Predicting the Wavelength of Patterned Vegetation in Drylands

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This talk can be downloaded from my web site

www.ma.hw.ac.uk/∼jas

Outline

Vegetation Patterns

Desert ecosystems provide a classic example of self-organised pattern formation.

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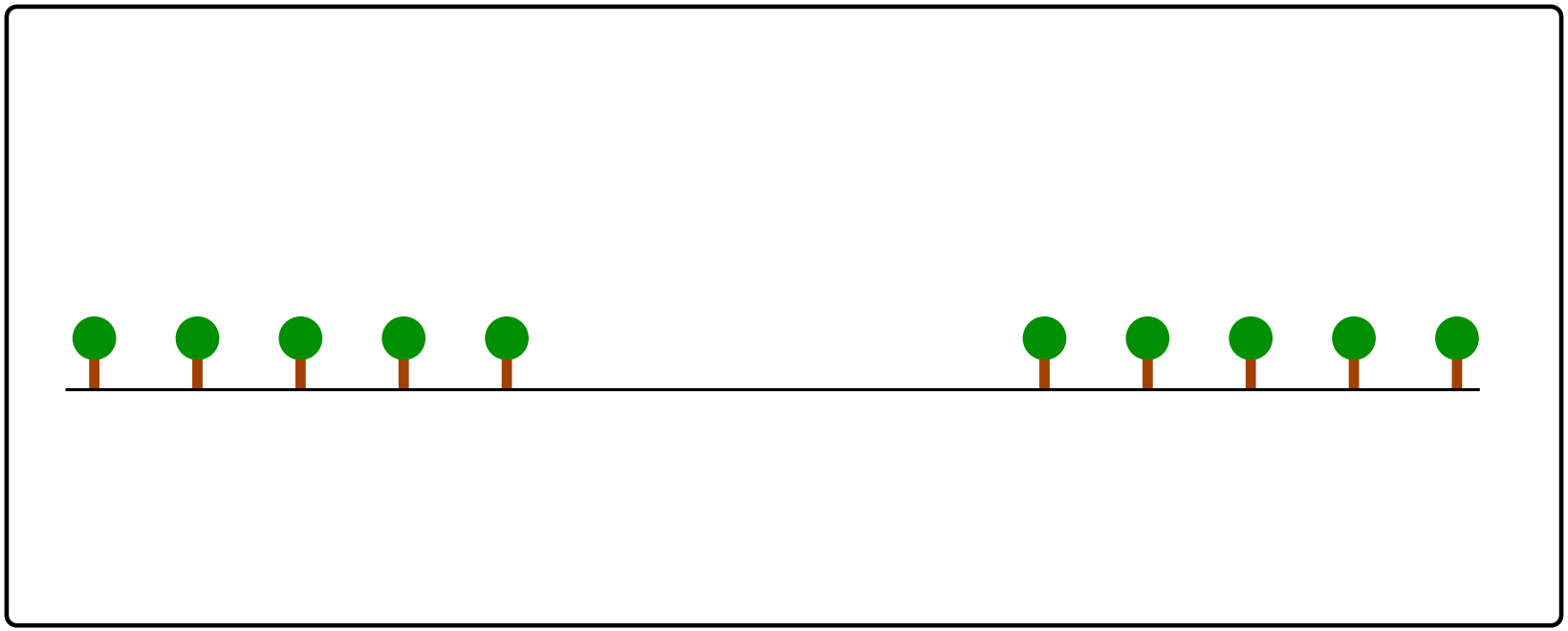

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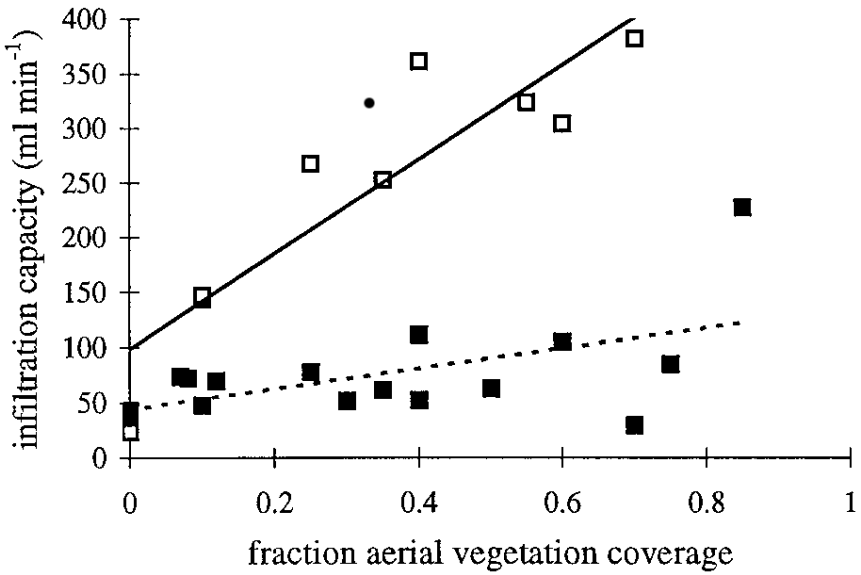

Data from Burkina Faso

Rietkerk et al
Plant Ecology 148: 207-224, 2000

More plants $\Rightarrow$ more roots and organic matter in soil
$\Rightarrow$ more infiltration of rainwater

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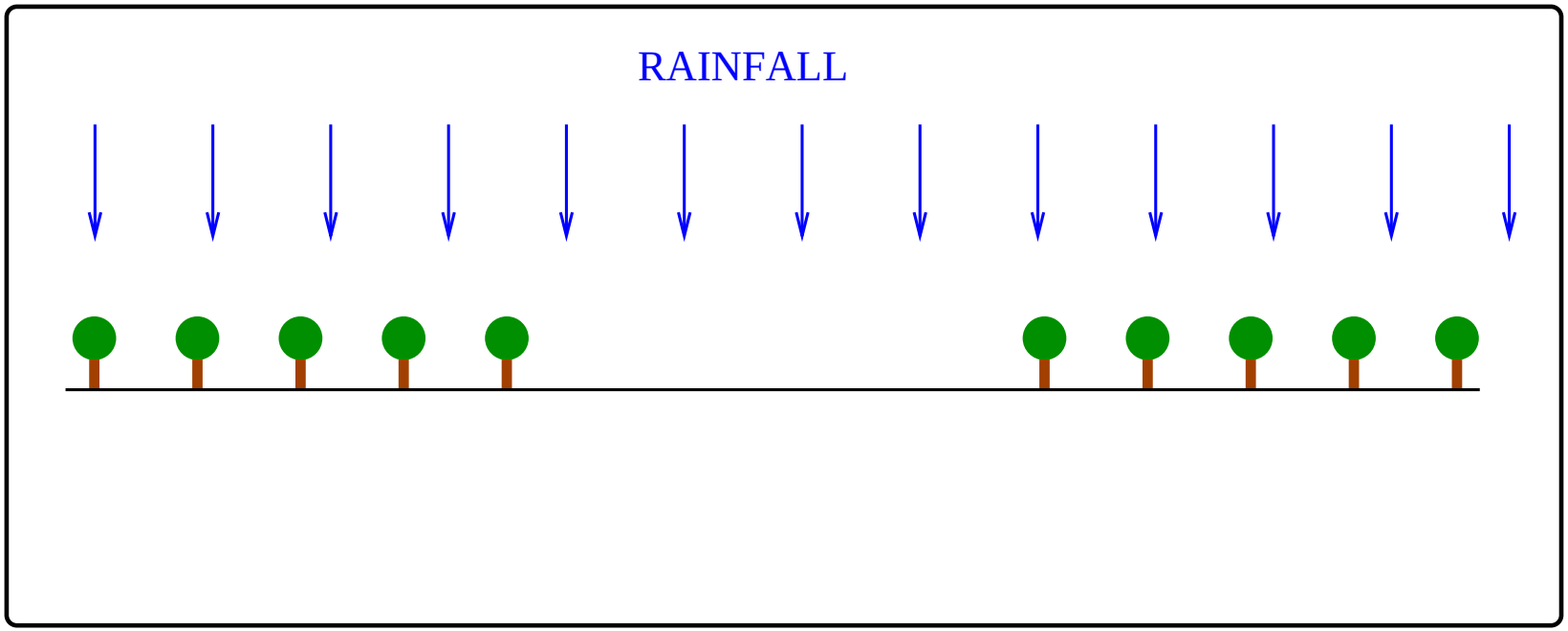

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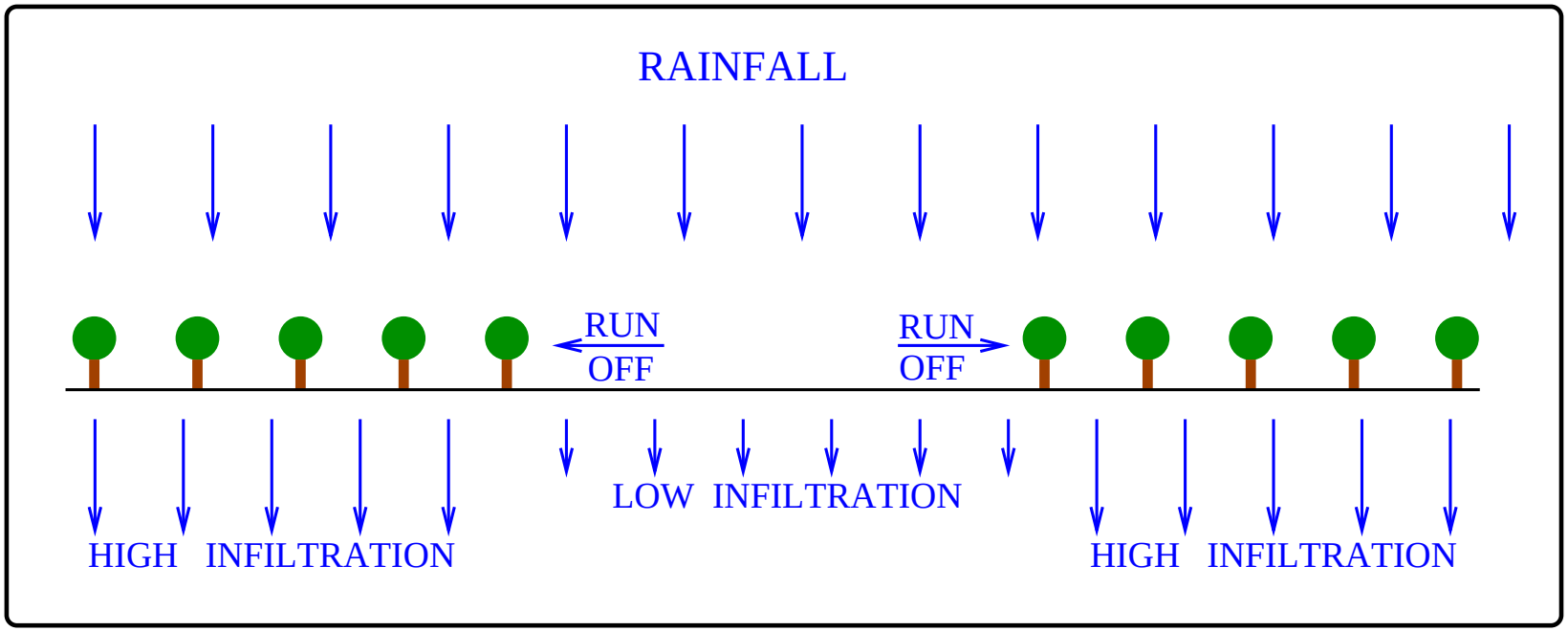

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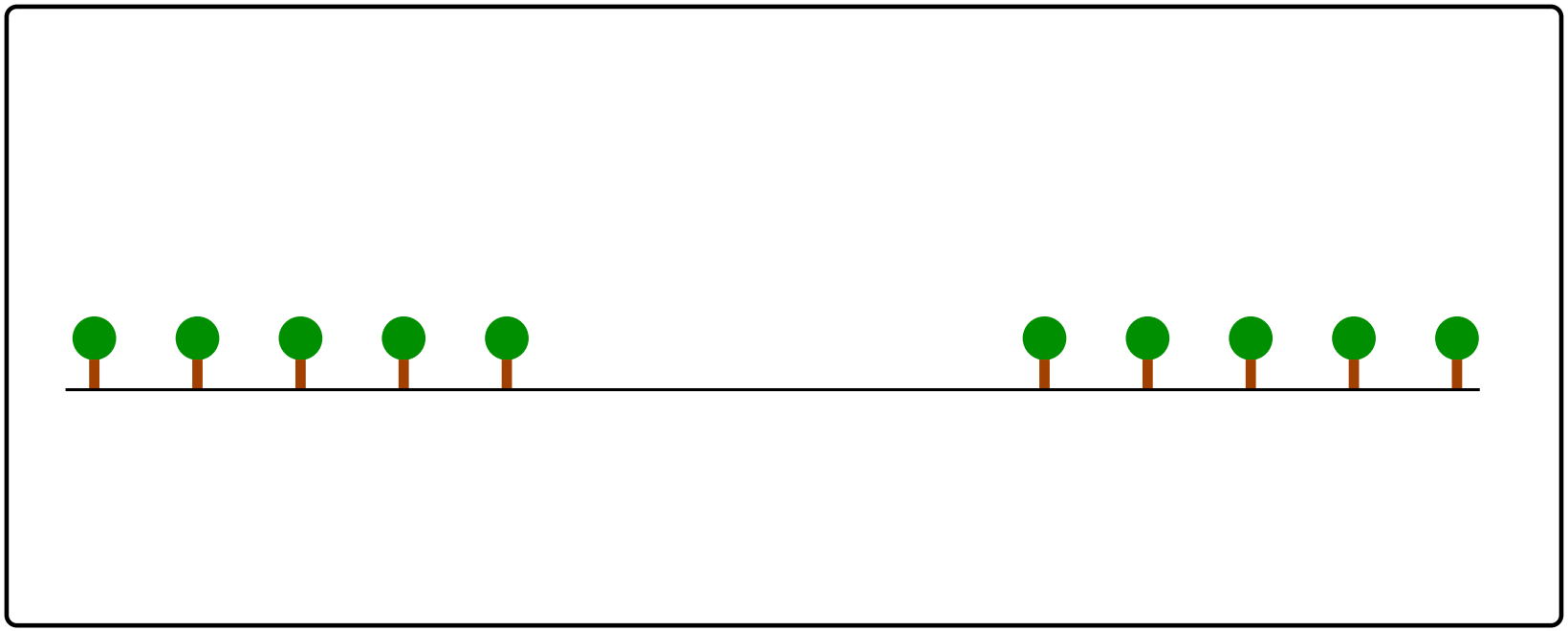

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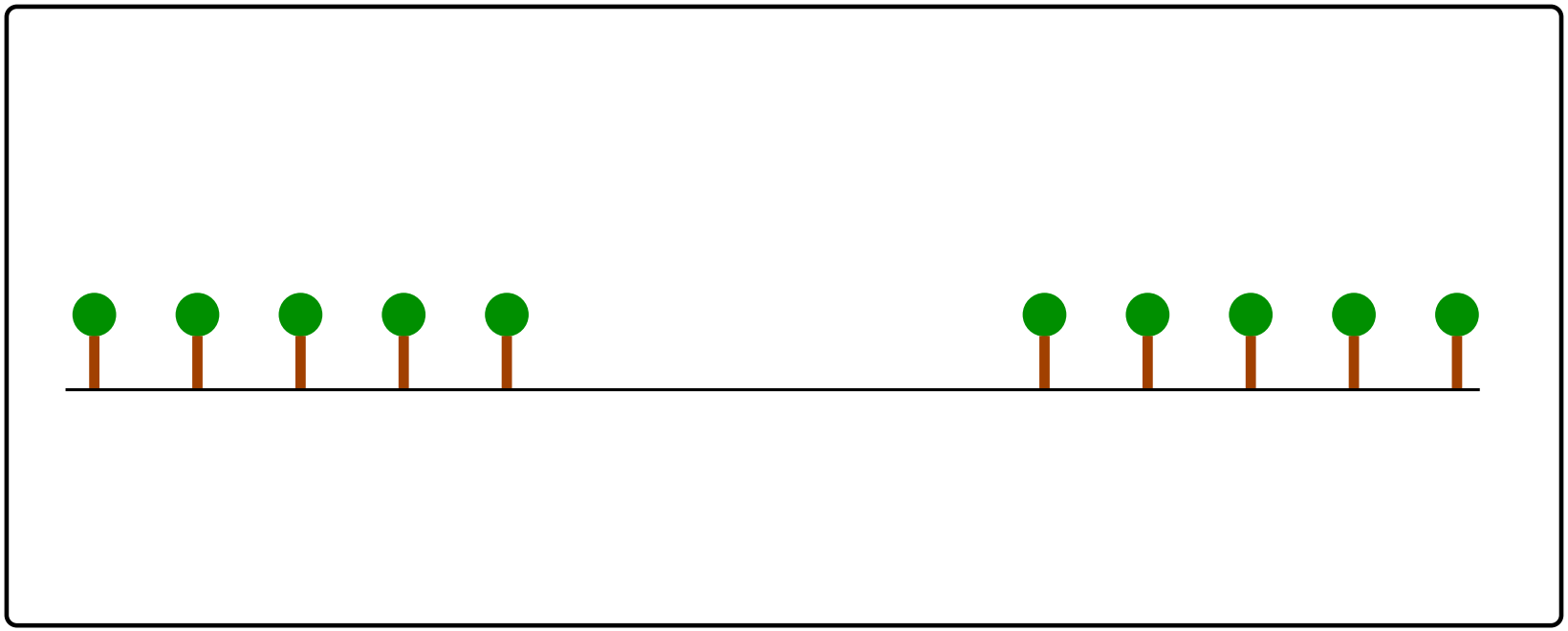

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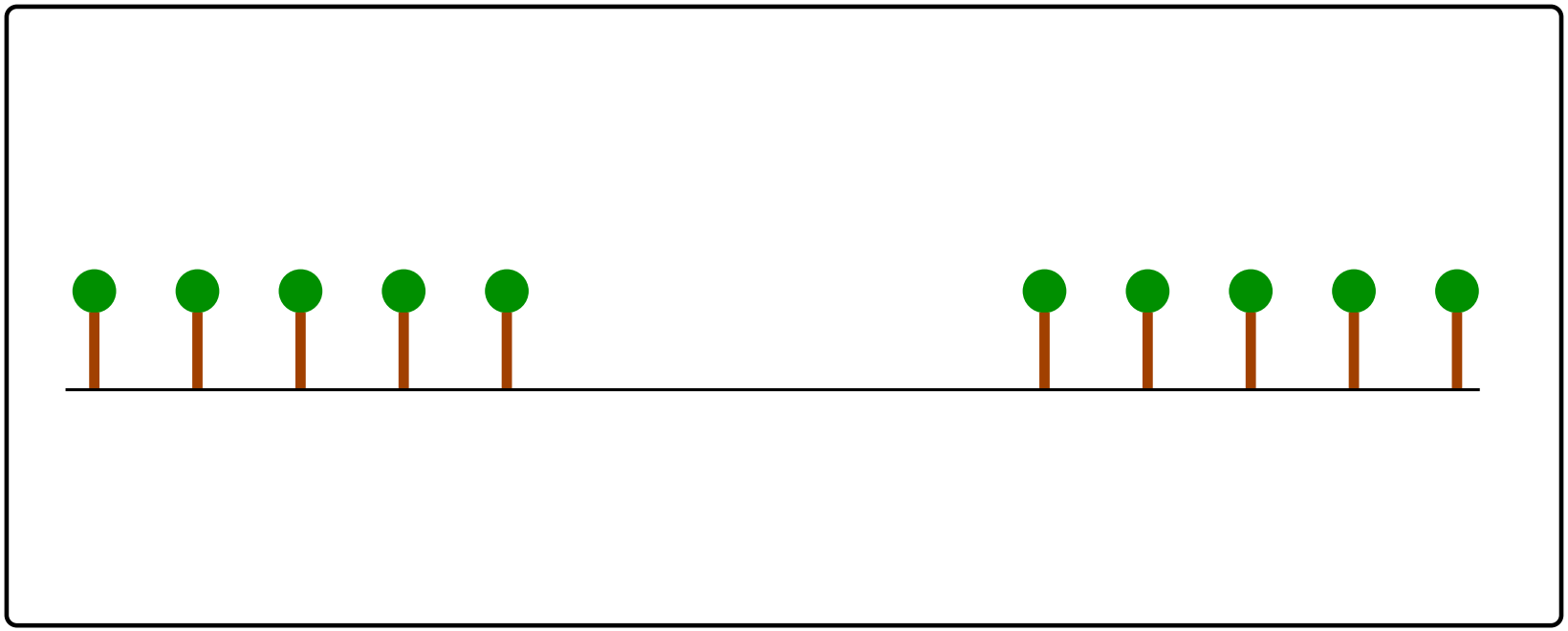

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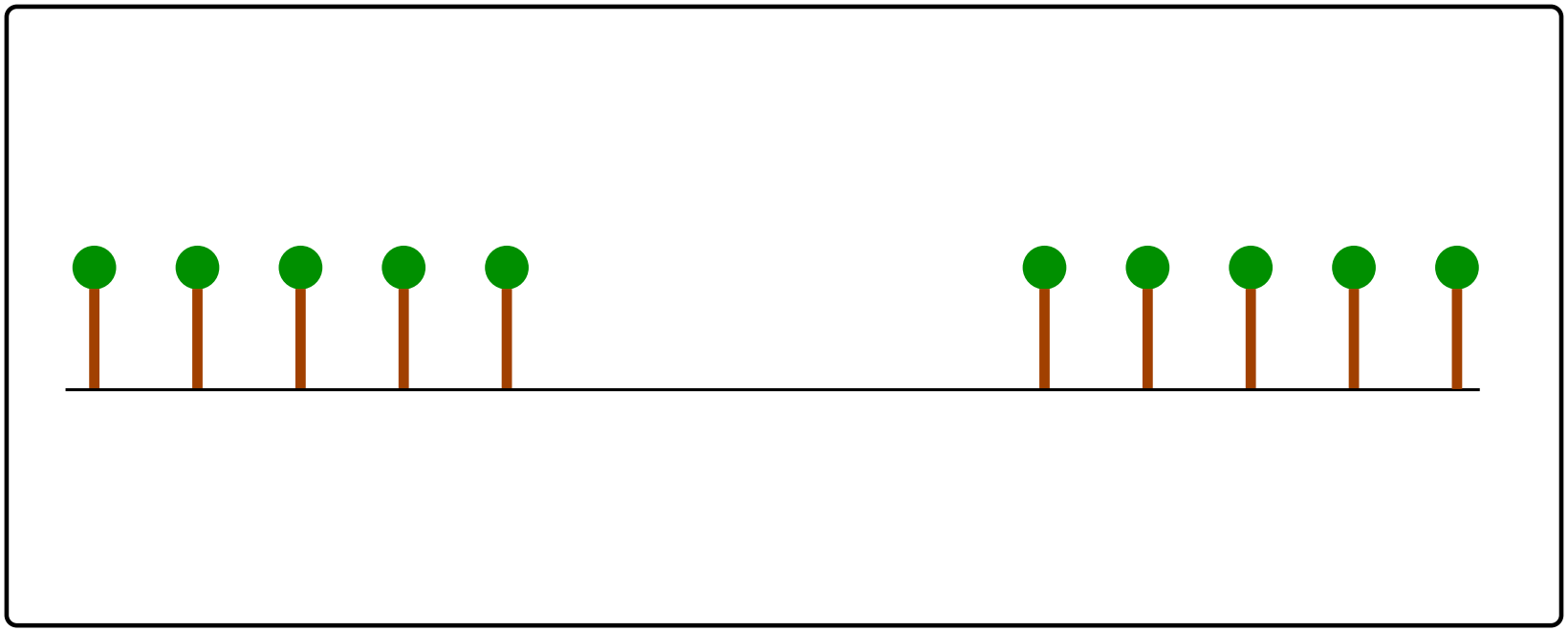

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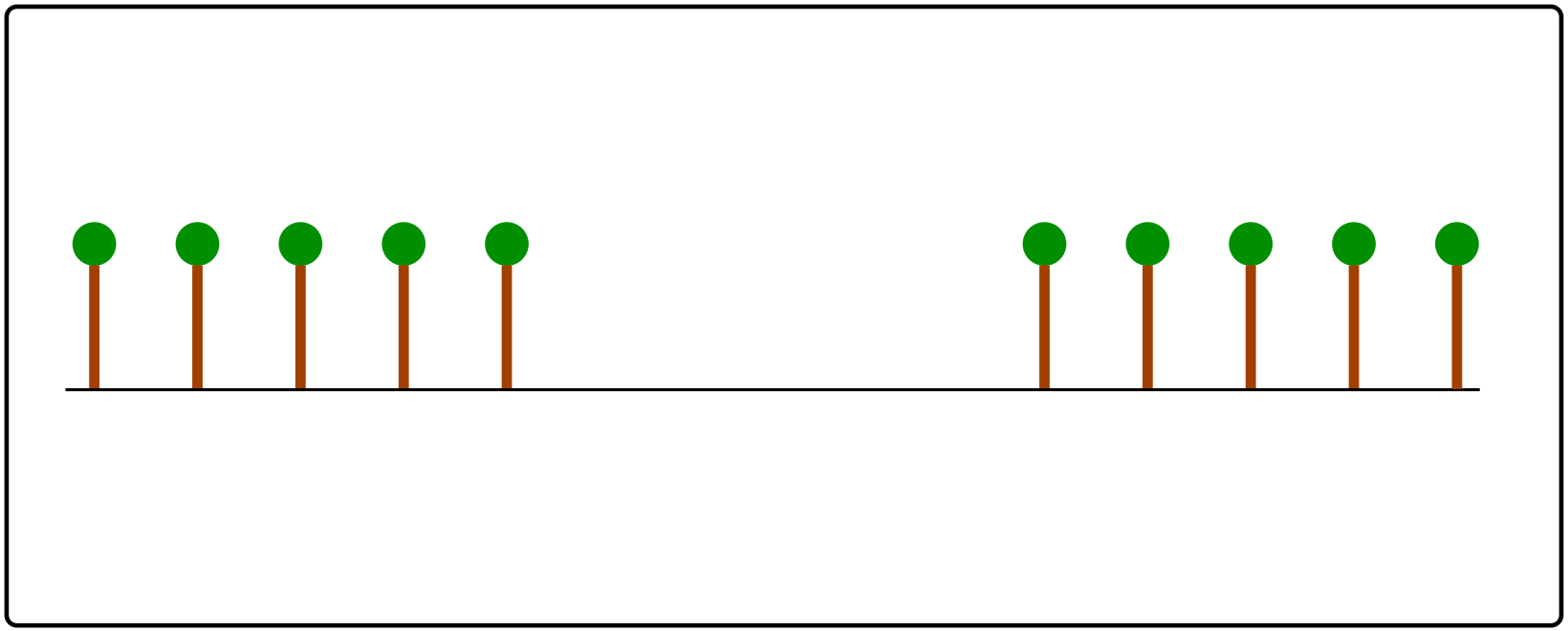

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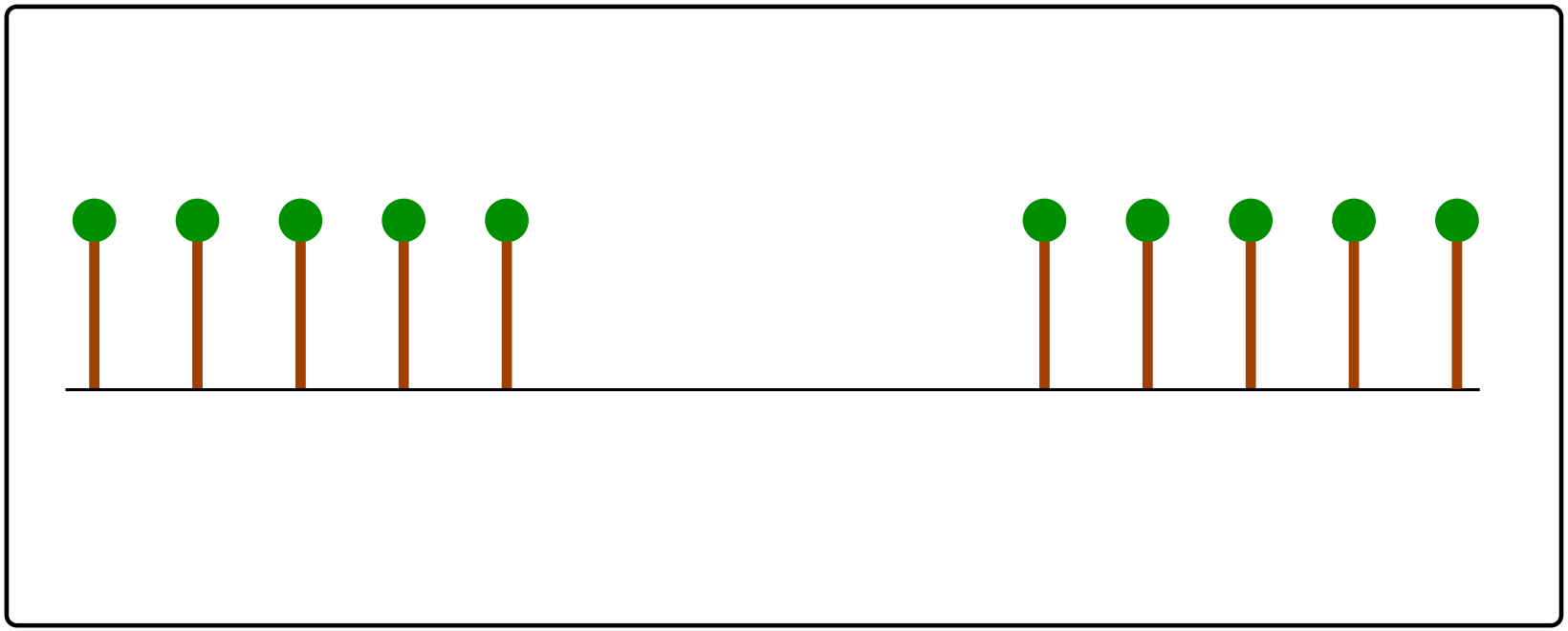

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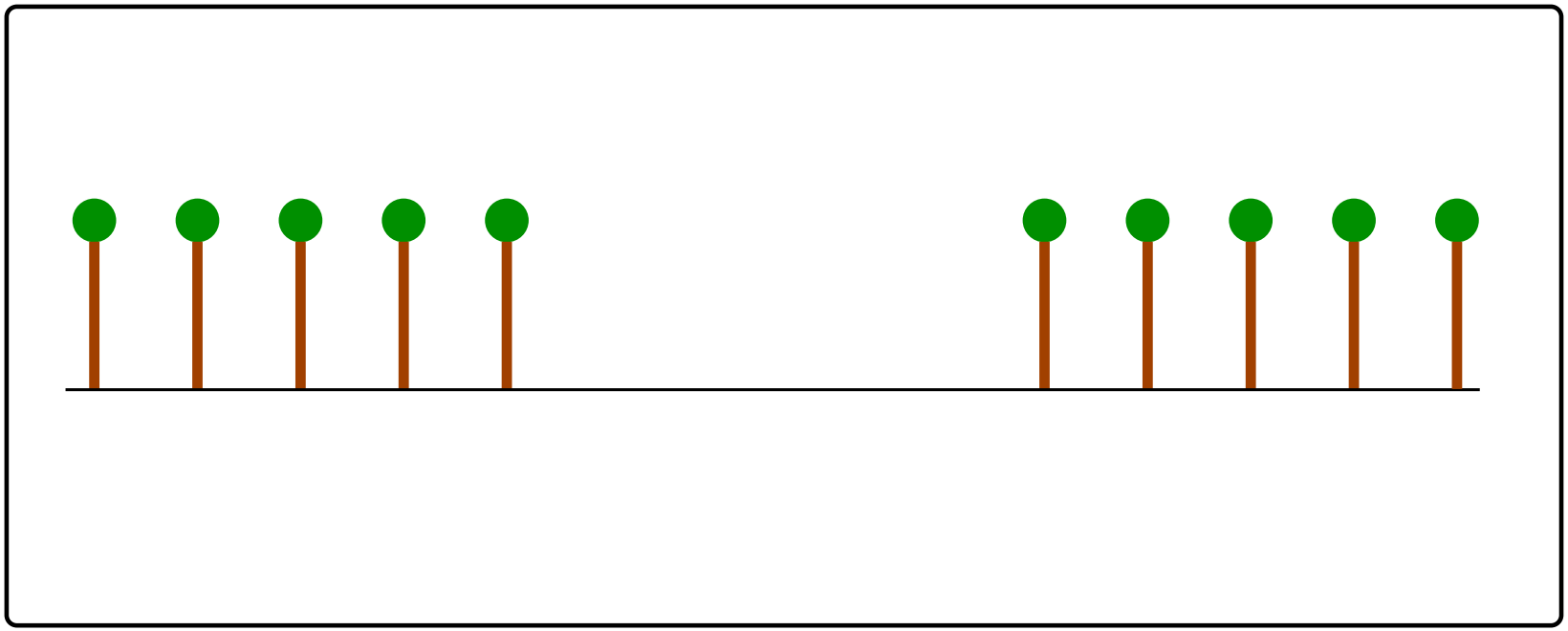

Banded Vegetation on Slopes

On slopes, run-off occurs in one direction only, giving striped patterns parallel to the contours.

Bushy vegetation in Niger

Mitchell grass in Australia

(Western New South Wales)

Banded vegetation patterns are found on gentle slopes in semi-arid areas of Africa, Australia, Mexico and S-W USA.

Banded Vegetation on Slopes

On slopes, run-off occurs in one direction only, giving striped patterns parallel to the contours.

Bushy vegetation in Niger

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Wavelength can be measured via remote sensing.

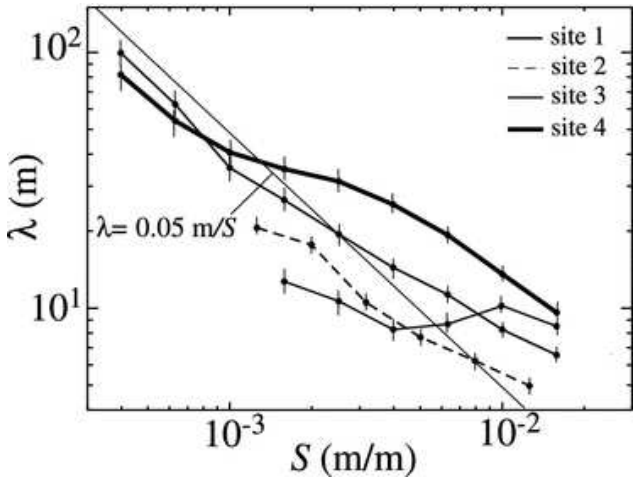
Remote Sensing of Elevation

Slope can also be measured remotely.

E.g. WorldDEM: online elevation data, 12 m resolution

Data on Wavelength vs Slope

Some recent studies have considered the relationshop between wavelength and slope.



Data from Nevada, USA (Pelletier et al, J. Geophys. Res. 117: F04026, 2012)

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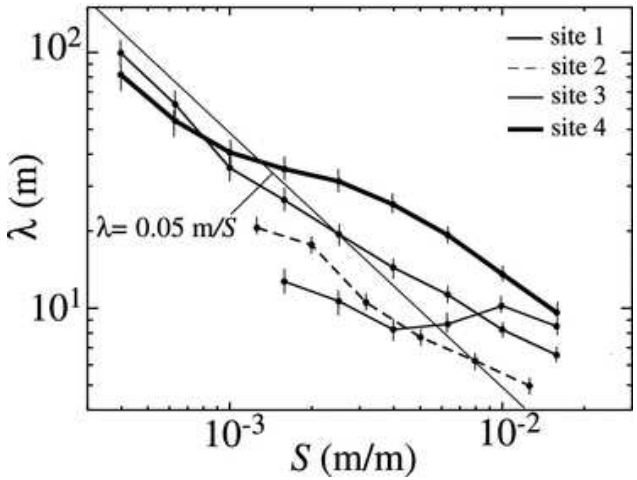

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What can we learn from combined data on wavelength and slope?

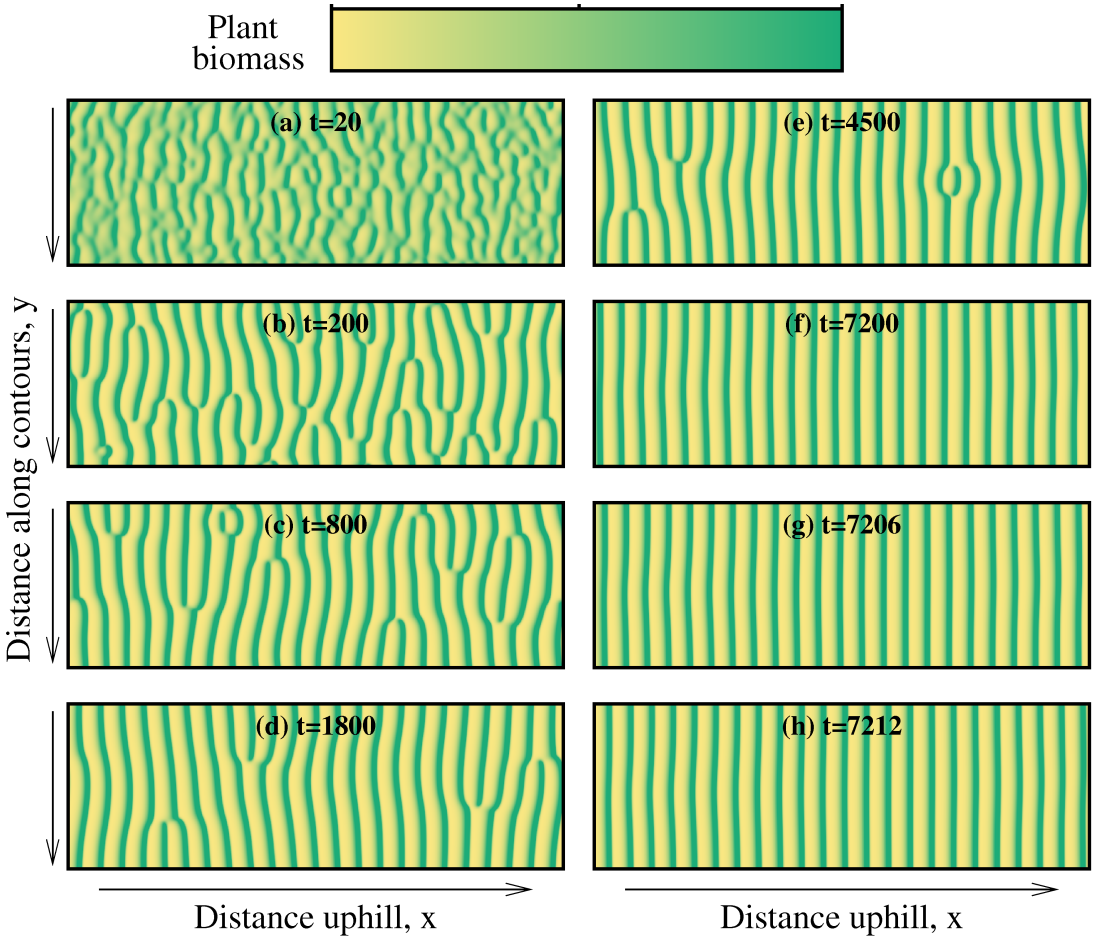
Outline

Mechanisms of Pattern Generation

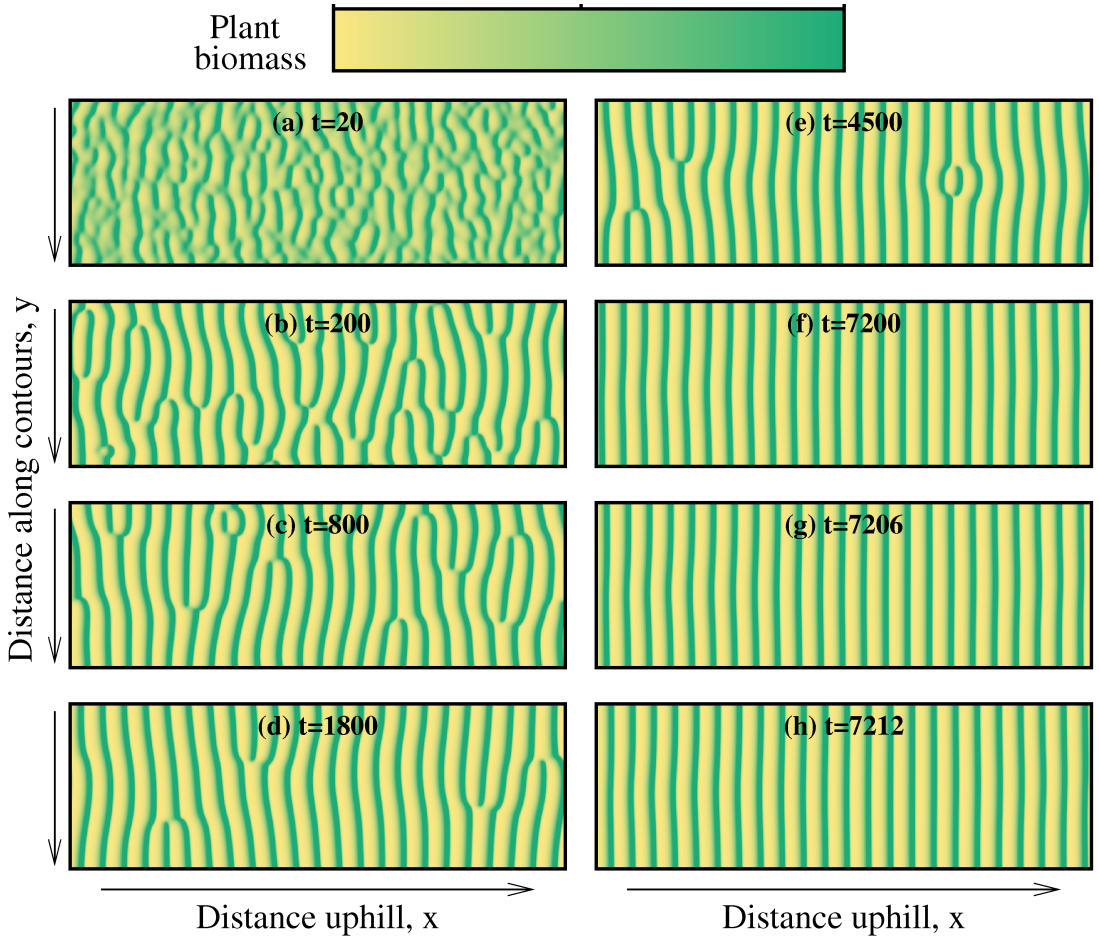
Vegetation patterns can originate in two ways:

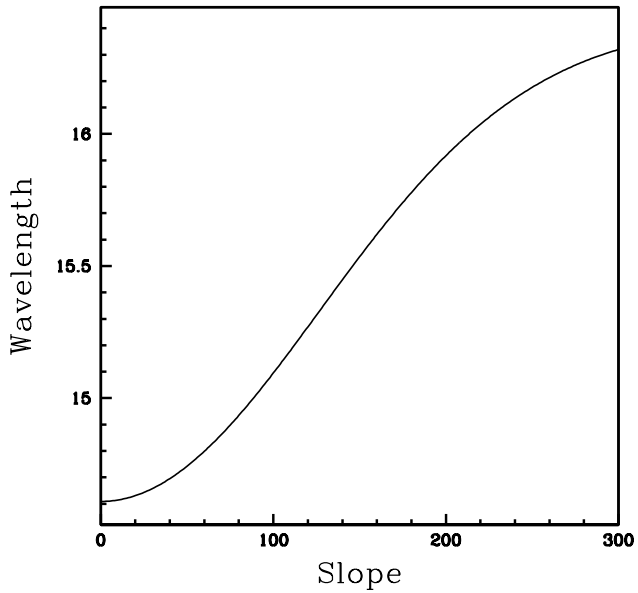
- Degradation of uniform vegetation
- Colonisation of bare ground

Degradation of Uniform Vegetation

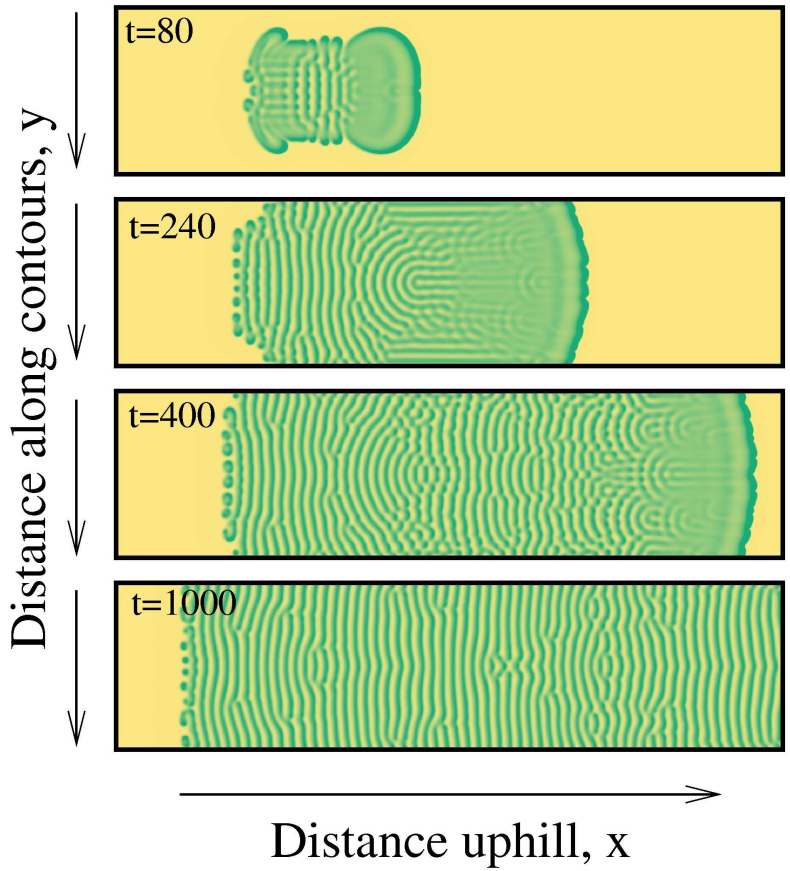


Degradation of Uniform Vegetation





Colonisation of Bare Ground



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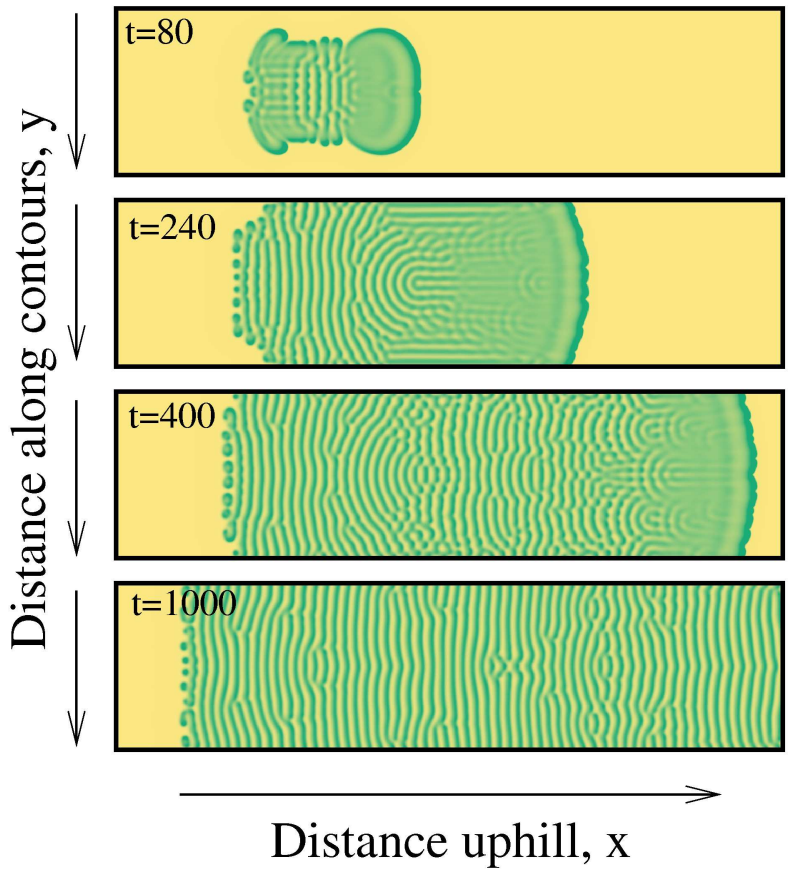
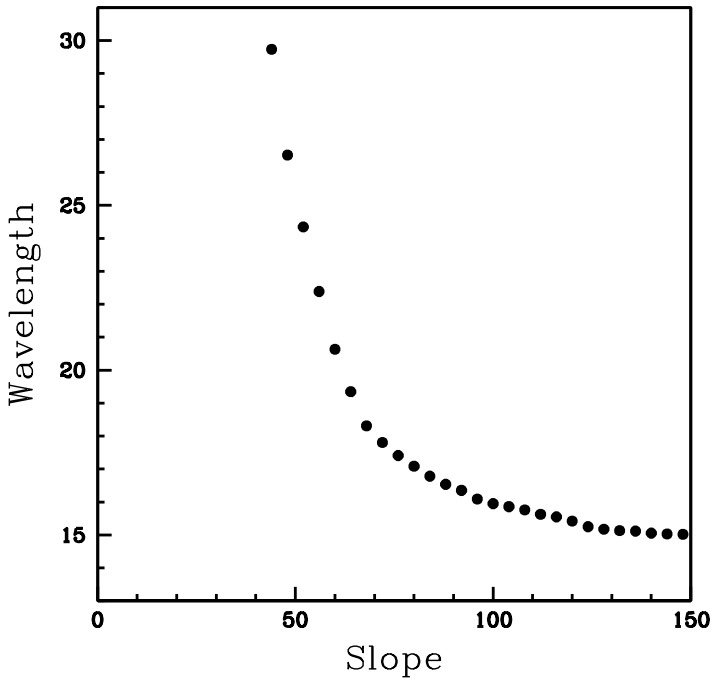




Wavelength vs Slope

Mathematical modelling predicts that:

- For patterns arising from degradation of uniform vegetation, wavelength is positively correlated with slope
- For patterns arising from colonisation of bare ground, wavelength is negatively correlated with slope

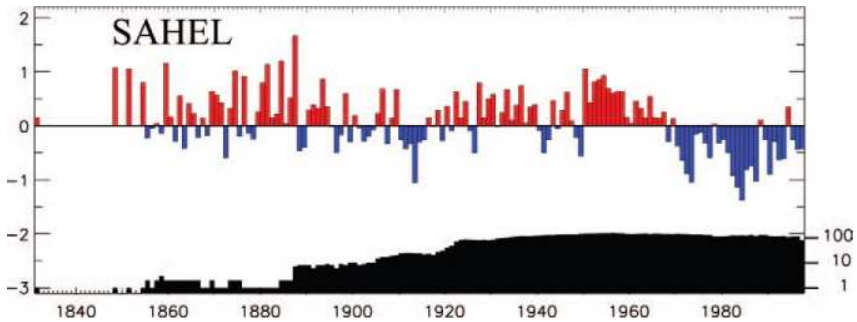
Outline

Vegetation Patterns in the African Sahel

- Patterned vegetation is widespread in the Sahel
- Several studies of banded vegetation show wavelength $\downarrow$ as slope $\uparrow$

Rainfall History in the Sahel

- The Sahara and Sahel have been arid for about 5000 years, but the level of aridity has varied significantly.
- The Sahel was relatively humid in the 16th and 17th centuries.



  - There is no direct data on rainfall before c. 1850
  - Proxy data: (i) lake levels, esp. Lake Chad; (ii) historical chronologies, e.g. Bornu Empire; (iii) memories of local peoples.

Rainfall History in the Sahel

- The Sahara and Sahel have been arid for about 5000 years, but the level of aridity has varied significantly.
- The Sahel was relatively humid in the 16th and 17th centuries.
- Reasonable assumption: areas with vegetation patterns today had uniform vegetation at the end of the 17th century.
- Since wavelength decreases with slope, my results imply that vegetation must have died out and then recolonised since the end of the 17th century.
- The most severe drought since 1700 was c. 1738-1756. So today's vegetation patterns result from recolonisation since 1760.

Outline

Conclusions

Wavelength is positively correlated with slope $\Rightarrow$ vegetation pattern originated by degradation of uniform vegetation

Wavelength is negatively correlated with slope $\Rightarrow$ vegetation pattern originated by colonisation of bare ground

Main message: combined wavelength–slope data is much more valuable than wavelength data alone.

Reference

J.A. Sherratt: Using wavelength and slope to infer the historical origin of semi-arid vegetation bands. *Proc. Natl. Acad. Sci. USA*, in press (2015), doi: 10.1073/pnas.1420171112.

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