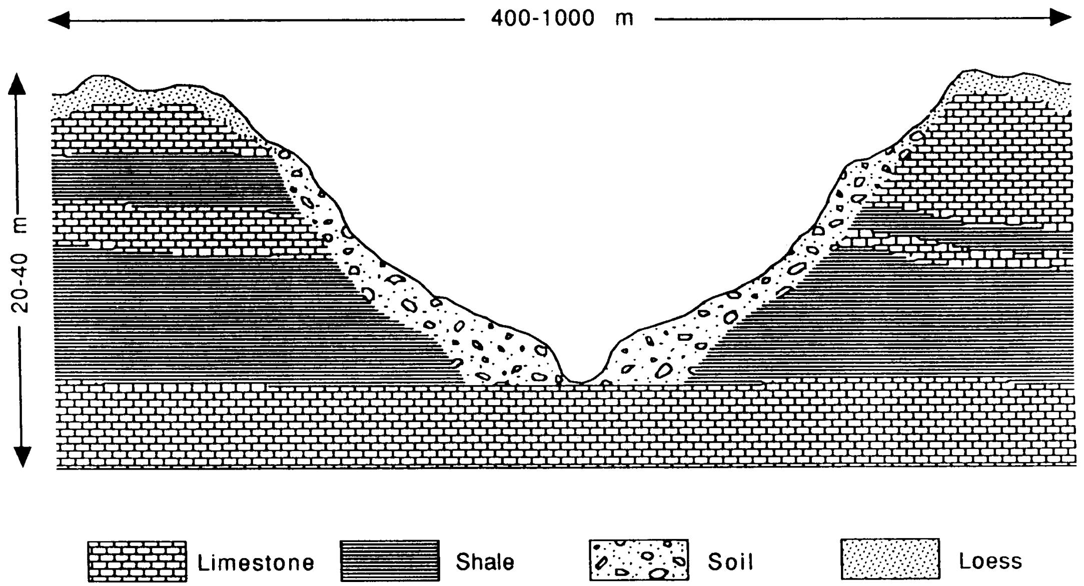


FIG. 1. An idealized cross section through a Konza watershed. Soil depth increases downslope, but incision to bedrock may occur in the ephemeral channel. Loess caps may occur on ridgetops as shown, although not all ridgetops have such deposits. Transects used in this study spanned four such toposequences; physiological studies were carried out in lowland positions, usually just above the drainage channels, and on steep limestone sites at slope shoulders.

I'm pretty sure this picture was done entirely without benefit of a computer

Data across landscapes

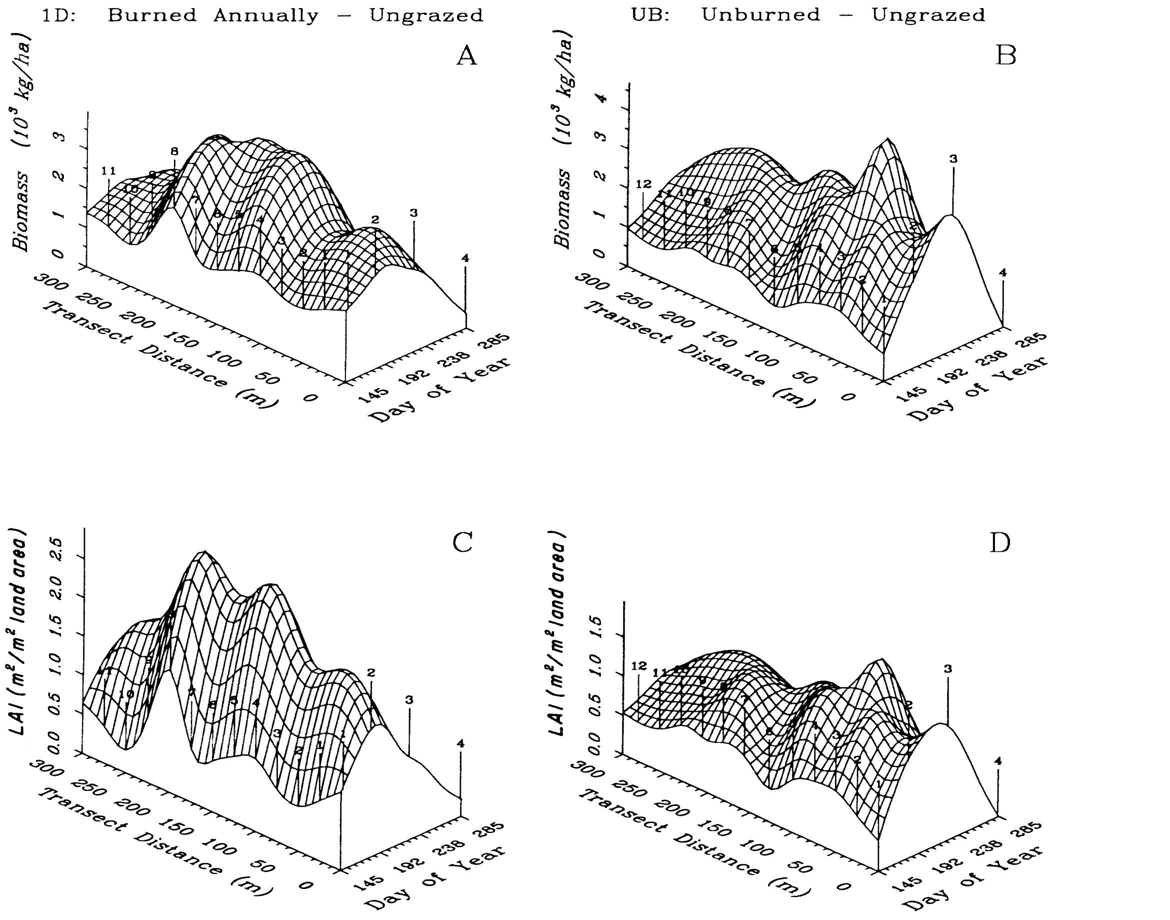


FIG. 3. Biomass and leaf area index (LAI) data from transects shown in Fig. 2. Surfaces are plotted as a function of transect distance and time (the four IFCs in 1987). Sample points and IFC dates are indicated by numbered posts. (A) and (B) Live aboveground biomass for burned and unburned transects, respectively. (C) and (D) LAI across the same transects. LAI was computed using equations from Table 1.

Nitrogen (V_{cmax}) across landscapes.

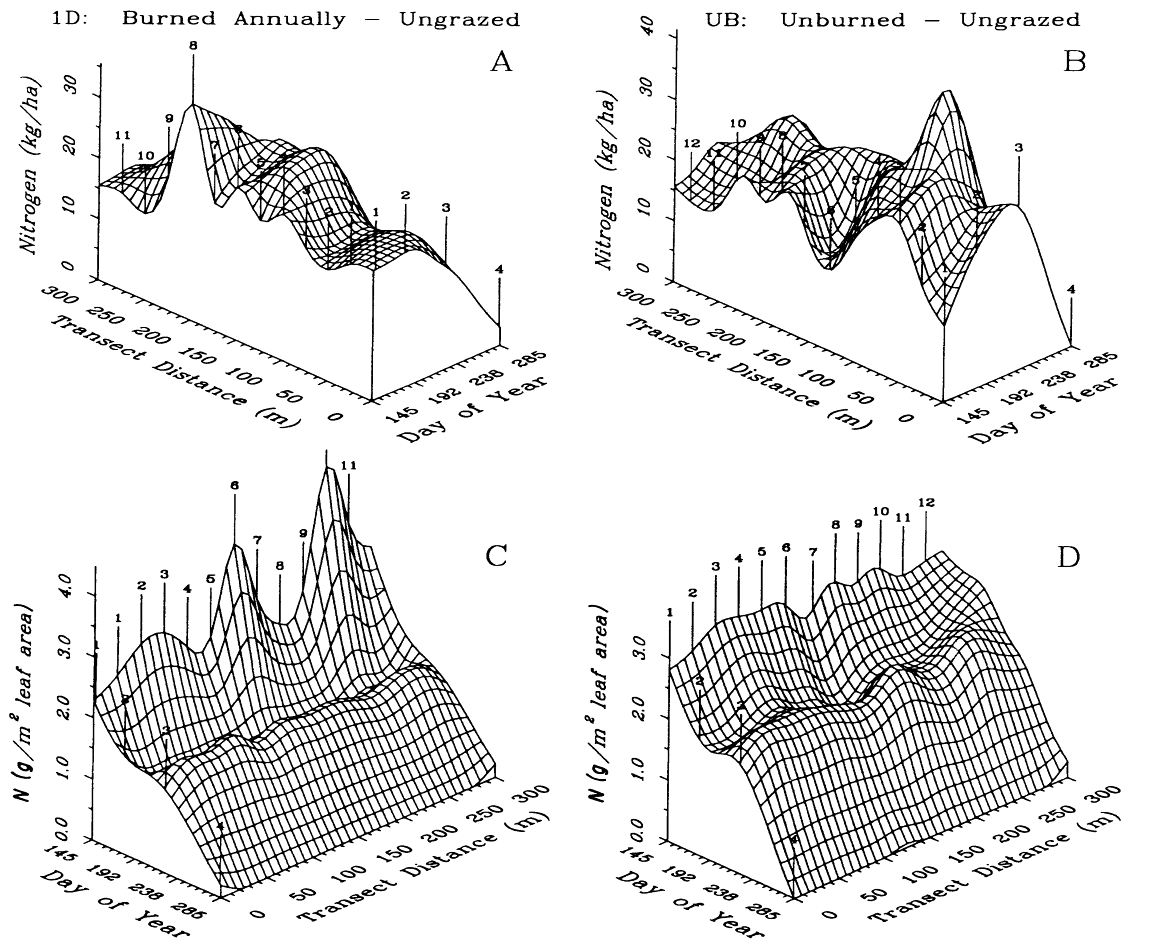


FIG. 4. N data from transects shown in Fig. 2, plotted against transect distance and time as in Fig. 3. (A) and (B) N mass in live vegetation, per unit sample area. (C) and (D) N per unit leaf area (N mass per unit sample area LAI), a correlate of maximum photosynthetic rate. There was no live biomass at IFC 4. Note that (C) and (D) were rotated to best display dynamics.

The relationship between light interception and nitrogen limitation

Nitrogen -limited

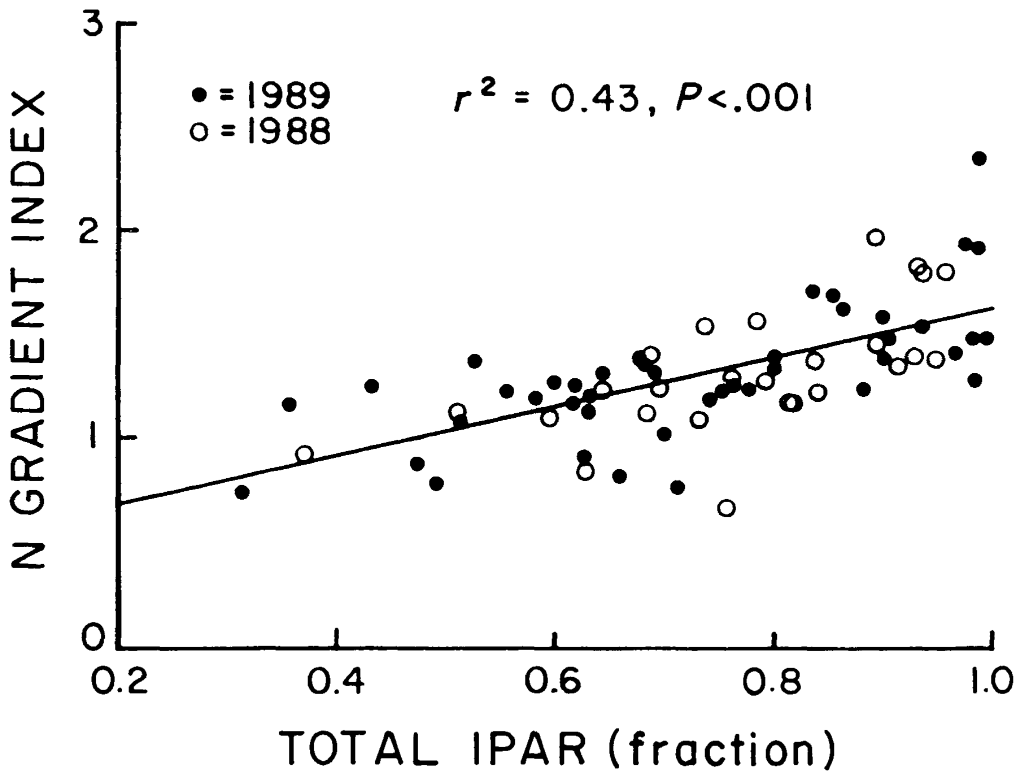


FIG. 6. The N gradient index ([N] in the top canopy layer/[N] in the bottom canopy layer) plotted against total IPAR (expressed as fraction of incoming PAR) for 1988 and 1989. As IPAR increased, the gradient in N allocation within the canopy became steeper.

Light-limited

V_{cmax} scaling in real canopies

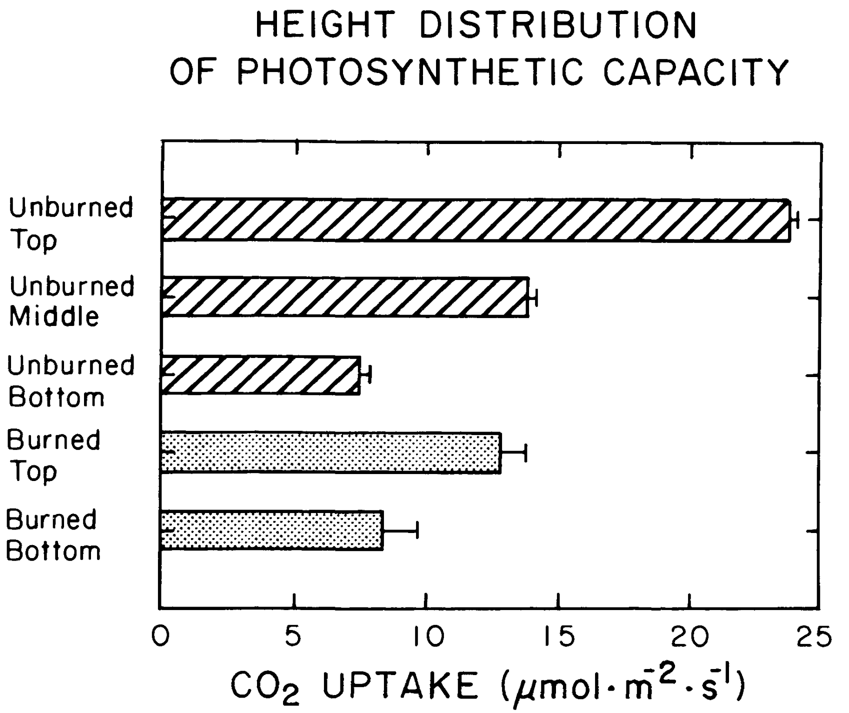
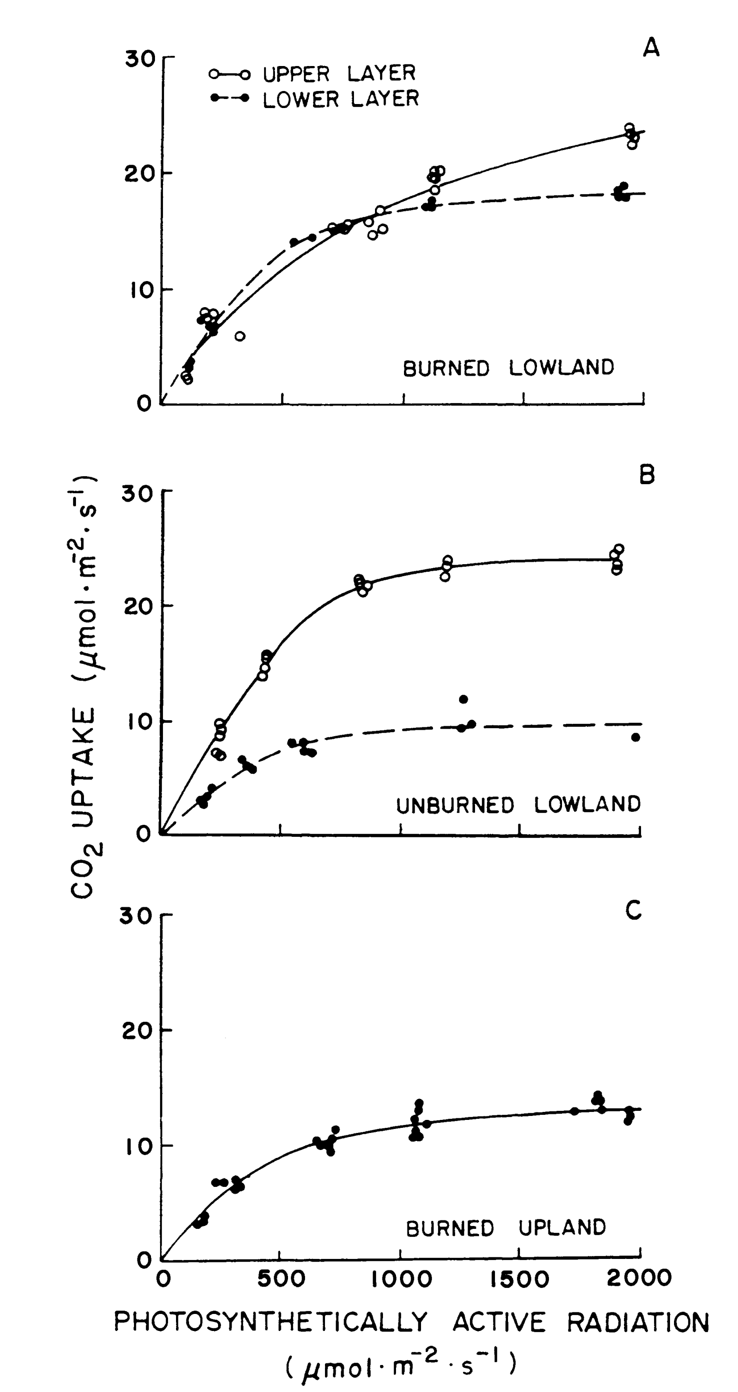


FIG. 9. Photosynthetic capacity by height for unburned (hatched) and burned (stippled) canopies. Note the rapid decline in capacity with height and the steeper gradient of photosynthetic capacity (top : bottom = 3.19) in the taller, more productive unburned sites compared to the unproductive burned sites (1.53). Error bars show 1 SD. Data are from 1989.

Light response curves, stratified by depth in the canopy

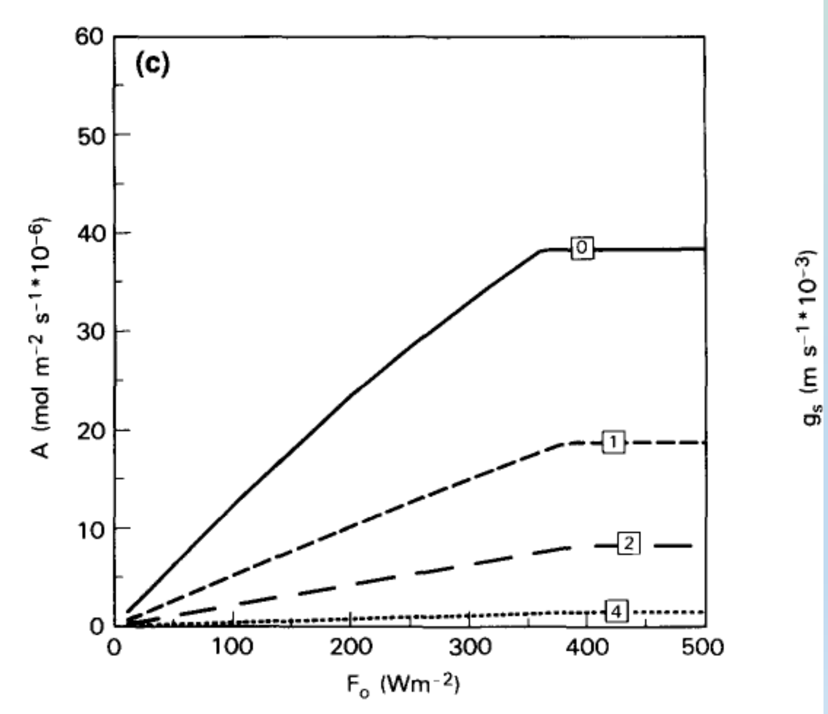


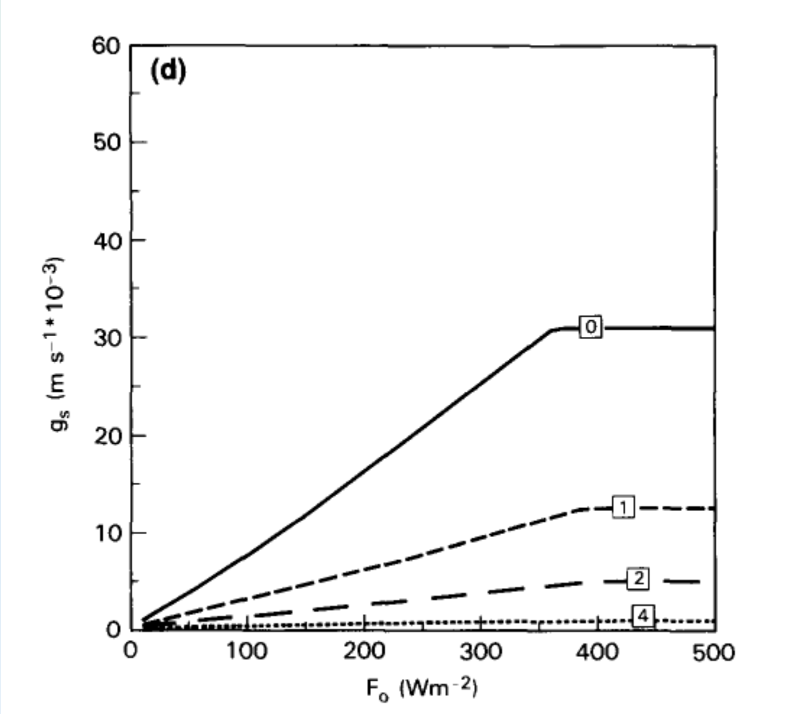
Scaling rules: light extinction and photosynthetic capacity
Simulated response curves

the general pattern matches the prediction from theory—A_{max} and leaf nitrogen [N]—should scale with the time-integral of the absorbed local PAR

or

$$V_m = V_{m0}\overline{f(L)}$$





Scaling rule, ✓, now, what's the answer?

- Knowing how A scales through a canopy, can we get the right daily, weekly, annual GPP?
- It remains complex to integrate over diurnal, synoptic and seasonal time scales..
- FIFE provided the first answers, sustained eddy covariance data!

Pioneering eddy covariance research in FIFE..

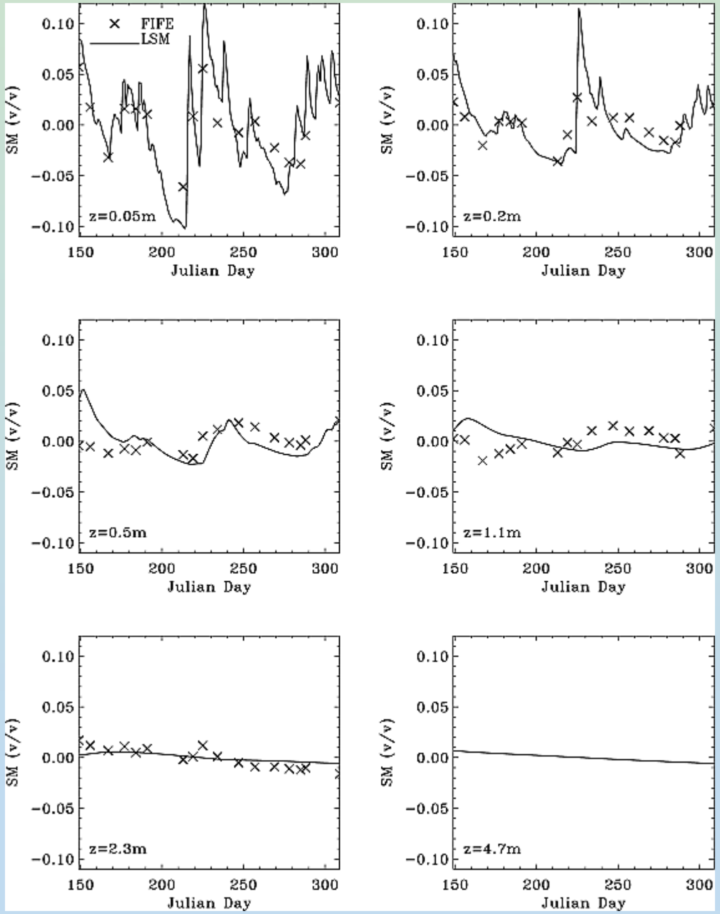
<u>A few reminders:</u>

1. FIFE Eddy covariance data provided the first flux data from a major integrated campaign and over ecologically meaningful time scales.

2. Flux data from FIFE have been used by nearly every modeling group to develop improved A – R and ET models.

Still in routine, daily use by modelers…

A case study for land model evaluation: Simulation of soil moisture amplitude damping and phase shift
(Wu, Geller and Dickinson, 2002)

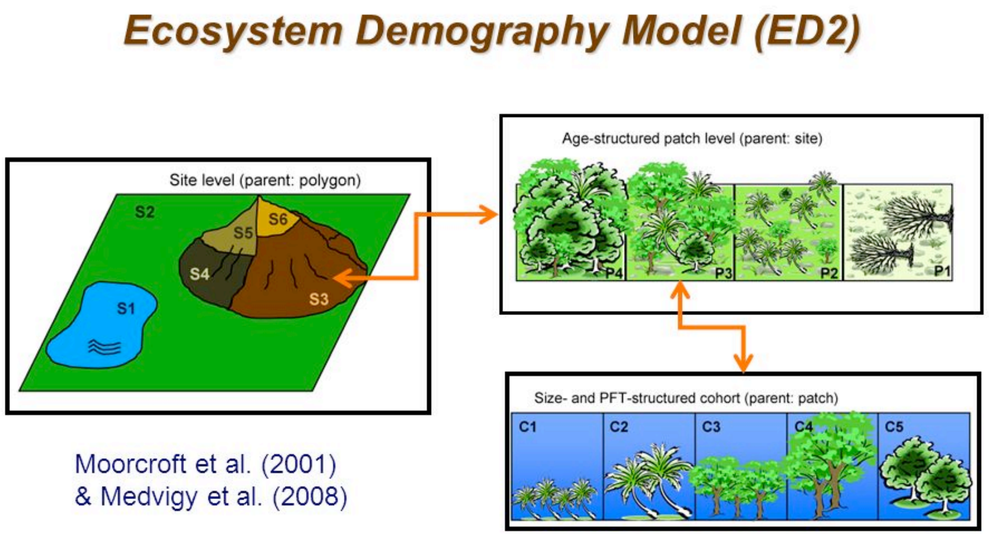


Journal of Geophysical Research: Atmospheres
[Volume 107, Issue D24,](#) pages ACL 20-1-ACL 20-13, 26 DEC 2002 DOI: 10.1029/2001JD001405
http://onlinelibrary.wiley.com/doi/10.1029/2001JD001405/full#jgrd9437-fig-0001

Work at the Konza established linkages between the biophysical and biogeochemical that are still being fully absorbed into models

- We still don't fully understand nutrient limitation,
- Links between nutrient and physical (light, water) controls remain a frontier
- Does nutrient limitation equilibrate to energy availability (Schimel et al 1997) or does the geochemical evolution of soil control energy harvesting?

So, scaling from leaf to canopy, routine, and now the standard for modeling, we're now combining leaf/canopy and individual-based modeling



Traditional 'big leaf' model
v.s.
Age and Size structured model

As we enter the era of forest demographic models to address longer timescales and changing disturbance regimes

Lessons learned

- FIFE catalyzed the fusion between atmospheric and ecosystem science via radiation and turbulence (a hallmark of NASA programs): made a huge contribution to Earth System Science.
- FIFE resulted in two breakthroughs in canopy scaling theory, and canopy model validation that enabled both land surface and remote sensing-driven modeling for decades to come.
- FIFE established a precedent of close partnership between modelers and observationalists that has accelerated the pace of science.
- There are still open questions hidden in plain site in FIFE, BOREAS and LBA data!
- Field Campaigns are addictively fun-many of us are still doing them long after we should know better.