Trees, fires and elephants

applying ecological theory to science-society issues in southern Africa

Dr Bob Scholes
Ecosystem Processes and Dynamics Research Group
Natural Resources and Environment, CSIR
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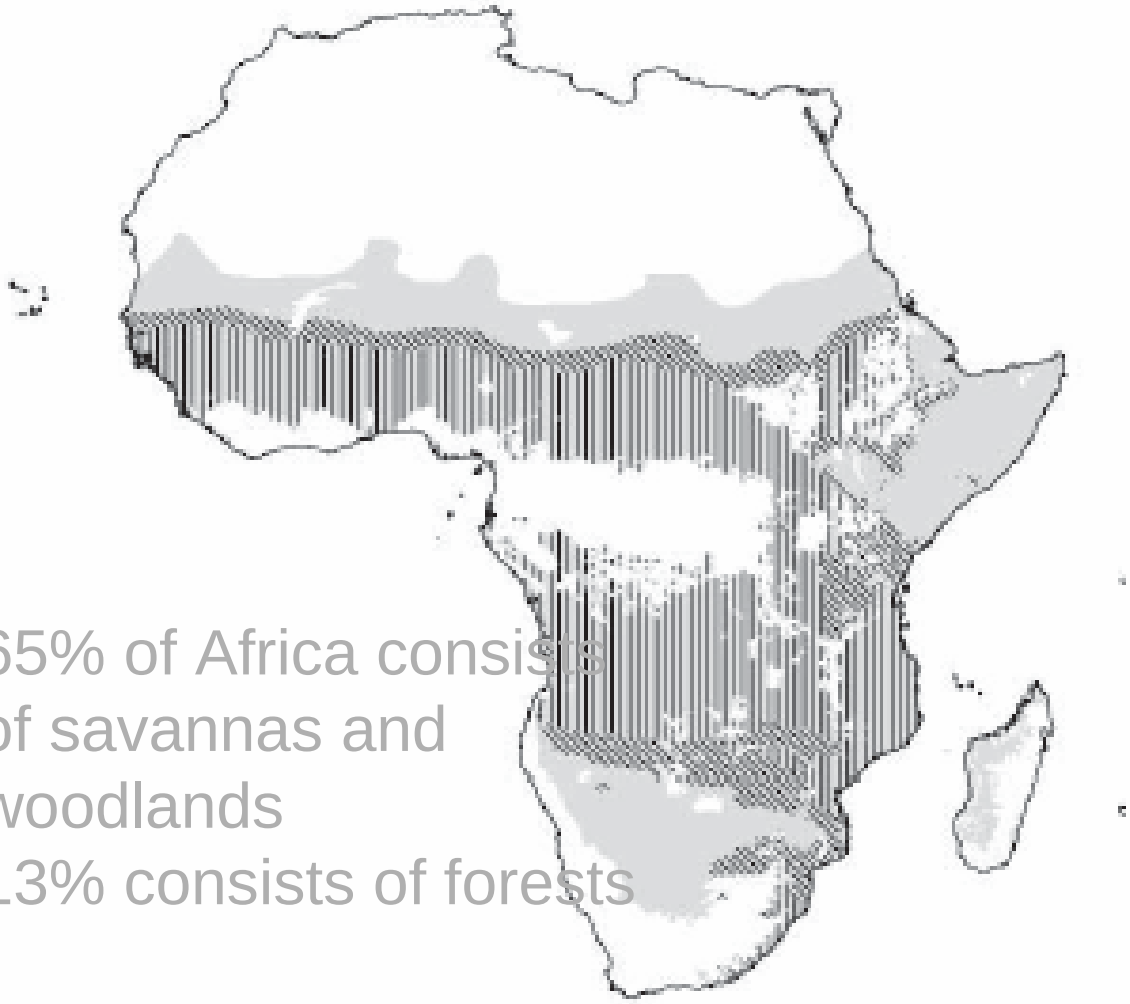
our future through science

Wooded lands in Africa



65% of Africa consists of savannas and woodlands
13% consists of forests

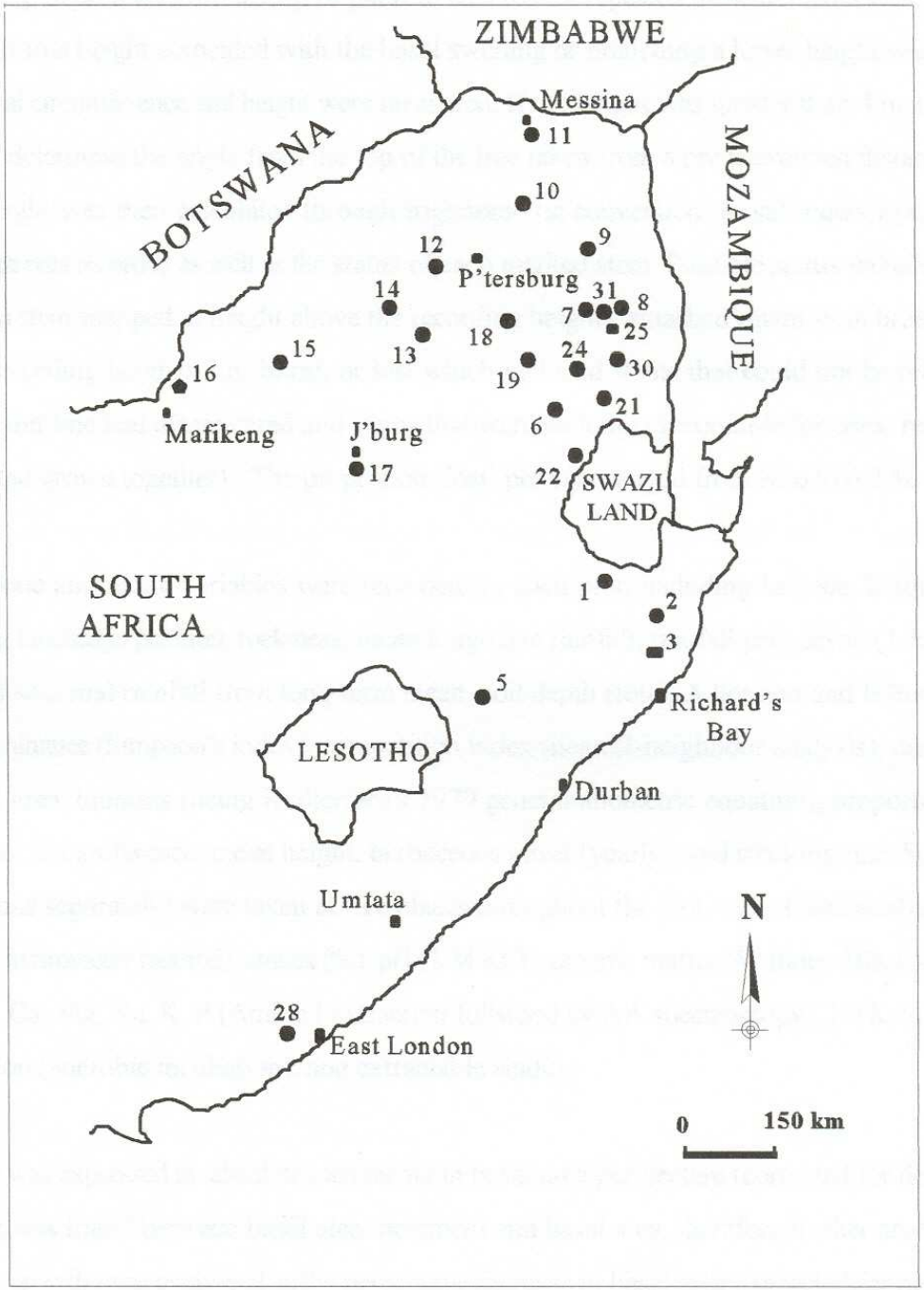
Fundamental question:

What controls the growth rate of trees in savannas?

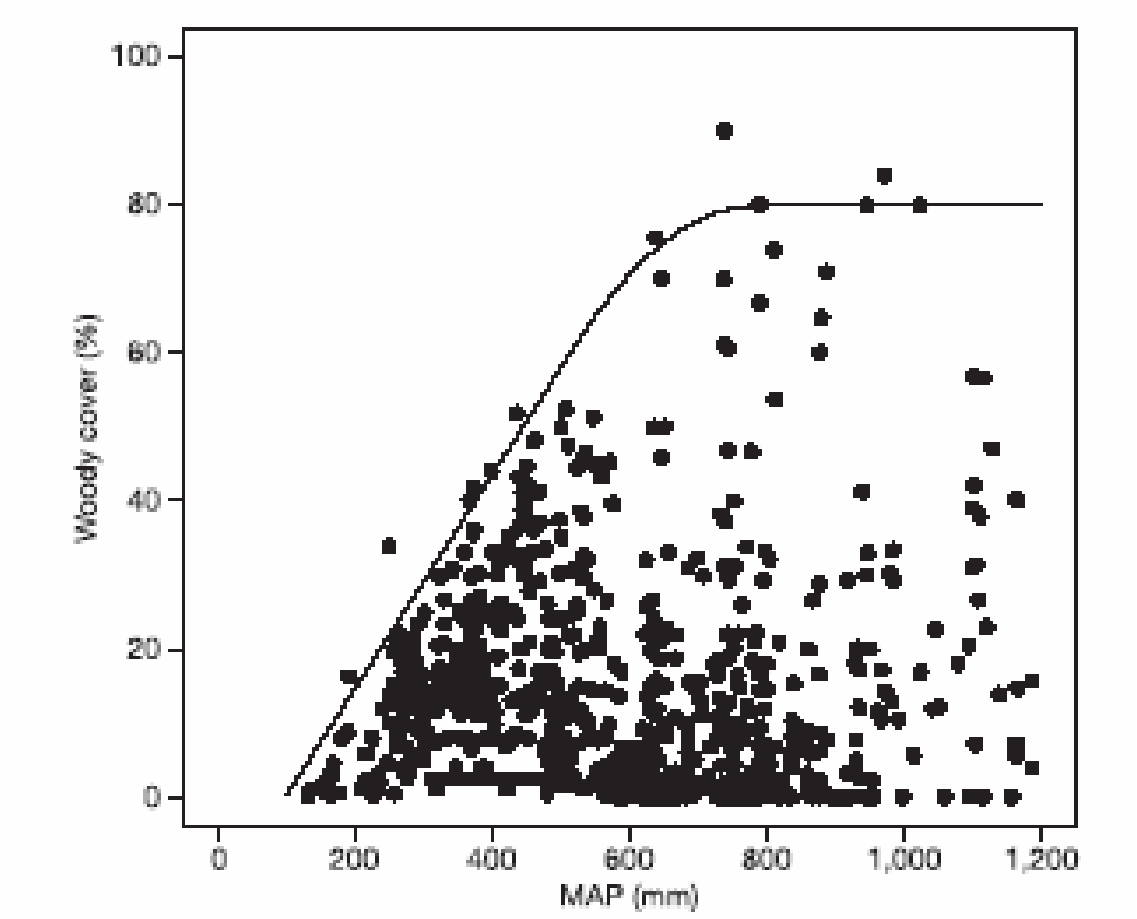
- Moisture?
- Nutrient supply?
- Competition with other trees?
- Competition with grasses?
- Temperature?

The Shackleton dataset

Tree growth measured every year for 6 years in 50 sites throughout the Savanna biome in South Africa



Finding an upper envelop to tree biomass



Sankaran et al 2005 Determinants of woody cover in African savannas *Nature* 438, 846-849

A predictive model

$$\frac{\Omega}{T_{\Omega t}} = \frac{T_{max} - T}{T_{max}} \quad \text{0.19 e}^{-0.2\nearrow} \text{ T}$$

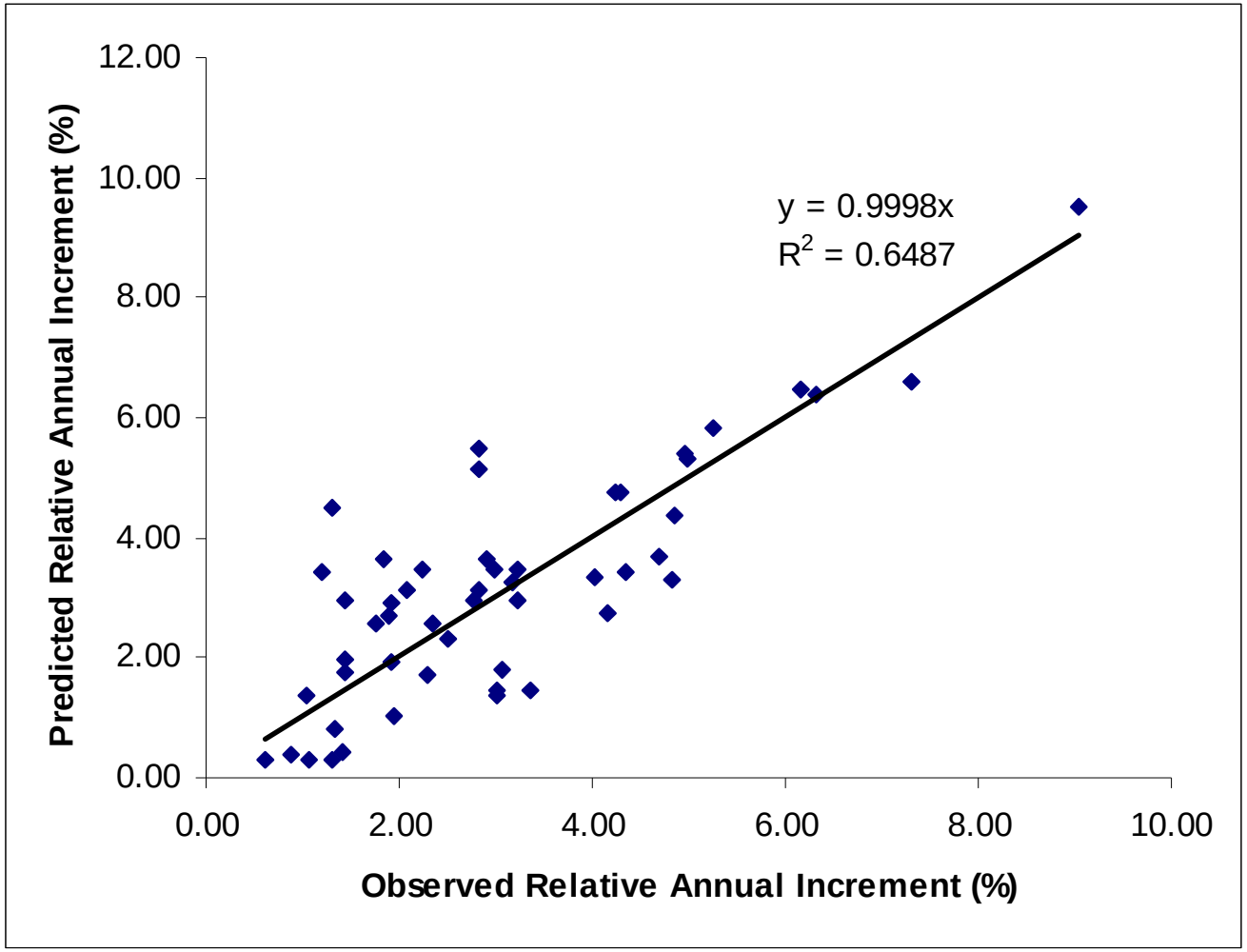
Where

T = tree basal area (m^2/ha)

T_{max} = maximum T for a given site, predicted from MAP

$\nearrow$ = mean stem diameter, (cm)

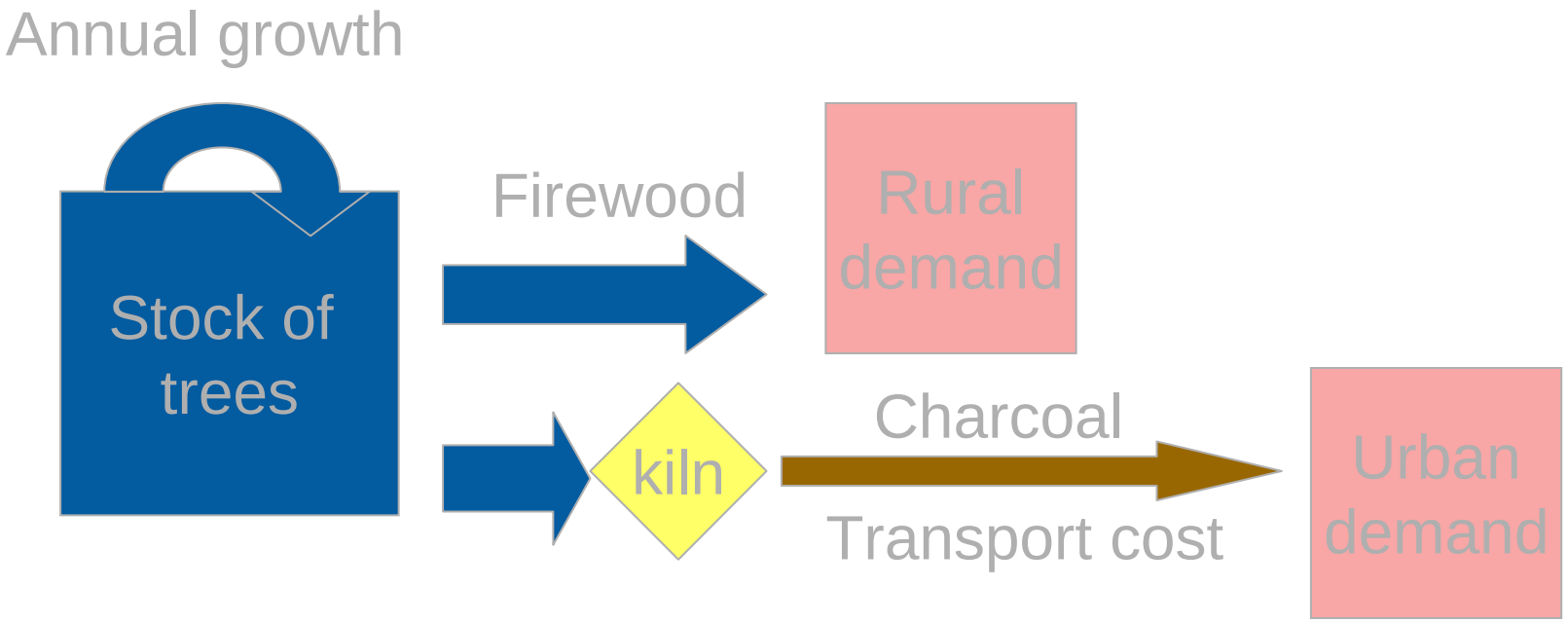
Model validation



Application #1
The African Fuelwood Crisis

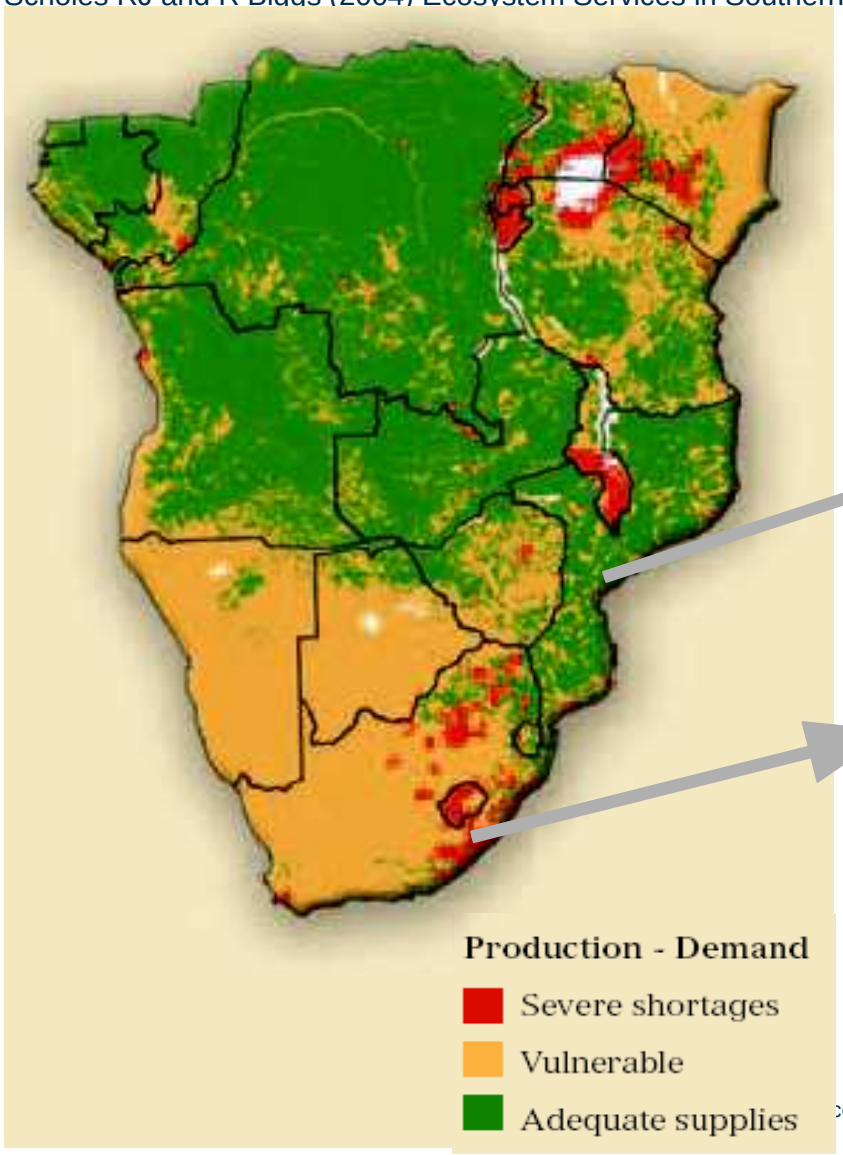
- The majority of people in Africa use wood or charcoal as their primary energy source
- Experts have for several decades predicted the immanent exhaustion of the supply

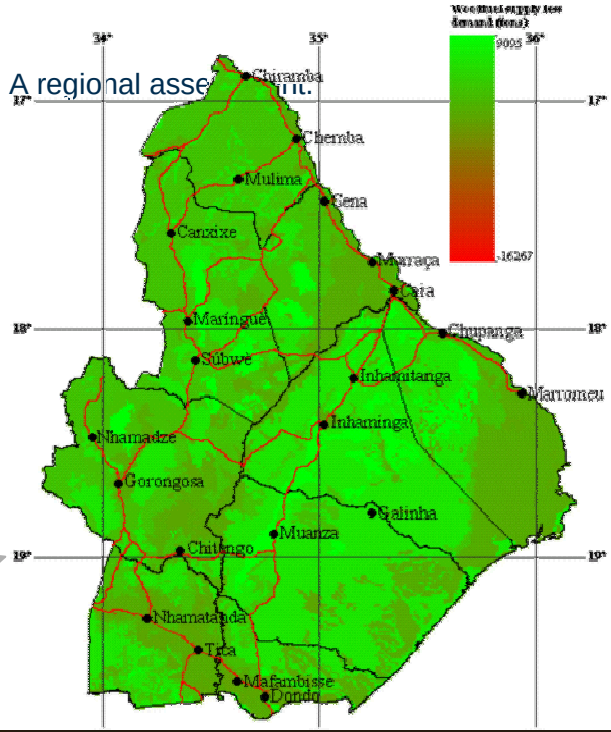
A wood supply-and-demand model

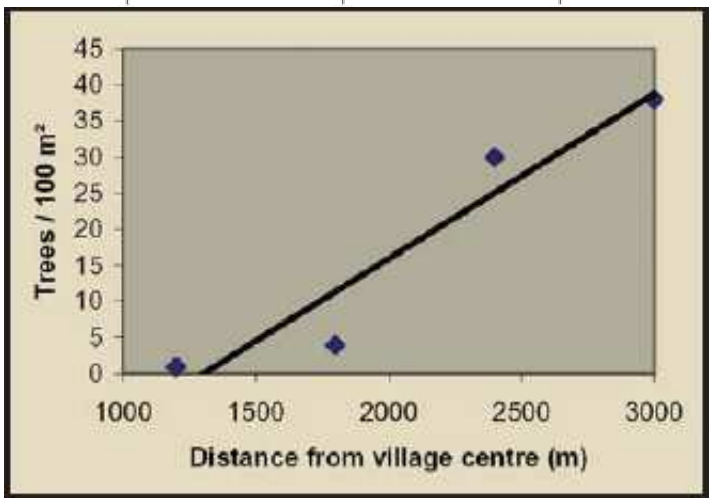


Fuelwood supply less demand

Scholes RJ and R Biggs (2004) Ecosystem Services in Southern Africa: A regional asse[illegible]nt.







co.za

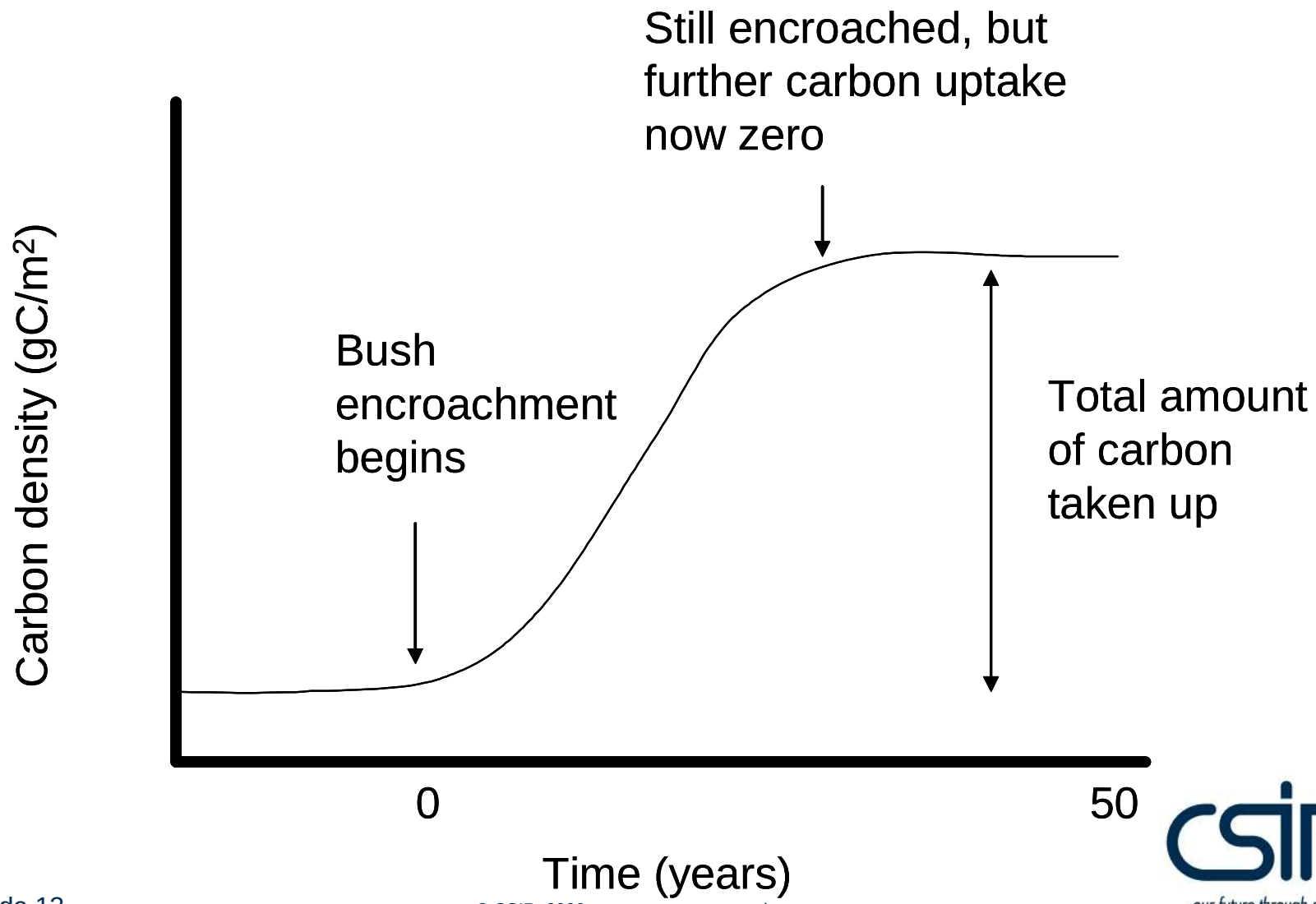
Is there a woodfuel crisis?

- There are local shortages, but no regional crisis
  Wood production >> wood use
- Wood use tends to be self-limiting due to the high transport costs
- A regional-scale model, driven with local-scale data, was able to identify the hotspots of unsustainable use correctly

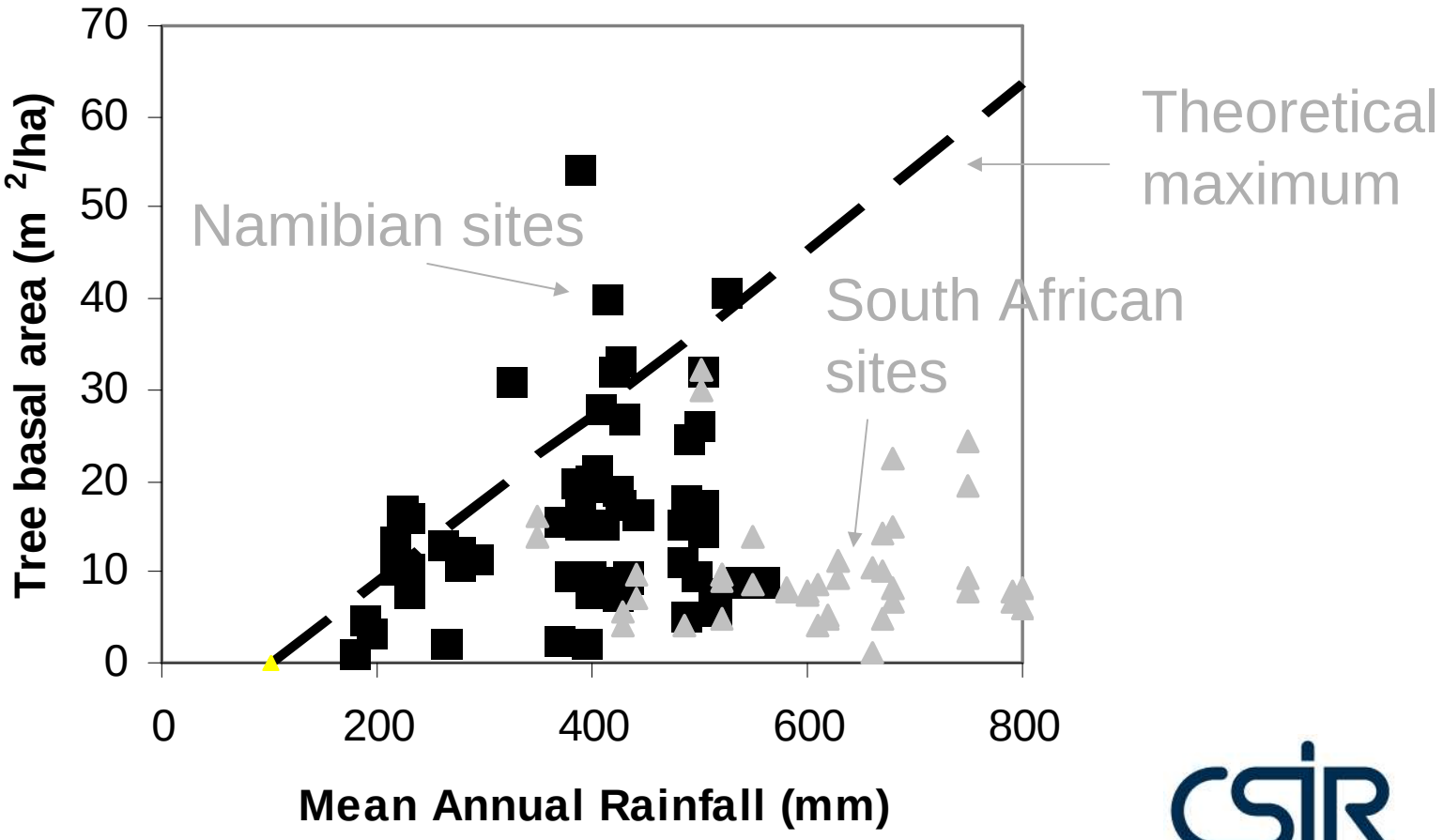
Application #2
The carbon balance of Namibia

- As a signatory to the UN Framework Convention on Climate Change, Namibia needed to report its greenhouse gas emissions
- The emissions are small in global terms
- A ‘sink term’ due to bush encroachment was uncertain and potentially large

How bush encroachment sucks up carbon



Encroachment has occurred over nearly 400 00 km² (half of Namibia)



Findings

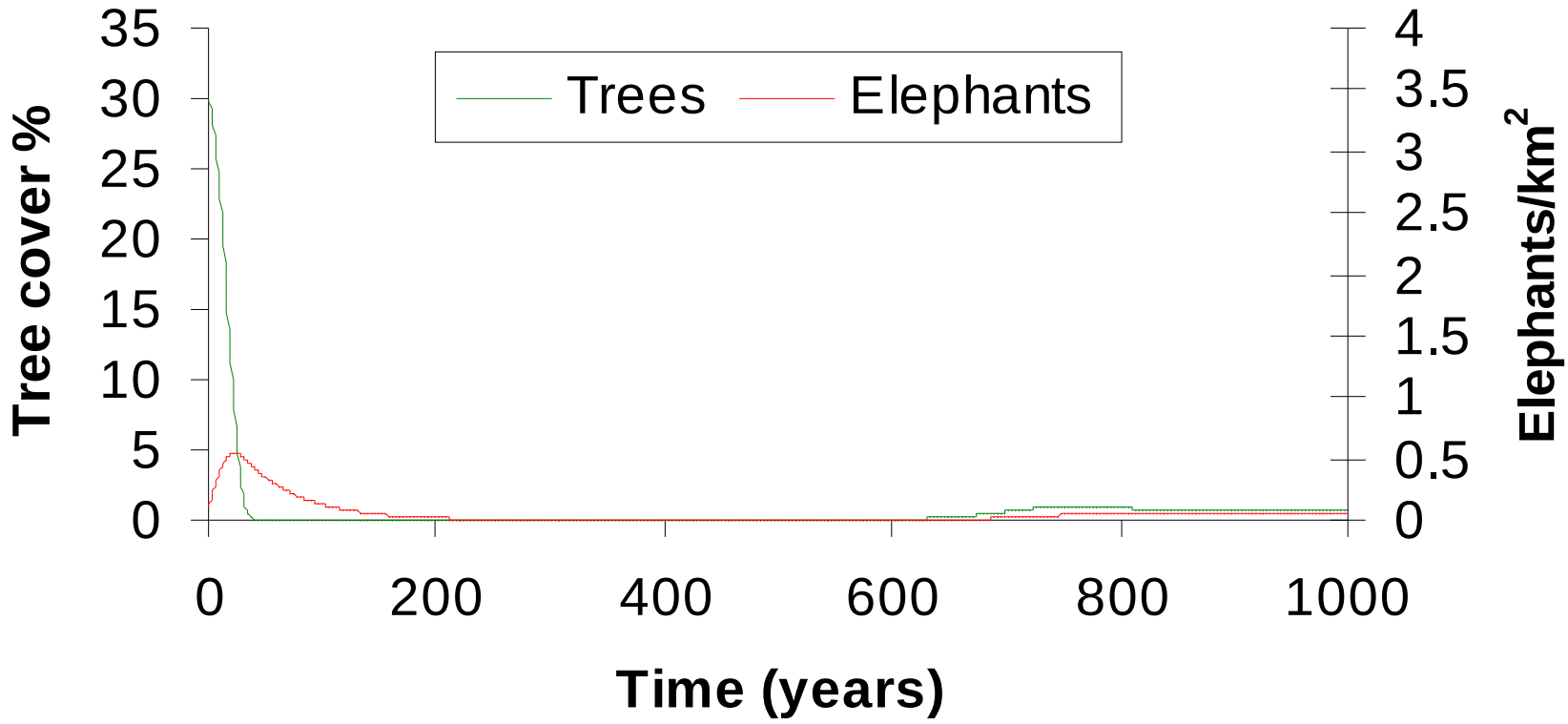
- 620 million tonnes of carbon have been taken up by bush encroachment in Namibia over the past 50 years
- ~45 Tg CO_2/y
- Namibian industrial, transport and agricultural emissions are about 5 TgCO_2eq/y
- Namibia has a large net uptake of greenhouse gases!

Application #3
Elephant numbers and conservation

- Elephant populations in Botswana, Zimbabwe, Namibia and South Africa are growing at 6-8% per year and have reached 250 000
- This is associated with radical transformation of woodlands, which may threaten other species
- Will the elephant populations stabilise at an acceptable level, or will they need to be culled?

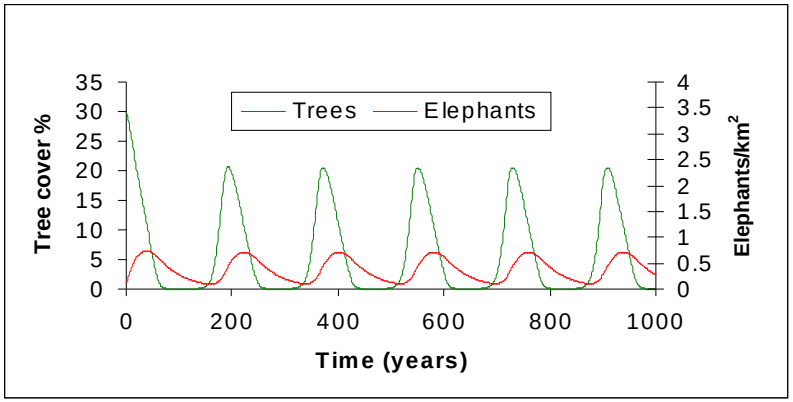
Elephants will eliminate mature trees
(Tree growth rate 3%/y, elephant growth 6%/y)

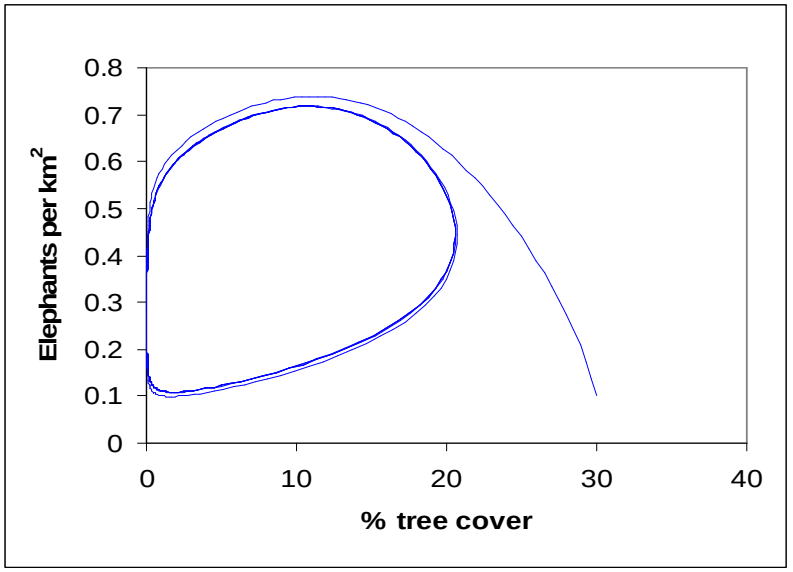
Caughley, G 1976 The Elephant problem - an alternate hypothesis E Afr Wild J 14, 265-283



Stable limit cycle with coppice

coppice growth 19%/y, elephant growth 6%/y

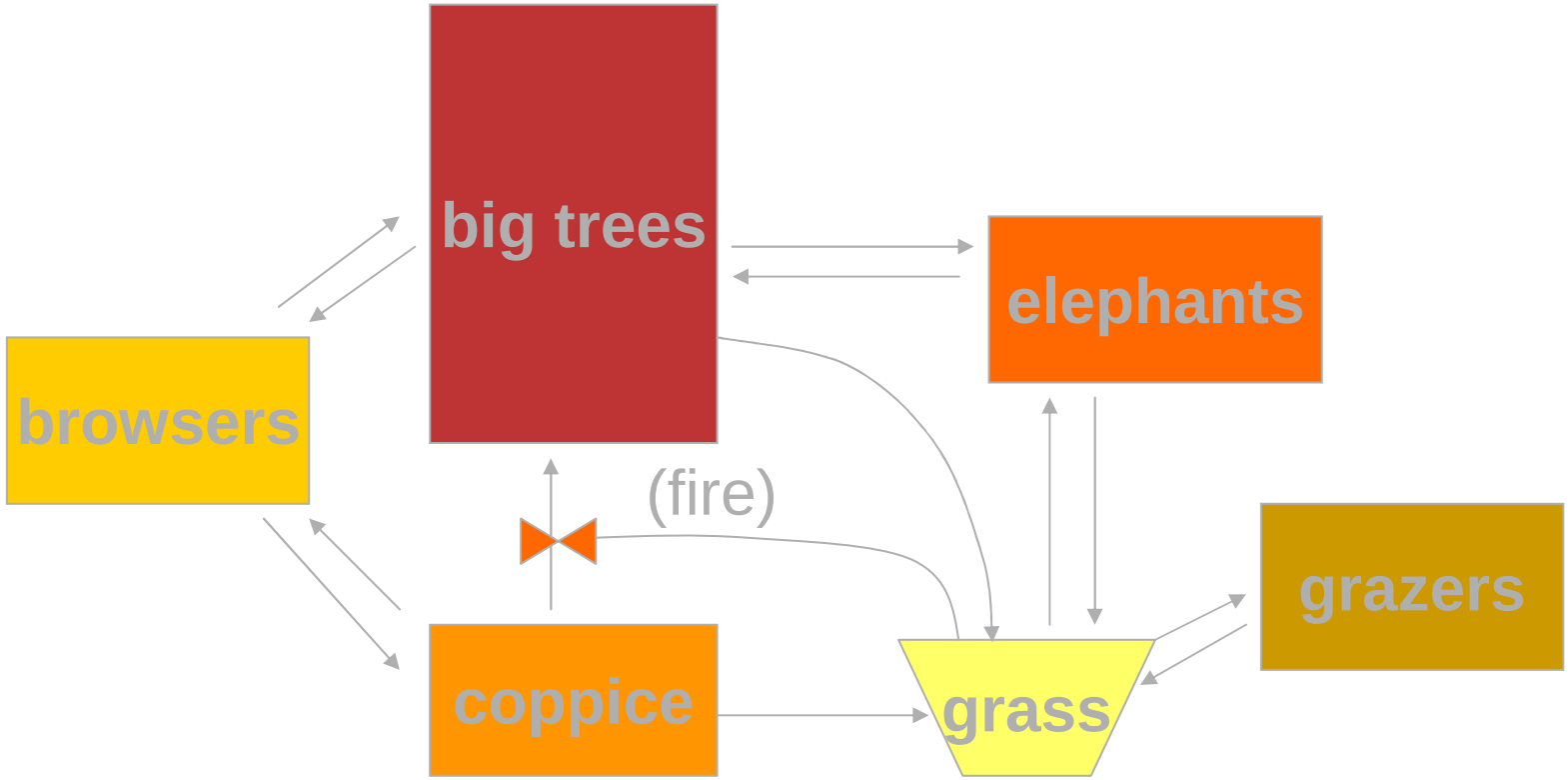




Insights so far

- Realistic parameter values do not permit an elephant-mature woodland coexistence
- Coppicing species can coexist with elephants in a stable limit cycle with a 200 year period

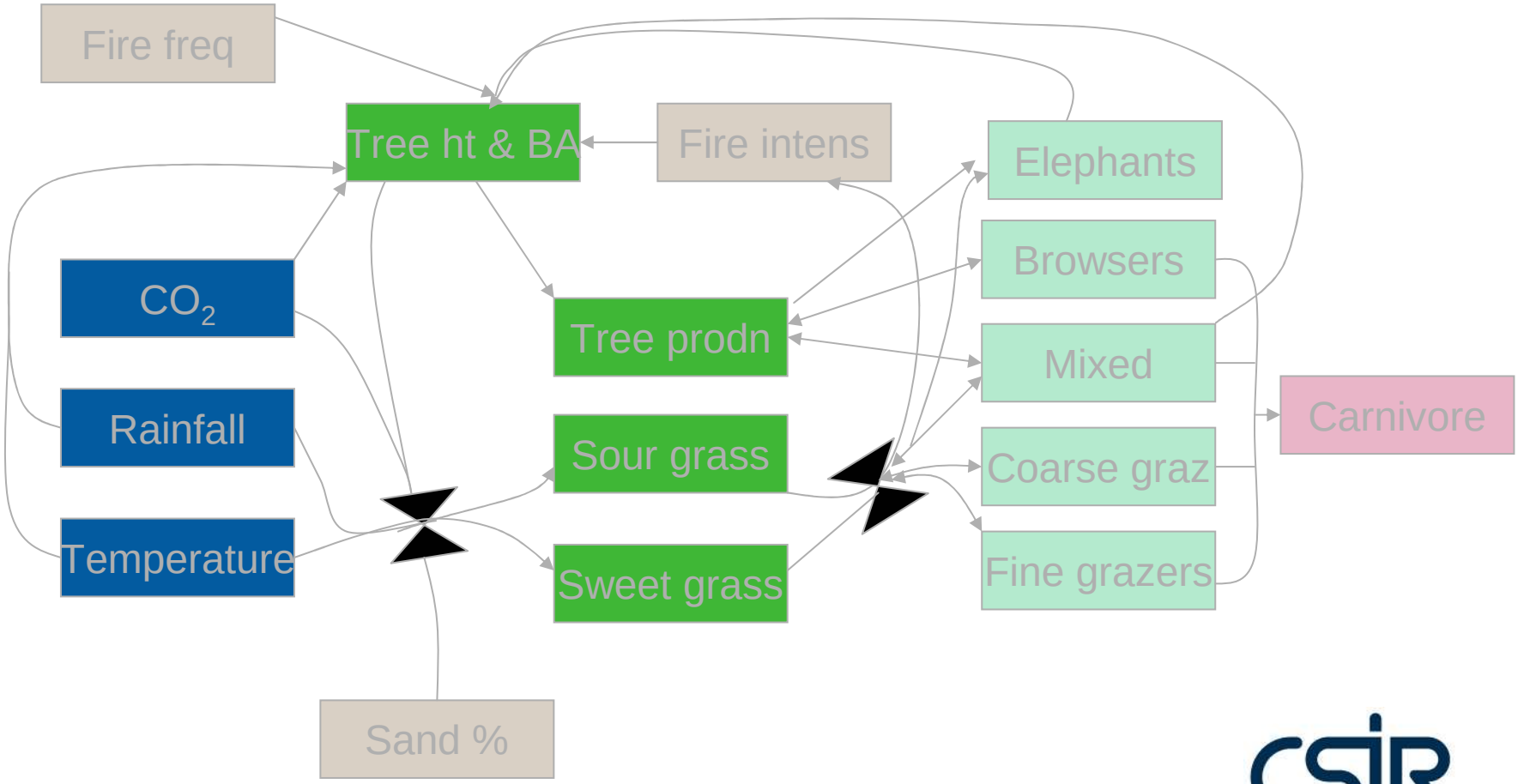
A more realistic model



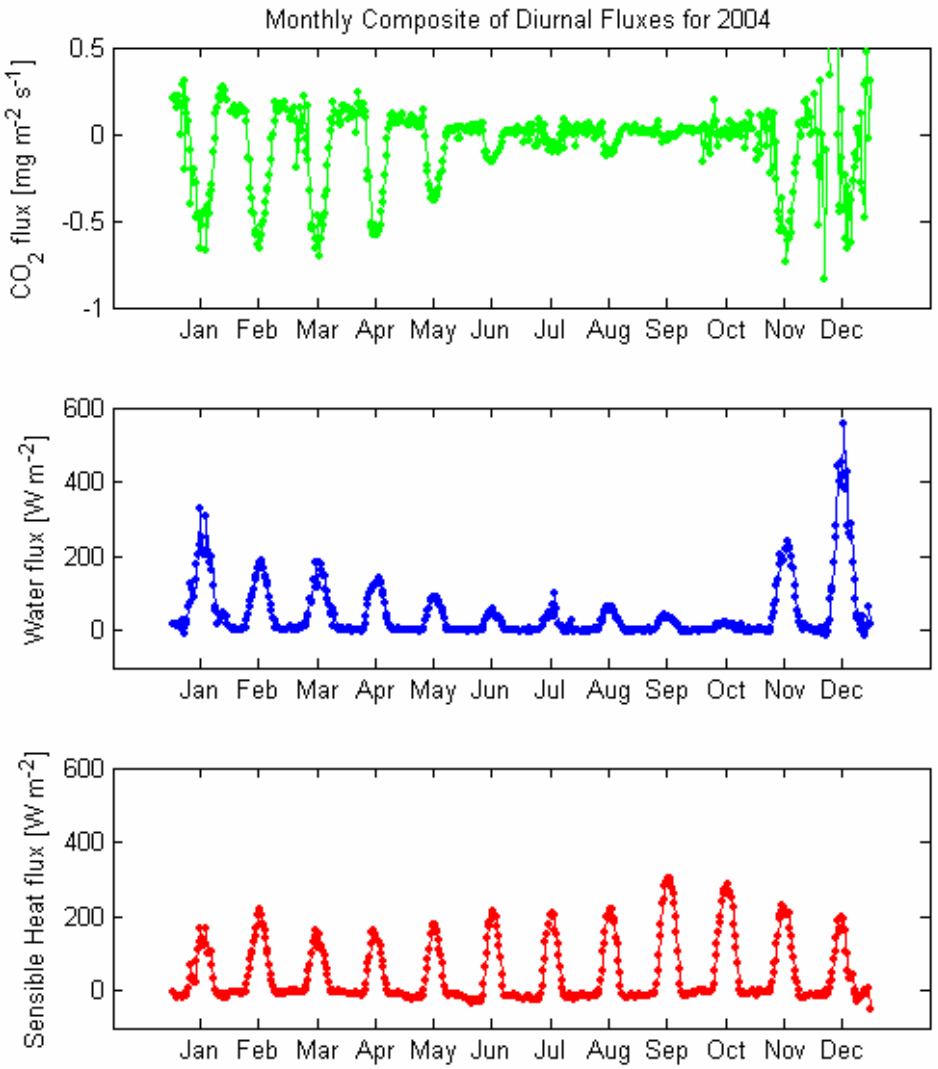
Application #4
Climate change and the Kruger Park

- The lowveld is predicted to become warmer, drier and higher in CO_2 by the end of this century
- Will this lead to a change in habitat suitability and wildlife carrying capacity?

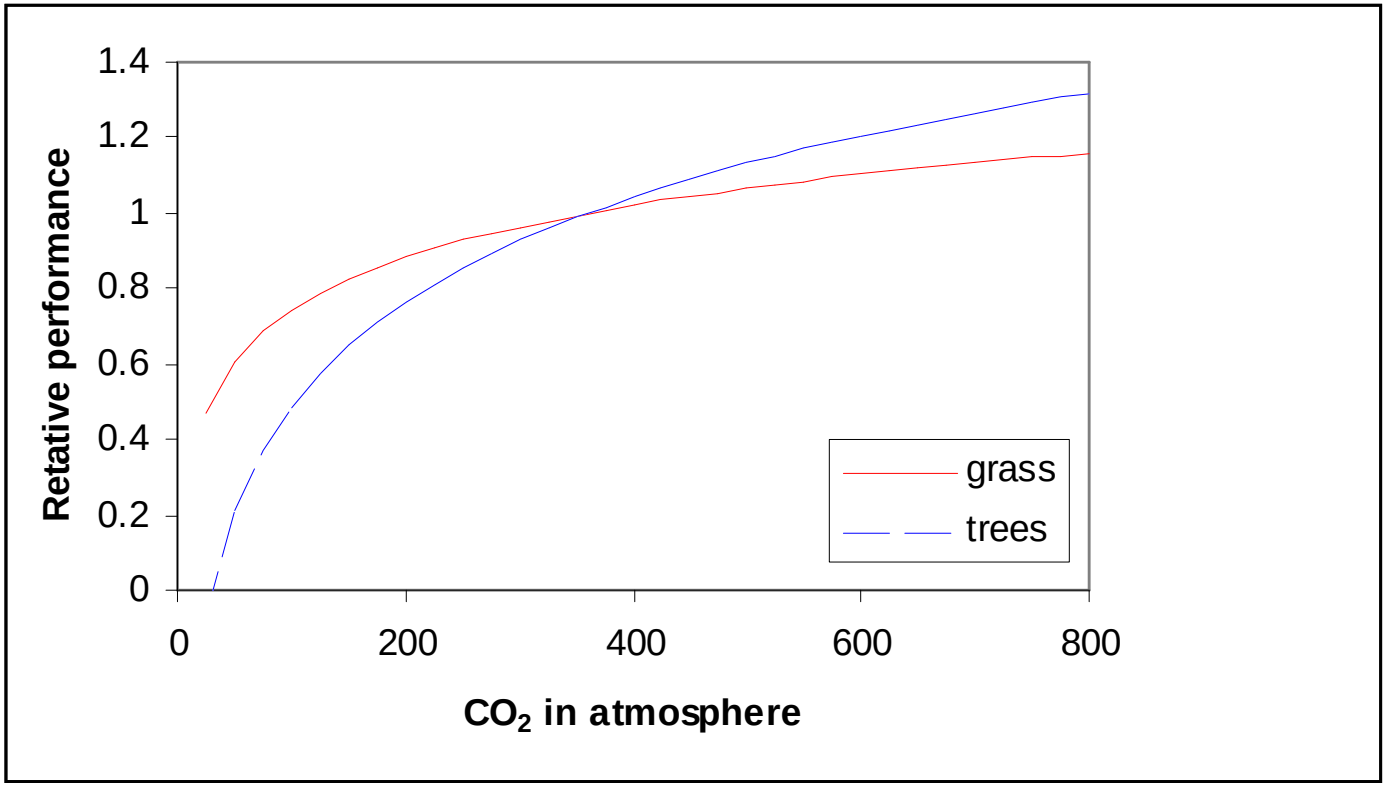
Basic savanna system model



Skukuza flux tower



Effect of CO_2 on NEP

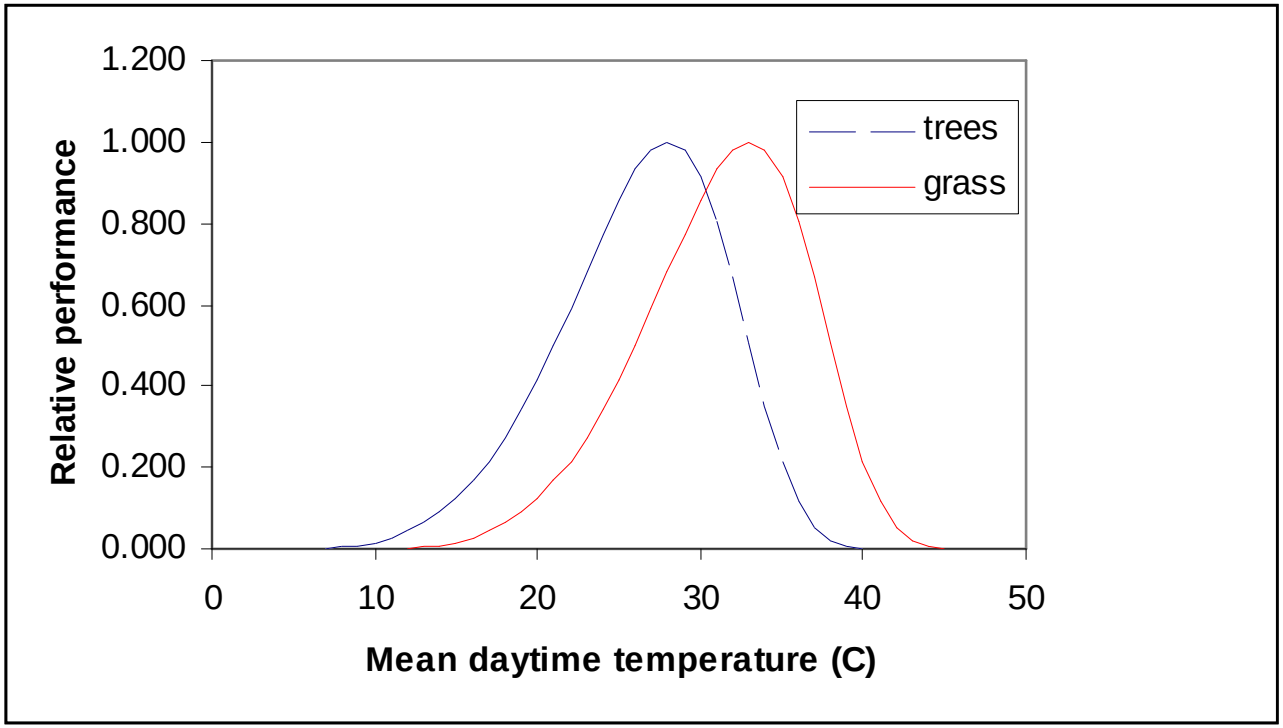


$$F(CO_2) = 1 + \beta \ln([CO_2]/[CO_{2ref}])$$

β~ 0.4 for trees, 0.2 for grass

$[CO_{2ref}] = 360$ ppm

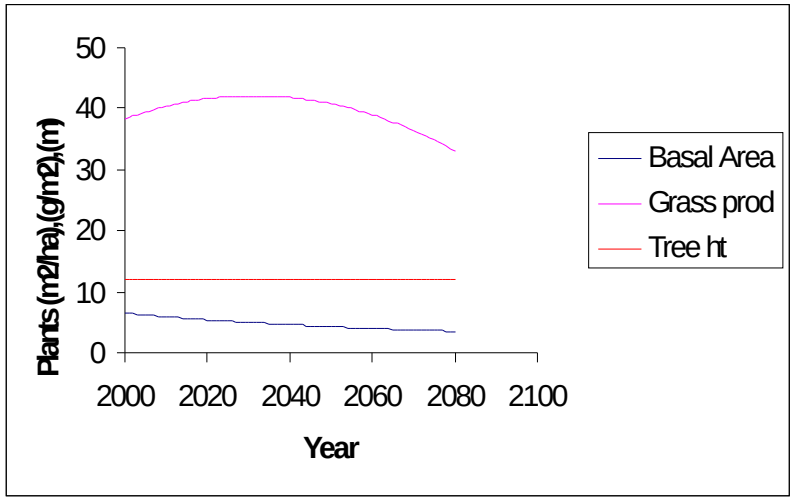
Effects of temperature on NEP

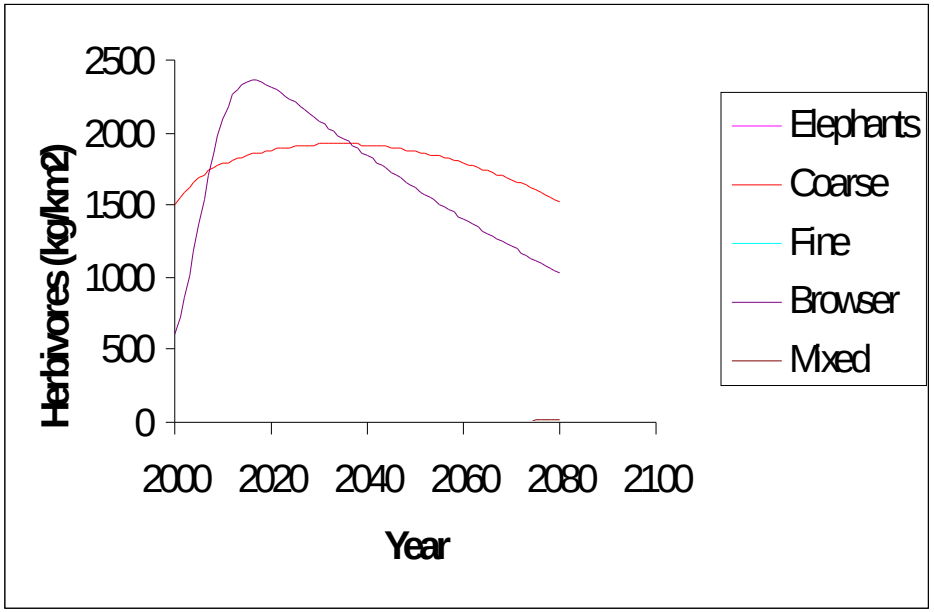


$$f[T] = e^{c*(1-\{[(b-T)/(b-a)]^{d}\}/d} * (b-T)/(b-a)^{c}$$

a = position of optimum ~ 28°C for trees, ~33°C for grasses
b =temperature below which no growth occurs ~5C trees, 10C grass
c = steepness of curve below optimum ~3
d = steepness of curve above optimum ~7

Projected impacts
A2 scenario, Hadley GCM





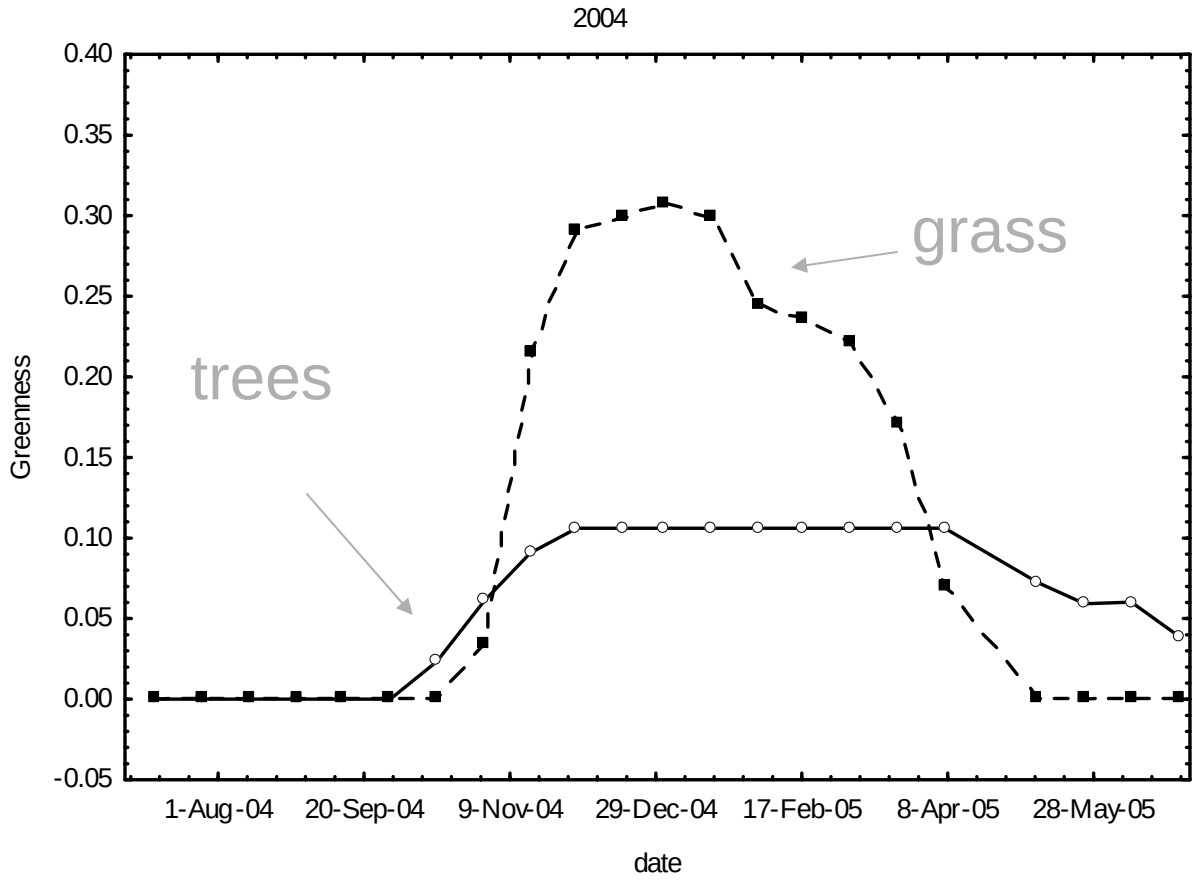
Conclusions

- Water and temperature effects can overwhelm the CO_2 effect
- Substantial changes in herbivore stocking rate are possible in the future
- The outcome of climate-change induced habitat change depends on how fires and elephants are managed

New directions

Predicting tree and grass phenology

What makes trees and grasses go green?



Archibald, S and R Scholes (submitted) Global Change Biology

Summary

By paying attention to a few fundamental questions in savanna ecology over a period of a decade, we have been able to shed light on several issues of social, economic and political importance

The End