25 january 2019

Emergent patterns – from field to formulae

Program

12:50	*Robbin Bastiaansen*	**Minimizing biomass loss for banded vegetation in dryland ecosystems**
13:30	*Mara Smeele*	**Nutrient recycling model: a conserved reaction-diffusion system**
14:10	*Anna van der Kaaden*	**Understanding carbonate mound growth**
14:50		***~ Break ~***
15:10	*Roeland van de Vijsel*	**Complex drainage patterns from cascading scale-dependent feedbacks**
15:50	*Olfa Jaïbi*	**Fairy circles: a localised manifestation of multi-front structures in semi-arid ecoystems**

Minimizing biomass loss for banded vegetation in dryland ecosystems

Robbin Bastiaansen

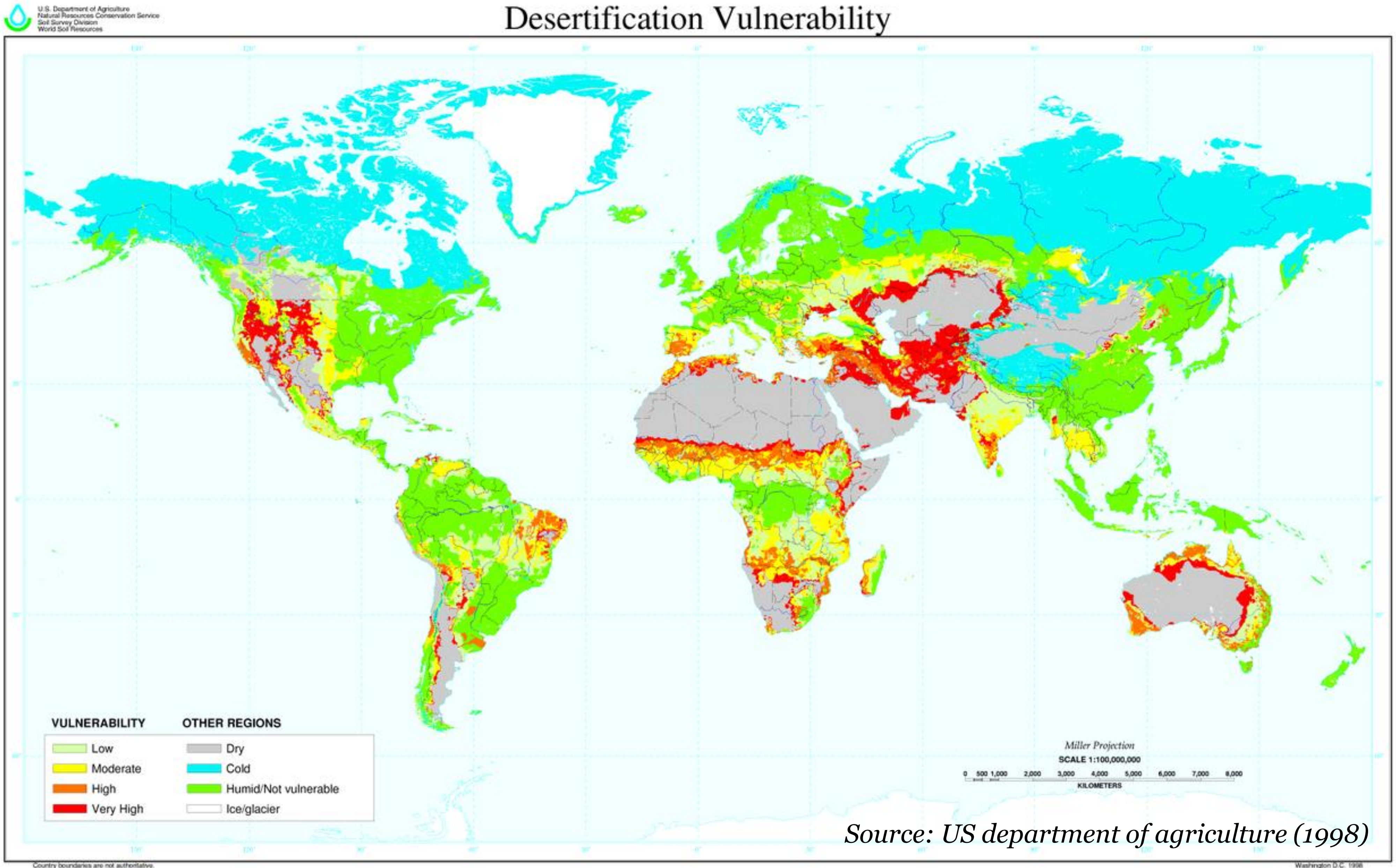
25 January 2019

Universiteit Leiden
The Netherlands

The desertification process

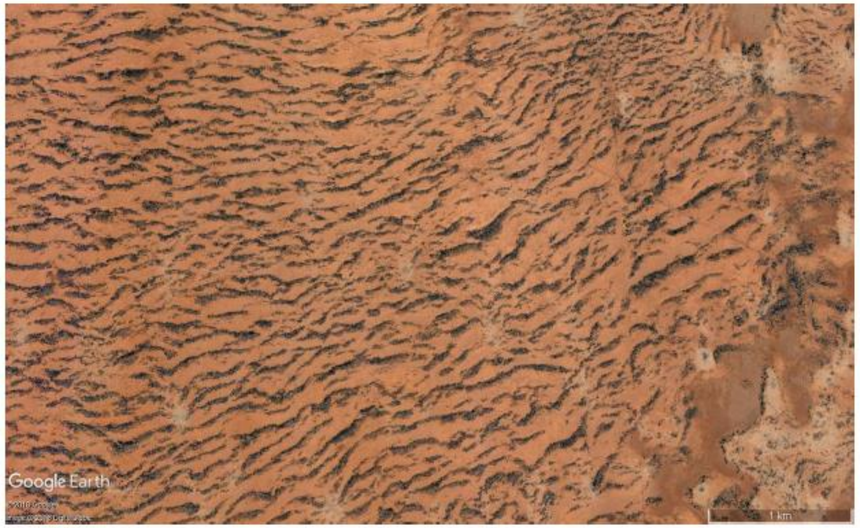
?

Desertification vulnerability

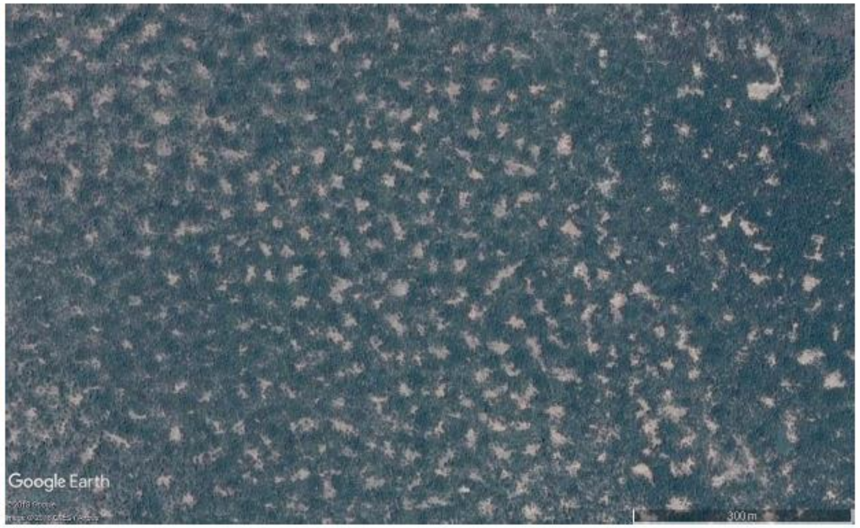


Source: US department of agriculture (1998)

The desertification process - patterns

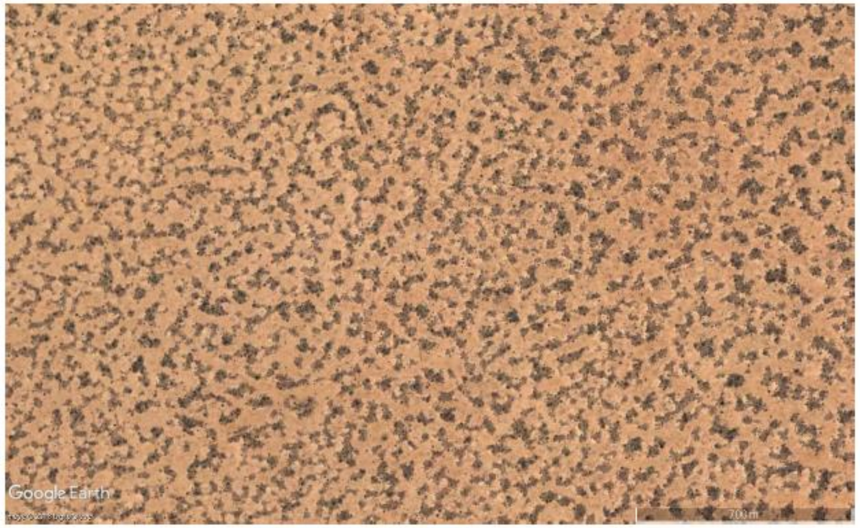


(a) Bands in Somalia



(b) Gaps in Niger

(c) Spots in Zambia



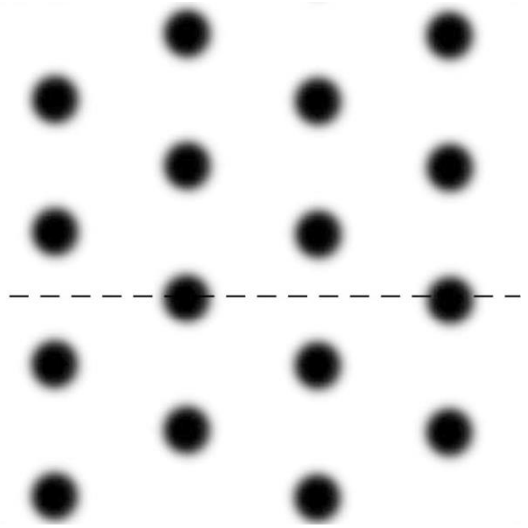
(d) Maze in Sudan

Mathematical treatment of biomass loss

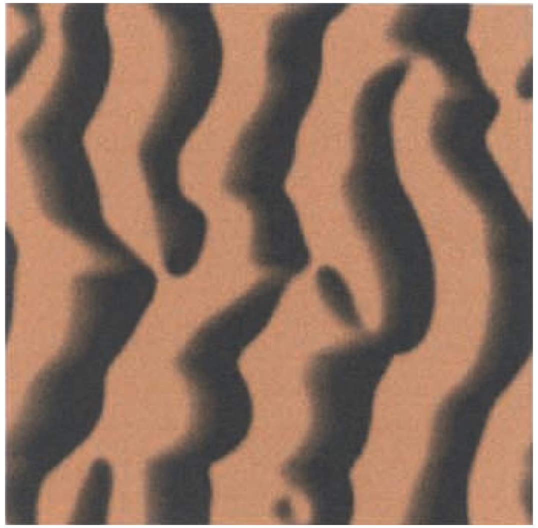
Translating ecology to mathematics:

Vegetation patterns ↔ localized structures

Seperation of scales ↔ small parameter



Source: Gilad et al (2004)



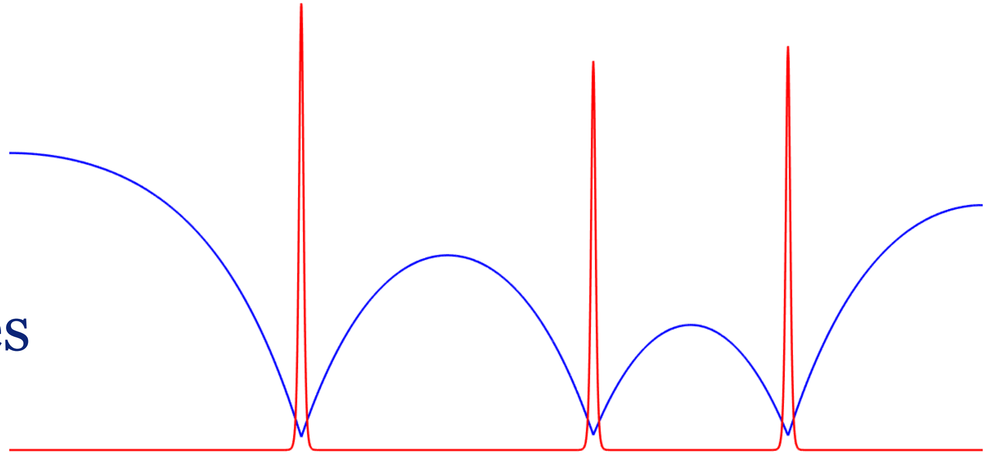
Source: Rietkerk et al (2002)

Mathematical paper:

→ *Dynamics of disappearing pulses* [Bastiaansen, Doelman (2019)]

This presentation:

1. Summary 'Dynamics of disappearing pulses'
2. Minimizing biomass using maintenance strategies



A simple ecosystem model

Extended-Klausmeier model

$$w_t = w_{xx} - w + a - wv^2$$
$$v_t = D^2 v_{xx} - mv + wv^2$$

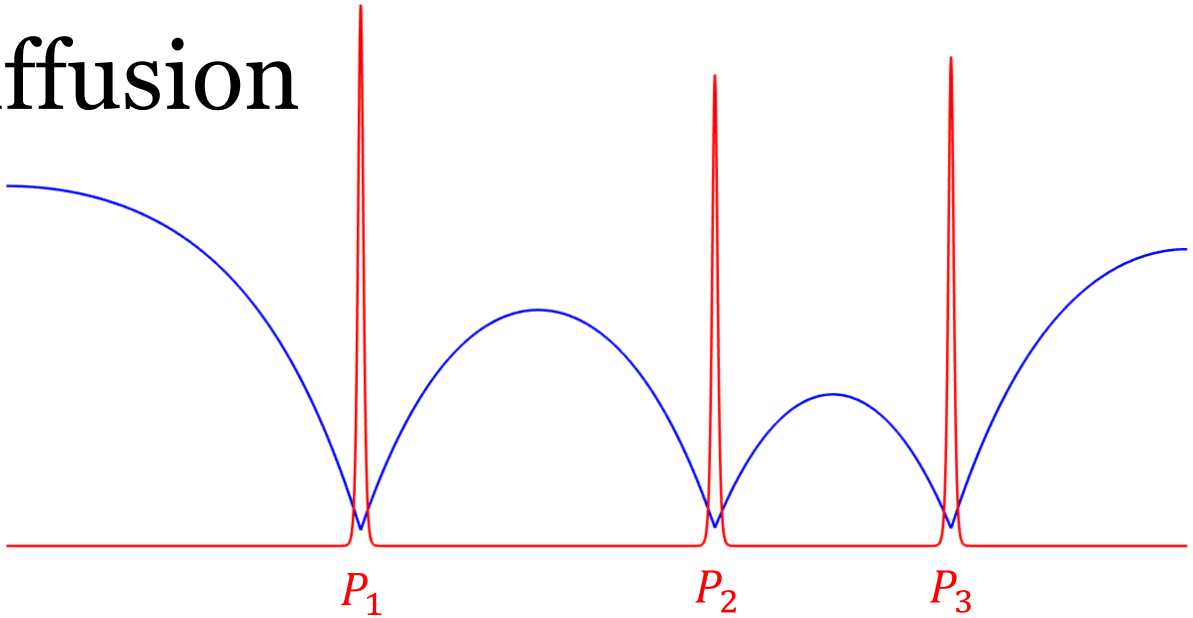
w : water

v : vegetation

D : ratio of diffusion

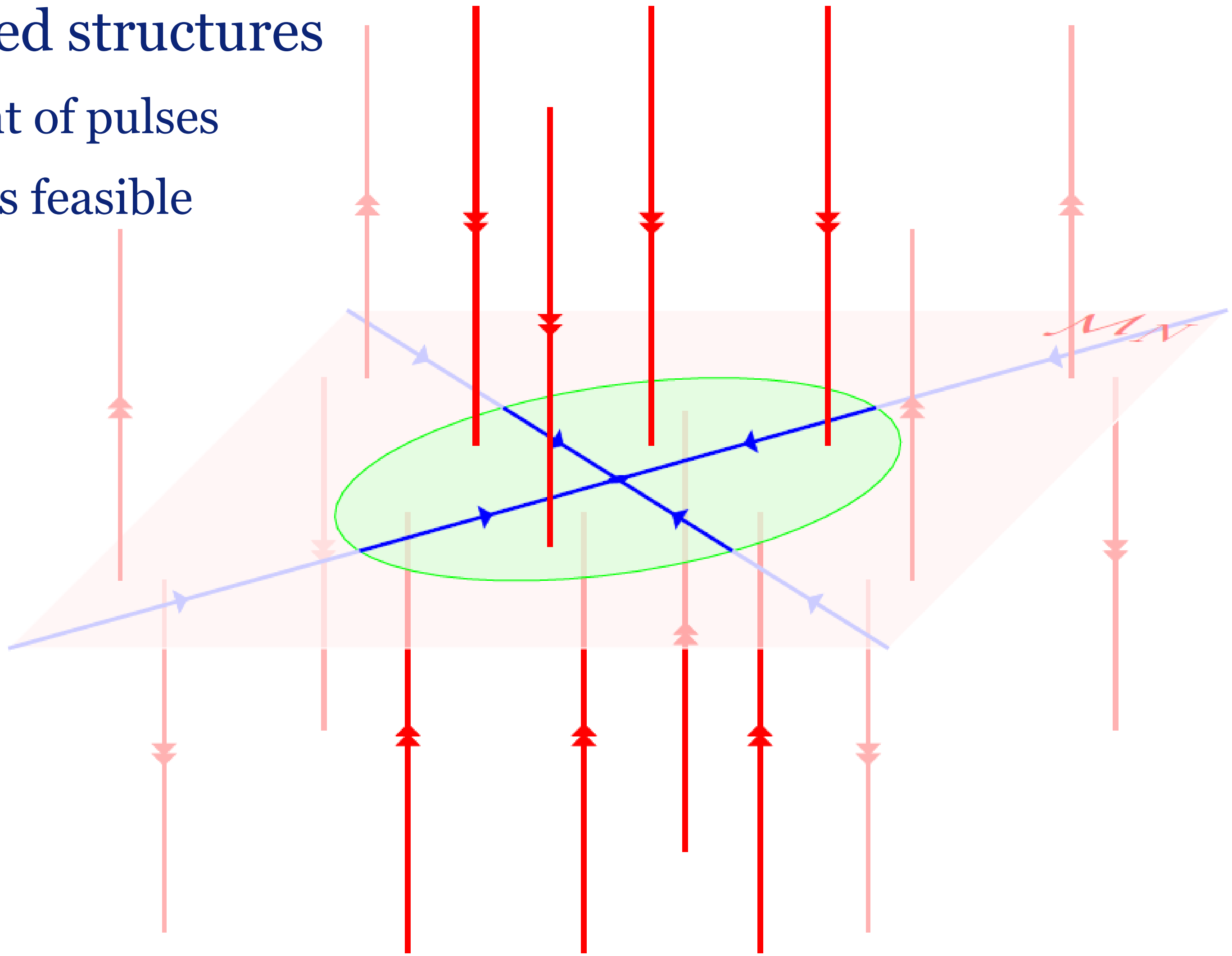
a : rainfall

m : mortality



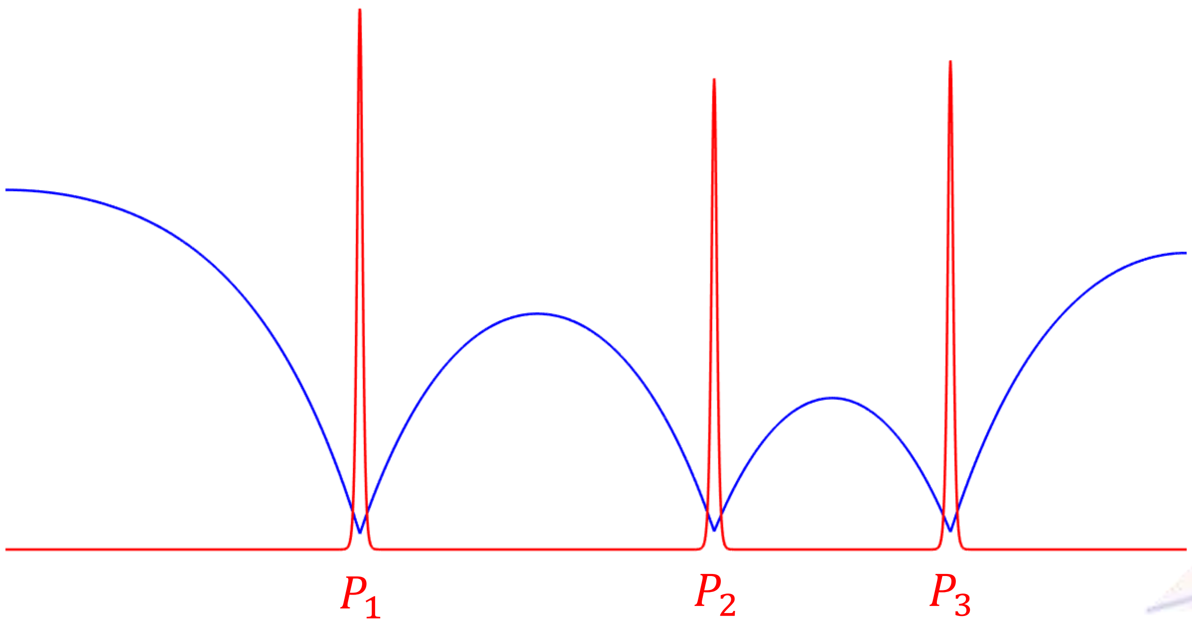
Understanding pulses in the model

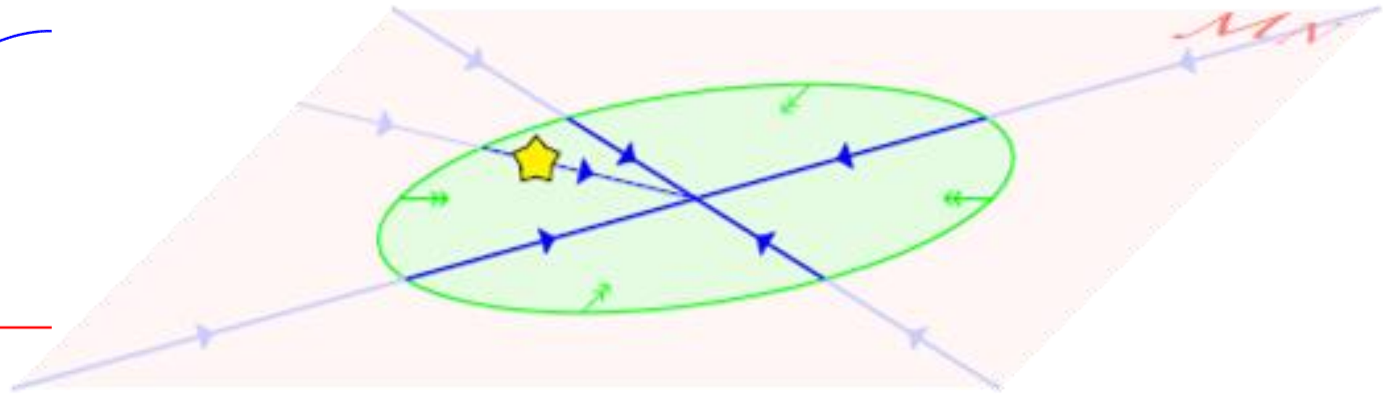
- PDE: infinite-dimensional state space
- Reduction possible because of localized structures
  1. Pulse-location ODEs: describe movement of pulses
  2. Stability criterium: test if configuration is feasible



Pulse-location ODE

$$\frac{dP_j}{dt} = \frac{Da^2}{m\sqrt{m}}\left[w_x({P_j}^+)^2 - w_x({P_j}^-)^2\right]$$

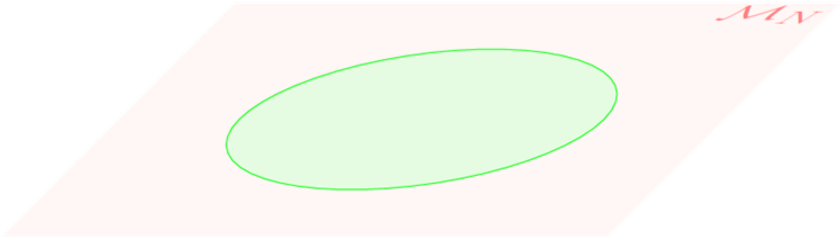




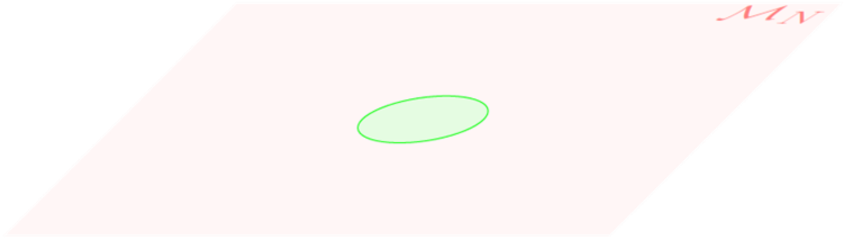
Stability criterium

Enough resources to sustain all vegetation patches?

Depends on **amount of rainfall** and **distance between patches**



(a) high rainfall

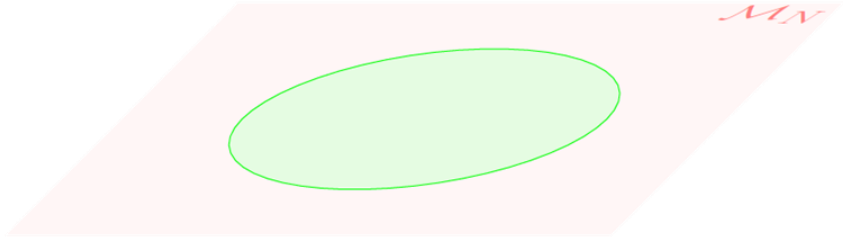


(b) low rainfall

Stability criterium

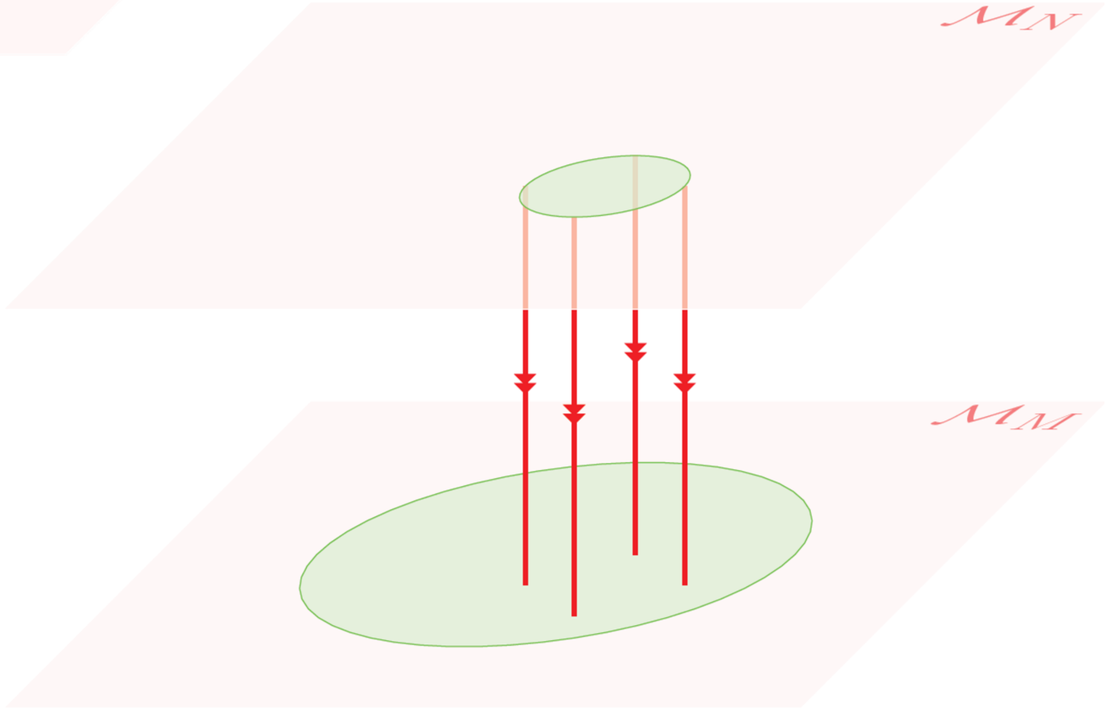
Enough resources to sustain all vegetation patches?

Depends on **amount of rainfall** and **distance between patches**



(a) high rainfall **(b)** low rainfall

What happens when outside feasible region?

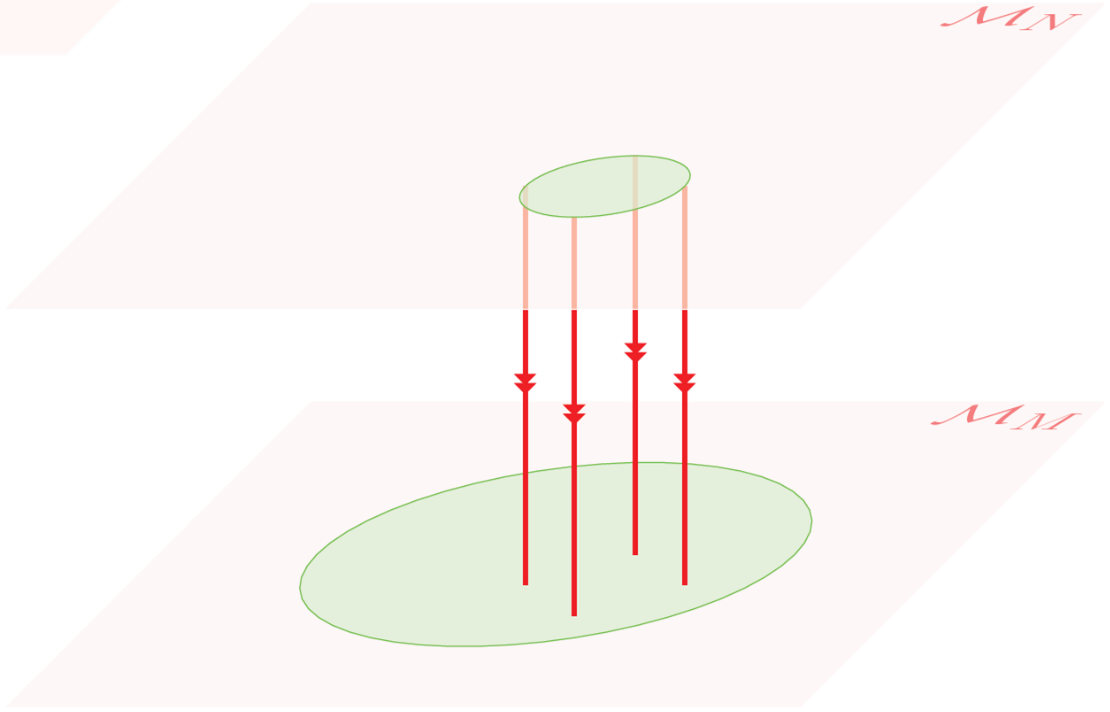


Stability criterium

Enough resources to sustain all vegetation patches?

Depends on **amount of rainfall** and **distance between patches**

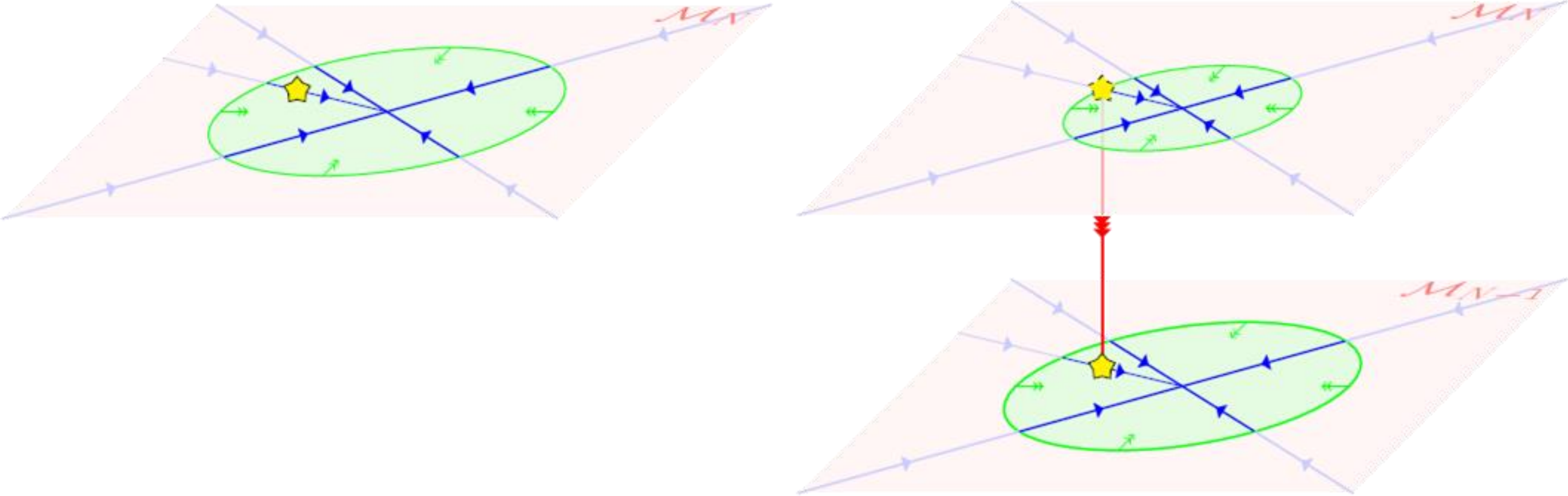
(a) high rainfall   **(b)** low rainfall



What happens when outside feasible region?

irregular configuration:	**One** patch disappears (least amount of biomass)
regular configuration:	**Half** of the patches disappears (wavelength doubling)

Dynamics of disappearing pulses (1)

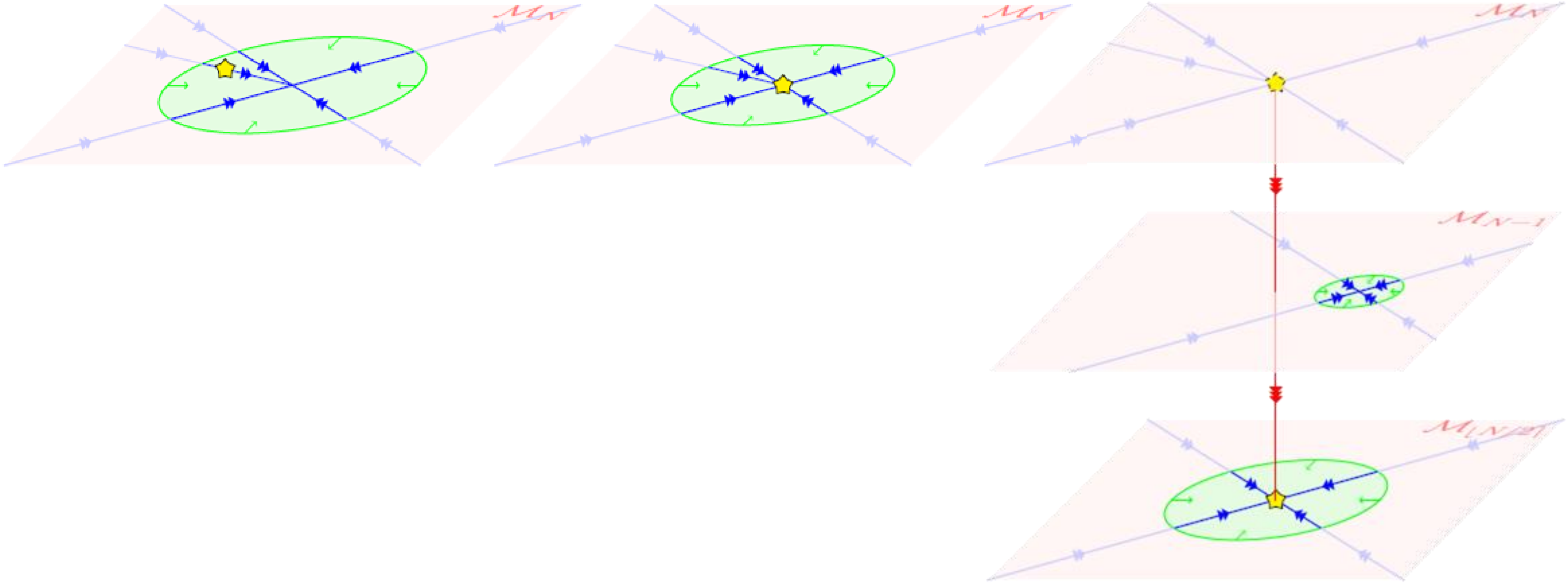


(a) initial configuration

(b) at/after destabilization

fast climate change

Dynamics of disappearing pulses (2)



(a) initial configuration (b) regular pattern achieved (c) at/after destabilization

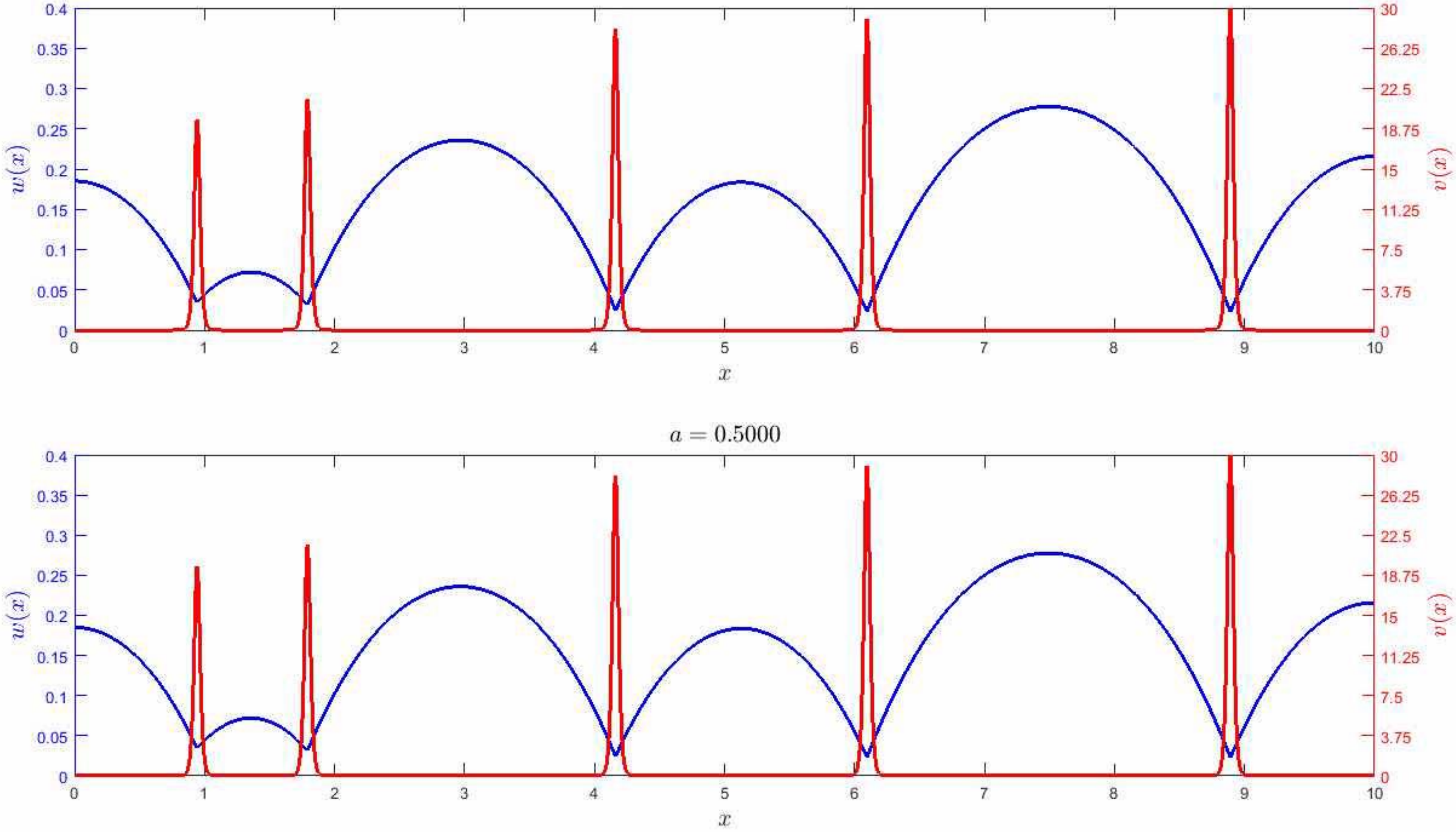
slow climate change

Dynamics of disappearing pulses (3)

Rate of climate change

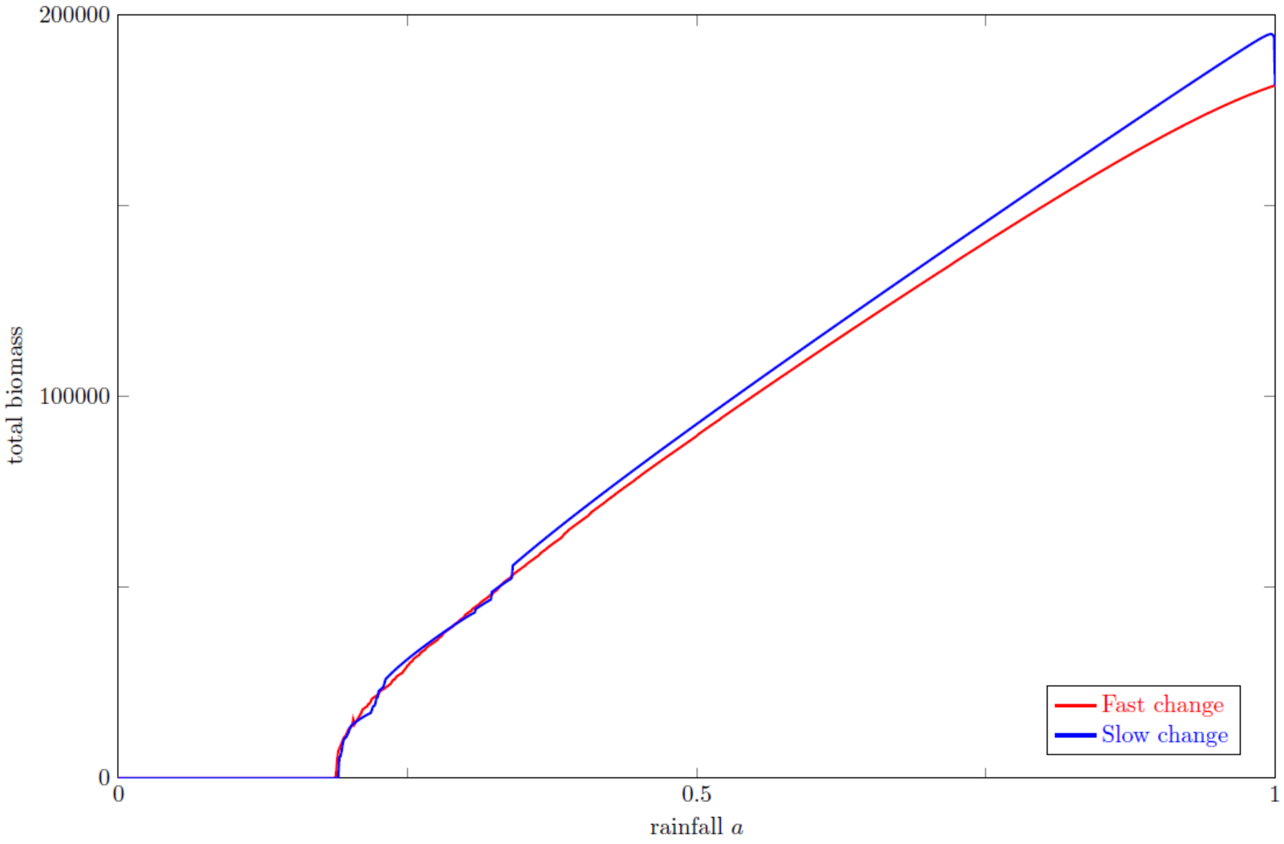
FAST

SLOW



Optimizing biomass

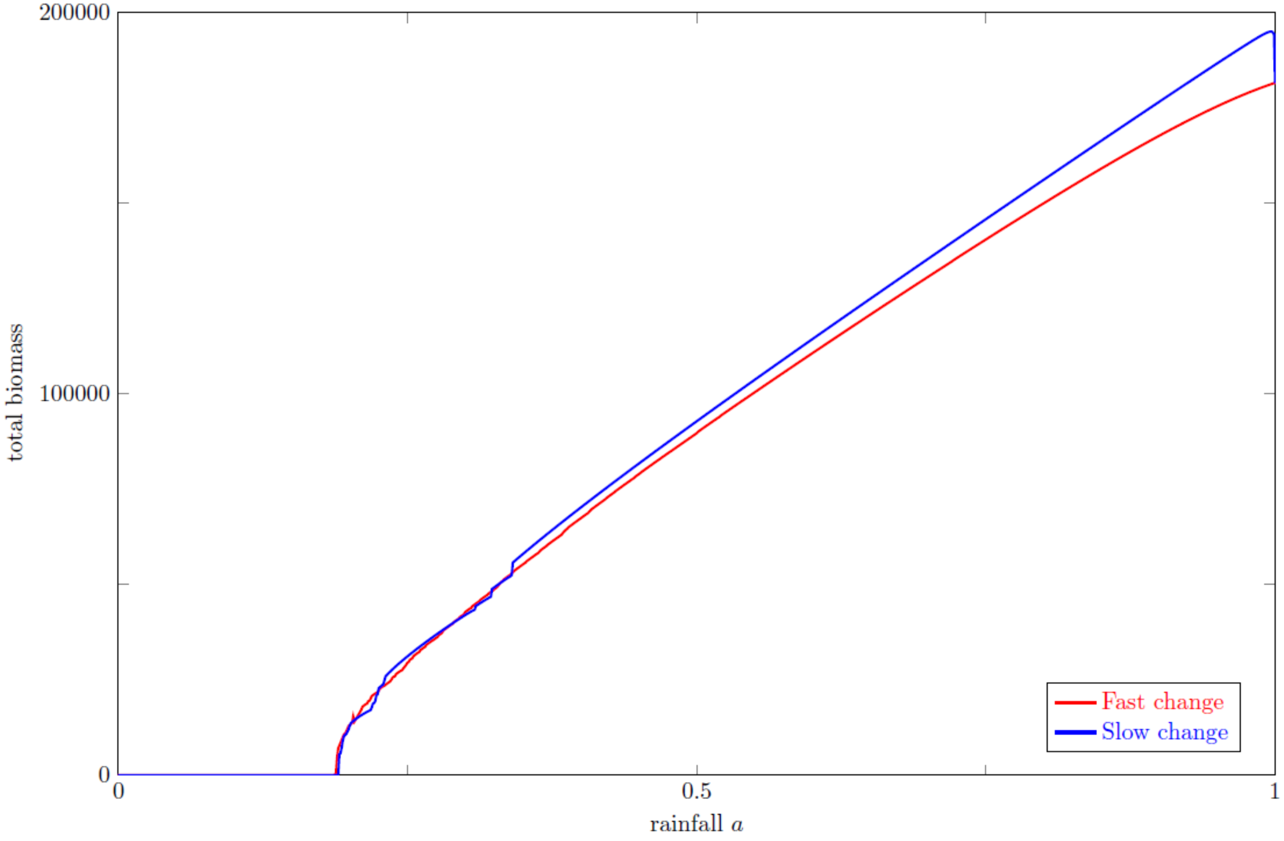
Important question: how is biomass optimized (for any particular rainfall value)?



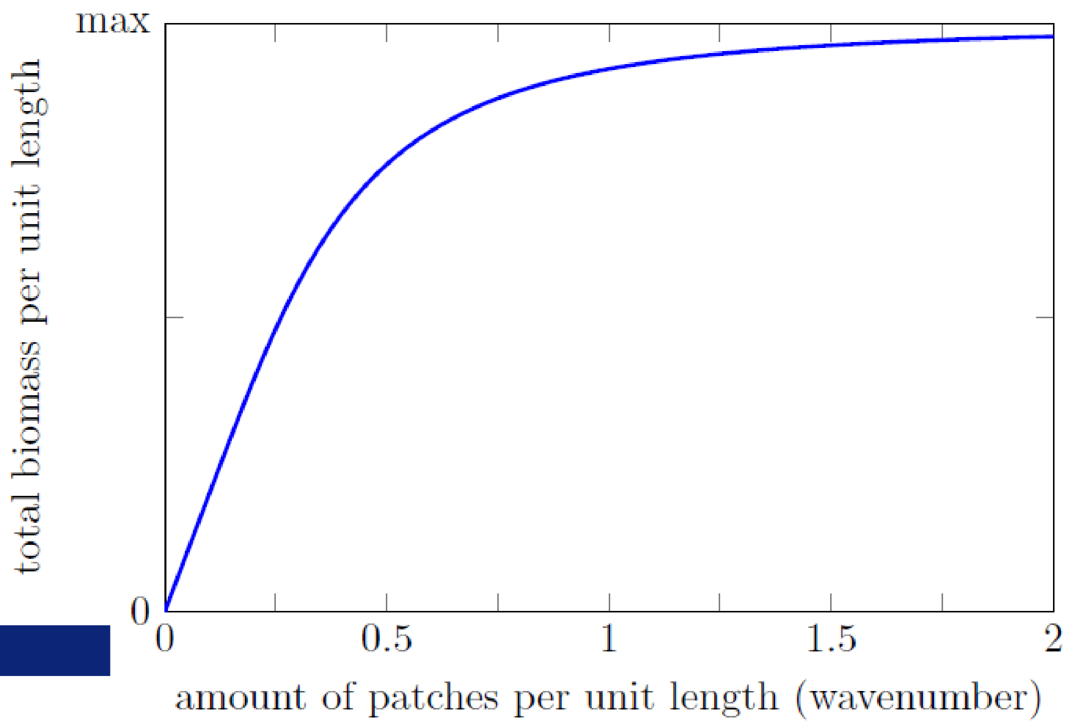
Total biomass is optimized in **regular patterns**

Optimizing biomass

Important question: how is biomass optimized (for any particular rainfall value)?

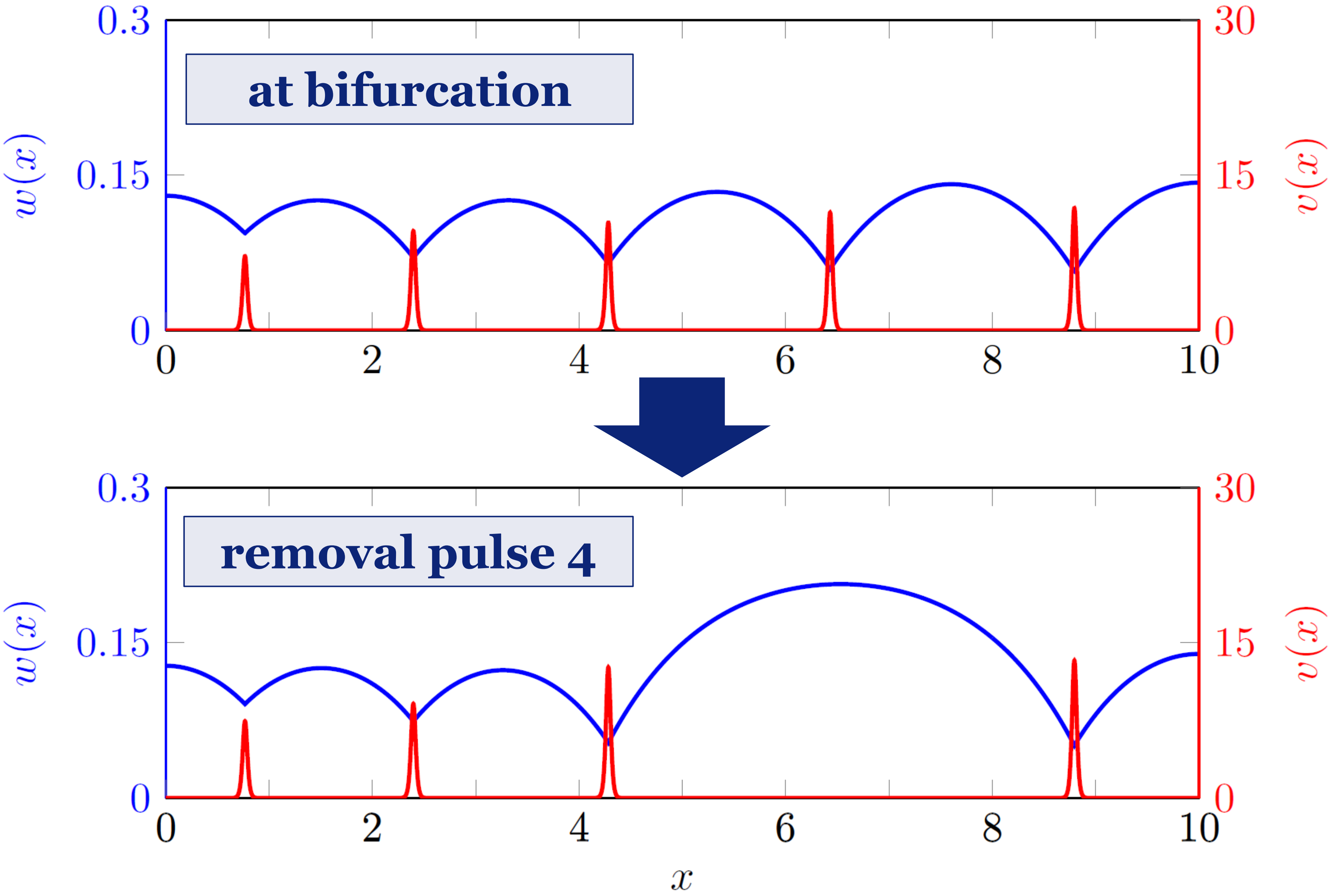


Total biomass is optimized in **regular patterns**

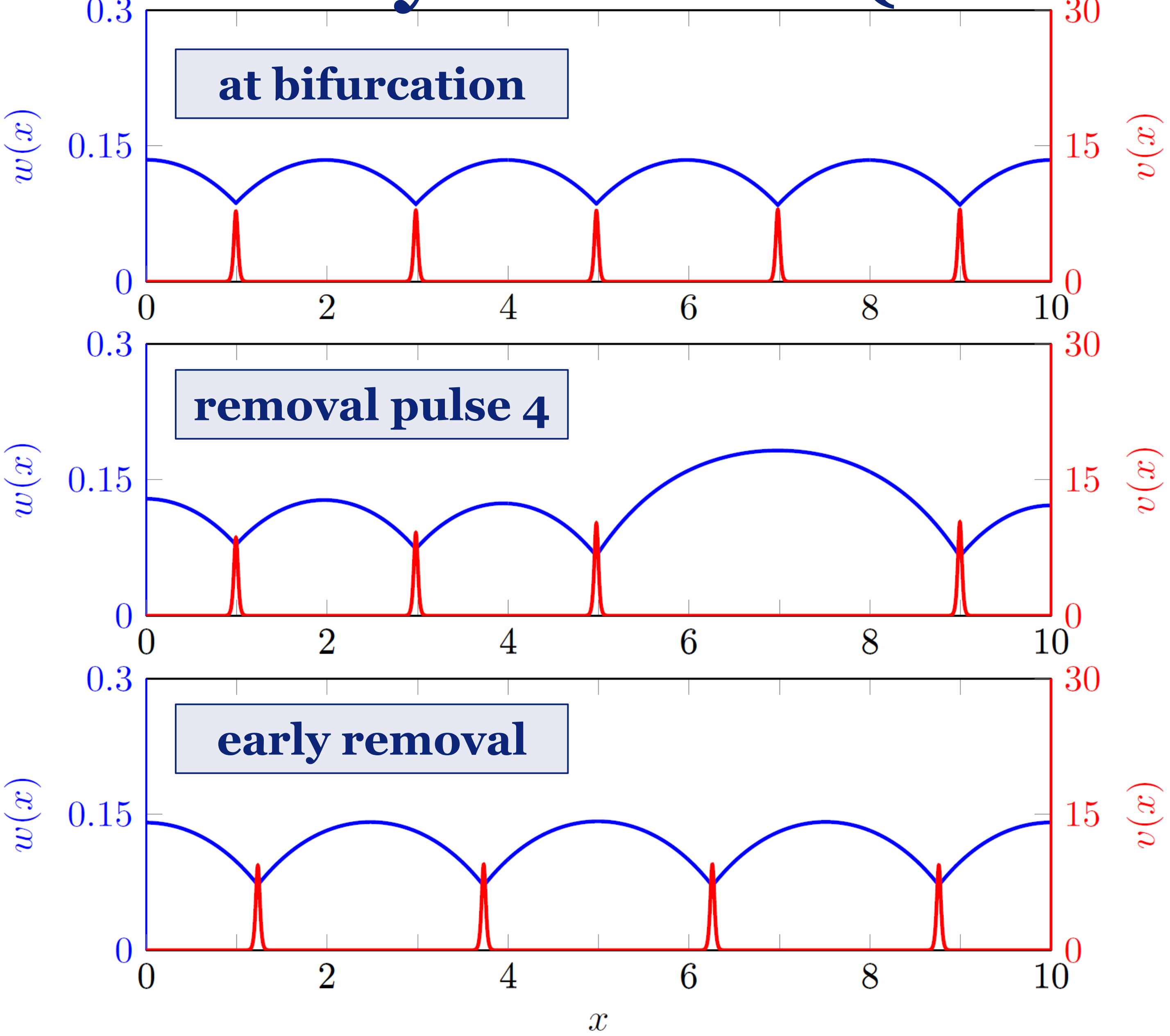


More total biomass when there are **more patches**

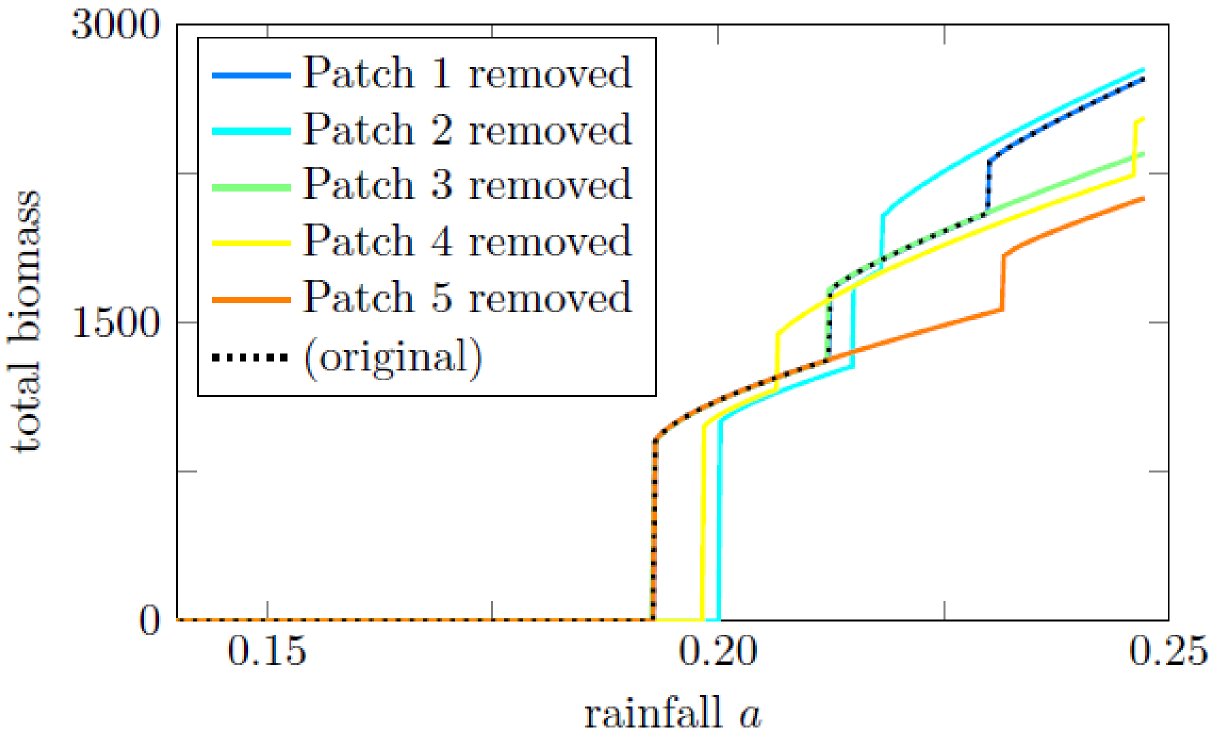
Strategy #1: pre-emptive removal



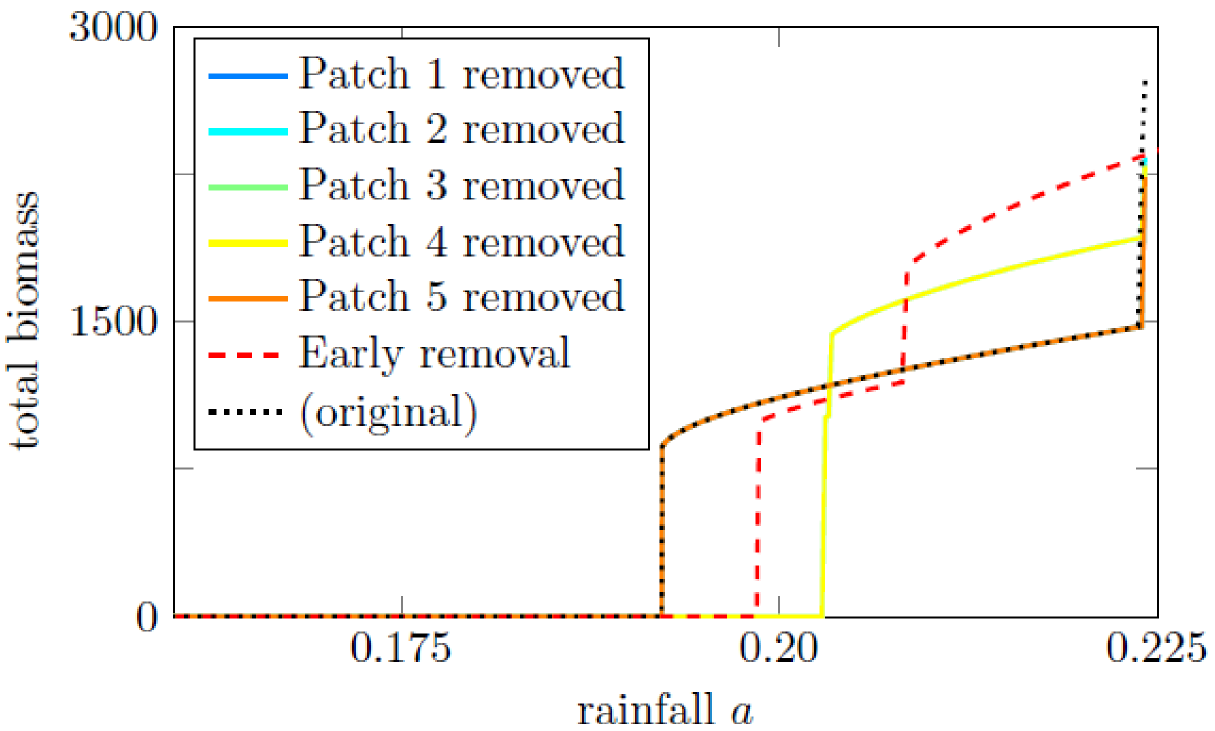
Strategy #2: early removal (for slow change)



Strategies #1 & #2: simulation results



(a) Fast climate change

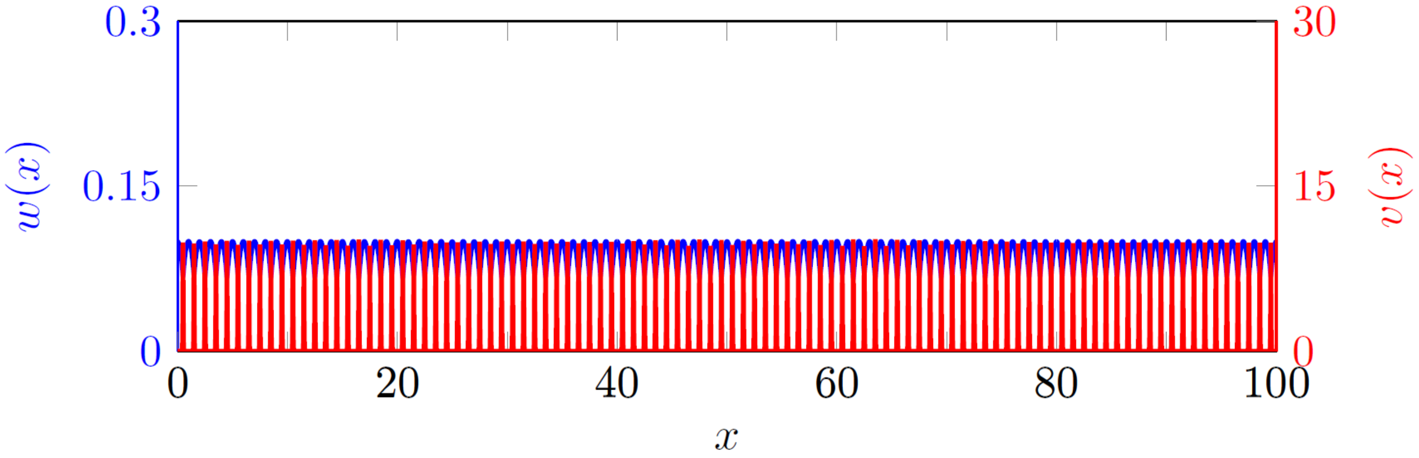


(b) Slow climate change

→Short term benefits possible if right patches are removed

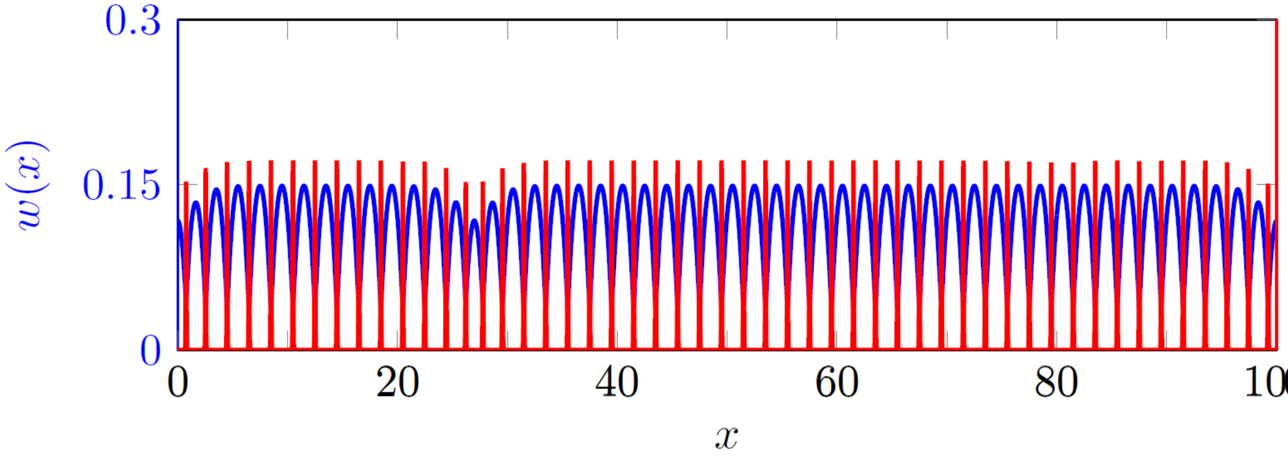
→Long term benefits unclear

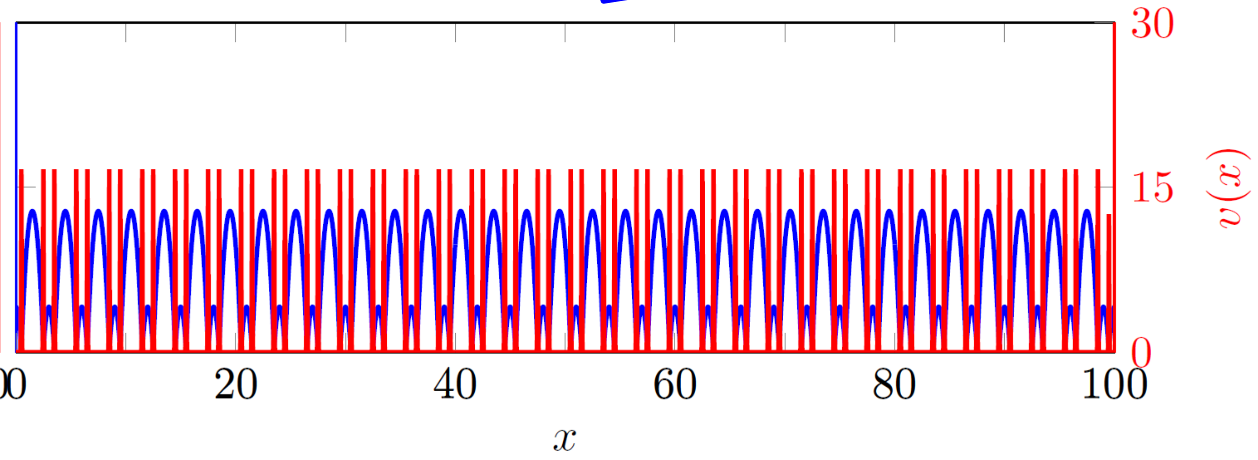
Strategy #3: removal of $\lfloor N/3 \rfloor$ patches



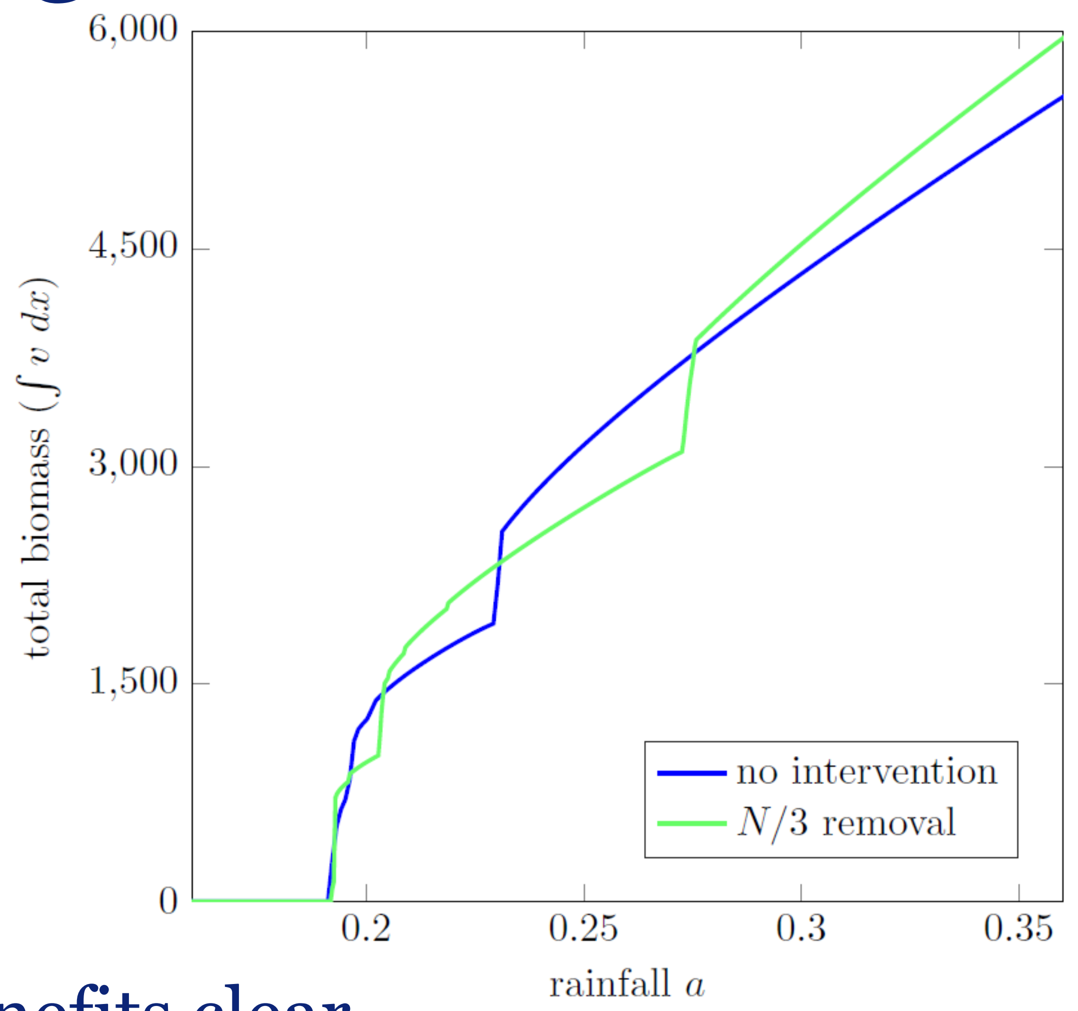
No intervention – **Half** of patches gone

Intervention – Only **third** of patches gone





Strategy #3: simulation results

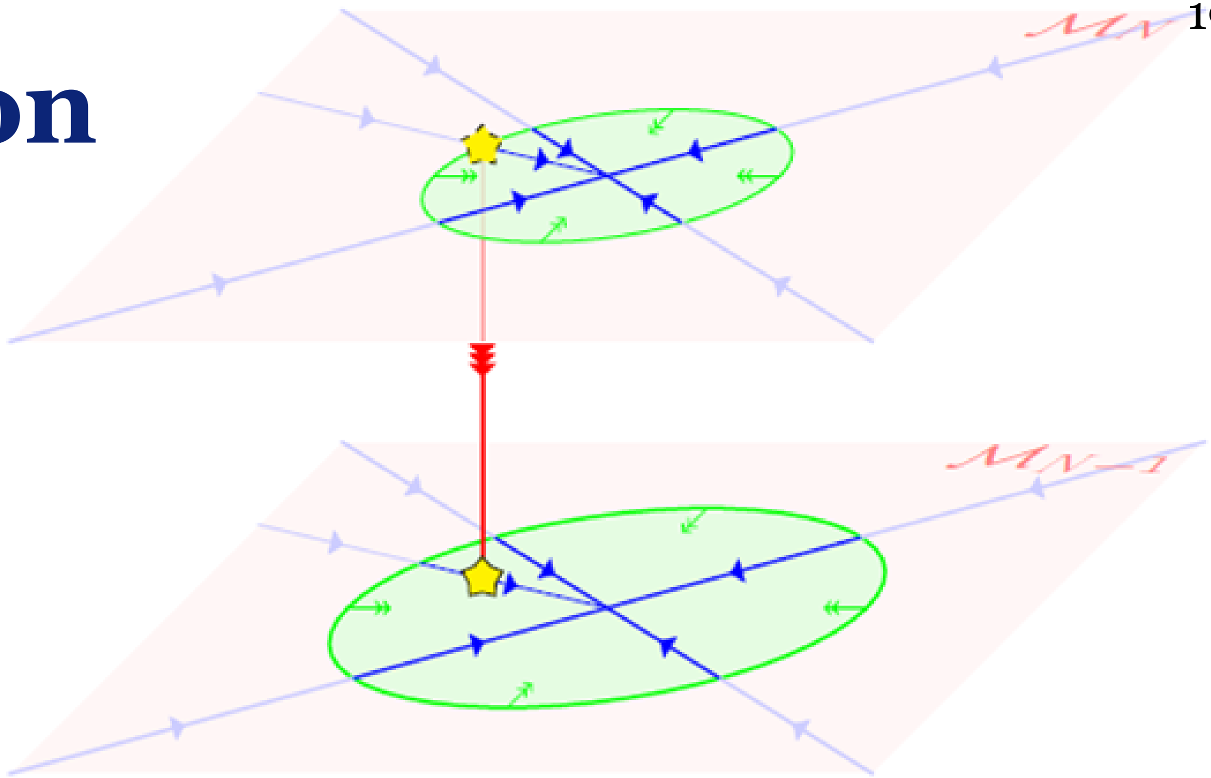


→Short term benefits clear

→Long term benefits unclear

- Next bifurcation occurs sooner

Conclusions/Discussion



Biomass optimization:

1. As many vegetation patches as possible
2. Aim for more regular configurations

Maintenance strategies:

- Short-term benefits possible
- Long-term benefits unclear/unpredictable (without constant monitoring)

Discussion points:

- Alternate maintenance techniques?
- Alternate questions/issues that can be handled with mathematical techniques?
- Possible extensions or hiccups?