NOT FOR FURTHER DISTRIBUTION – LECTURE MATERIAL ONLY

Ecology of southern African savanna ecosystems

Llewellyn C Foxcroft
Kruger National Park
South African National Parks
&
DST-NRF Centre for Invasion Biology
Stellenbosch University

Savanna Systems

- What are they?
- Where?
- How do they work?
  - Tree-grass interactions
    - Why do savannas fluctuate between grassland and woodland?
  - Key drivers in changing & maintaining savannas

East Africa

NOT FOR FURTHER DISTRIBUTION – LECTURE MATERIAL ONLY

SAVANNA
A wealth of knowledge – for example 16 books (1983 – 2008); "tropical savanna" OR "subtropical savanna“ 8130 hits

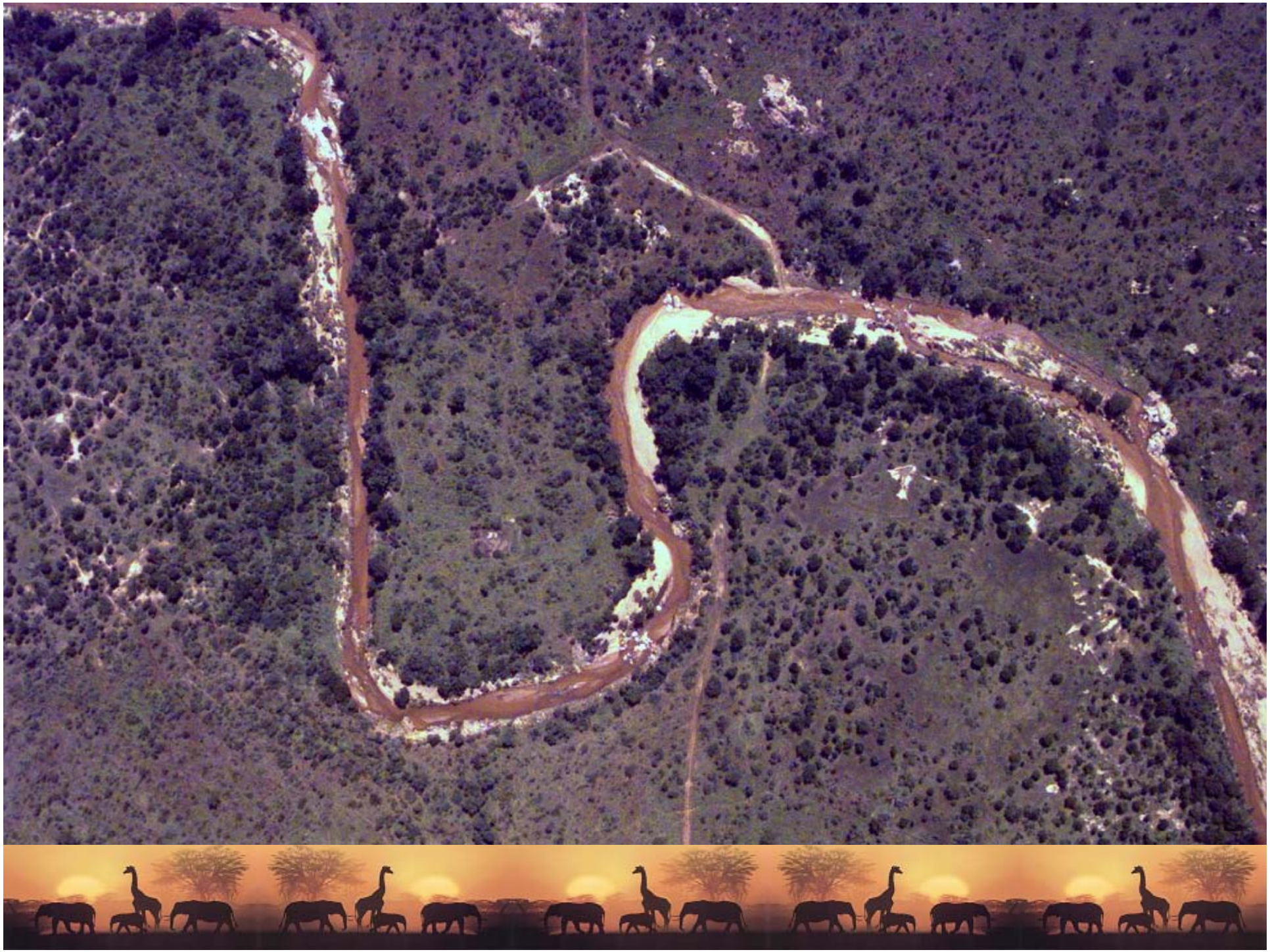
1. Bourlière F (ed) (1983) Ecosystems of the world 13. Tropical savannas. Elsevier, Amsterdam
2. Carson WP, Schnitzer SA (eds) (2008) Tropical Forest Community Ecology. Wiley-Blackwell, Chichester, UK,
3. Coe M, McWilliams N, Stone G, Packer M (eds) (1999) Mkomazi: the ecology, biodiversity and conservation of a Tanzanian savanna. Royal Geographical Society, London, UK
4. Cole MM (1986) The savannas. Biogeography and geobotany. Academic Press, Harcourt, Brace Javanovich Publishers, London
5. Cowling RM, Richardson DM, Pierce SM (eds) Vegetation of Southern Africa. Cambridge University Press, Cambridge
6. du Toit JT, Rogers KH, Biggs HC (eds) (2003) The Kruger experience, ecology and management of savanna heterogeneity. Island Press, Washington, D.C., USA
7. Huntley BJ, Walker BH (eds) (1982) Ecology of tropical savannas. Ecological studies 42, Springer-Verlag, Berlin
8. Owen-Smith N (1988) Megaherbivores. The influence of very large body size on ecology. Cambridge University Press, Cambridge, UK
9. Pennington RT, Lewis GP, Ratter JA (eds) (2006) Neotropical savannas and seasonally dry forests – plant diversity, biogeography, and conservation. CRC Press, Boca Raton, FL, USA
10. Scholes RJ, Walker BH (1993) An African savanna: synthesis of the Nylsvley study. Cambridge University Press, Cambridge, UK
11. Shorrocks B (2007) The biology of African savannas. Oxford University Press, Oxford, UK
12. Sinclair ARE, Arcese P (eds) (1995) Serengeti II: dynamics, management and conservation of an ecosystem. University of Chicago Press, Chicago
13. Sinclair ARE, Norton-Griffiths M (eds) (1979) Serengeti: dynamics of an ecosystem. University of Chicago Press, Chicago
14. Sinclair ARE, Packer C, Muduma SAR, Fryxell JM (eds) (2008) Serengeti III: Human impacts on ecosystem dynamics. University of Chicago Press, Chicago
15. Solbrig OT, Medina E, Silva JF (eds) (1996) Biodiversity and savanna ecosystem processes. Ecological Studies 121, Springer-Verlag, Berlin
16. Werner PA (ed) (1991) Savanna ecology and management: Australian perspectives and intercontinental comparisons. Blackwell, Melbourne

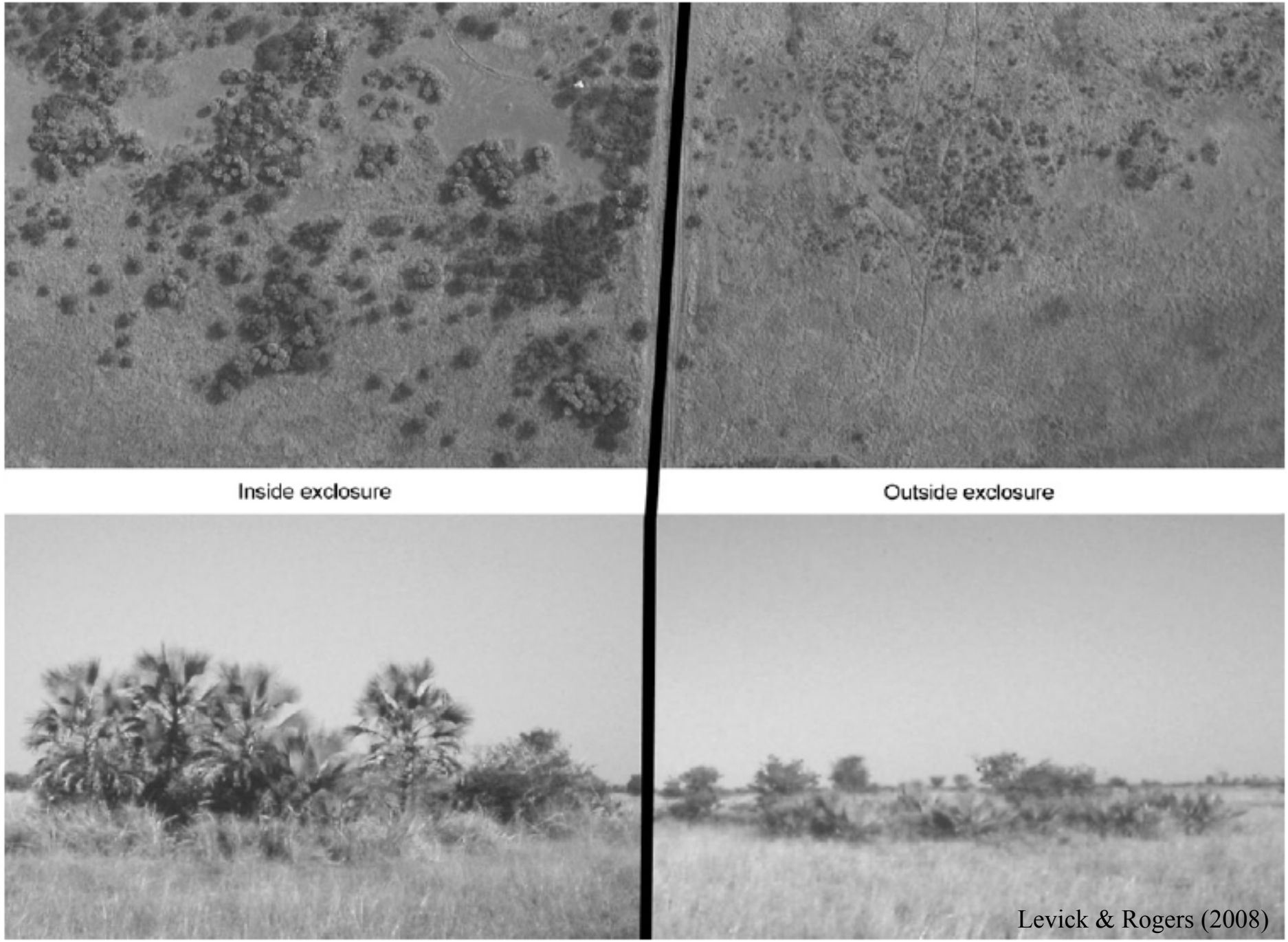
Definition:

Tropical vegetation type co-dominated by a largely continuous layer of grasses (<2m) and a discontinuous woody tree layer.

– Characterized by:

- hot wet season and warm dry season;
- usually high fire frequency;
- high habitat heterogeneity (at small & large scales)





Levick & Rogers (2008)

Importance of savanna

- Many millions of people depend on savanna to sustain livelihoods
  - fuel wood harvest, livestock grazing, small to large scale agriculture

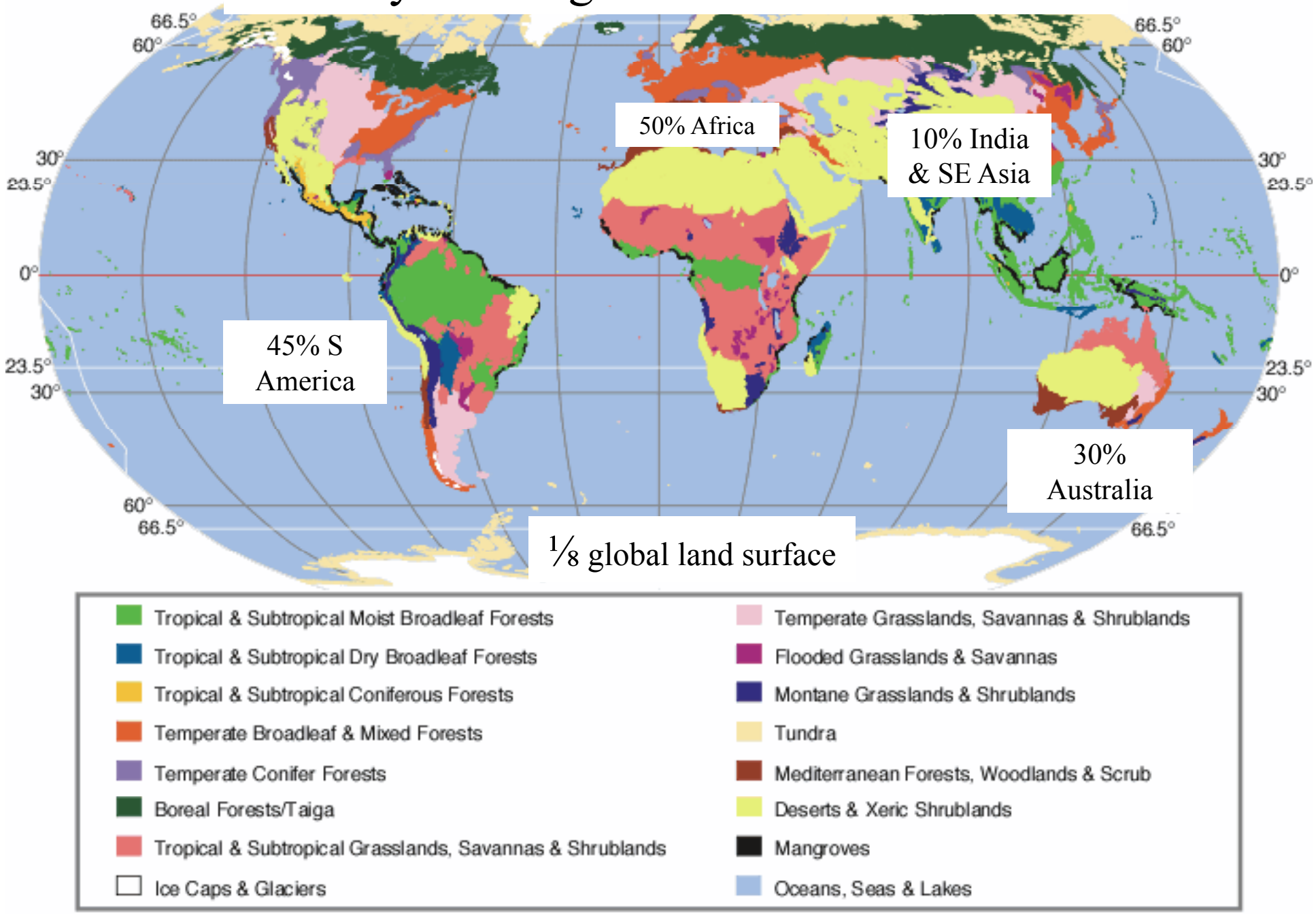
Importance of savanna

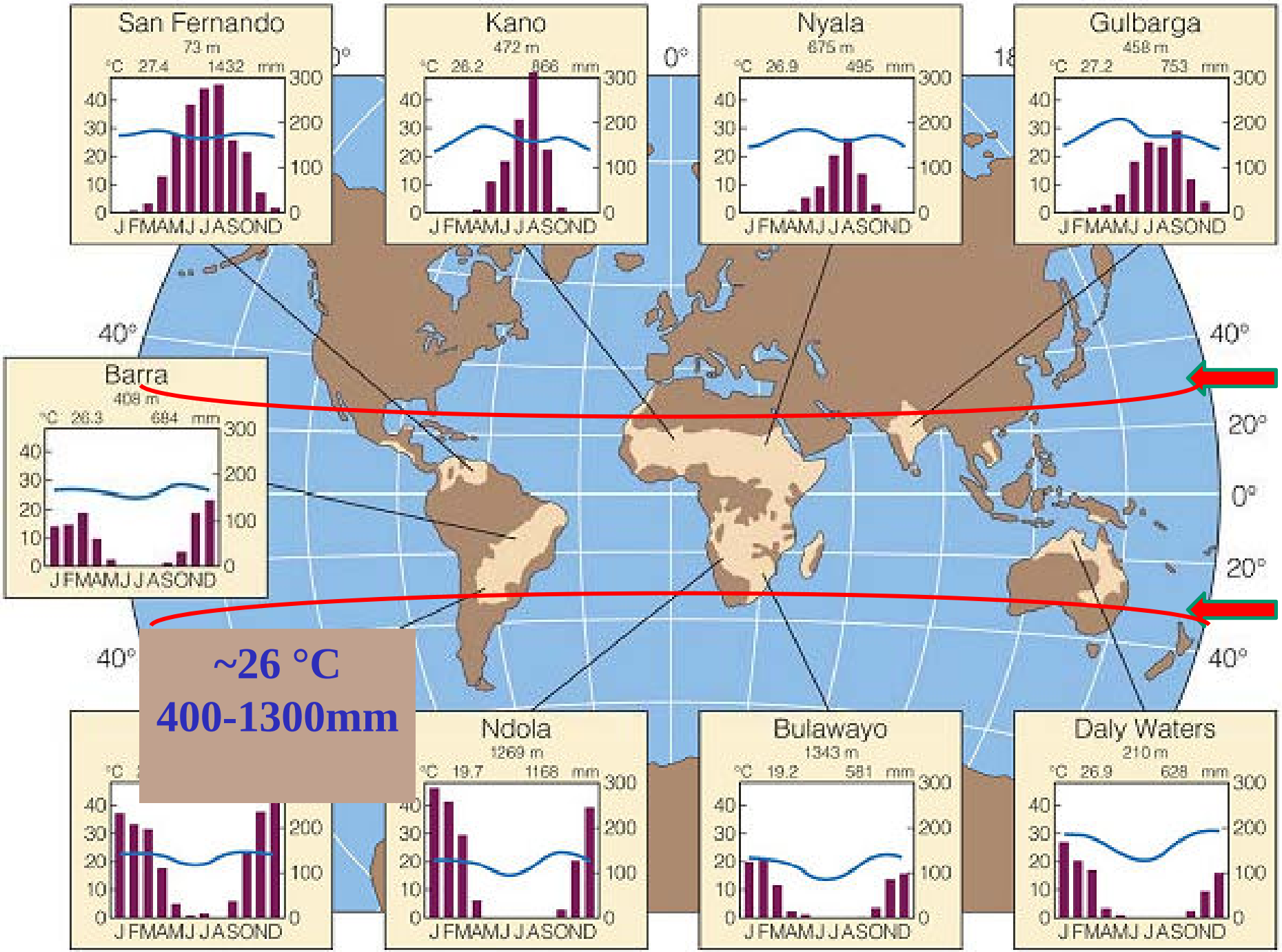
- > savannas subjected range of anthropogenic influences and impacts/disturbances.
- > know these impacts have been happening for millennia
- > thus humans will have had an important co- role to shaping savannas.

- Regular natural disturbances:
  - vary from regular low intensity
  - to large infrequent disturbance (LID)
    - floods, fires, droughts, mega-herbivores, high numbers of large herbivores.

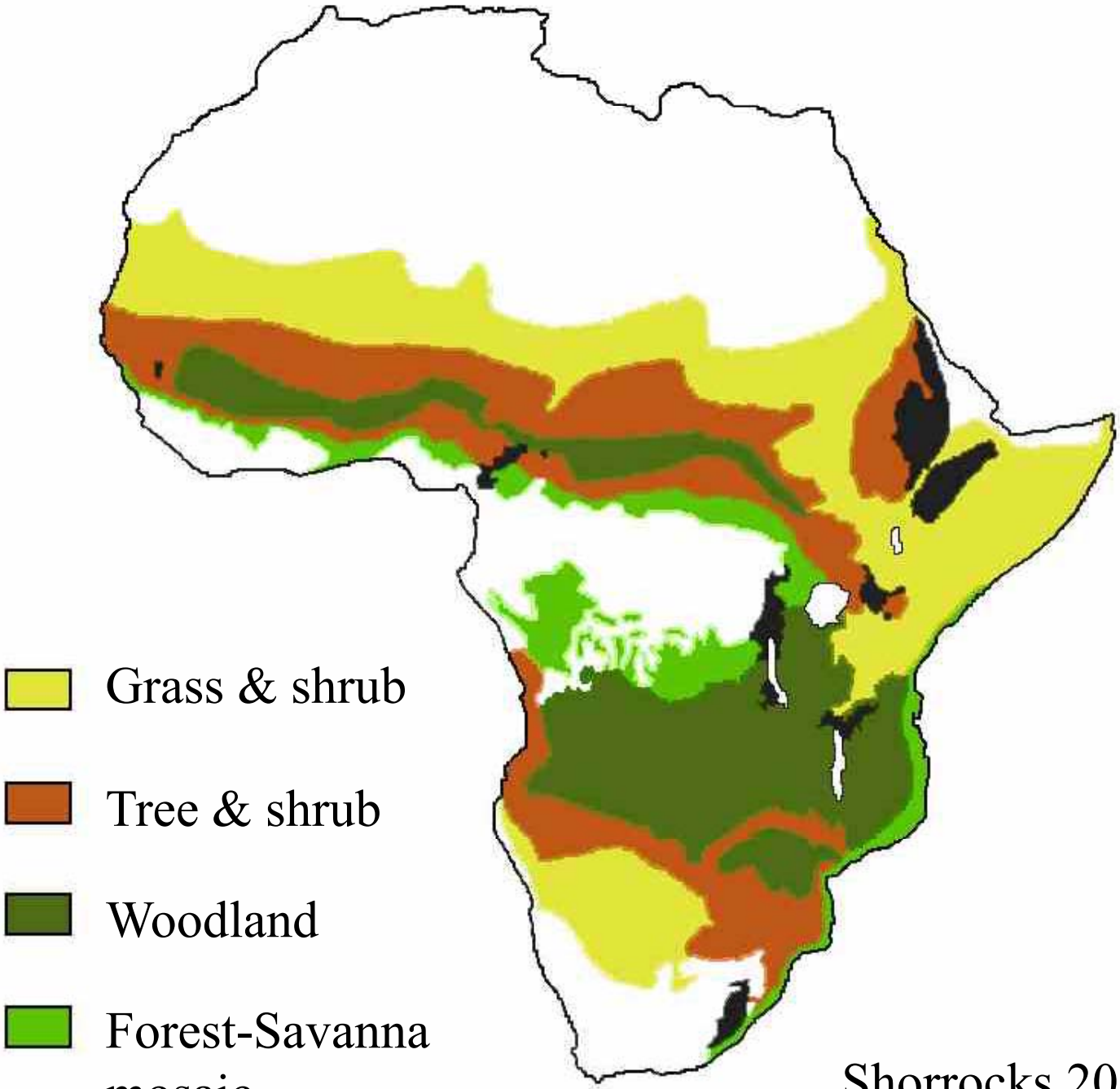
- Highly resilient to disturbance
  - have the ability to recover to a former condition following perturbation
  - 'Magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control behavior' (Holling and Gunderson, 2002)

Globally 2nd Largest biome = 15 x 10^6 km^2

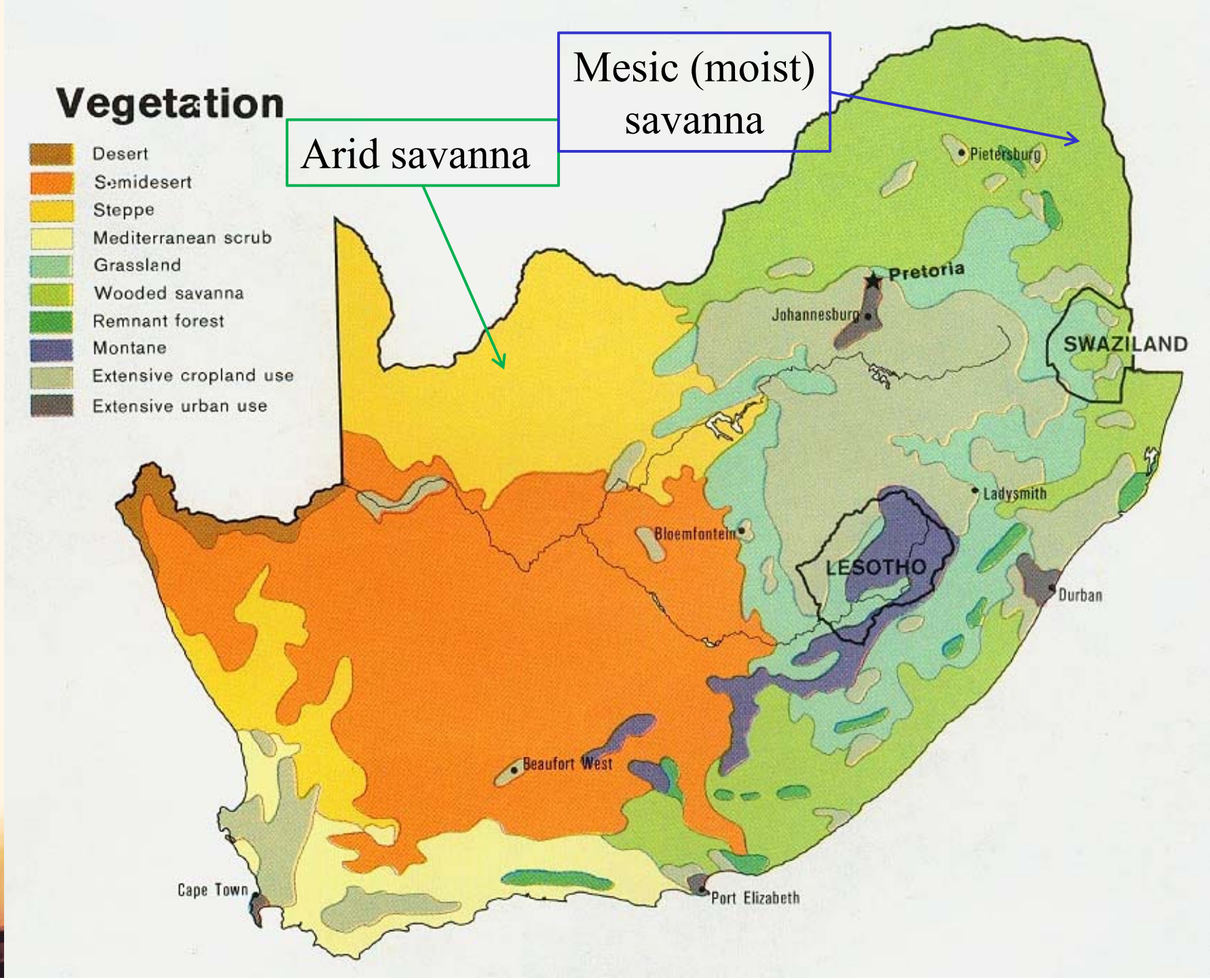




Copyright © 2006 Pearson Education, Inc., publishing as Benjamin Cummings



Shorrocks 2007


Vegetation
Desert
Semidesert
Steppe
Mediterranean scrub
Grassland
Wooded savanna
Remnant forest
Montane
Extensive cropland use
Extensive urban use
Arid savanna
Mesic (moist) savanna
Pietersburg
Pretoria
Johannesburg
SWAZILAND
Ladysmith
Bloemfontein
LESOTHO
Durban
Beaufort West
Cape Town
Port Elizabeth

Southern African savanna

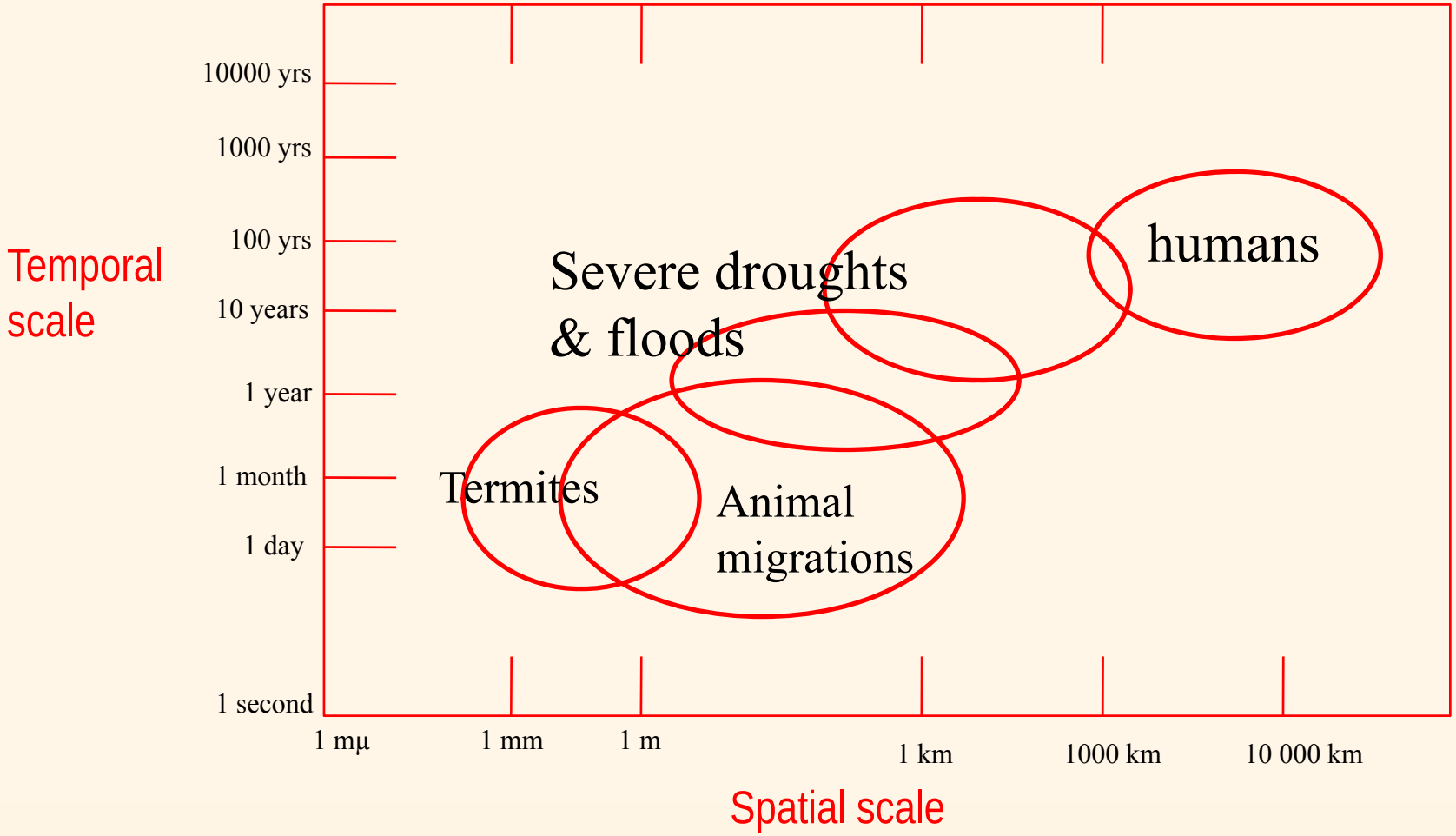
- Moist savanna systems: ~ 600 - 1500 mm rainfall / annum, eastern parts of southern Africa
  - Nutrient poor, broadleaved (mesophyllous)

- Relatively arid regions: ~ 400 - 800 mm rainfall / annum, western parts of southern Africa
  - Nutrient rich, fine leaved (nanophyllous) savanna

(Scholes 1997)

Basis of savanna systems:

- origin, age, nature and dynamics of savannas not easy to understand-
  - many approaches and models to unraveling the roles and importance of the many drivers.
- temporal changes –
  - variations in extent and distribution of savannas from glacial to interglacial cycles, through to short term cycles in the last few hundred years


Temporal scale
10000 yrs
1000 yrs
100 yrs
10 years
1 year
1 month
1 day
1 second
1 mμ
1 mm
1 m
1 km
1000 km
10 000 km
Spatial scale
humans
Severe droughts & floods
Termites
Animal migrations

Drivers of savannas & savanna change?

•is pattern of vegetation (heterogeneity) a consequence of large mammals?
•is the large mammal biomass controlled by abiotic template of water and nutrients?

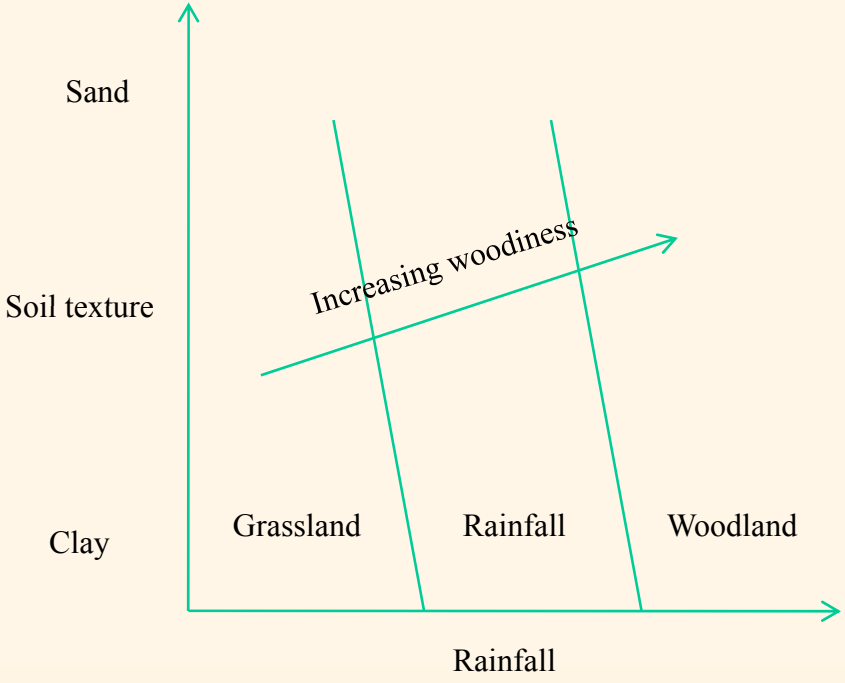
No: coupled system- cannot be described by top-down or bottom-up controllers.
•Multiple feedback loops

•Spatial patterns, abundance of tree – grass product of: unpredictableinteractions of: climate, geomorphology, topography, soils (fertility, moisture, catena position), herbivory, fire (frequency & intensity), carnivores, mega-herbivores, large herbivores

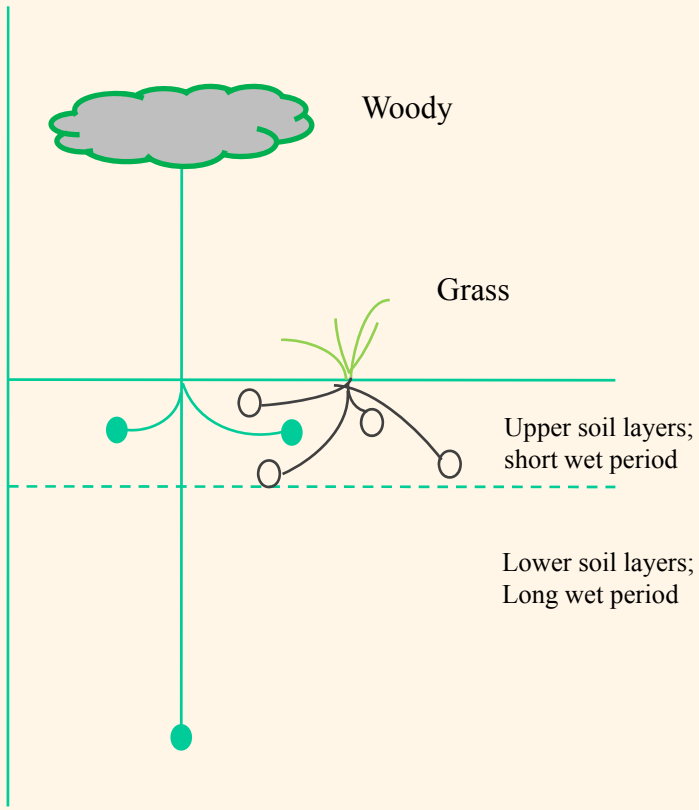
A proliferation of models of tree – grass interactions:

- Walker Noy-Meir model
- Walther hypothesis (minimum savanna model & advanced
- generalized fire – grass – animal

Soil and rainfall conditions giving rise to savanna vegetation



Walker & Noy-Meir (1982) Ecology of tropical savannas.

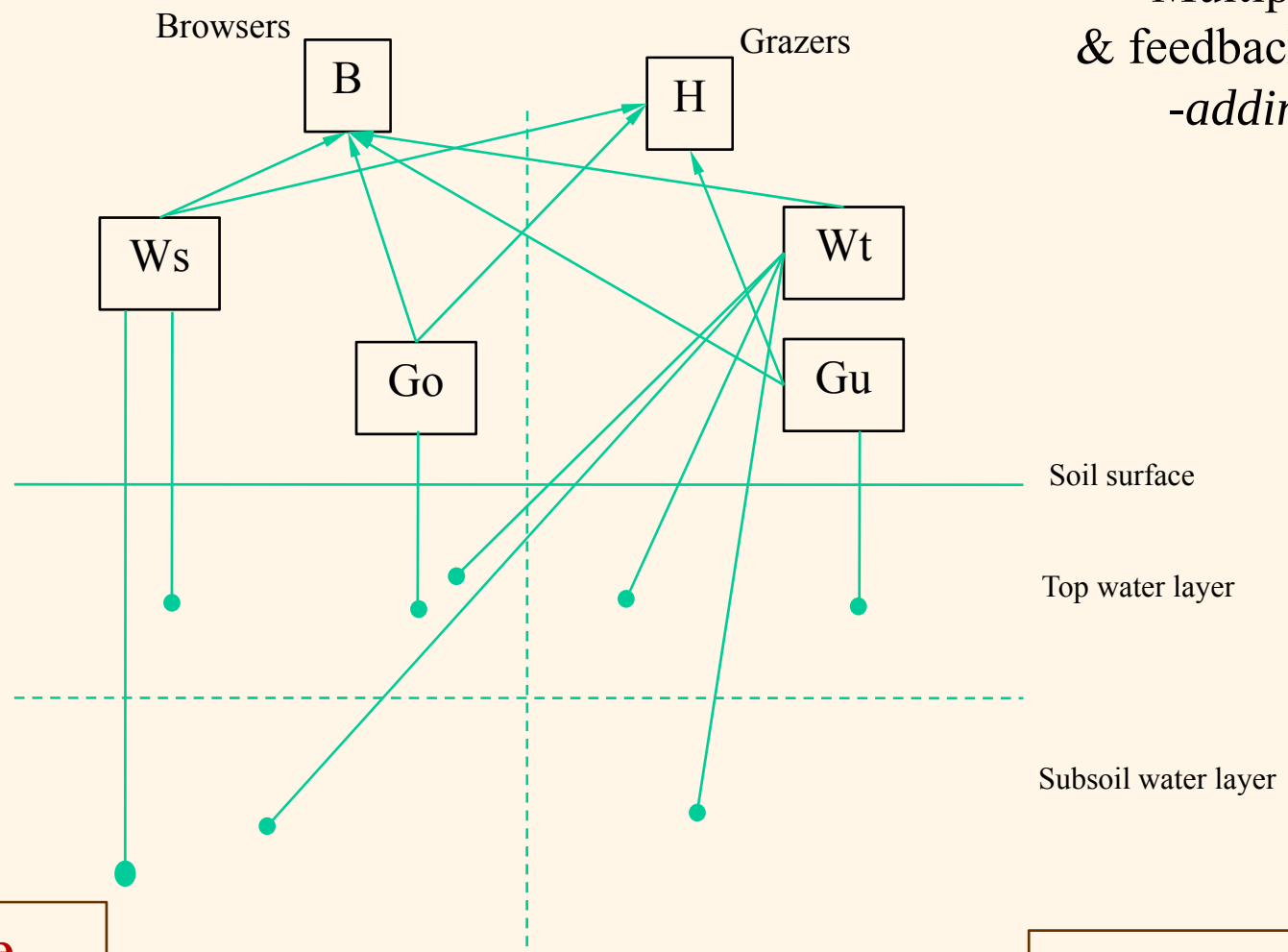


Niche separation by:
-water availability
-rooting depth

Minimum model for savanna:
tree – grass co-existence

Walker & Noy-Meir (1982) Ecology of tropical savannas.
Based on the *Walter hypothesis* (Walther 1971)

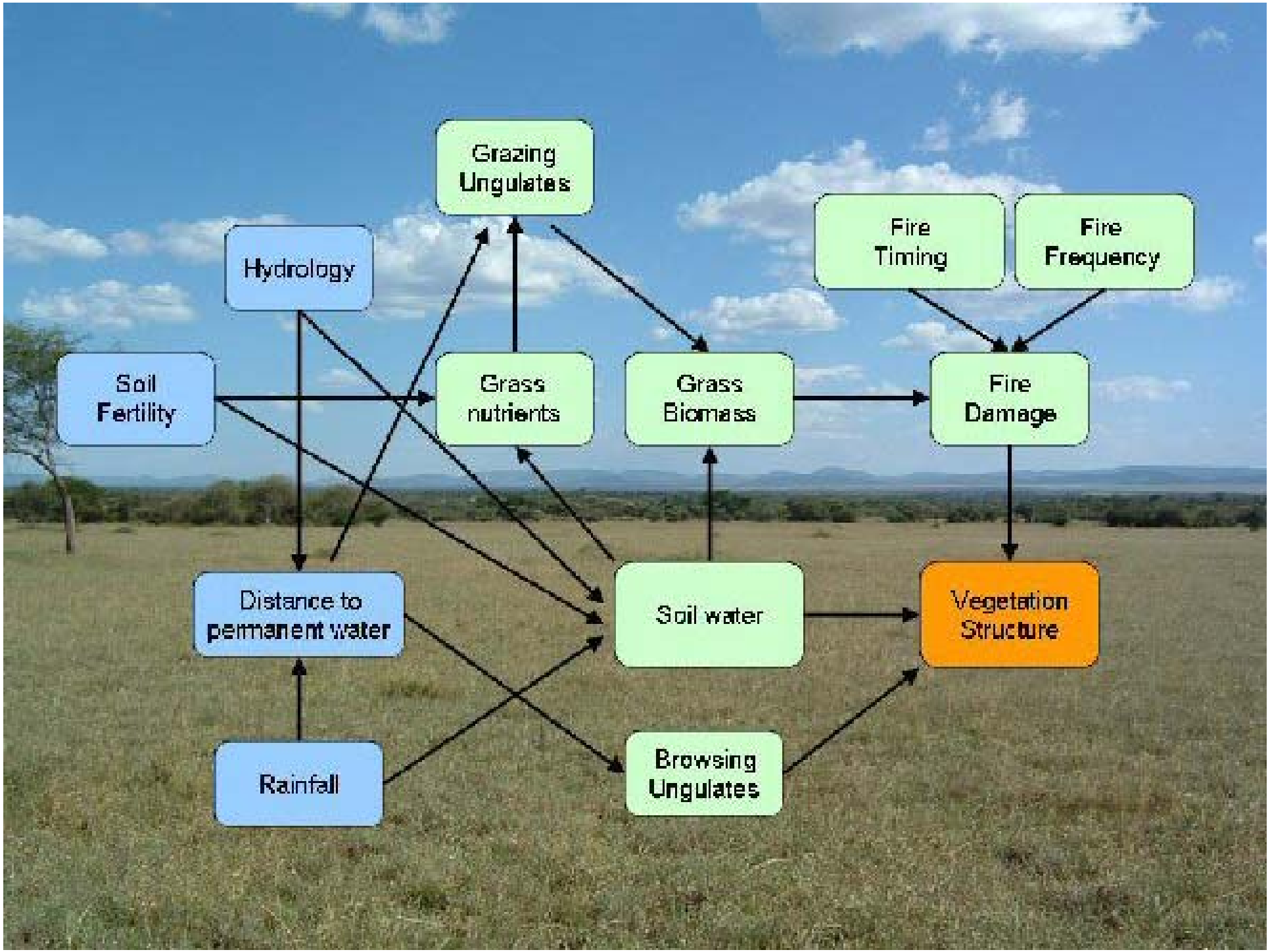
Multiple interactions & feedback mechanisms *-adding browsers & grazers*



Dense shrubs ⟷ Sparse tree

Extended savanna model:
Ws,t= woody trees & shrubs
Go,u= Grass under trees & in open
B,H=Browsers & grazers
T,S= Top- & sub-soil water

Walker & Noy-Meir (1982) Ecology of tropical savannas.


Grazing Ungulates
Hydrology
Fire Timing
Fire Frequency
Soil Fertility
Grass nutrients
Grass Biomass
Fire Damage
Distance to permanent water
Soil water
Vegetation Structure
Rainfall
Browsing Ungulates

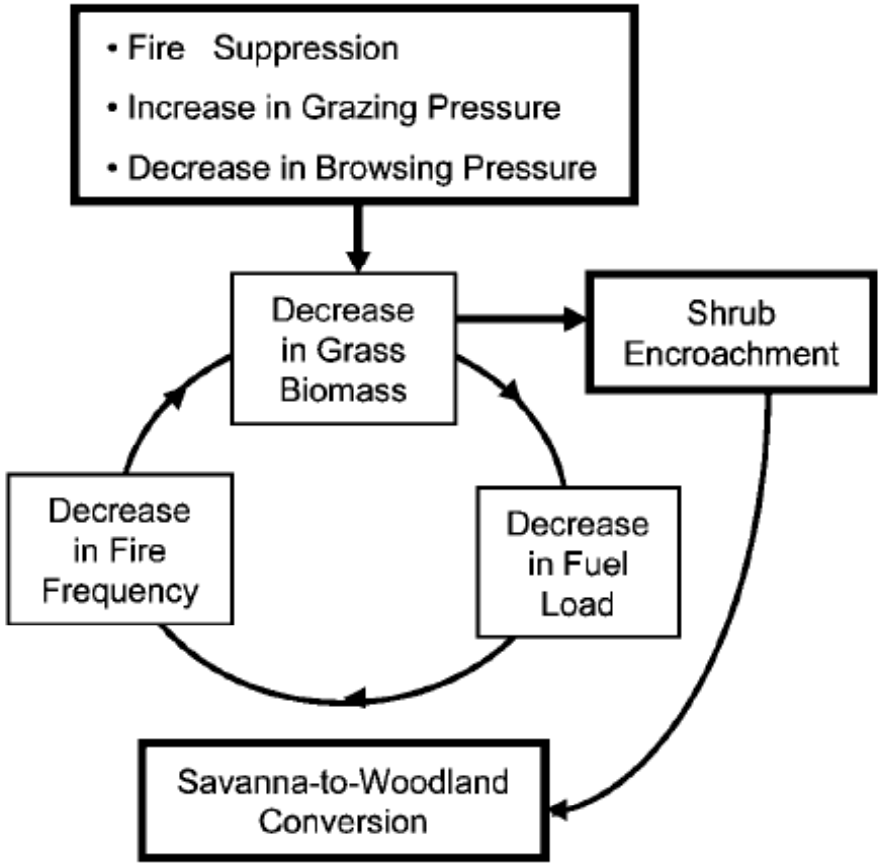
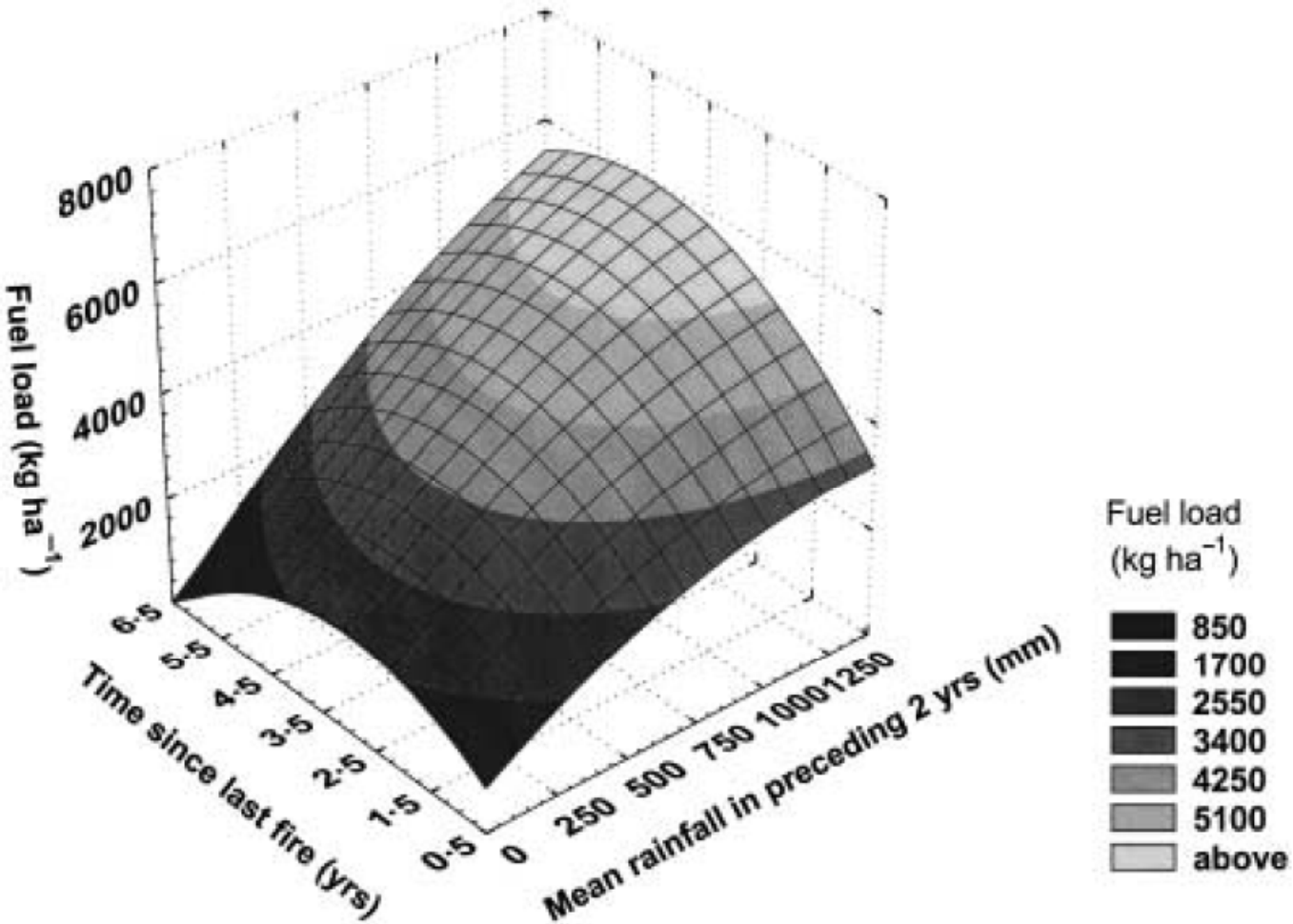


Figure 1: Schematic representation of the positive feedbacks in vegetation-disturbance dynamics.

Fire as the driver: Fire-Induced Tree-Grass Coexistence

D'Odorico, Laio, Ridolfi (2006) American Naturalist

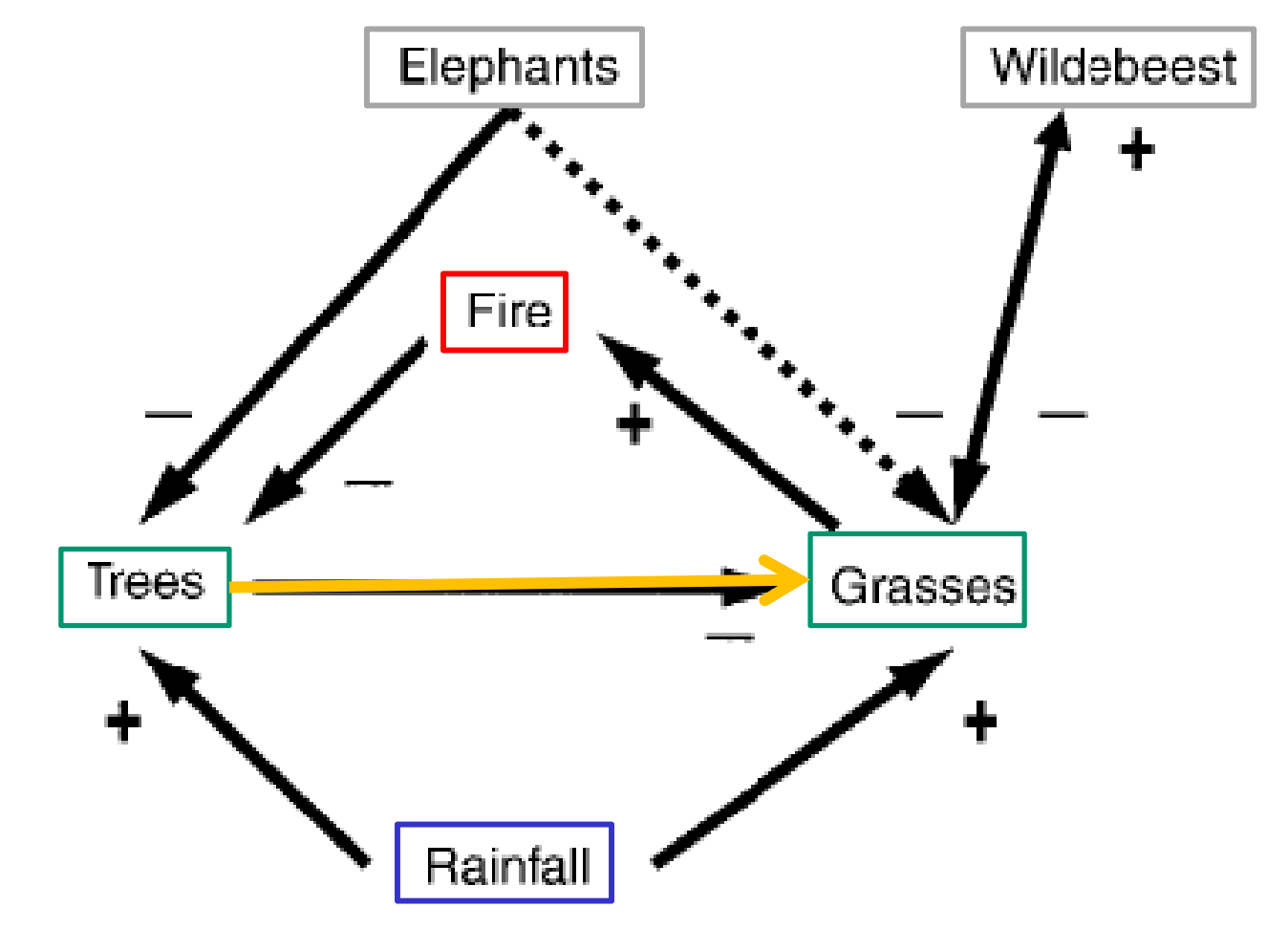
(Govender et al 2006)



Effect of time since the last fire
Mean annual rainfall in the preceding 2 years
Grass fuels loads

Predict fire with 3 variables

- Animal impact on biomass?
- Rainfall impact on animal numbers?
- etc..



Holdo, Holt, Fryxell (2009) Ecol App.

Role of carnivores?

- lions, hyaena; leopard, wild dog, cheetah, & others less of a role:
  - > Lions and herbivores could in principle influence herbivore number & distribution
  - > vegetation structure and ecosystem properties (> biomass > fire> soil feedbacks).

- BUT,
  - Although probably a role at smaller scales
  - No evidence for this at large scale

- Variance in herbivores controlled largely by rainfall > grass productivity

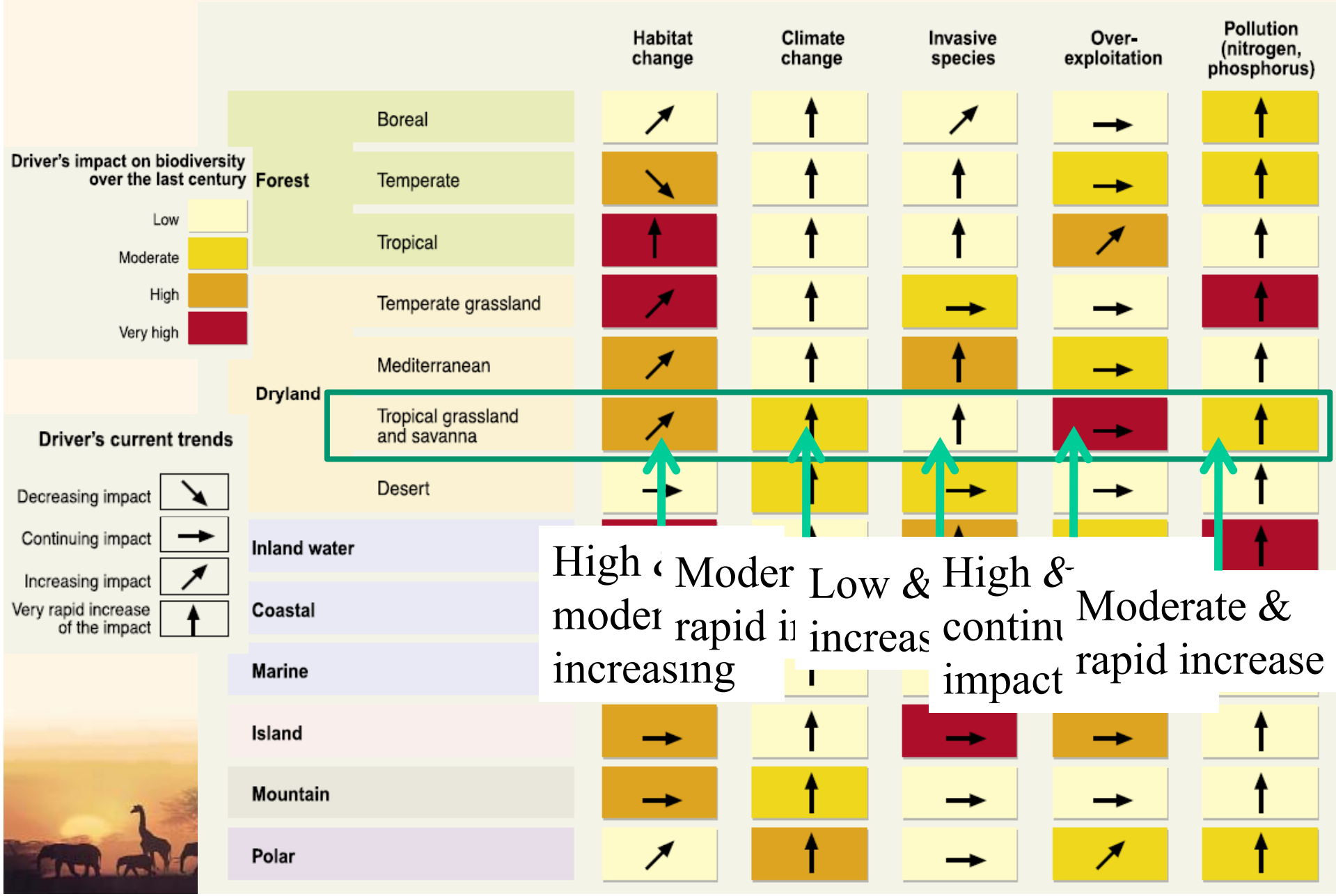
Control by mega-herbivores

- Mega-herbivores: >1000km;

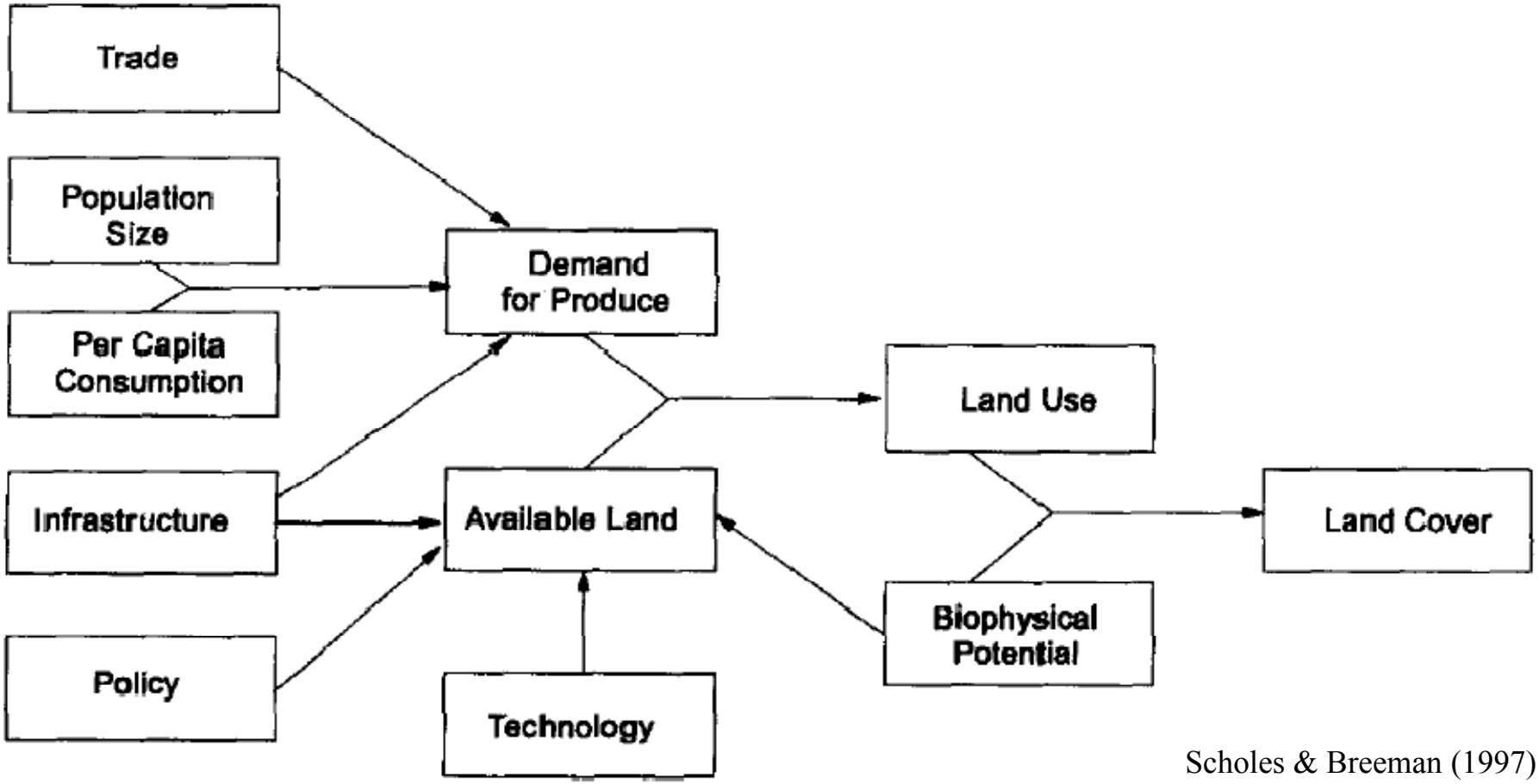
  ♂ Elephant ~ 7500kg, white rhino 2150kg, hippo 2000kg, giraffe 1300kg, black rhino 1300kg)
- Elephants can change vegetation structure (ecosystem engineers / keystone species)
- White rhino grazers- contribute to maintaining areas in short grass state- grazing lawns
- Hippos forage mainly within 2km of permanent water, but will travel up to 20km / night – high grazing impact along river – upland boundary
- Giraffe feeding up to level ~ 6m - impact structure of vegetation and can impact flowing and seeding of trees & impact seed production

http://www.youtube.com/watch?v=oPdn-jK-MqM

Threats to savannas (Millennium Ecosystem Assessment)

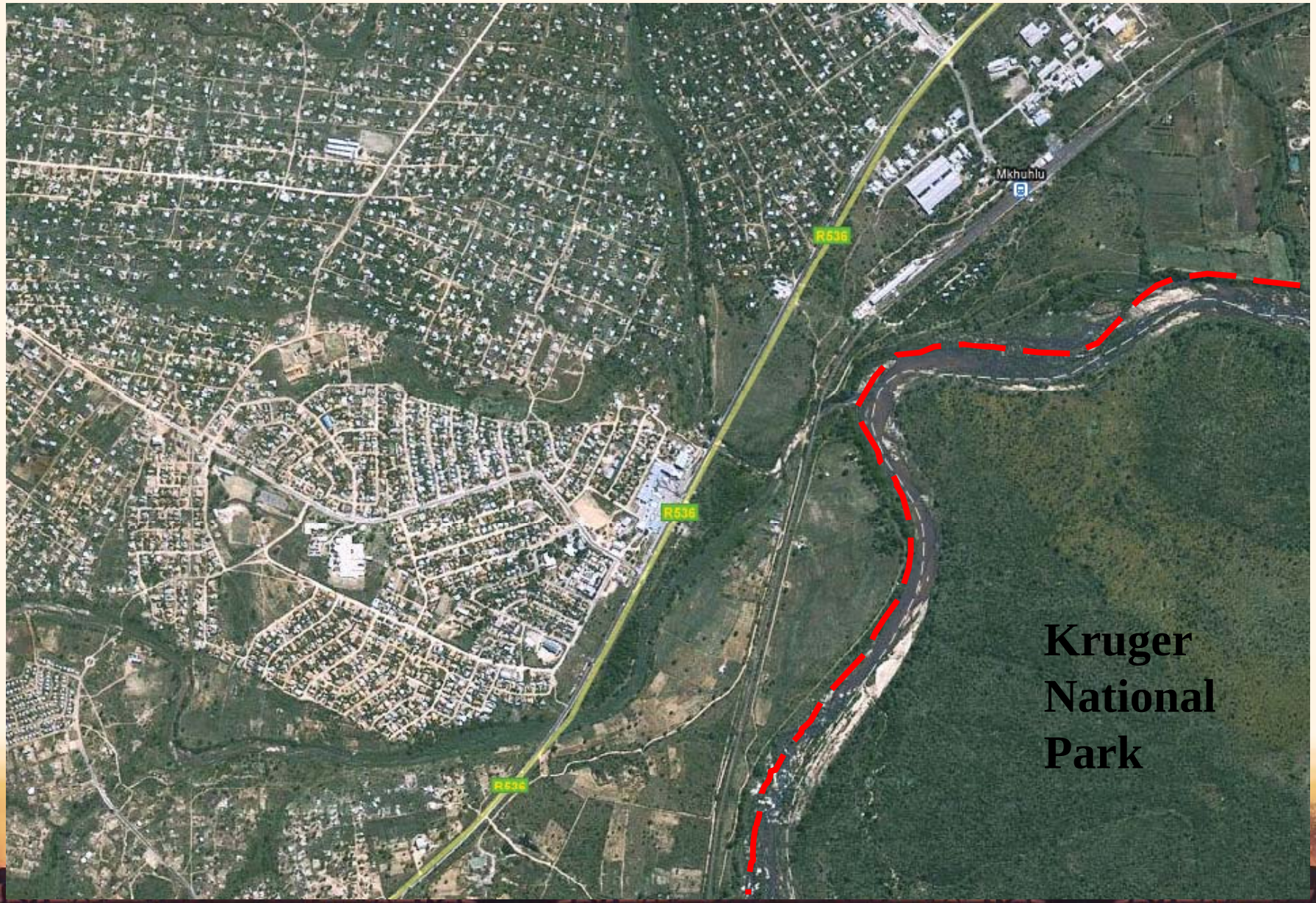


Major factors driving land use & land cover change



Scholes & Breeman (1997)

Savanna land use change



Typical invasive species from three savanna regions

Neotropics (South America)

Melinis minutifolia
(Poaceae; molasses grass)

Photo M Carlos

Kruger National Park

Opuntia stricta
(Cactaceae; sour prickly pear)

Photo LC Foxcroft

arid savanna in South Africa

Echinopsis spachiana
(Cactaceae; torch cactus)
invading.

Photo DM Richardson.

Queen Elizabeth National Park, Uganda

Opuntia monocantha
(Cactaceae; drooping prickly pear).

Photo M. Rejmánek.

northern Australian savannas

Andropogon gayanus
(Poaceae; Gamba grass)

Photo S Setterfield.

Cairns, Australia

Themeda quadrivalvis
(Poaceae; Giant Cangaroo Grass)

Photo M. Rejmánek.

central savannas of Venezuela

Hyparrhenia rufa (Poaceae; thatching grass)

Photo Z. Baruch

NOT FOR FURTHER DISTRIBUTION – LECTURE MATERIAL ONLY