# Predicting the Wavelength of Patterned Vegetation in Drylands

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Oxford Desert Conference, 16-17 April 2015

This talk can be downloaded from my web site www.ma.hw.ac.uk/~jas

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Predicting the wavelength of patterned vegetation in drylands

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- 2

Vegetation Patterns Banded Vegetation on Slopes Data on Wavelength vs Slope

#### Outline



- The Generation of Vegetation Patterns
- 3 Case Study: The African Sahel
- 4 Conclusions and References



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Vegetation Patterns Banded Vegetation on Slopes Data on Wavelength vs Slope

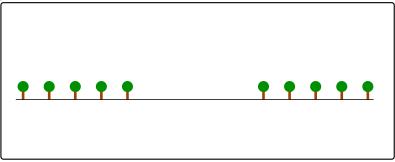
#### Vegetation Patterns

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

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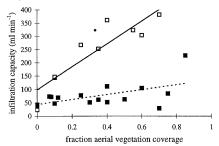


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#### Vegetation Patterns

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





Data from Burkina Faso Rietkerk et al Plant Ecology 148: 207-224, 2000

 $\begin{array}{l} \mbox{More plants} \Rightarrow \mbox{more roots and organic matter in soil} \\ \Rightarrow \mbox{more infiltration of rainwater} \end{array}$ 

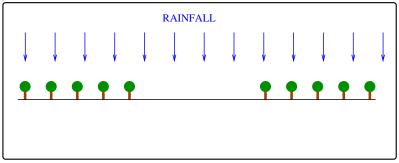
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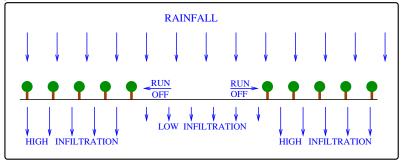
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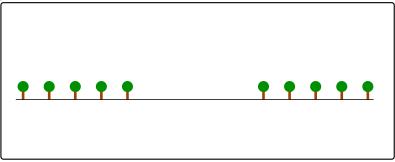


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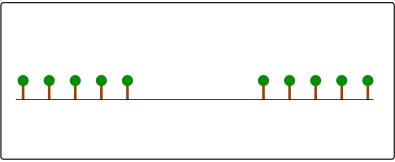
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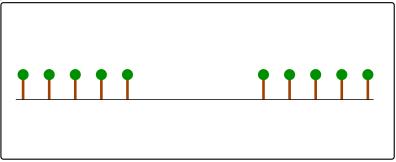
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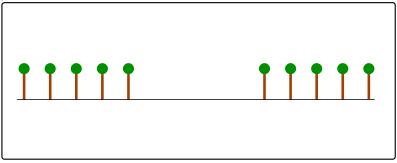
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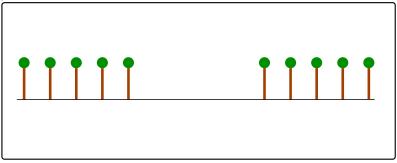
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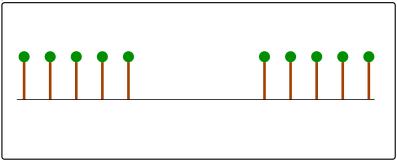
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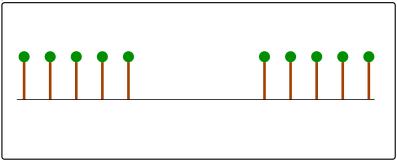


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Vegetation Patterns Banded Vegetation on Slopes Data on Wavelength vs Slope

# 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.

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# Banded Vegetation on Slopes

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Bushy vegetation in Niger



Mitchell grass in Australia (Western New South Wales)

#### Wavelength can be measured via remote sensing.

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#### Remote Sensing of Elevation

#### Slope can also be measured remotely.

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





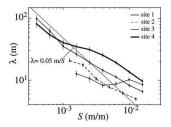
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### Data on Wavelength vs Slope

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



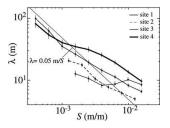
Data from Nevada, USA (Pelletier et al, J. Geophys. Res. 117: F04026, 2012)

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Vegetation Patterns Banded Vegetation on Slopes Data on Wavelength vs Slope

# 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)

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

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Mechanisms of Pattern Generation Degradation of Uniform Vegetation Colonisation of Bare Ground Navelength vs Slope

### Outline



#### 2 The Generation of Vegetation Patterns

- 3 Case Study: The African Sahel
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Mechanisms of Pattern Generation Degradation of Uniform Vegetation Colonisation of Bare Ground Wavelength vs Slope

#### Mechanisms of Pattern Generation

Vegetation patterns can originate in two ways:

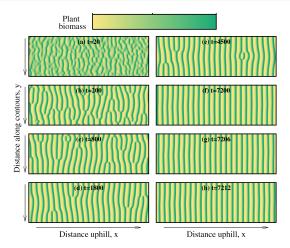
- Degradation of uniform vegetation
- Colonisation of bare ground



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Mechanisms of Pattern Generation Degradation of Uniform Vegetation Colonisation of Bare Ground Wavelength vs Slope

# Degradation of Uniform Vegetation



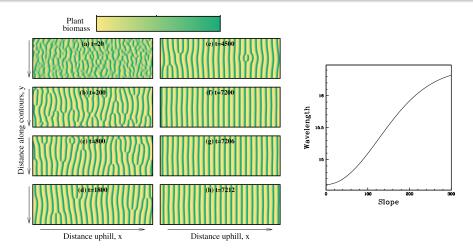
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# Degradation of Uniform Vegetation

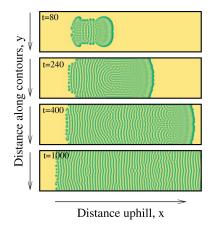


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Ecological Background The Generation of Vegetation Patterns Case Study: The African Sahel Colonisation of Bare Ground

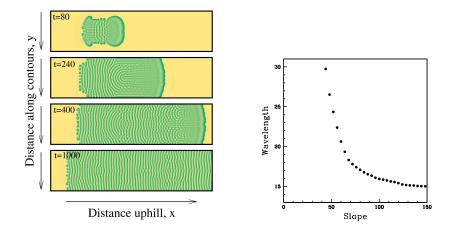
#### Colonisation of Bare Ground





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#### **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

Vegetation Patterns in the African Sahel Rainfall History in the Sahel





- 2 The Generation of Vegetation Patterns
- Case Study: The African Sahel
  - 4 Conclusions and References



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### Vegetation Patterns in the African Sahel



- Patterned vegetation is widespread in the Sahel
- Several studies of banded vegetation show wavelength ↓ as slope ↑

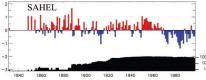
Vegetation Patterns in the African Sahel Rainfall History in the Sahel

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- 32

# 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.

Vegetation Patterns in the African Sahel Rainfall History in the Sahel

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# 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.

Conclusions Reference

#### Outline



- 2 The Generation of Vegetation Patterns
- 3 Case Study: The African Sahel
- Conclusions and References



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Conclusions Reference

#### Conclusions

#### Wavelength is positively correlated with slope ⇒ 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.



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Conclusions Reference

#### 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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Conclusions Reference

#### List of Frames



2

#### **Ecological Background**

- Vegetation Patterns
- Banded Vegetation on Slopes
- Data on Wavelength vs Slope

#### The Generation of Vegetation Patterns

- Mechanisms of Pattern Generation
   Degradation of Uniform Vegetation
- Colonisation of Bare Ground
- Wavelength vs Slope

#### Case Study: The African Sahel

- Vegetation Patterns in the African Sahel
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