Session 13: Animals in Extreme Environments

Invited Lecture

Management challenges of animal production on semiarid and Mediterranean rangelands: a simple model

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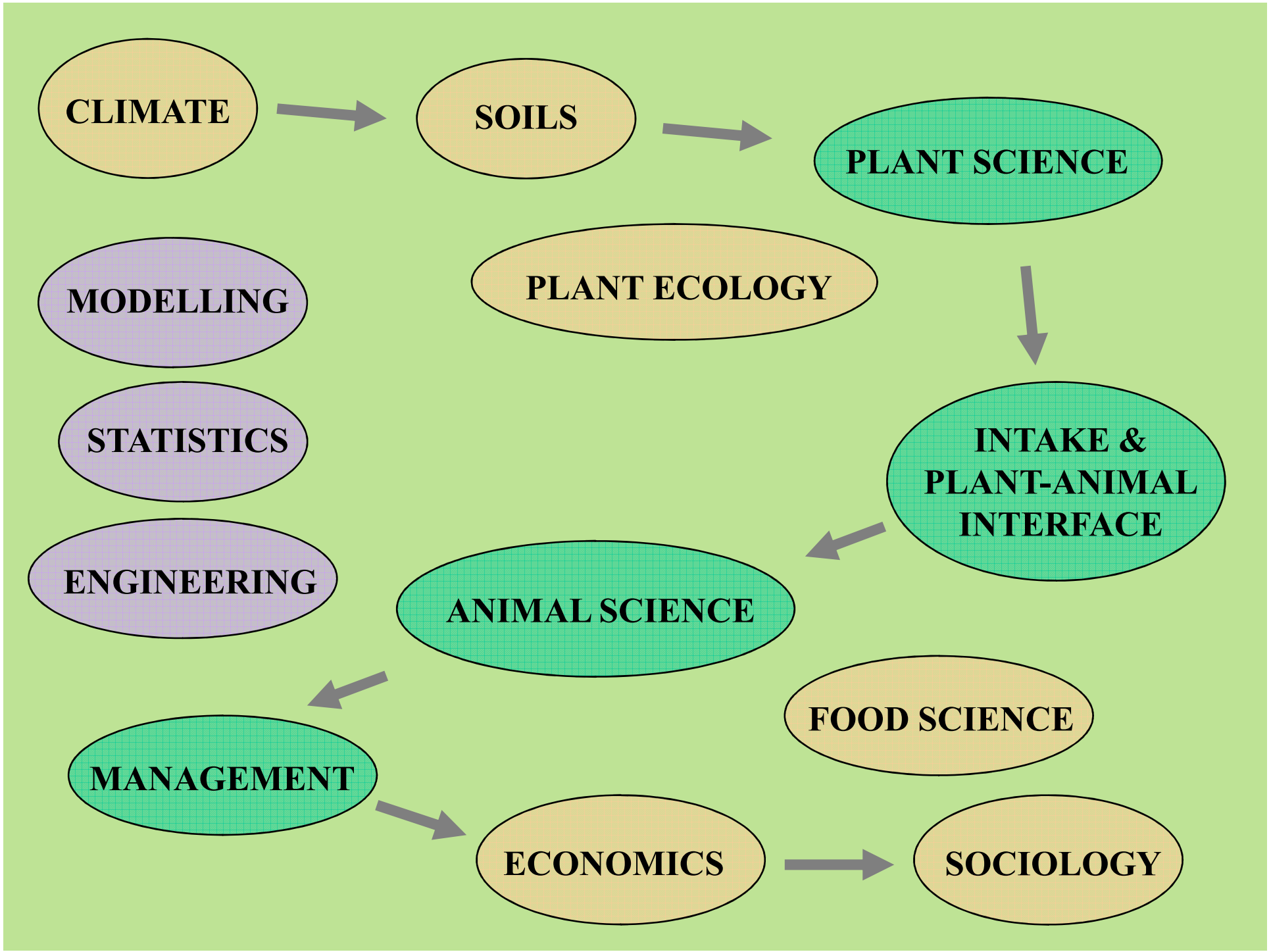
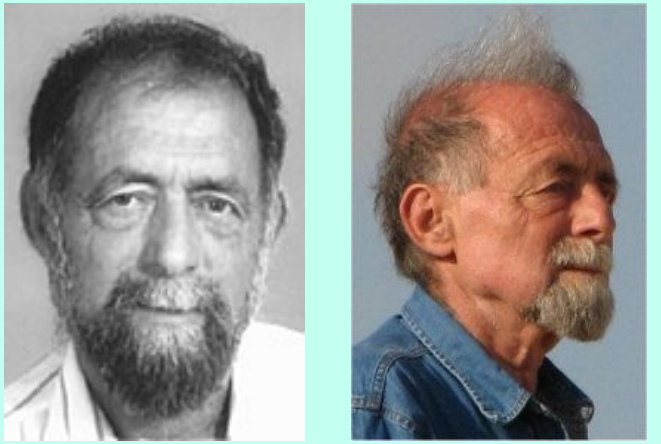

CLIMATE
SOILS
PLANT SCIENCE
MODELLING
PLANT ECOLOGY
STATISTICS
INTAKE & PLANT-ANIMAL INTERFACE
ENGINEERING
ANIMAL SCIENCE
FOOD SCIENCE
MANAGEMENT
ECONOMICS
SOCIOLOGY

Noy-Meir's model


1941 - 2009

Application of predator-prey theory to grazing systems dynamics and stability

Noy-Meir, I. (1975) Stability of grazing systems: an application of predator-prey graphs. Journal of Ecology, 63 (2) 459-481.

"*Everything should be made as simple as possible … but not simpler.*" Albert Einstein

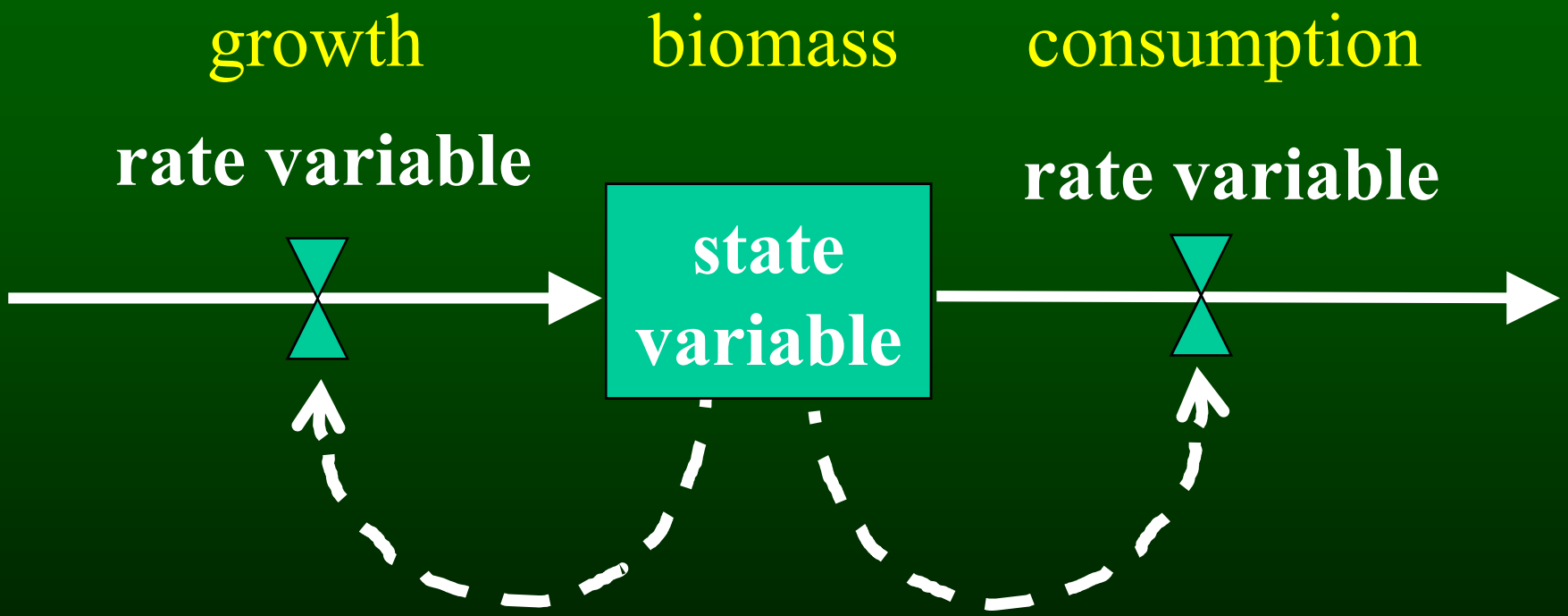
A simple two-function model of grazing system dynamics

The key processes:
growth and consumption

The growth function:
logistic

The consumption function:
inverted exponential

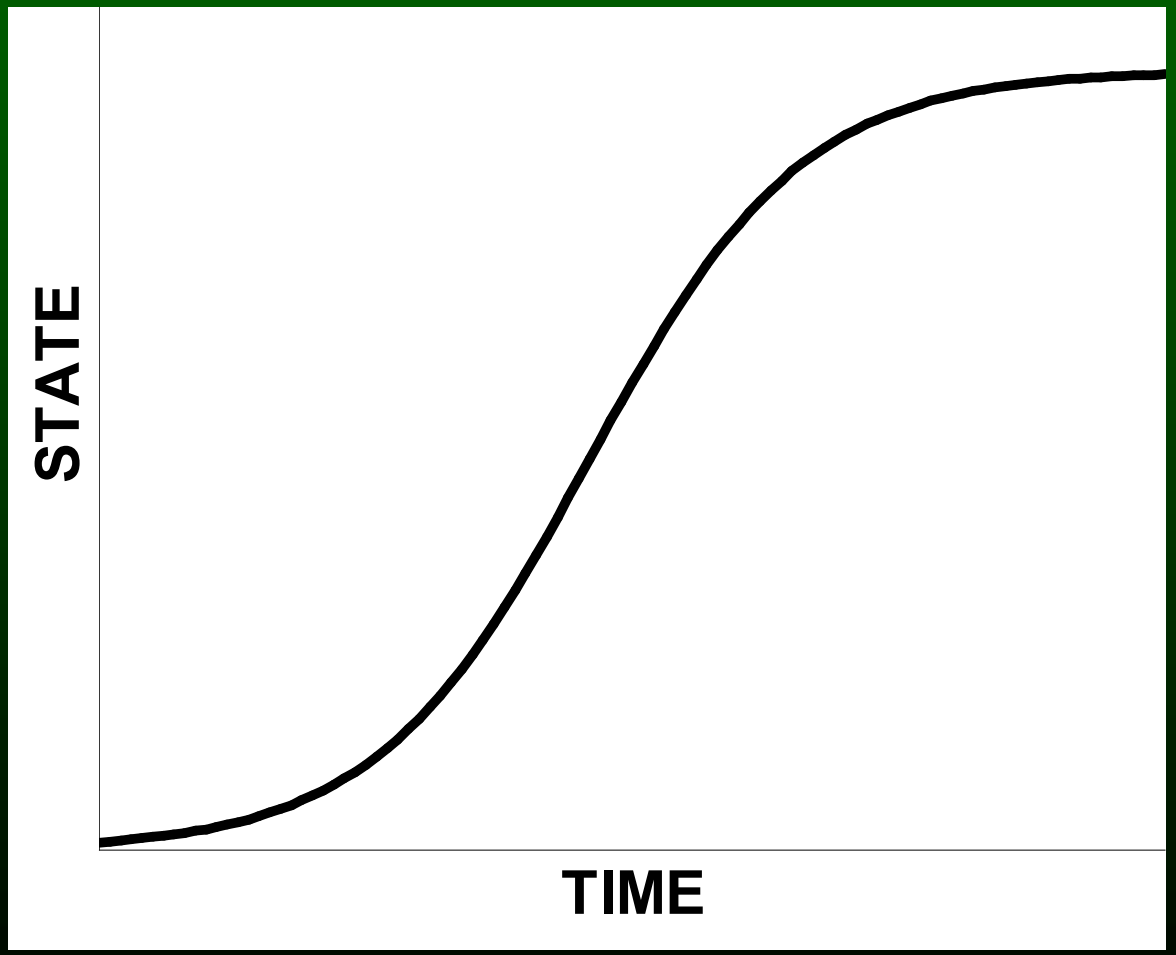
State-rate relationships



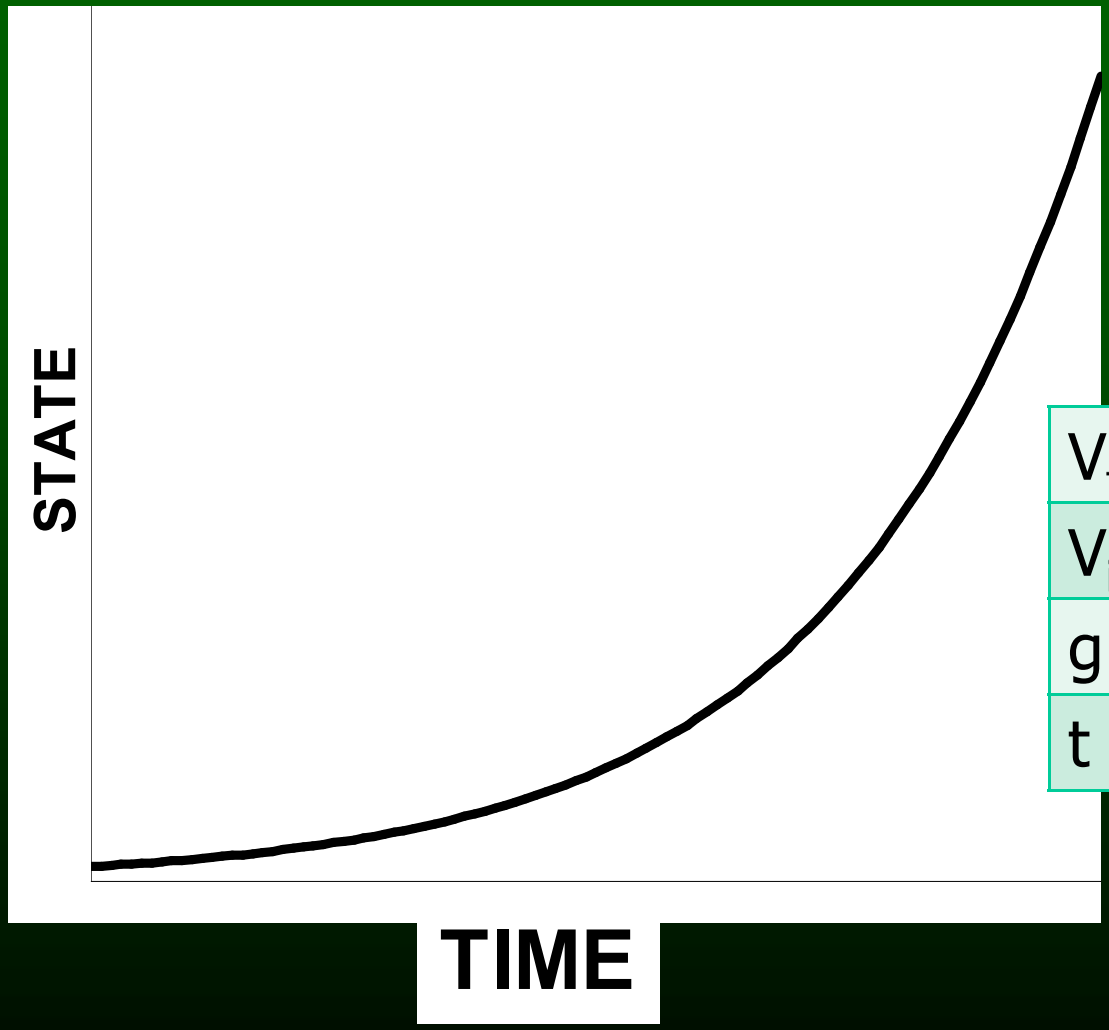
"*Do not worry about your difficulties in Mathematics. I can assure you mine are still greater.*" Albert Einstein

Logistic function

State variable = Herbage mass per unit area = V



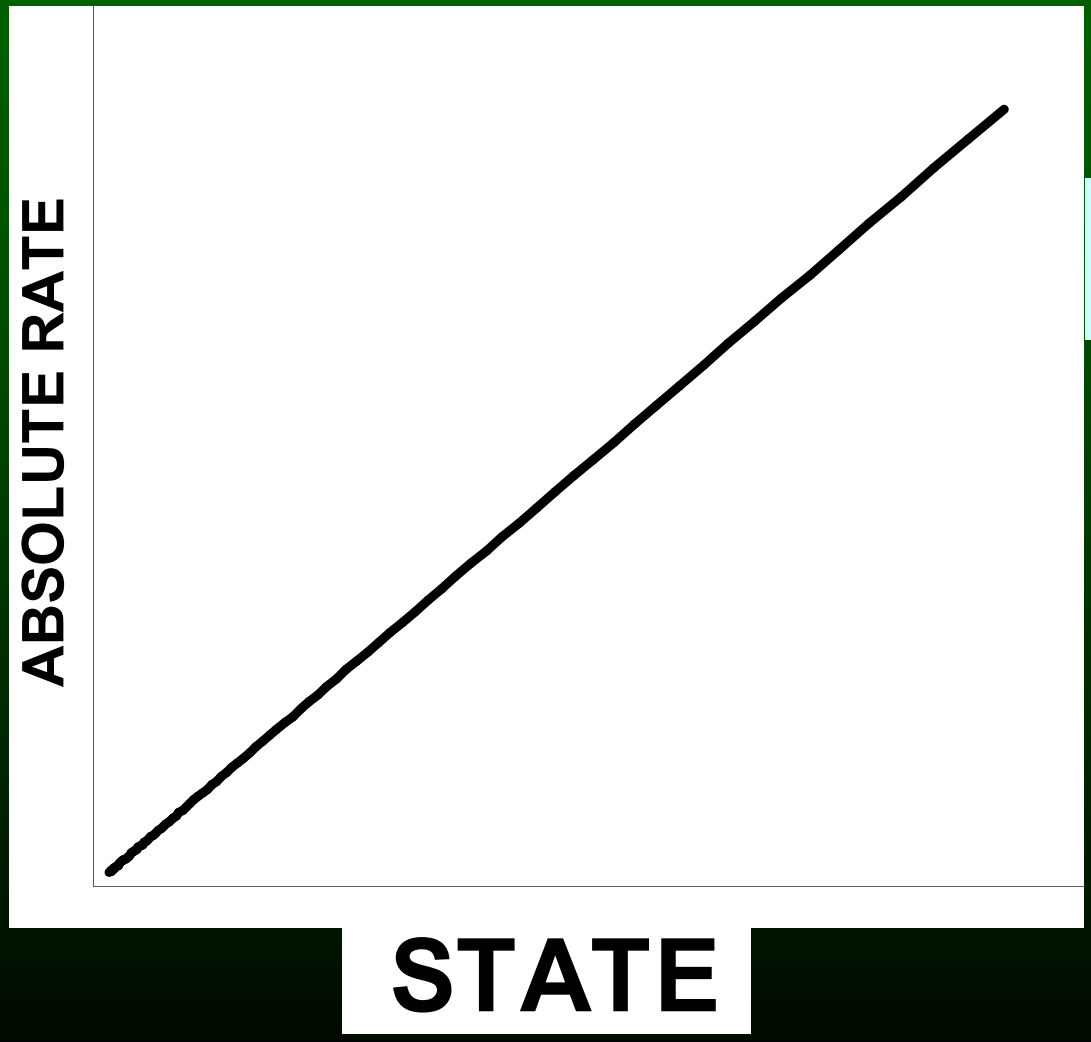
Exponential function: State versus time



$$V_t = V_i e^{g t}$$

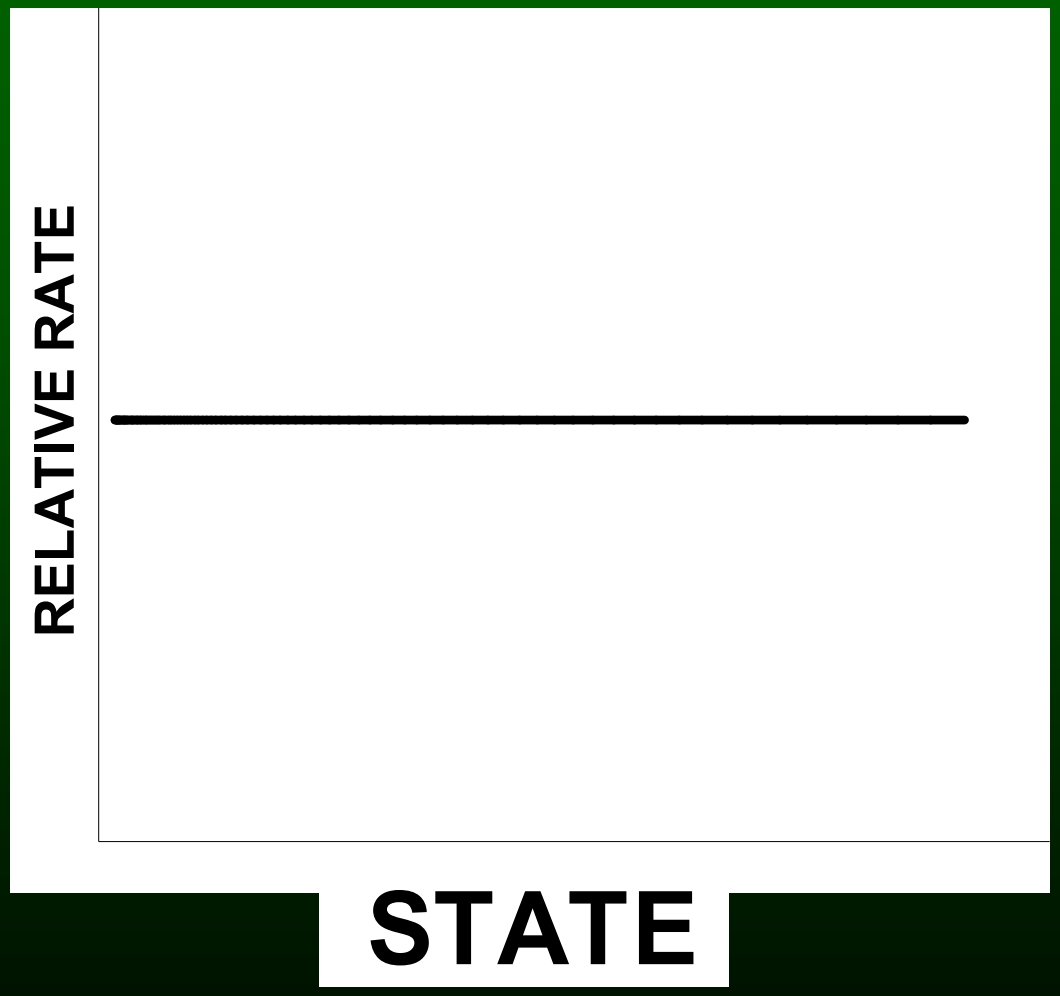
V_t	V at any time t
V_i	initial V
g	relative growth rate
t	time

Exponential function: State – rate relationship

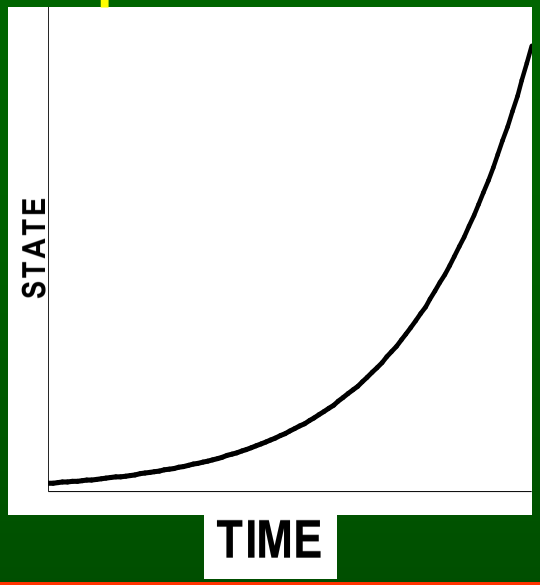


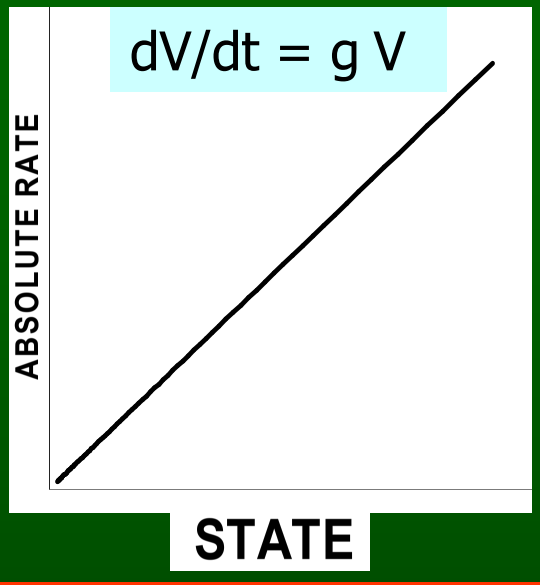
$$dV/dt = g\,V$$

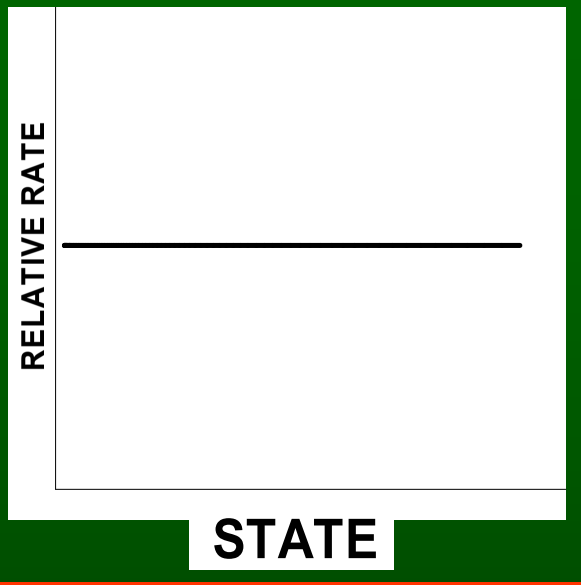
Exponential function: State – relative rate relationship



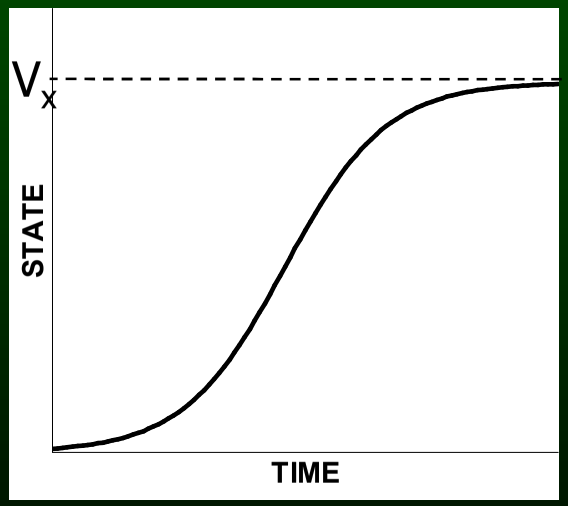
Exponential function

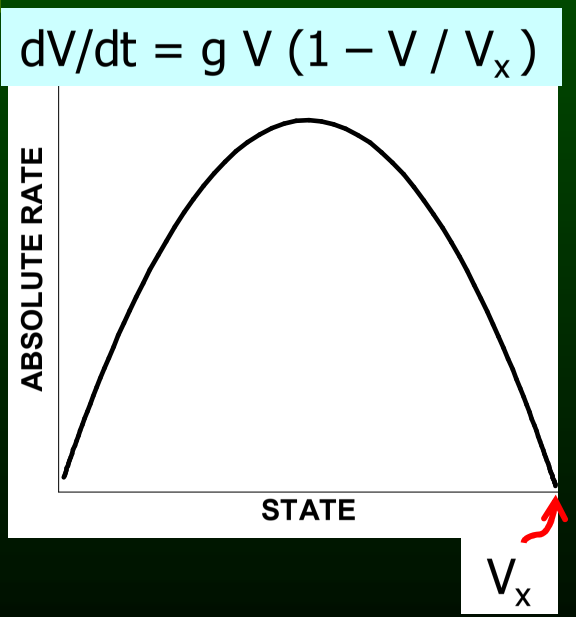


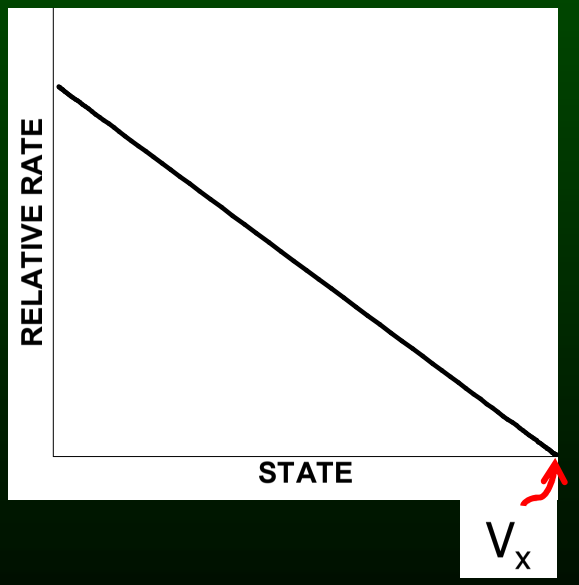




Logistic function



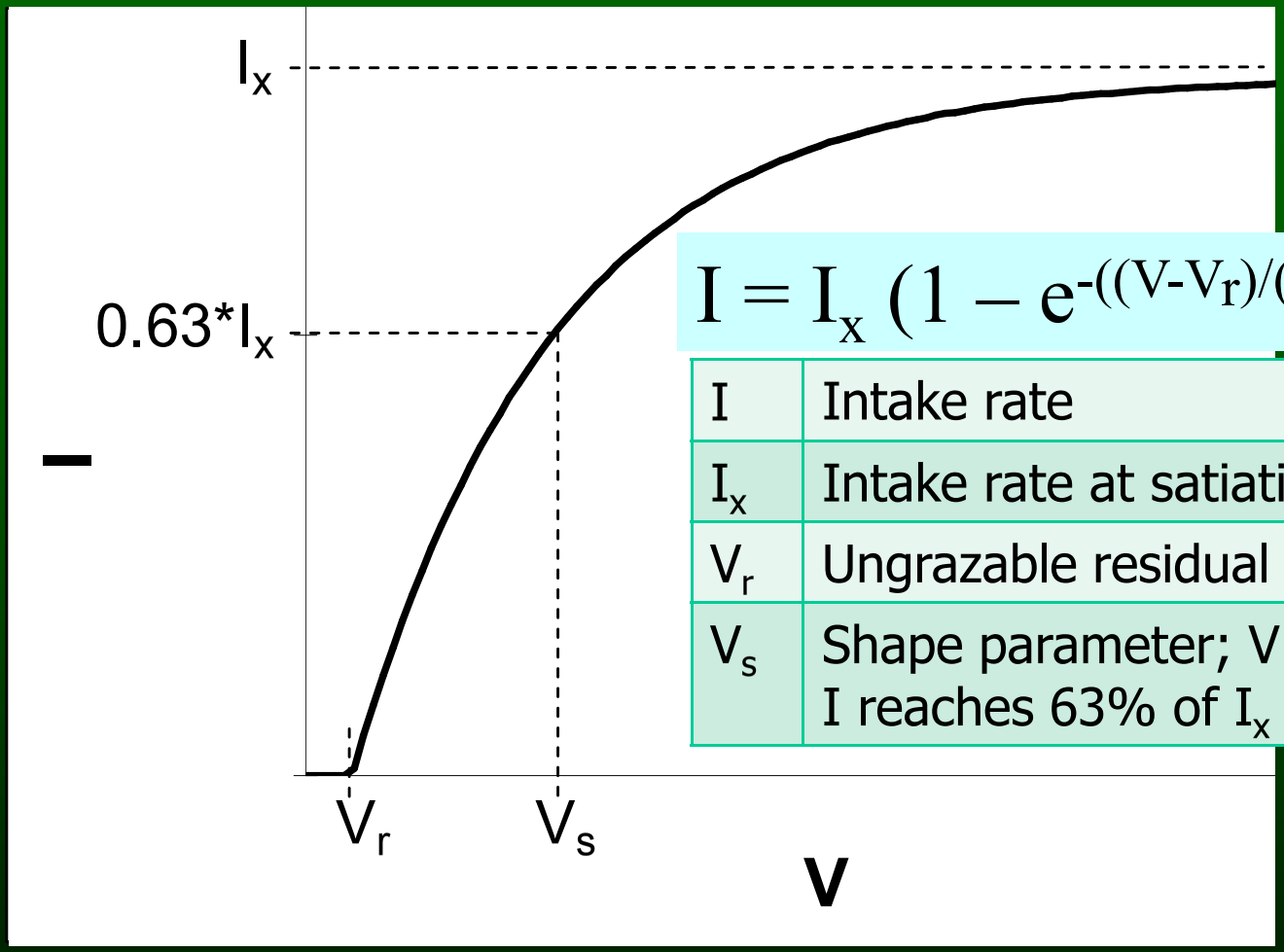




The consumption function

Rate variable

Rate of herbage intake per animal per day

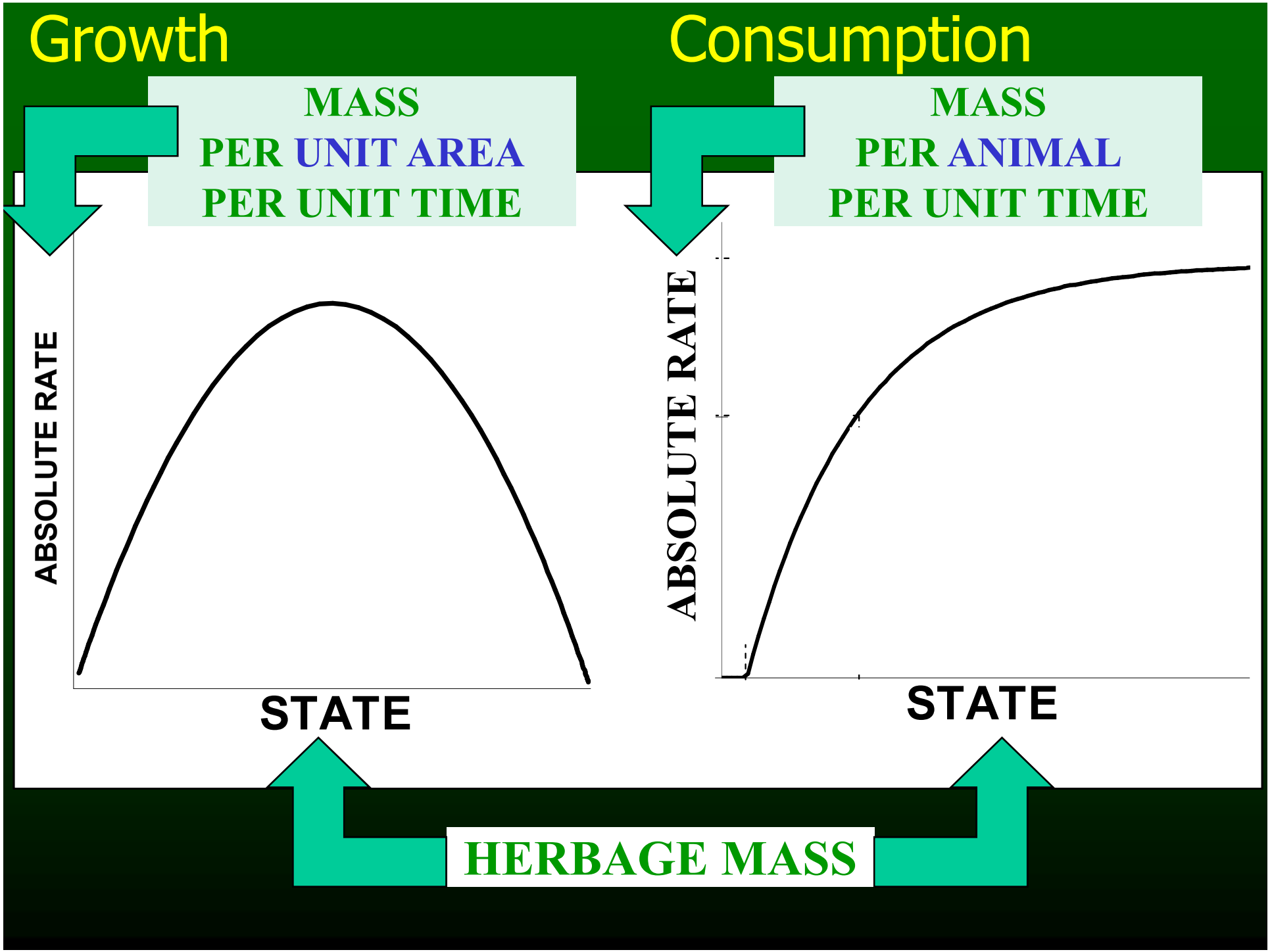


$$I = I_x \left(1 - e^{-((V-V_r)/(V_s-V_r))}\right)$$

I	Intake rate
I_x	Intake rate at satiation
V_r	Ungrazable residual V
V_s	Shape parameter; V at which I reaches 63% of I_x

State variable

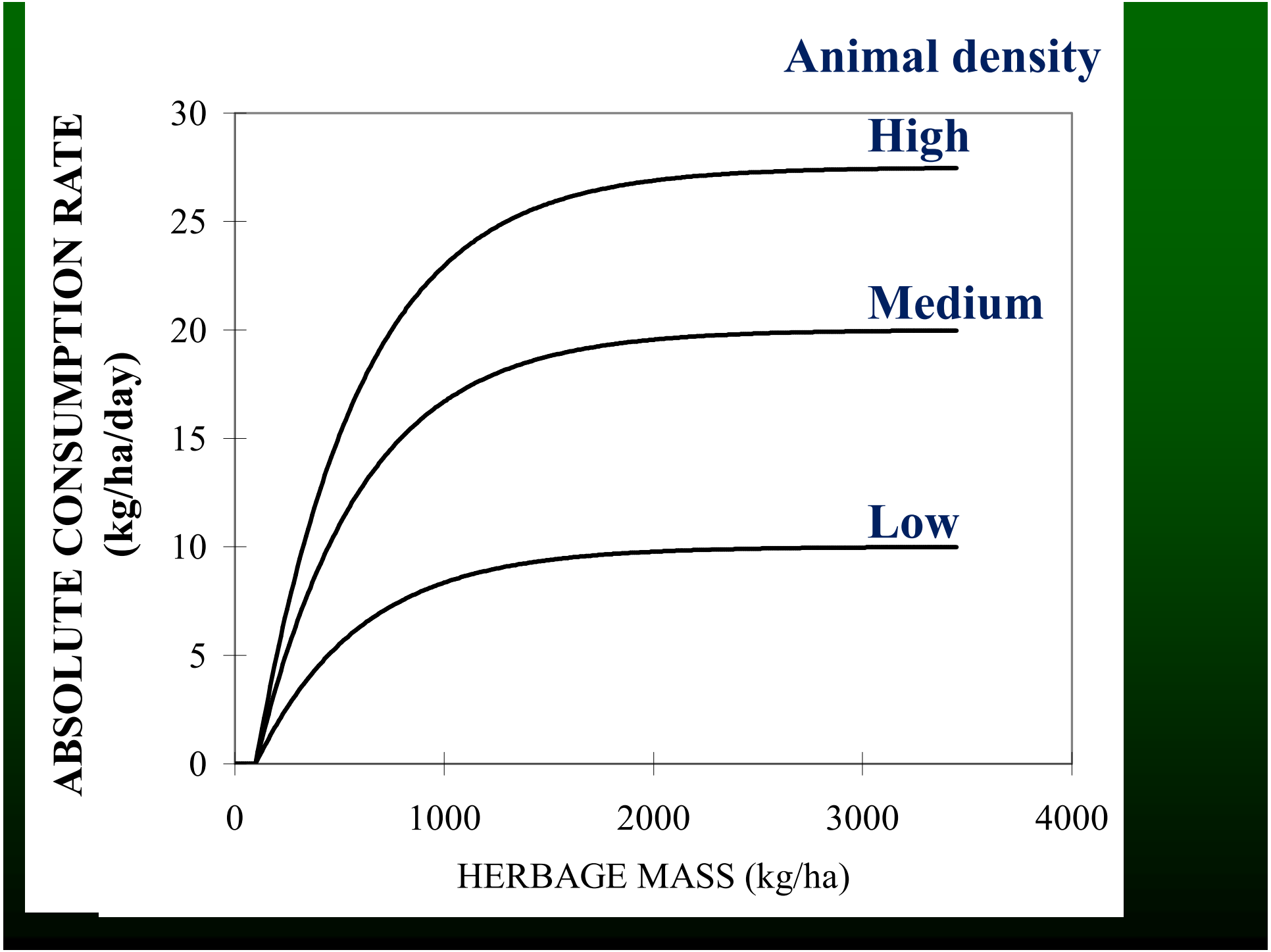
Quantity of herbage per unit area


Growth
Consumption
MASS
PER UNIT AREA
PER UNIT TIME
MASS
PER ANIMAL
PER UNIT TIME
ABSOLUTE RATE
STATE
ABSOLUTE RATE
STATE
HERBAGE MASS

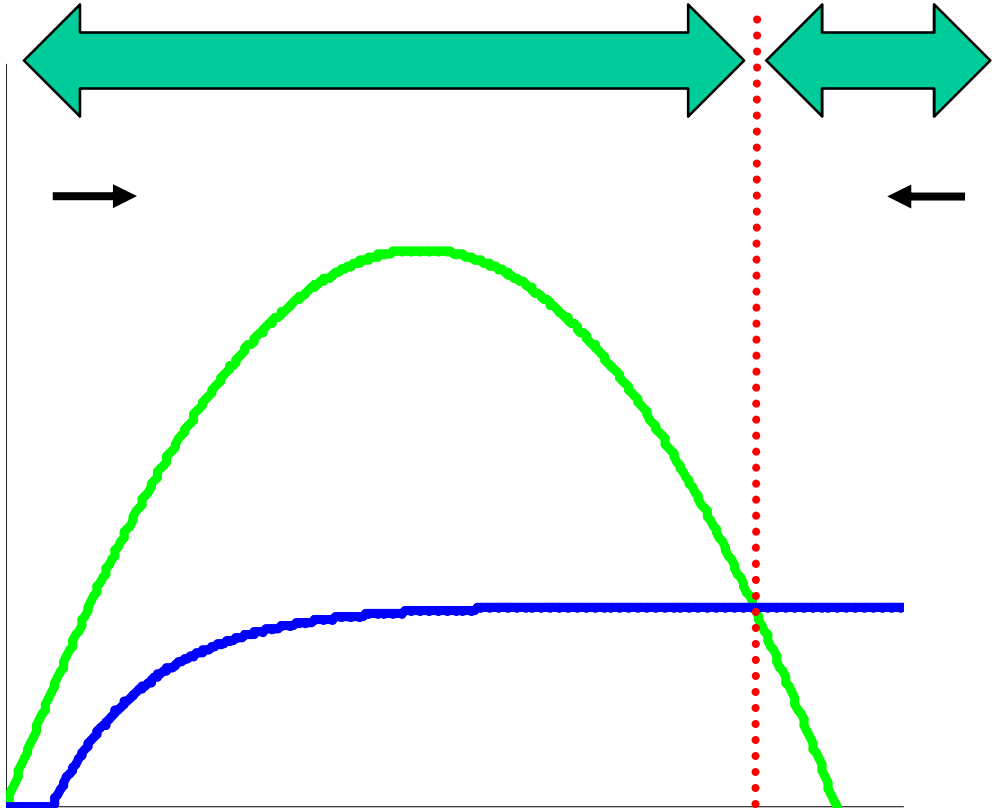
Key management control #1:

Number of animals per unit area
= animal density
= stocking rate

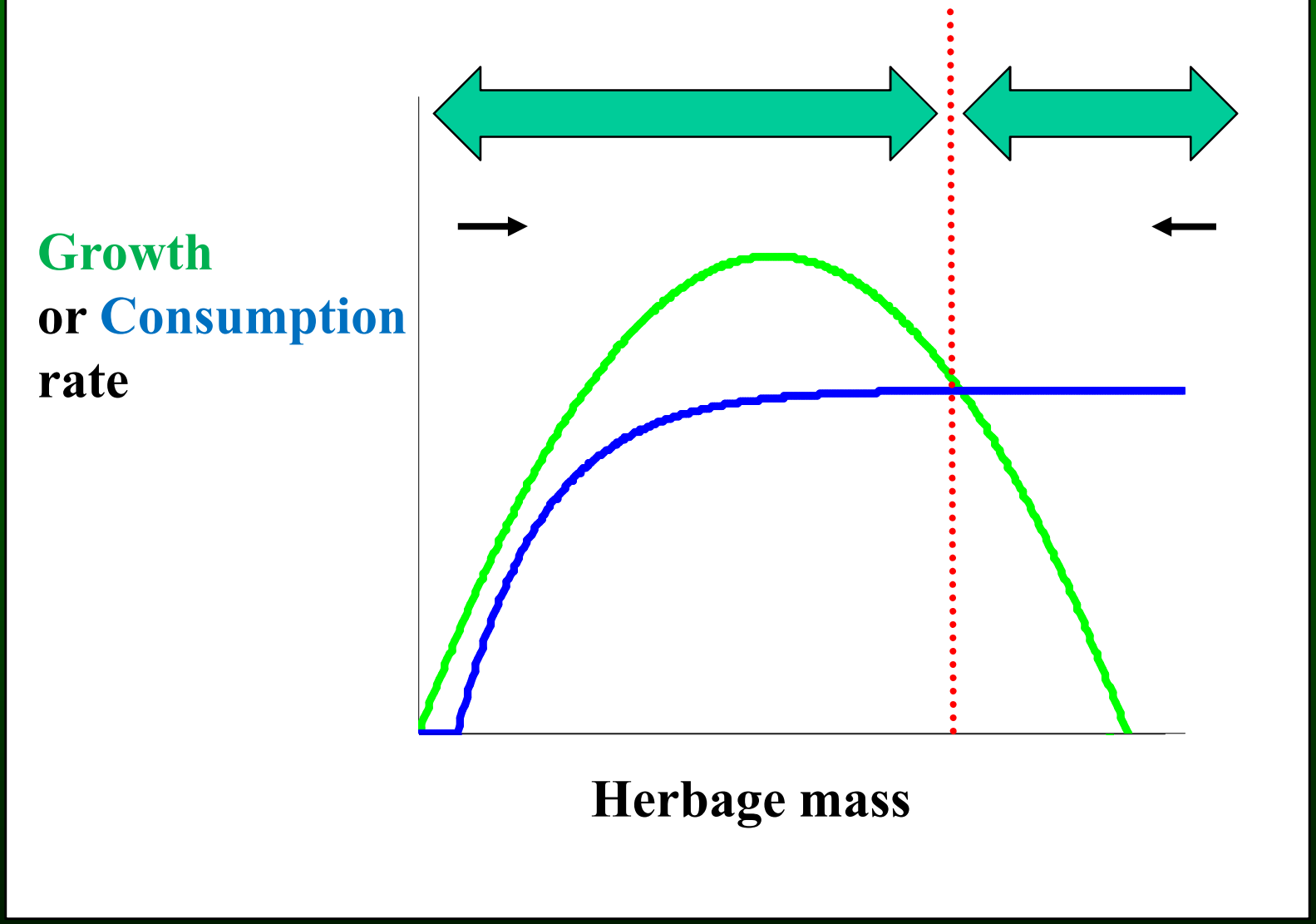
Consumption rate	×	**Animal density**	=	**Consumption rate**
Mass per animal per unit time		**Animals per unit area**		**Mass per unit area per unit time**

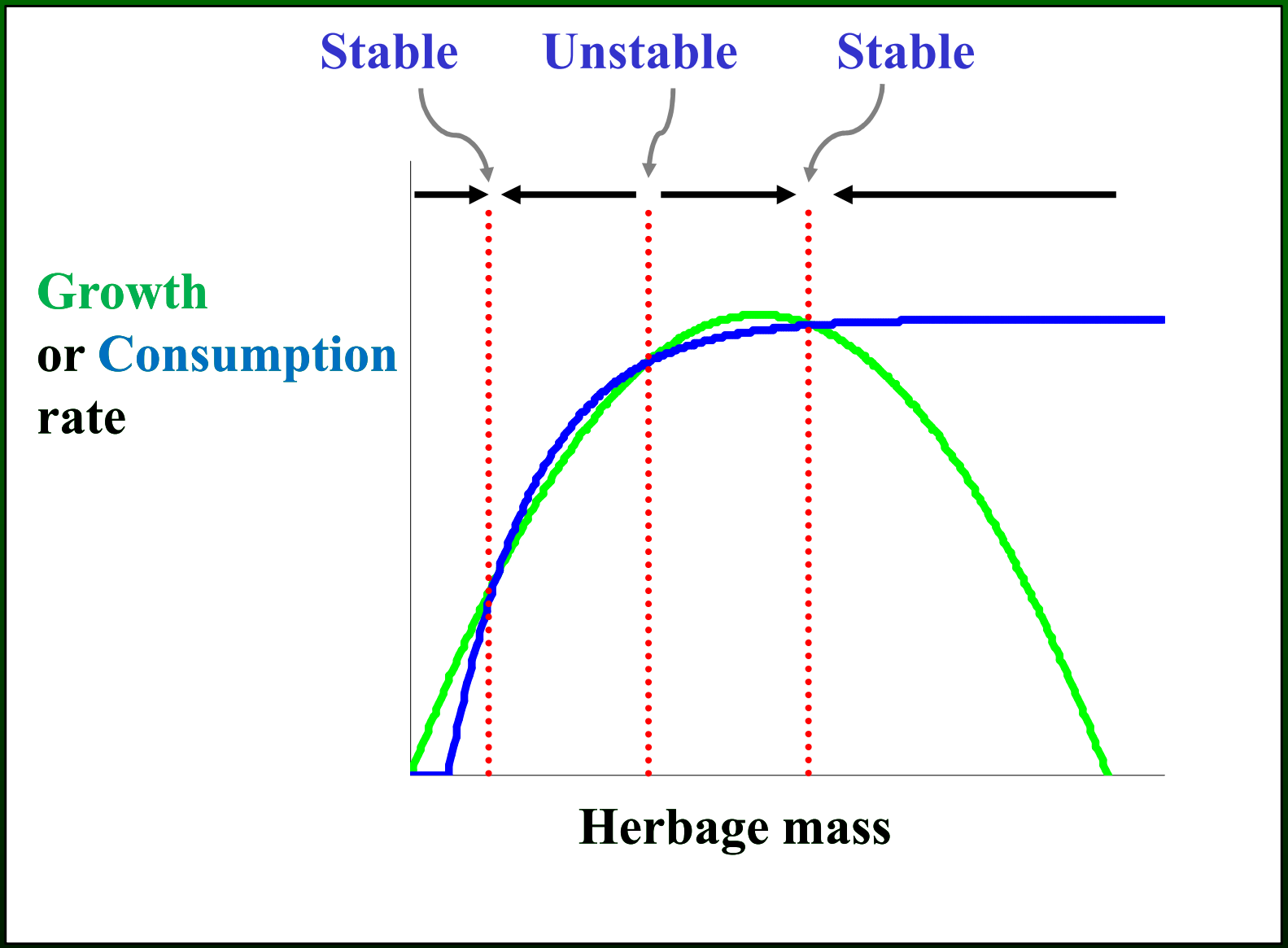

Animal density
High
Medium
Low
ABSOLUTE CONSUMPTION RATE
(kg/ha/day)
30
25
20
15
10
5
0
0
1000
2000
3000
4000
HERBAGE MASS (kg/ha)

Growth
or Consumption
rate

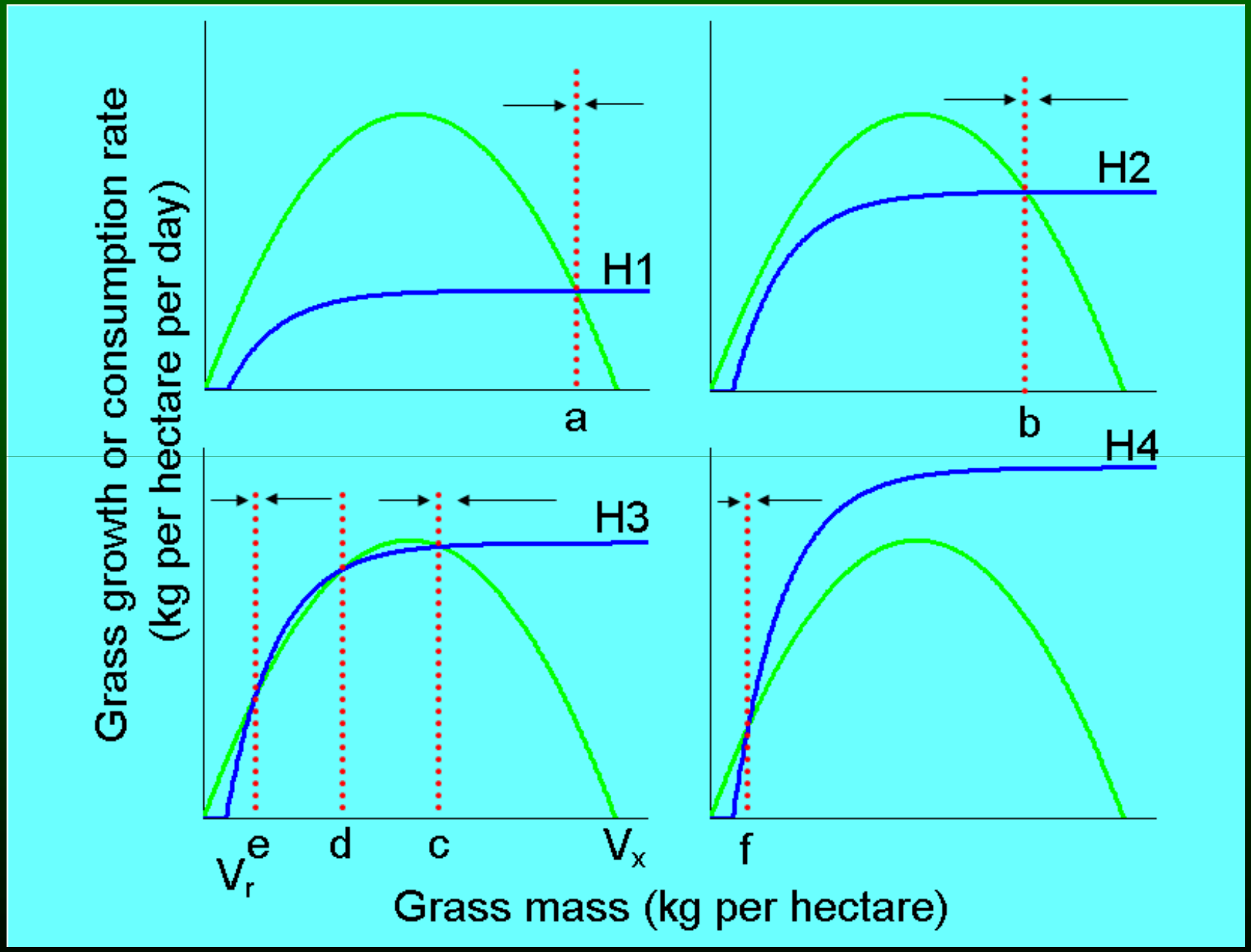


Herbage mass


Growth
or Consumption
rate
Herbage mass


Stable
Unstable
Stable
Growth
or Consumption
rate
Herbage mass

"continuous"


Grass growth or consumption rate
(kg per hectare per day)
H1
a
H2
b
H3
H4
e
d
c
V_r
V_x
f
Grass mass (kg per hectare)

Measures of system performance

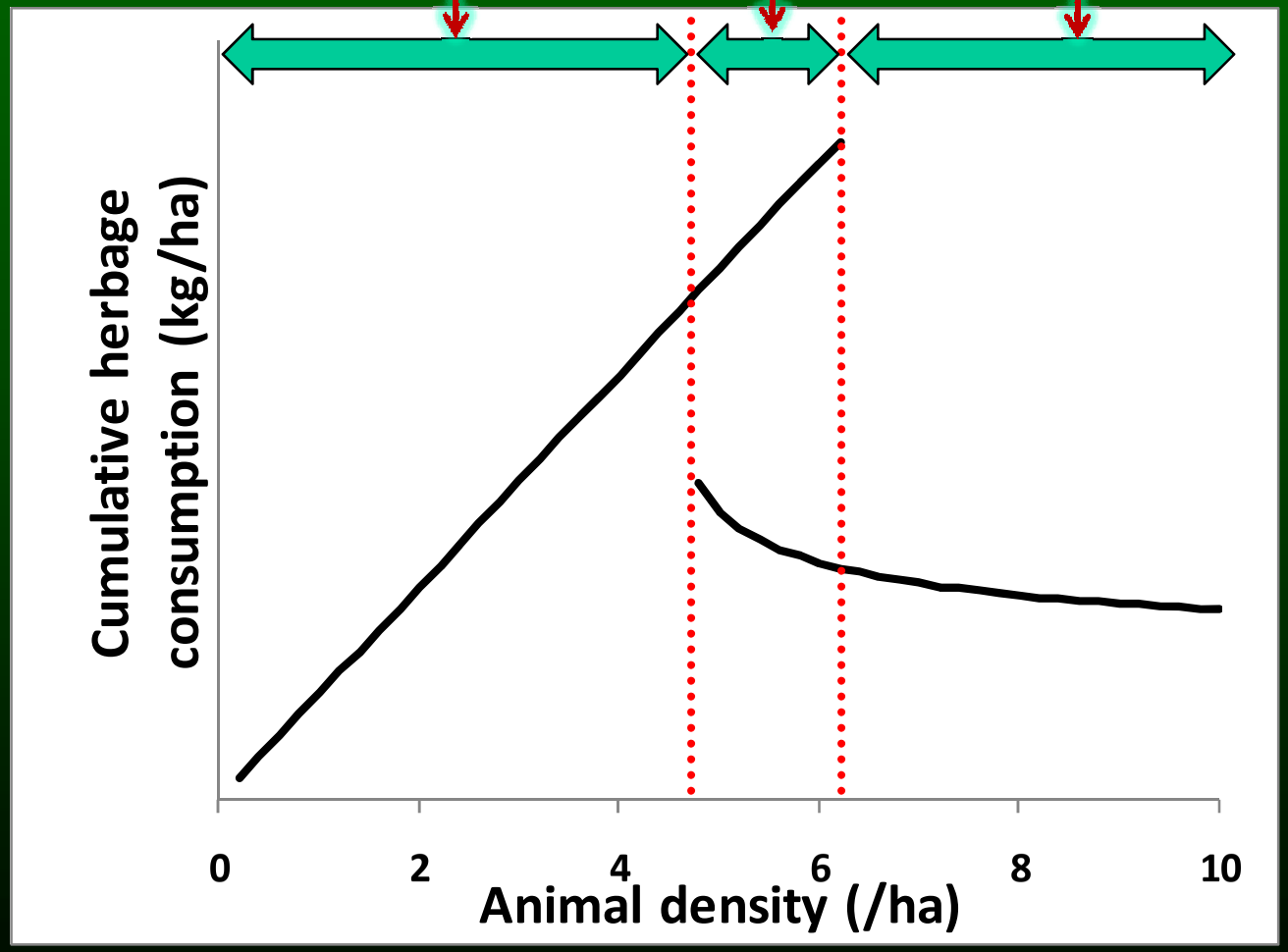
- Cumulative herbage consumption per unit area
- Biomass at equilibrium
- Primary productivity
- Cumulative herbage consumption per animal
- Efficiency of utilization

Cumulative herbage consumption PER UNIT AREA

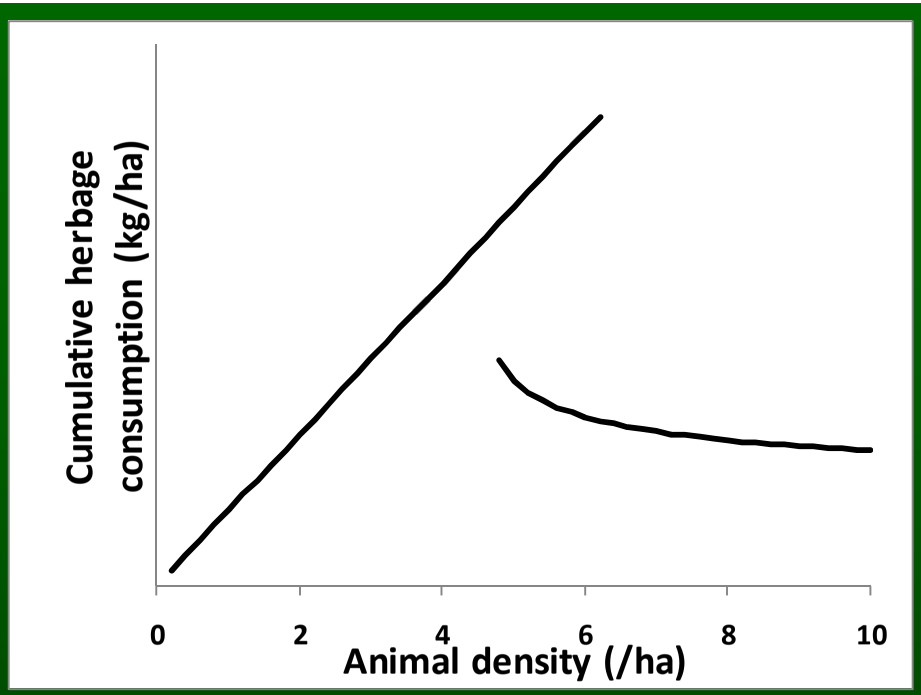
Single stable equilibrium at high V

Alternate stable states

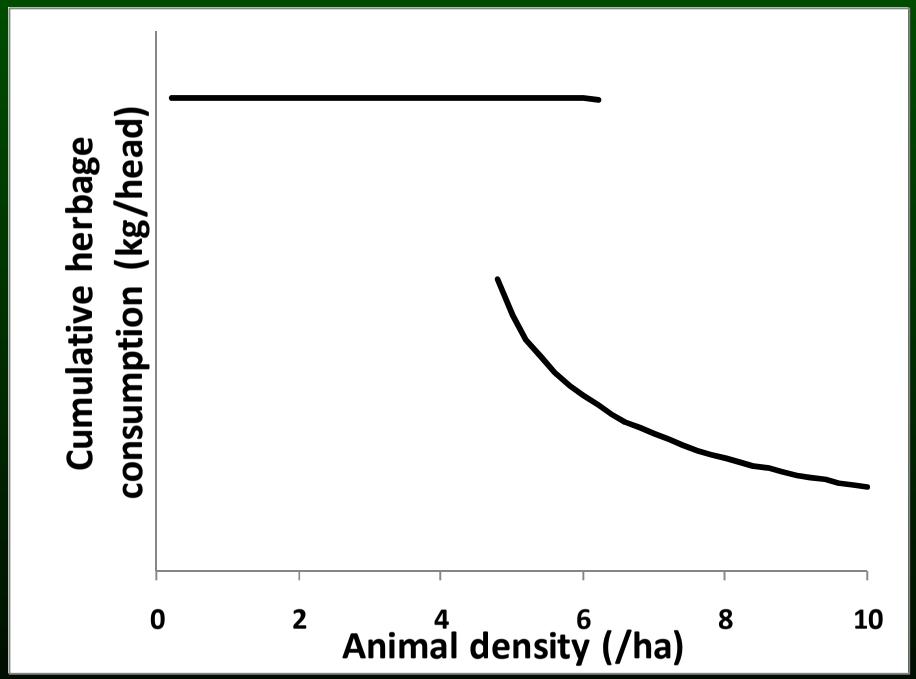
Single stable equilibrium at low V



Cumulative herbage consumption **PER UNIT AREA**



Cumulative herbage consumption **PER ANIMAL**



Key management control #1:

Number of animals per unit area

= animal density

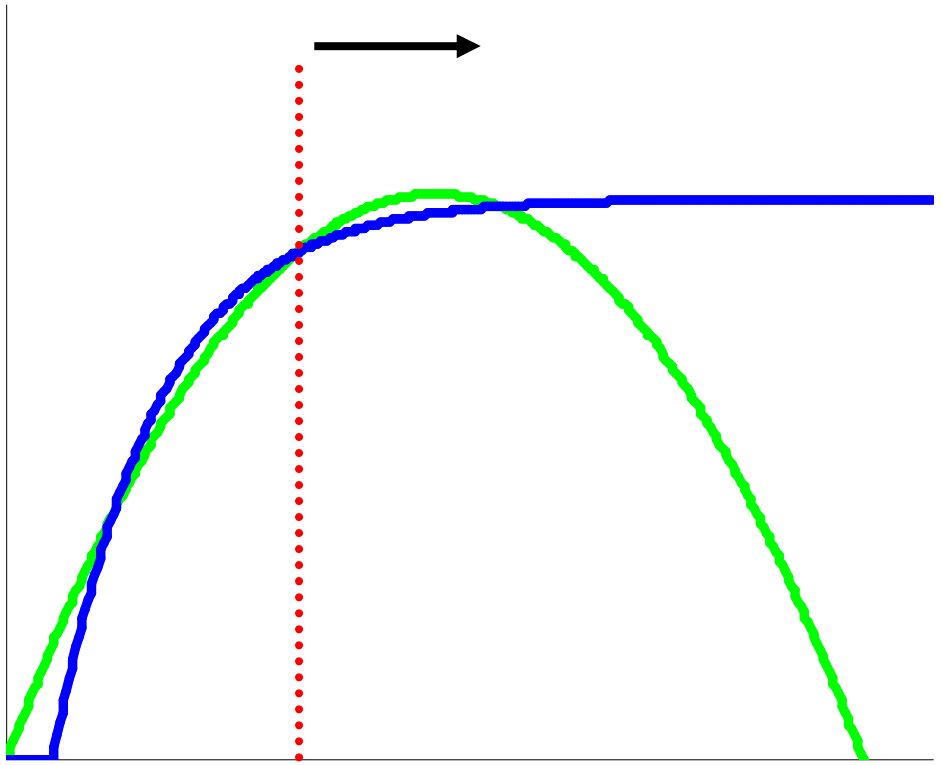
= stocking rate

Key management control #2:

Grazing deferment

(defer: wait, delay)

Growth
or Consumption
rate



Herbage mass

Deferment
Growth only

Grazing
Growth and consumption

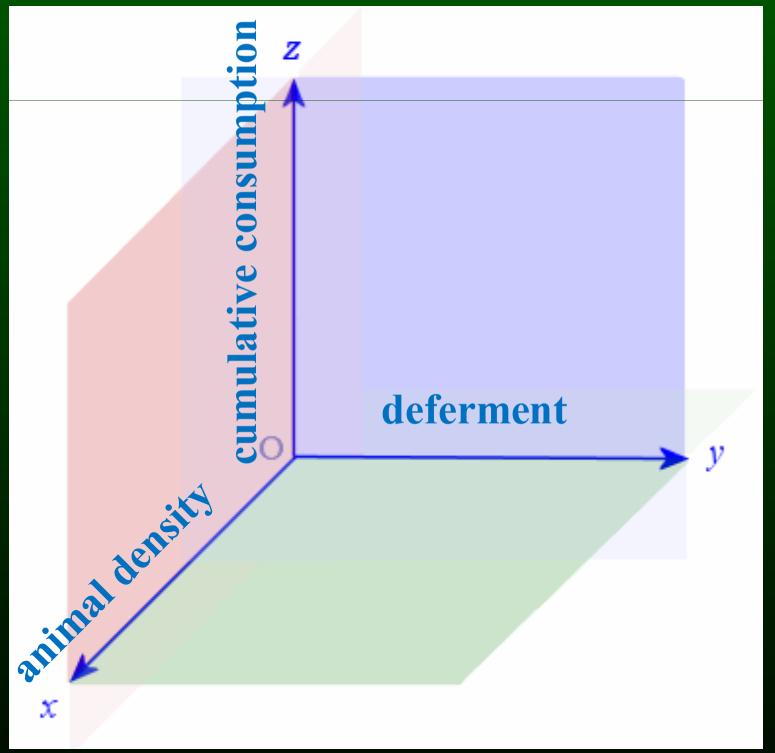
1 150

Day →

Simulation:

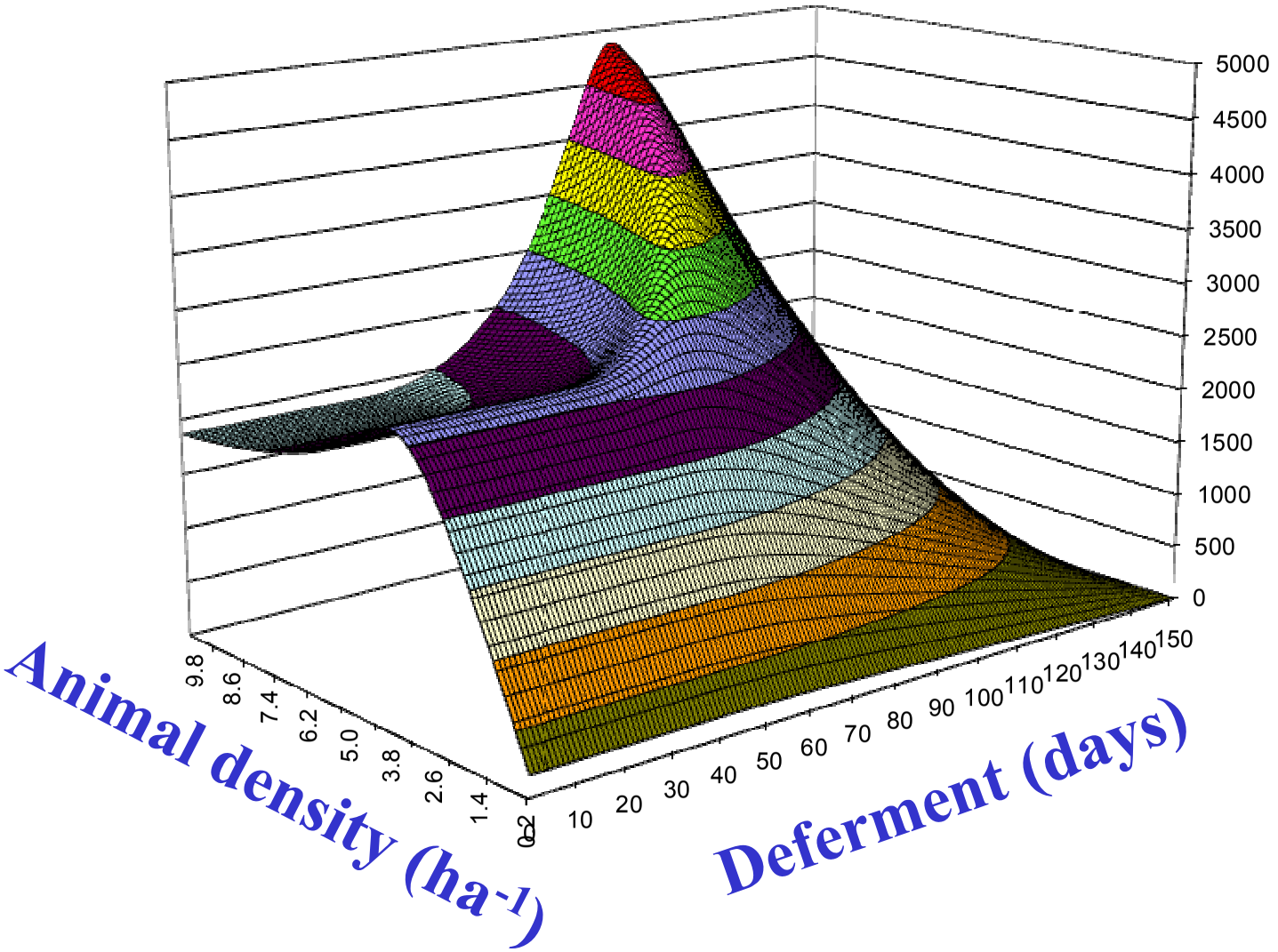
- Set animal density
- Set deferment
- Simulate 150 days of growth and consumption accordingly
- Compute cumulative consumption

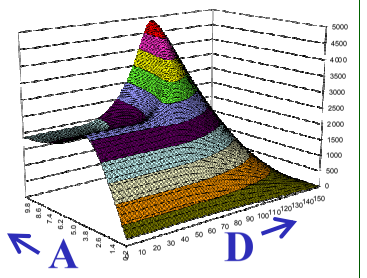
becomes 1 point on surface

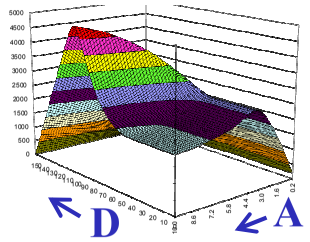


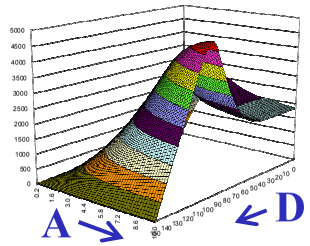
"seasonal"

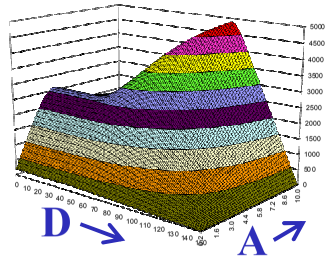
Cumulative herbage consumption per unit area (kg/ha)



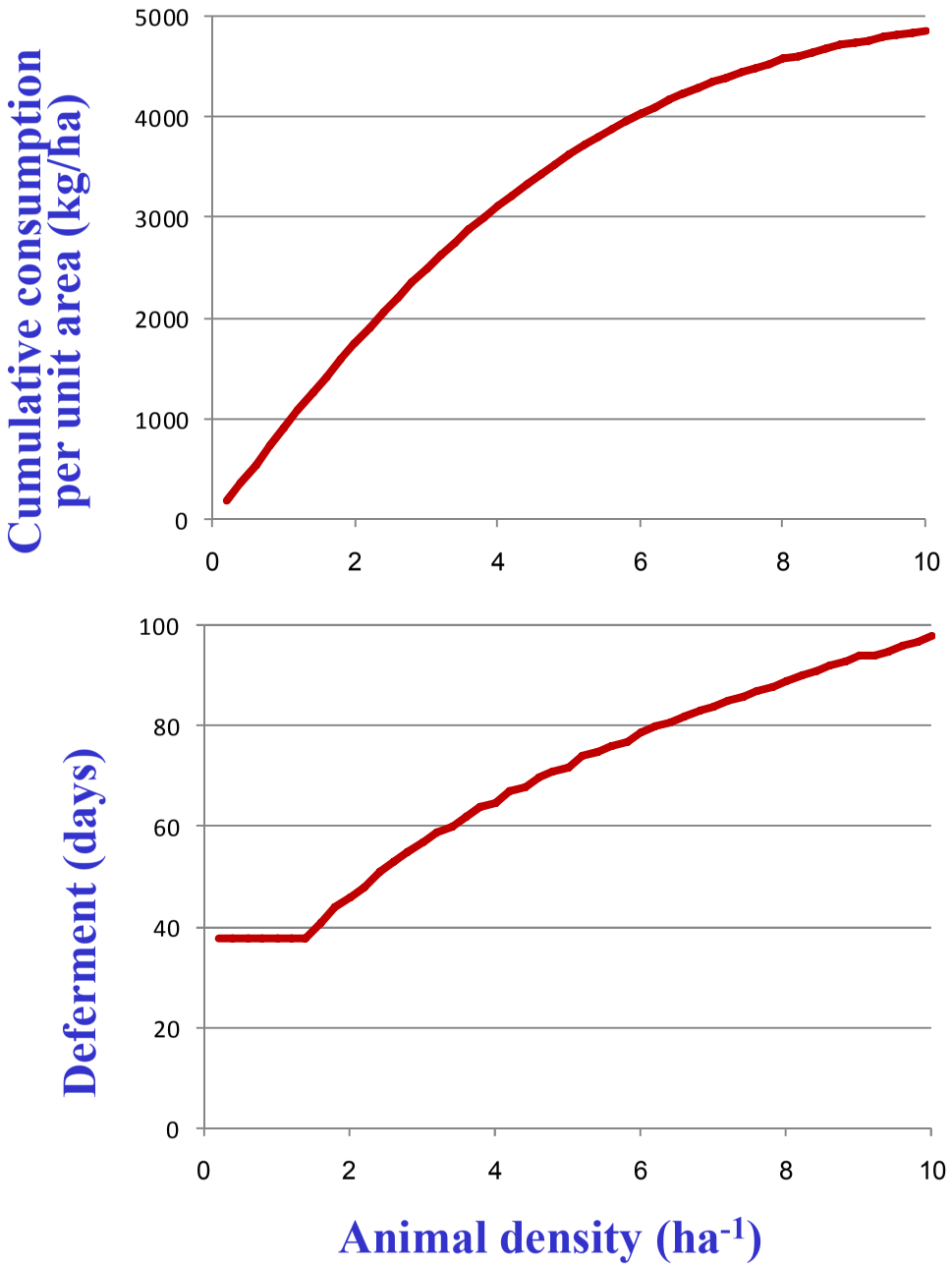




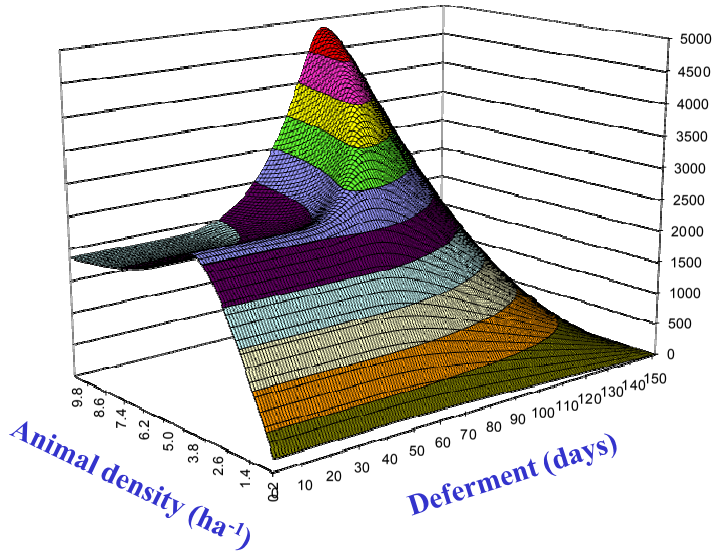




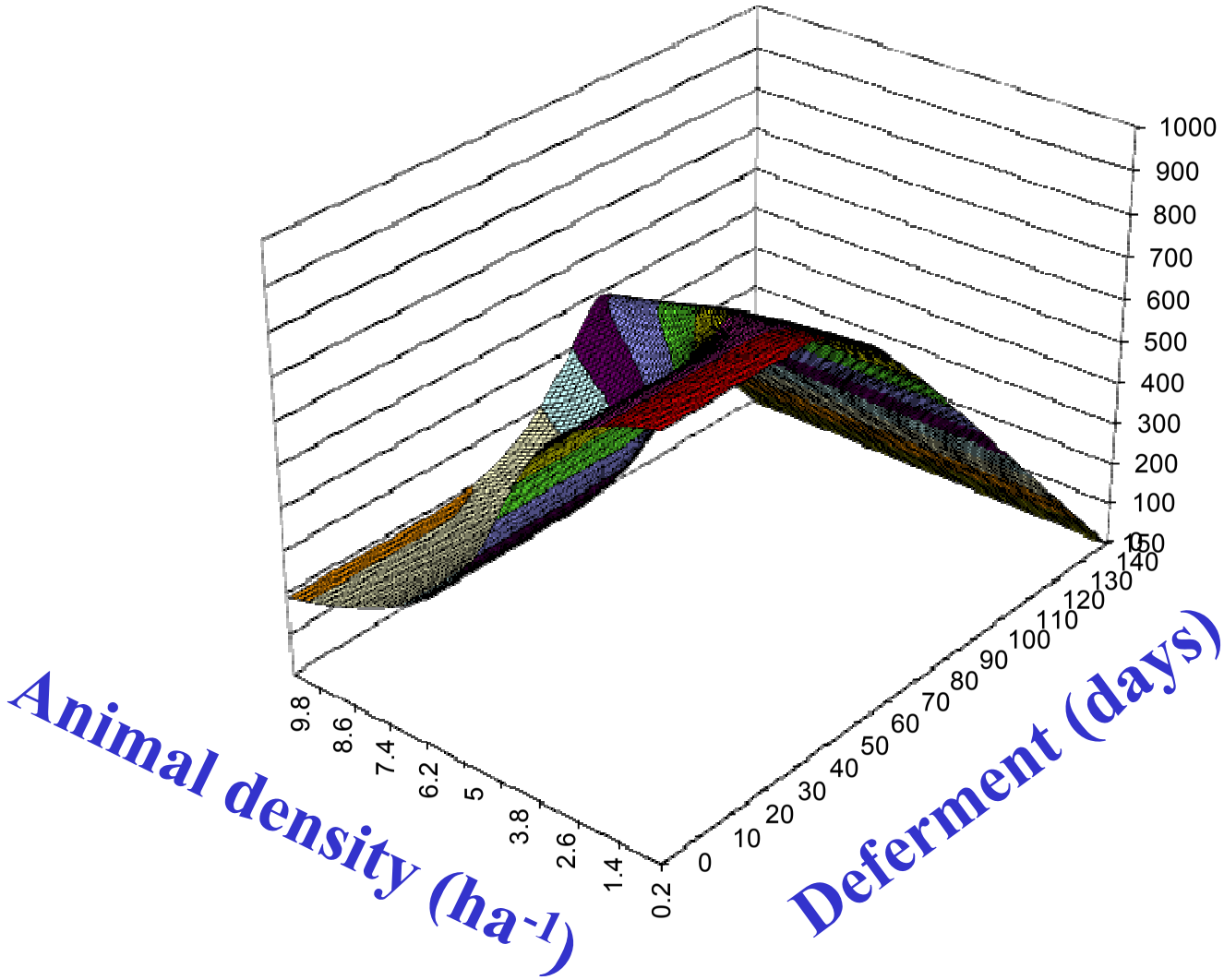
AT THE MAXIMUM

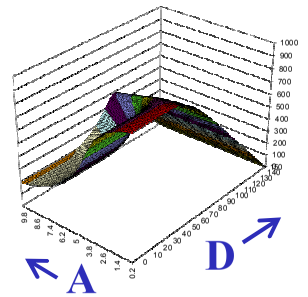


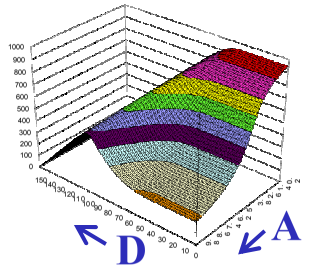
Cumulative consumption per unit area (kg/ha)

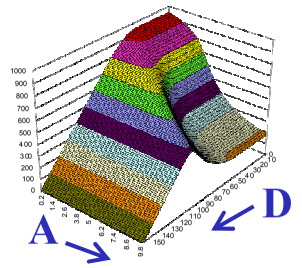


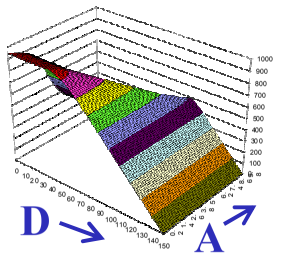
Cumulative herbage consumption per animal (kg)











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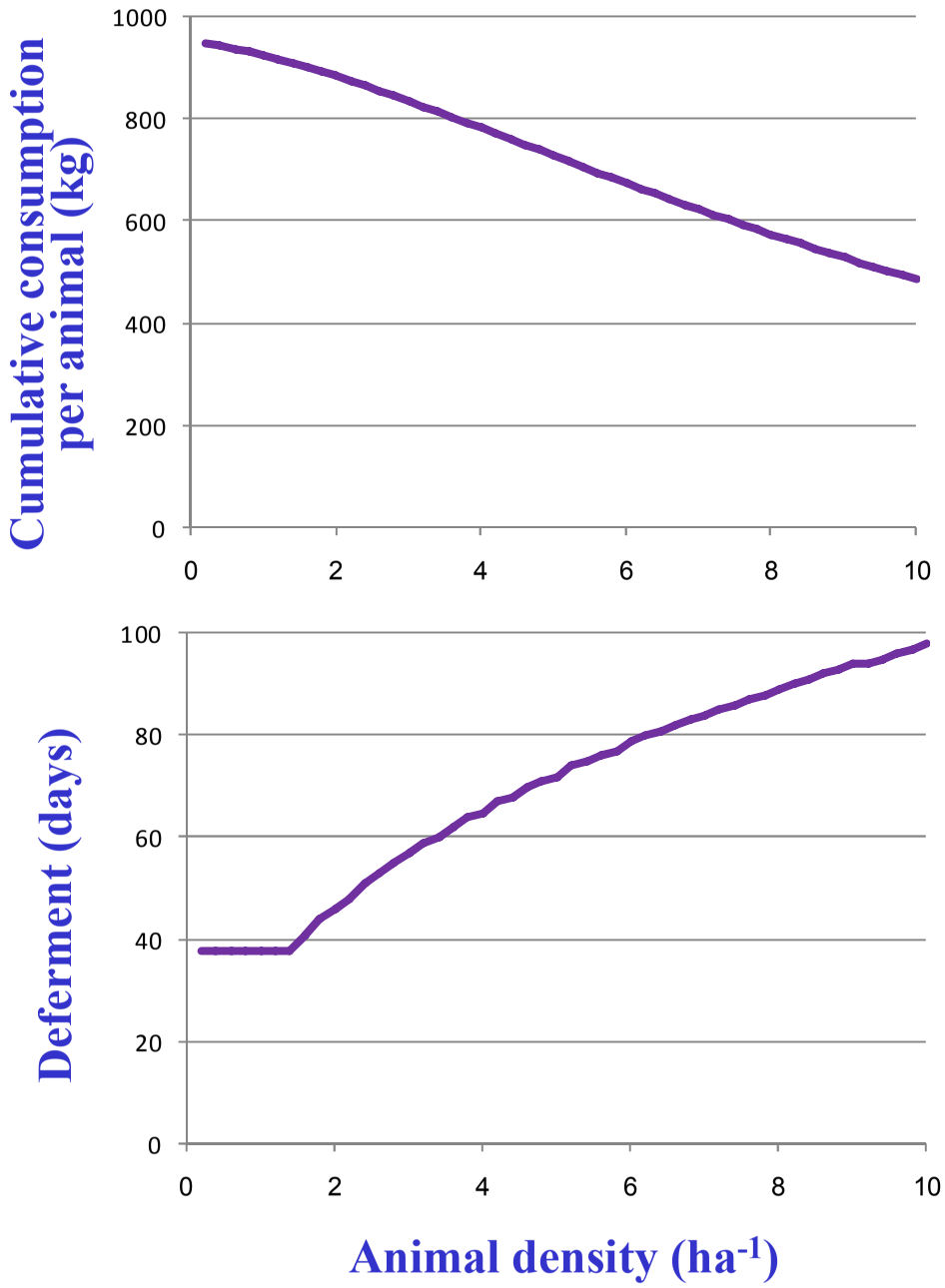
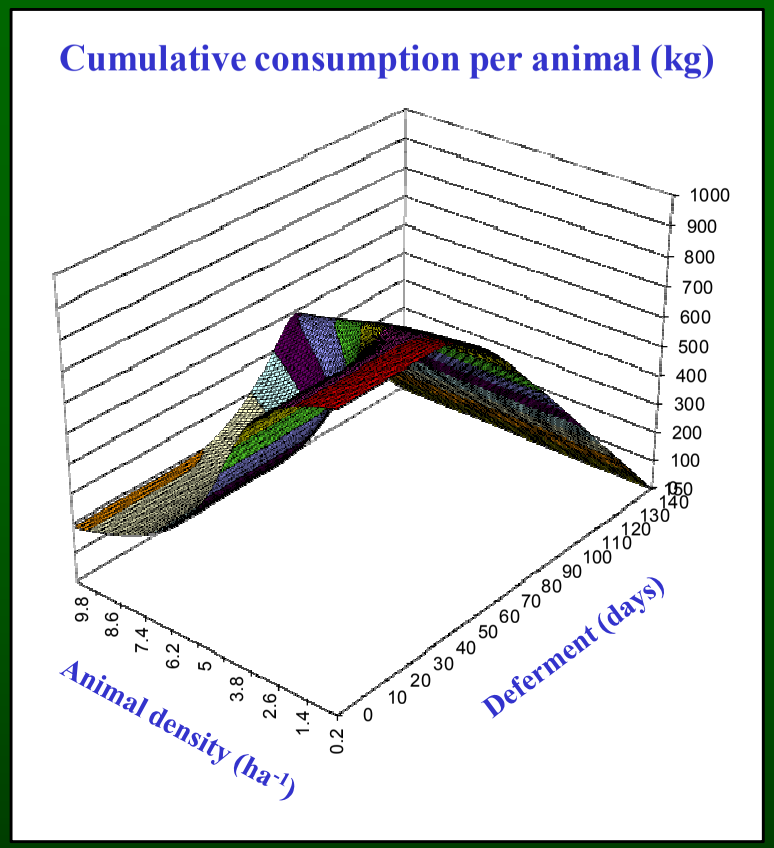




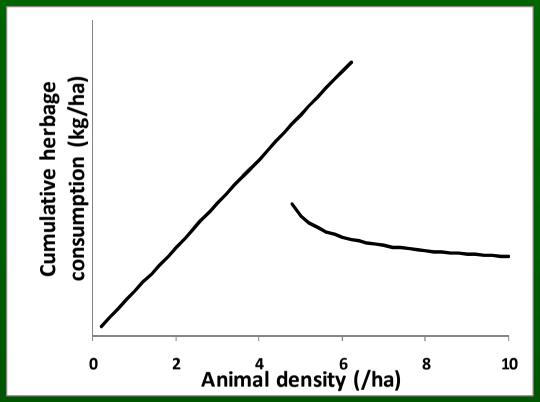
continuous

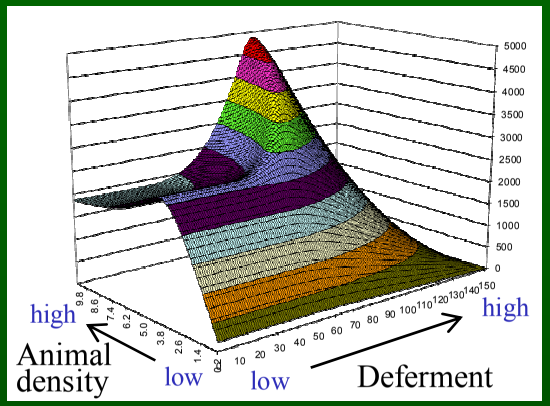
seasonal

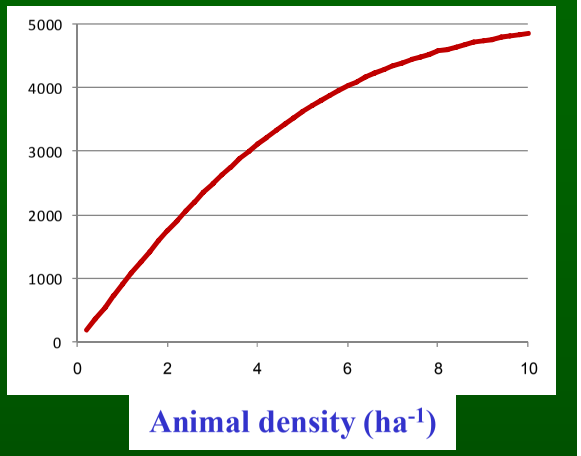
response surface

at maximum

PER UNIT AREA







PER ANIMAL