Complex River networks with Cellular Automata

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Outline

- Introduction
- Cellular Automata Model
- Simulation results
- From CA to network
- Network analysis
- Bifurcation
- Conclusion

Introduction

1. Simulate river networks with Cellular Automata
2. Analyse the emerging networks

Introduction

Simulate rivers over various terrains

Analyse the effect of terrain characteristics on the emergence of complex river networks

'How does the terrain affect the bifurcation ratio of a complex river network?'

Complexity

“The complexity of a river network is measured by the number of channels and the number of bifurcations.”

P. Topa, 2006

Cellular Automata Model

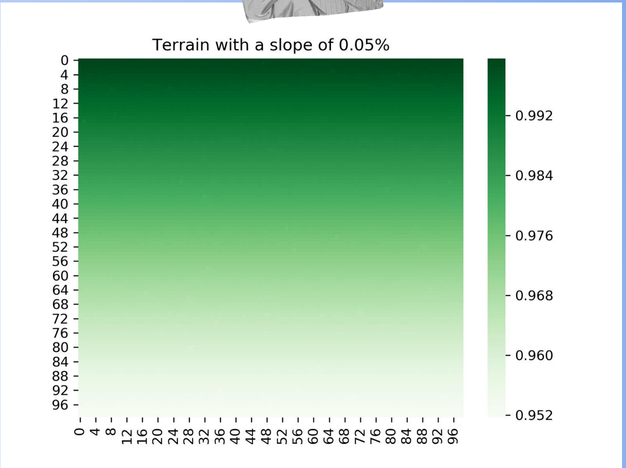
River characteristics

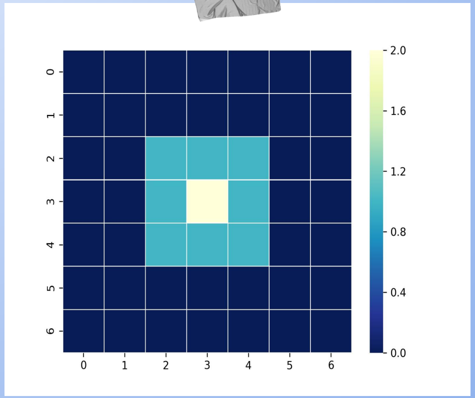
- ➔ A source cell
- ➔ Constant source & sink
- ➔ Slope landscape
- ➔ Vertical height difference

Two-dimensional CA

Properties

- *Lattice is a 2D grid*
- *Moore neighborhood*
- *Fixed boundary conditions*





Cell State

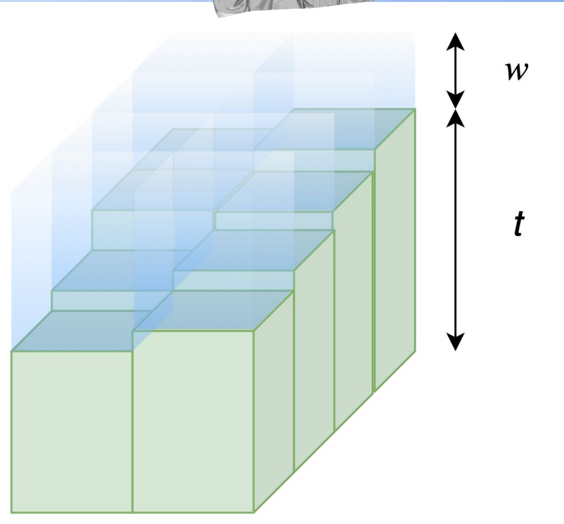
Rivers flow downhill and aim to find the steepest slope

Initialise terrain with decreasing height

Add random perturbations vertically

t: *elevation of the terrain*

w: *thickness of the water*



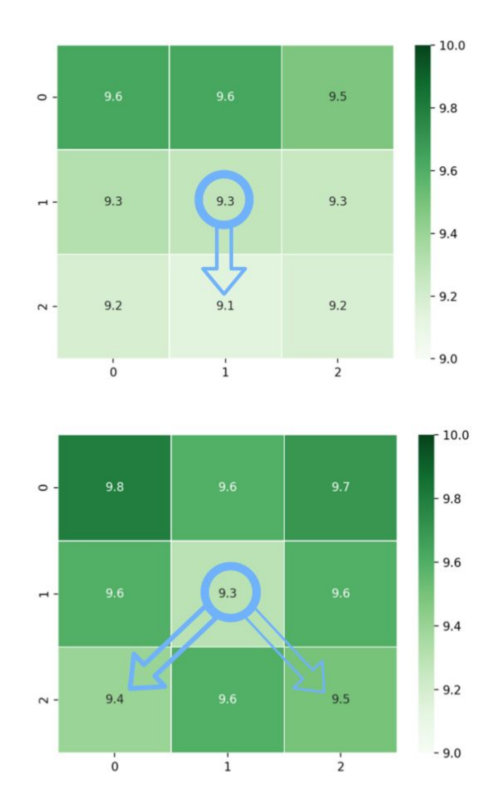
The Rules

Regular river flow:

A river flows to the neighbor with the lowest terrain height.

Bifurcation:

In the absence of a lower cell, the river splits proportionally to the two lowest cells in the Moore neighborhood.



100% of the water flows to the next cell

Two thirds flows to the left cell

One third flows to the right cell

The Rules

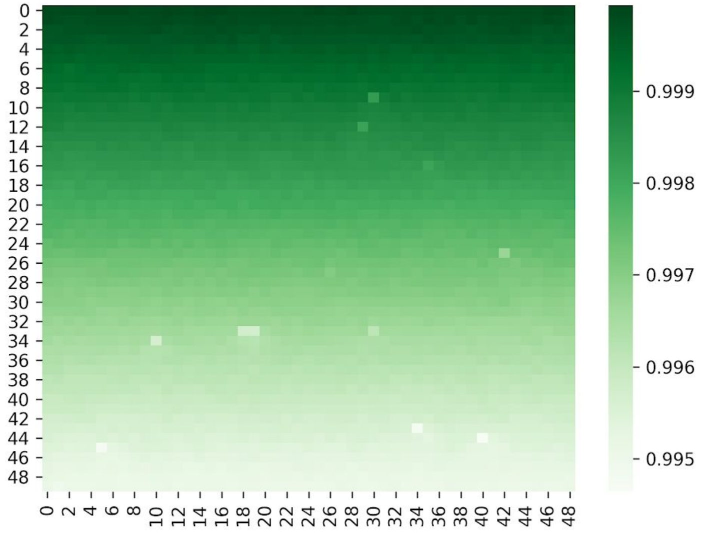
The amount of water carried by the river decreases over time.

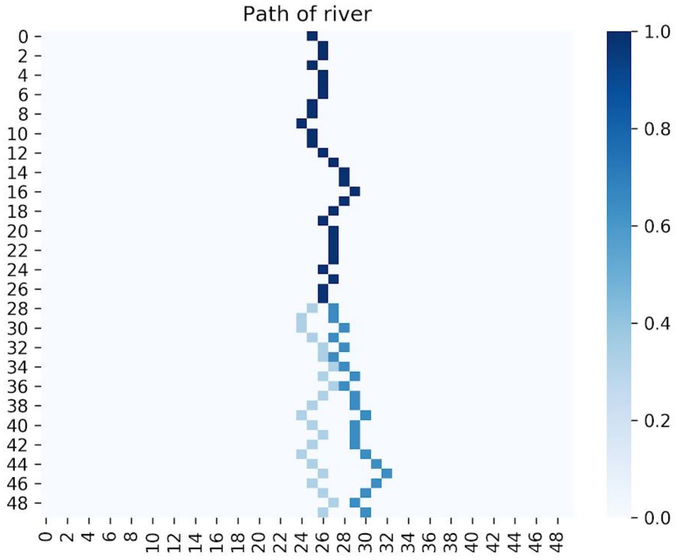
Water loss variable:

The percentage of water lost to the surroundings

Example

Slope of terrain: 0.01 % per step
Water loss variable: 0.08 % per step





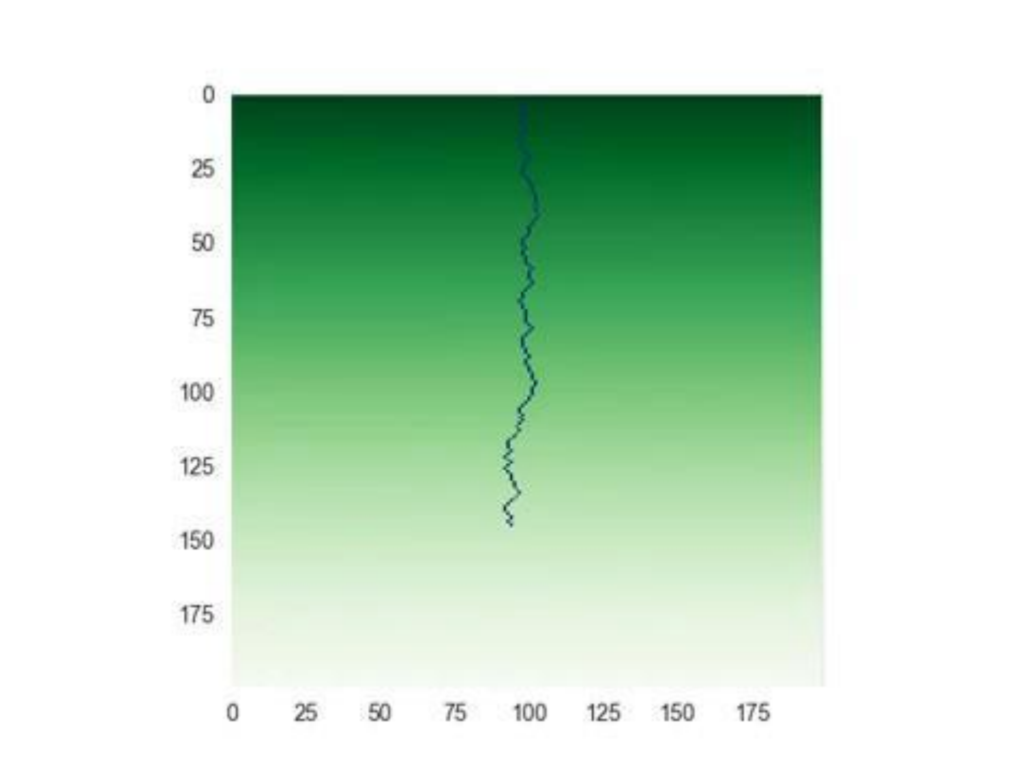
No branching for steep slope

Slope of terrain:

0.01 % per step

Water loss variable:

0.08 % per step



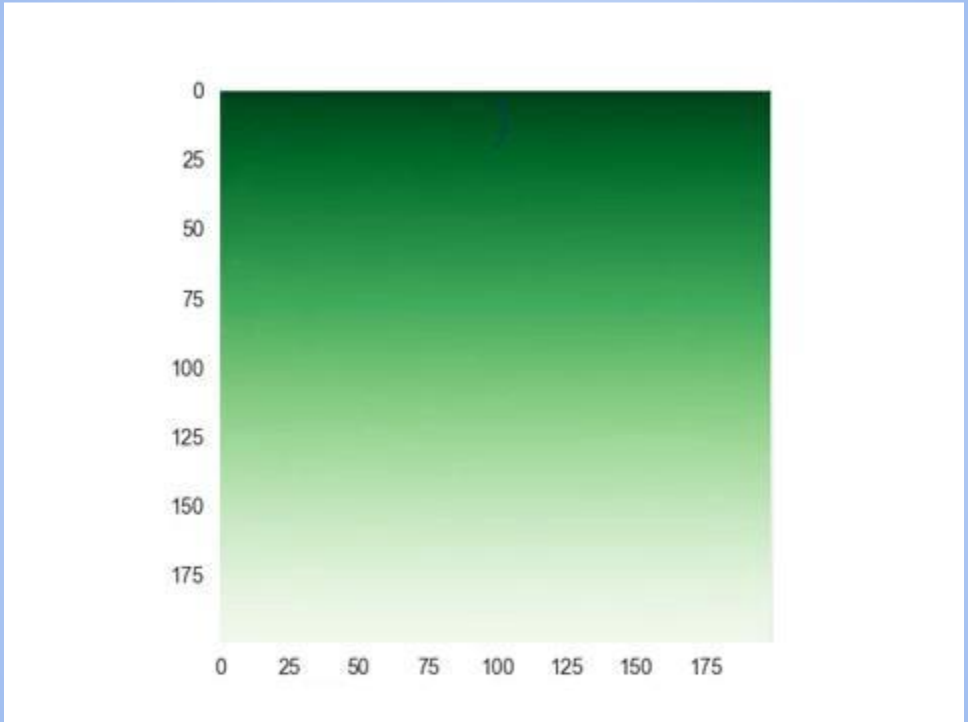
Branching for shallow slope

Slope of terrain:

0.0001 % per step

Water loss variable:

0.08 % per step



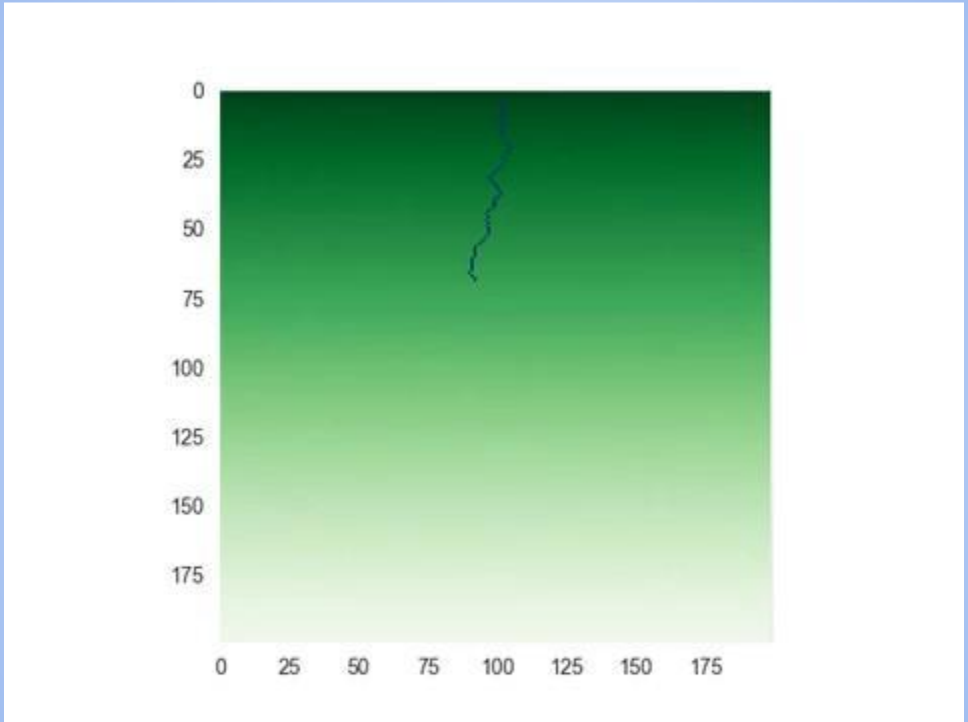
Low water loss, longer rivers

Slope of terrain:

0.01 % per step

Water loss variable:

0.0005 % per step



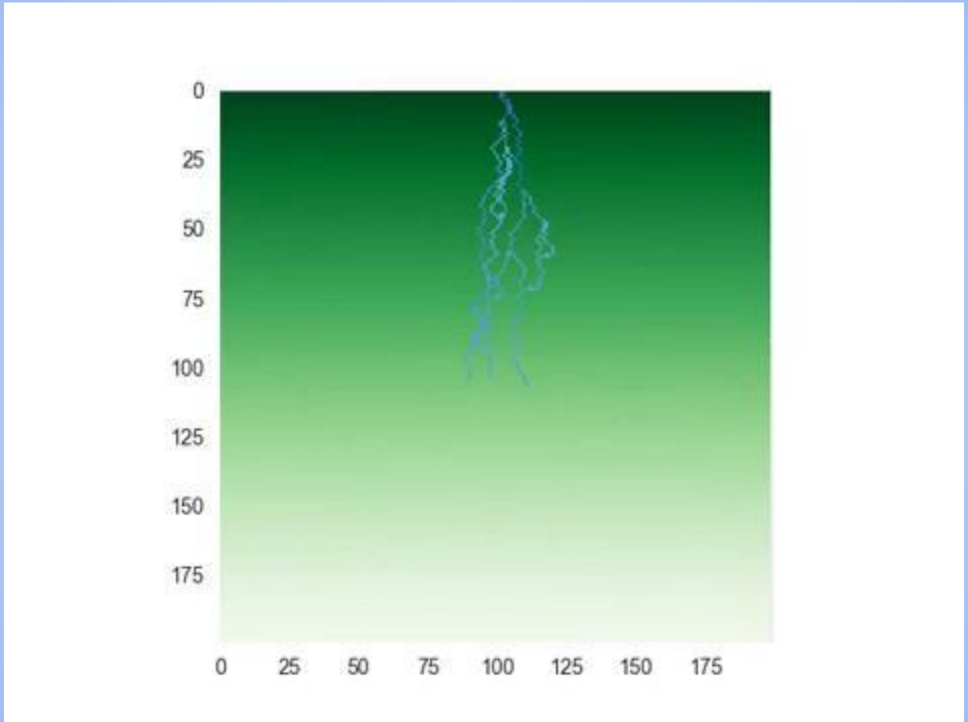
High water loss, shorter rivers

Slope of terrain:

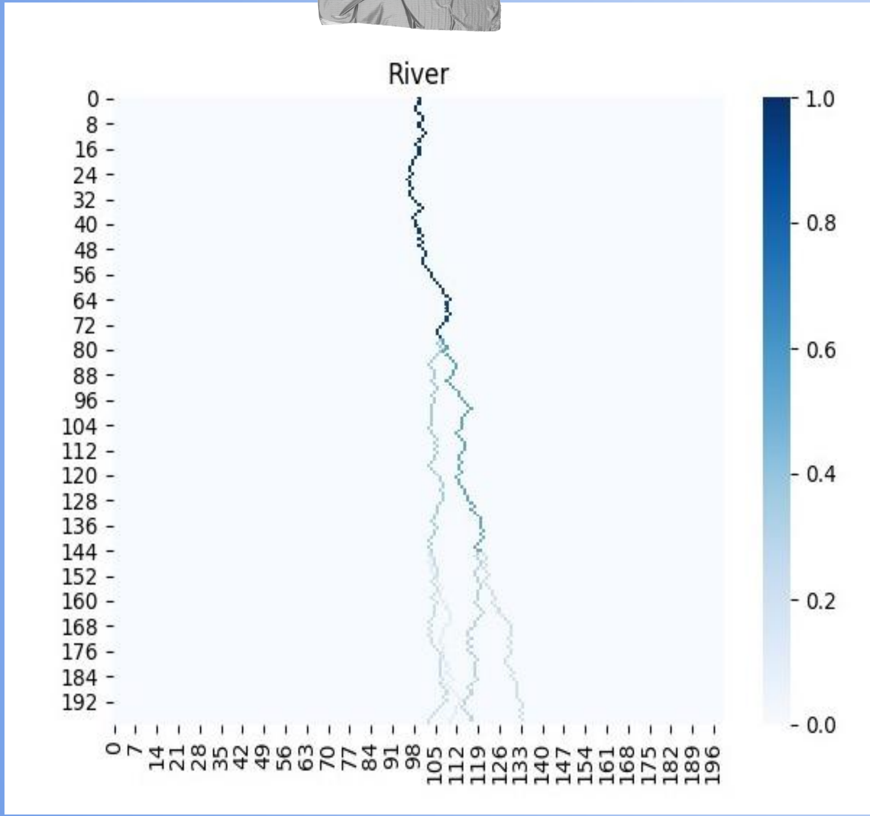
0.01 % per step

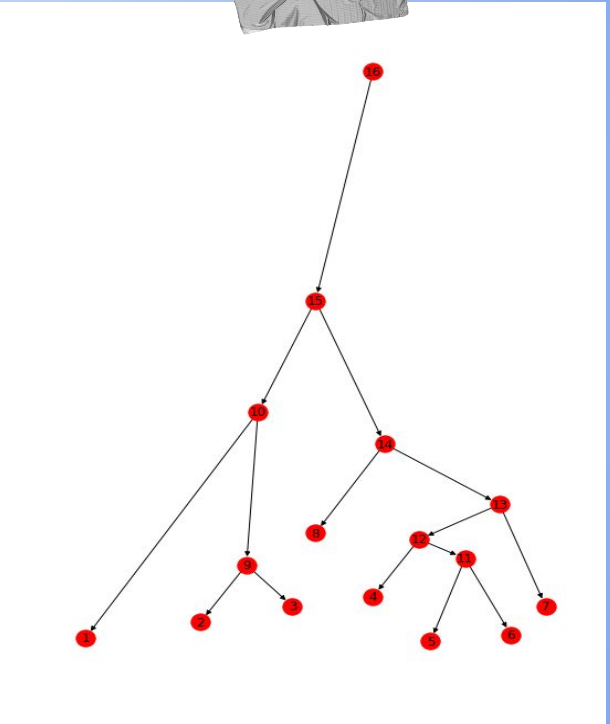
Water loss variable:

0.01 % per step

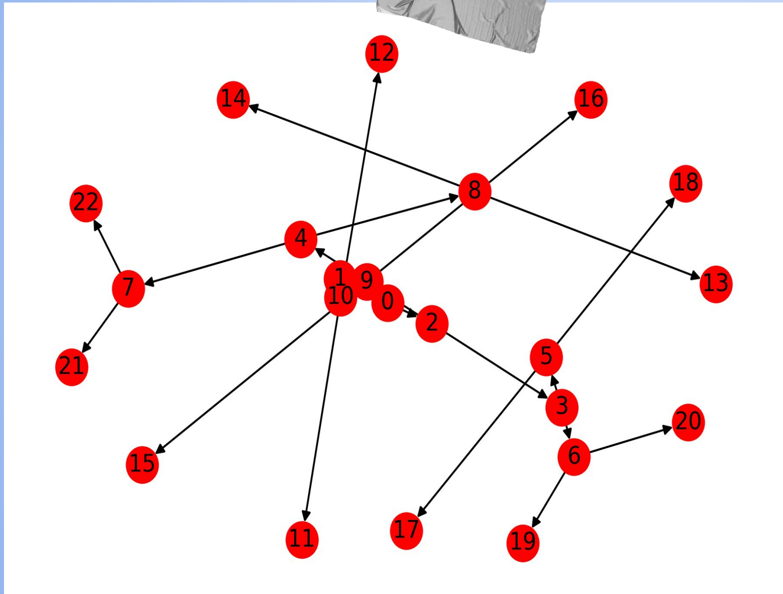


From CA to graph



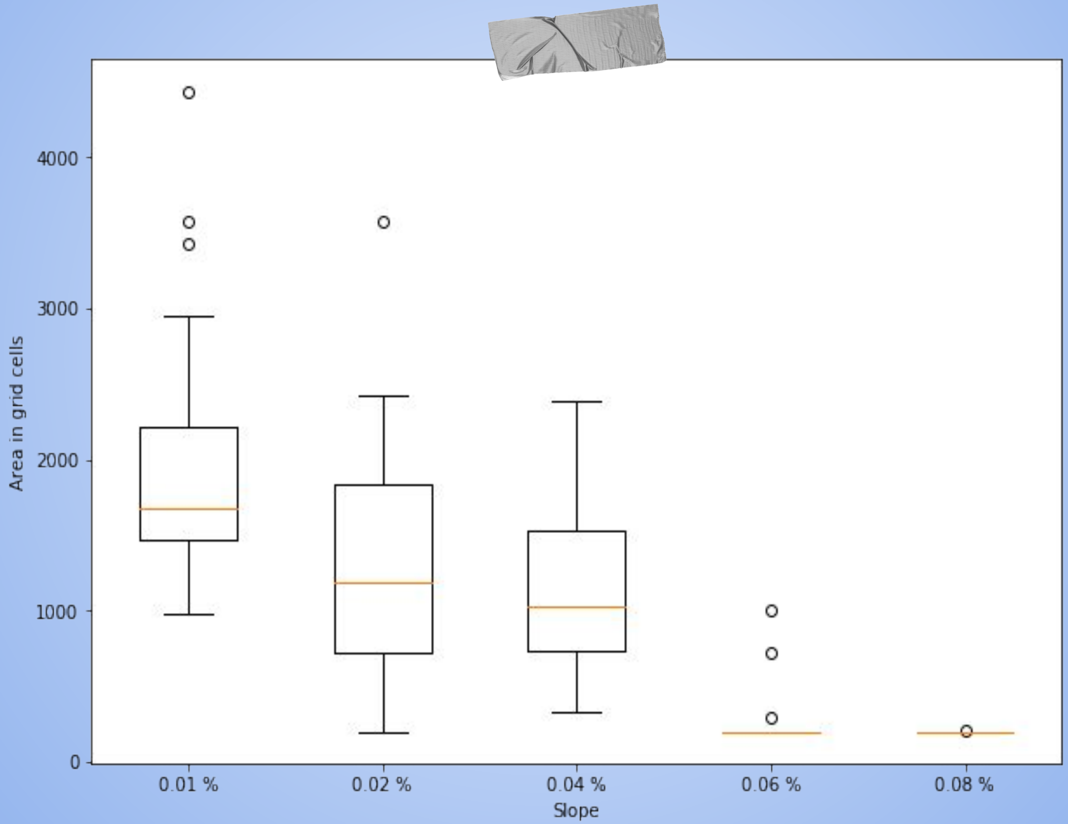


Graph



- ❖ Order channel
- ❖ Bifurcation order ratio
- ❖ River length order ratio
- ❖ Fractal Dimension

The Effect of slope on area size



The Strahler number

Horton-Strahler

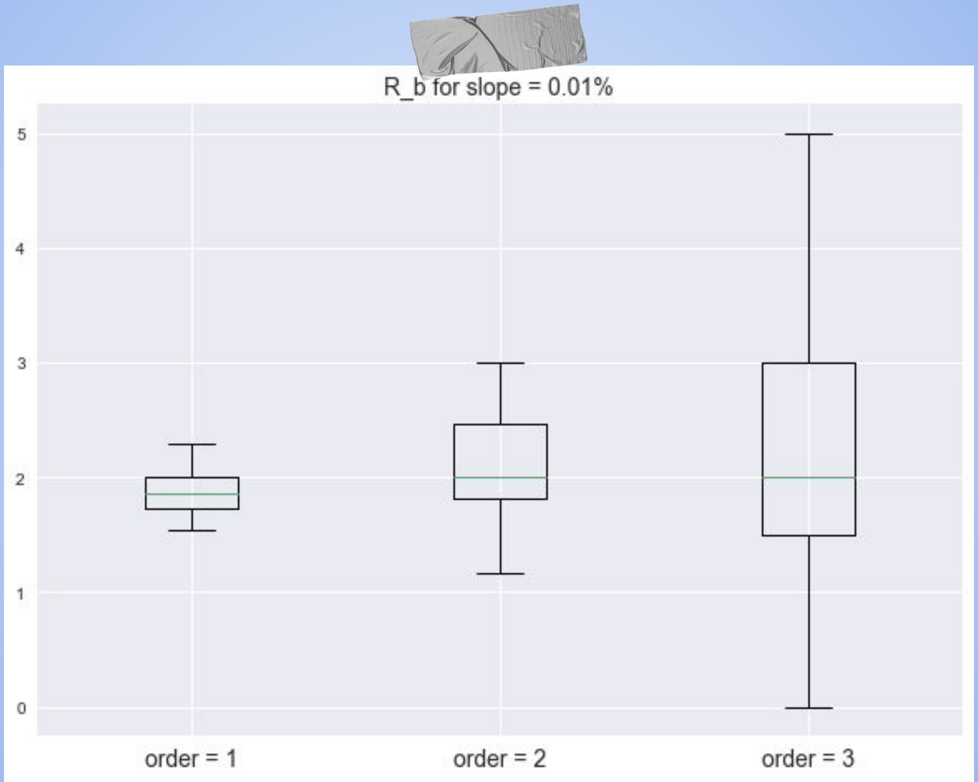
$$R_b = \frac{N_i}{N_{i+1}}$$

$$R_l = \frac{l_{i+1}}{l_i}$$

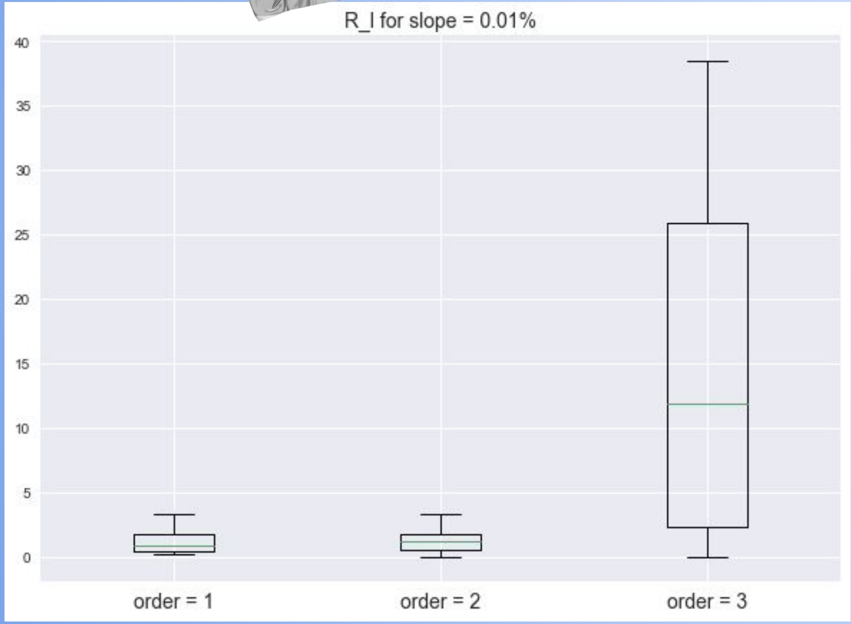
$$D = \frac{\ln R_b}{\ln R_l}$$

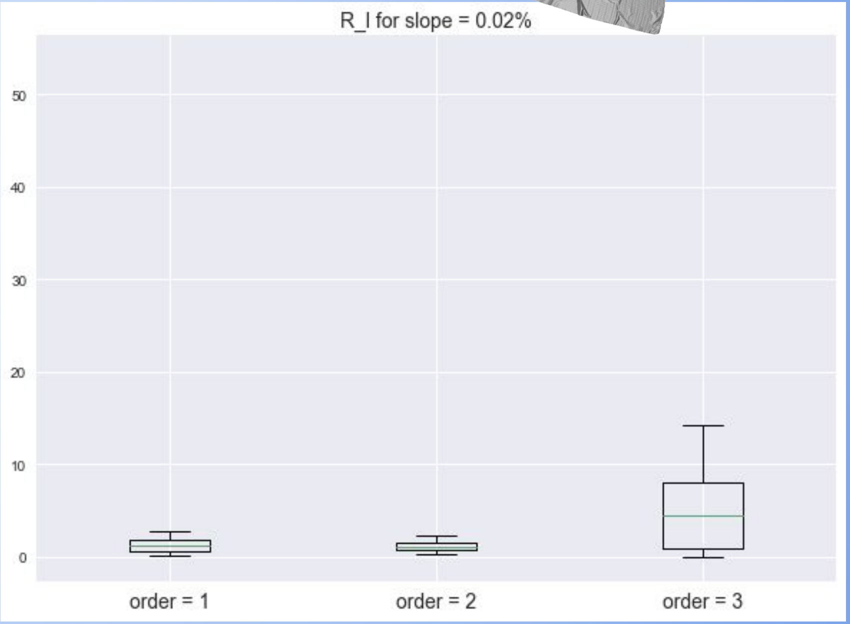
- Bifurcation coefficient R_b
- Length order R_l
- Fractal dimension D

Bifurcation Coefficient Ratio



Length ratio of segments





Fractal Dimension

Fractal paper: 1.24 +- 0.12

Slope percentage	0.01	0.02	0.04	0.06
Fractal Dimension	2.14	2.37	1.27	0.922

Conclusion

- Higher slope, lower branching ratio
- Shorter rivers with higher water loss
- Slope does affect the fractal dimension of the river basins

Conclusion

Suggestions for future work

- Multiple rivers from multiple source cells
- More complex terrain, for example by adding “hills”

Questions?

Reference

- Topa, P., Dzwinel, W., & Yuen, D. A. (2006). A multiscale cellular automata model for simulating complex transportation systems. *International Journal of Modern Physics C*, *17*(10), 1437-1459.

- Topa, P. (2006, September). A cellular automata approach for modelling complex river systems. In *International Conference on Cellular Automata* (pp. 482-491). Springer, Berlin, Heidelberg.