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Quantifying the Naturalness and Complexity of Landscape Photographs using their Fractal Dimensions

OPENspace seminar series

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Naturalness and
Complexity of
Landscape
Photographs using
their
Fractal Dimensions”*

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Definitions

Context and Literature review

Introduction

Landscape preference: Where people like to go, where they choose to live.

Evolutionary psychology:
Universal preference for natural environments

Main theories:

- Biophilia (E. O Wilson)
- Prospect-refuge (Appleton)
- Information Processing Theory (Kaplan)



Naturalness

Oxford English Dictionary:

“The quality of possessing the distinctive features of a naturally occurring object, landscape, etc.: the appearance of being unchanged or unspoilt by human intervention.”

“how close a landscape is to a **perceived** natural state” (Ode et al., 2009, p. 376)

- subjective
- context-dependent



Naturalness

The importance of vegetation

- Presence
- Proportions
- Forests > Fields

“vegetation can vary along a number of ecological and botanical dimensions. Similarly, a human-induced change can vary in terms of the type and intensity of development where specific human artefacts are involved.”

(Purcell and Lamb, 1998, p. 58)



Complexity

Information Processing Theory:

Evolution depends not only on food but also on cognitive processes.

	Understanding	Exploration
Immediate	Coherence	Complexity
Inferred	Legibility	Mystery

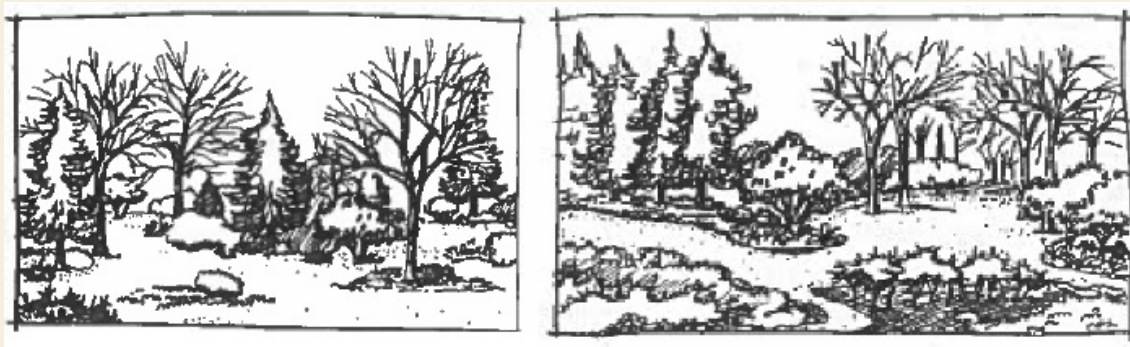


Image on the left is high in complexity and low in coherence; Image on the right is high in both.

From Kaplan et al. (1998)

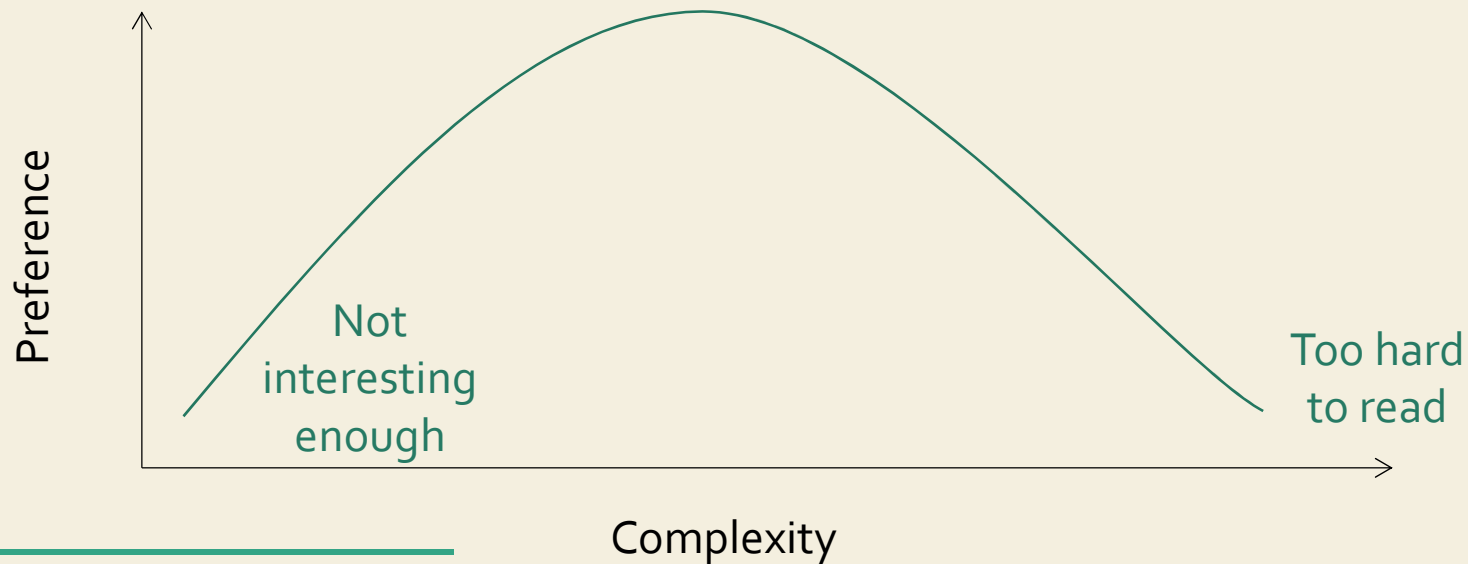


Complexity and Preference

Complexity: Diversity, visual variety, richness of the elements and features of the landscape, roughness, information content.

Is it Quantifiable?

Forsythe et al. 2011: Gif compressed size predicts **perceived complexity** in art.



Stamps, A. E. (2004). Mystery, complexity, legibility and coherence: A meta-analysis. *Journal of Environmental Psychology*, 24(1), 1–16.
Forsythe, A., Nadal, M., Sheehy, N., Cela-Conde, C. J., & Sawey, M. (2011). Predicting beauty: Fractal dimension and visual complexity in art. *British Journal of Psychology*, 102(1), 49–70. <https://doi.org/10.1348/000712610X498958>

Fractal Geometry

Concept established by **Benoit Mandelbrot** (1975)

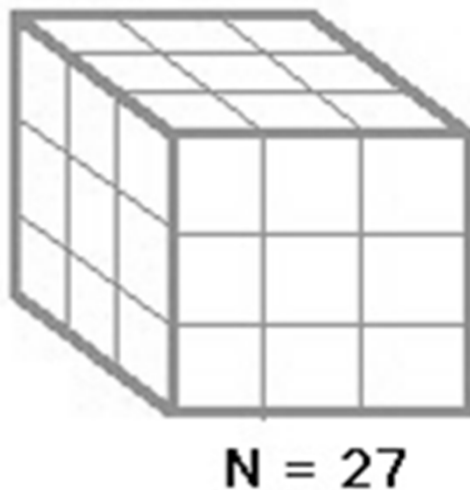
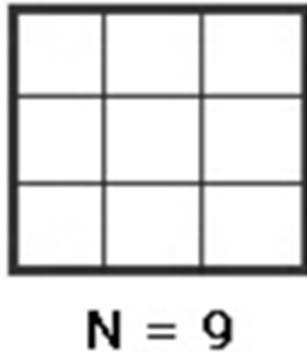
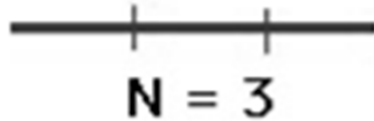
How long is the Coast of Britain?

"a rough or fragmented geometric shape that can be split into parts, each of which is (at least approximately) a *reduced-size copy* of the whole"
(Mandelbrot, 1982).

Fractal Dimension (D): "the object's degree of irregularity and break"(Mandelbrot, 1975)

Mandelbrot, B. B. (1975). *Les Objet Fractals: Forme, Hasard et Dimension*. Paris: France: Flammarion.
Mandelbrot, B. B. (1982). *The Fractal Geometry of Nature* (3d ed.). W. H. Freeman.





The Fractal Dimension

Fractal Dimension (*Hausdorff dimension*):

dimension 'D', multiplication factor 'm' and number of smaller objects 'N':

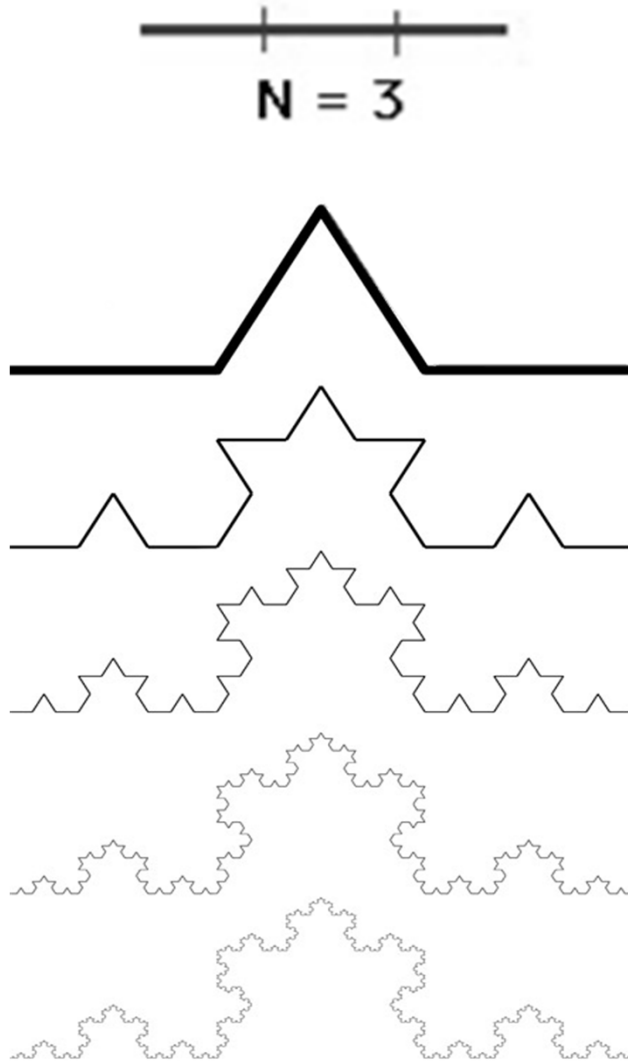
$$N = m^D$$

$$D = \frac{\log N}{\log m}$$

Where D is dimension, m the multiplication factor and N the number of smaller objects

Fractal: any object for which the Hausdorff Dimension > topological dimension





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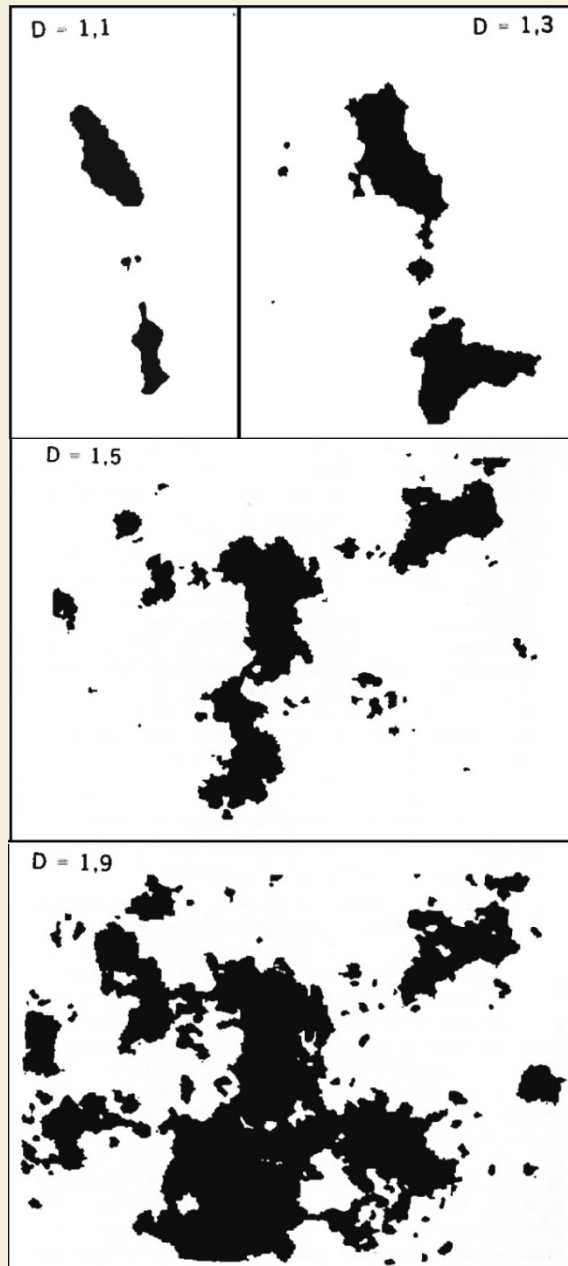
Fractal: any object for which the Hausdorff Dimension > topological dimension



The Fractal Dimension

“When D is near 1 [...], the coastline is too straight to be realistic. On the other hand, the coastline corresponding to $D = 1.3$ reminds us of the real Atlas” (Mandelbrot, 1982, p. 270).

Mandelbrot's
Islands



“The Geometry of Nature”

Structures showing aspects of **self-similarity** in Nature:

- Coastlines
- Rivers
- Mountain ranges
- Clouds
- Ferns
- Trees

But also lungs, blood vessels, and brain folds.

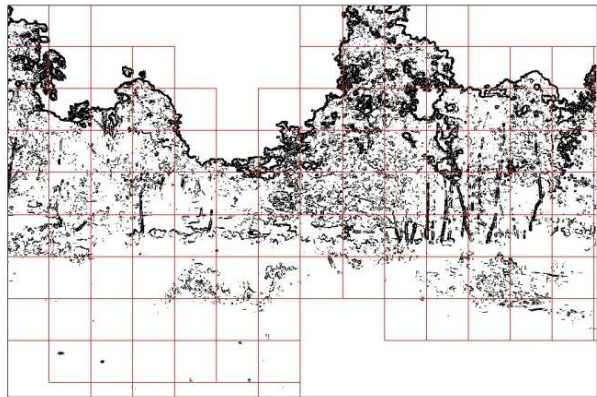
Physical fractals are **scalebound**, **random**, and their symmetry is **approximative**. D can only be **estimated**.



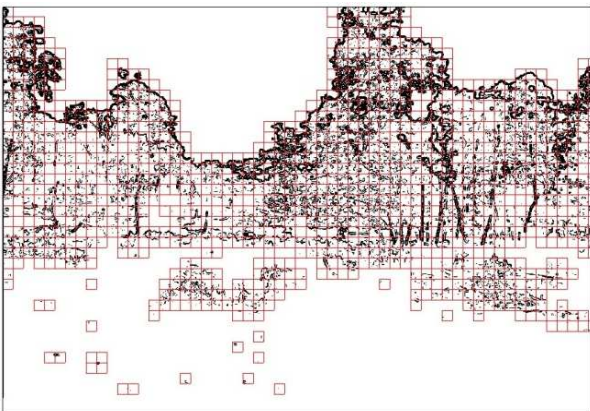
The Box-Counting Method

$$N(d) = \frac{1}{d^D}$$

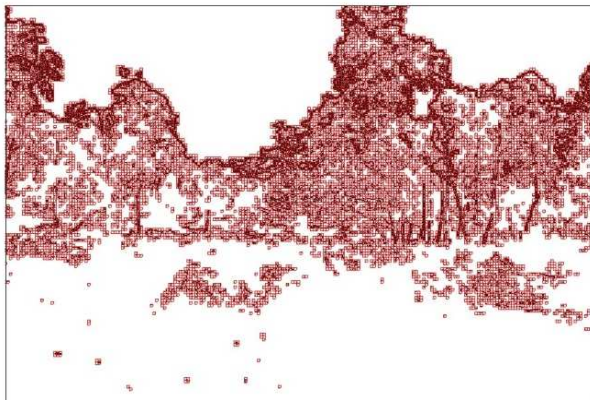
Where $N(d)$ is the number of boxes of linear size d filled by the pattern.



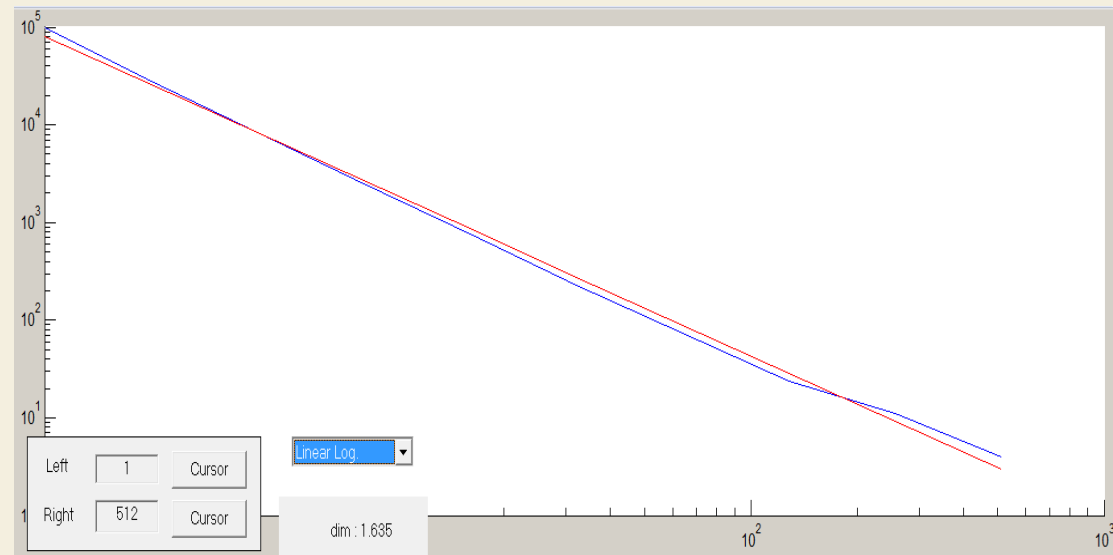
(a)



(b)



(c)



Only works on binary images with distinct object/background!





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*The Fractal Dimensions of Landscape Photographs as
Predictors of Preference*

Research Summary

Research Questions



1. **What is the fractal dimension of a landscape?**
 - a) How replicable are the results of a fractal analysis of a landscape image?
 - b) Is there any correlation between the properties of the landscape being analysed and its fractal dimension?

2. **Is it correlated with people's landscape preference?**



Image segmentation

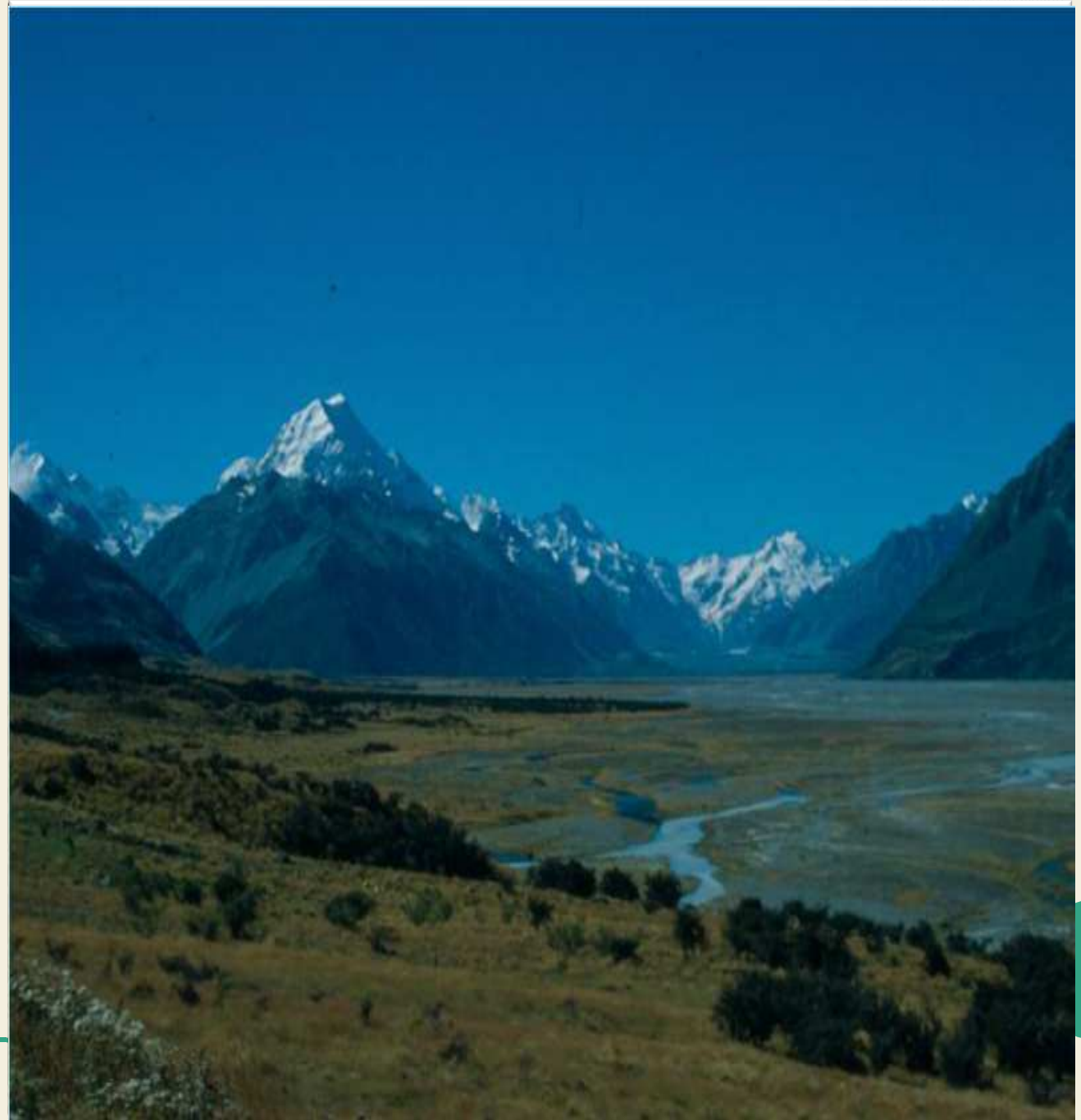


Image segmentation

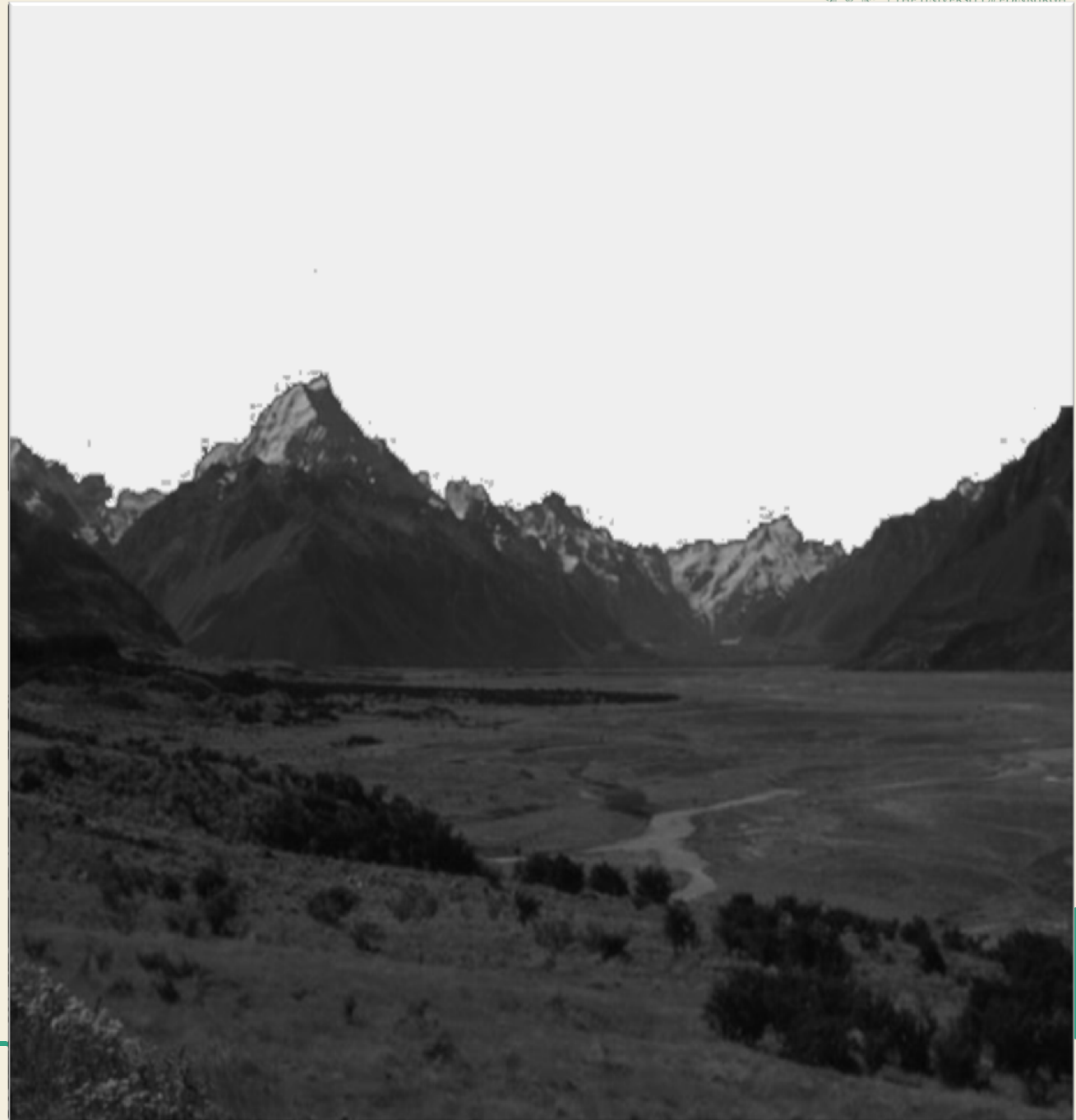


Image segmentation

I= 60

D=1.58

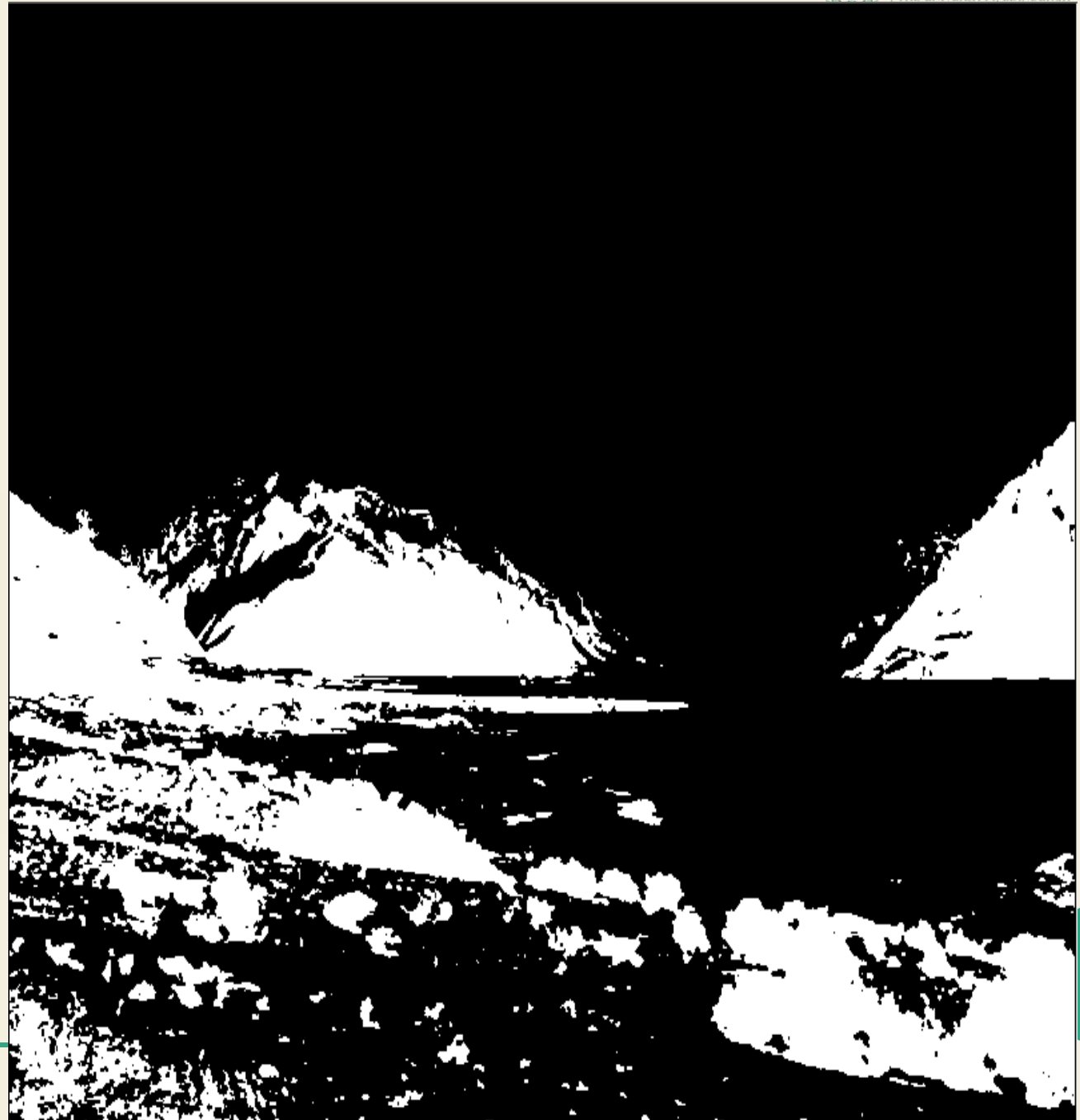


Image segmentation

I= 65

D=1.54

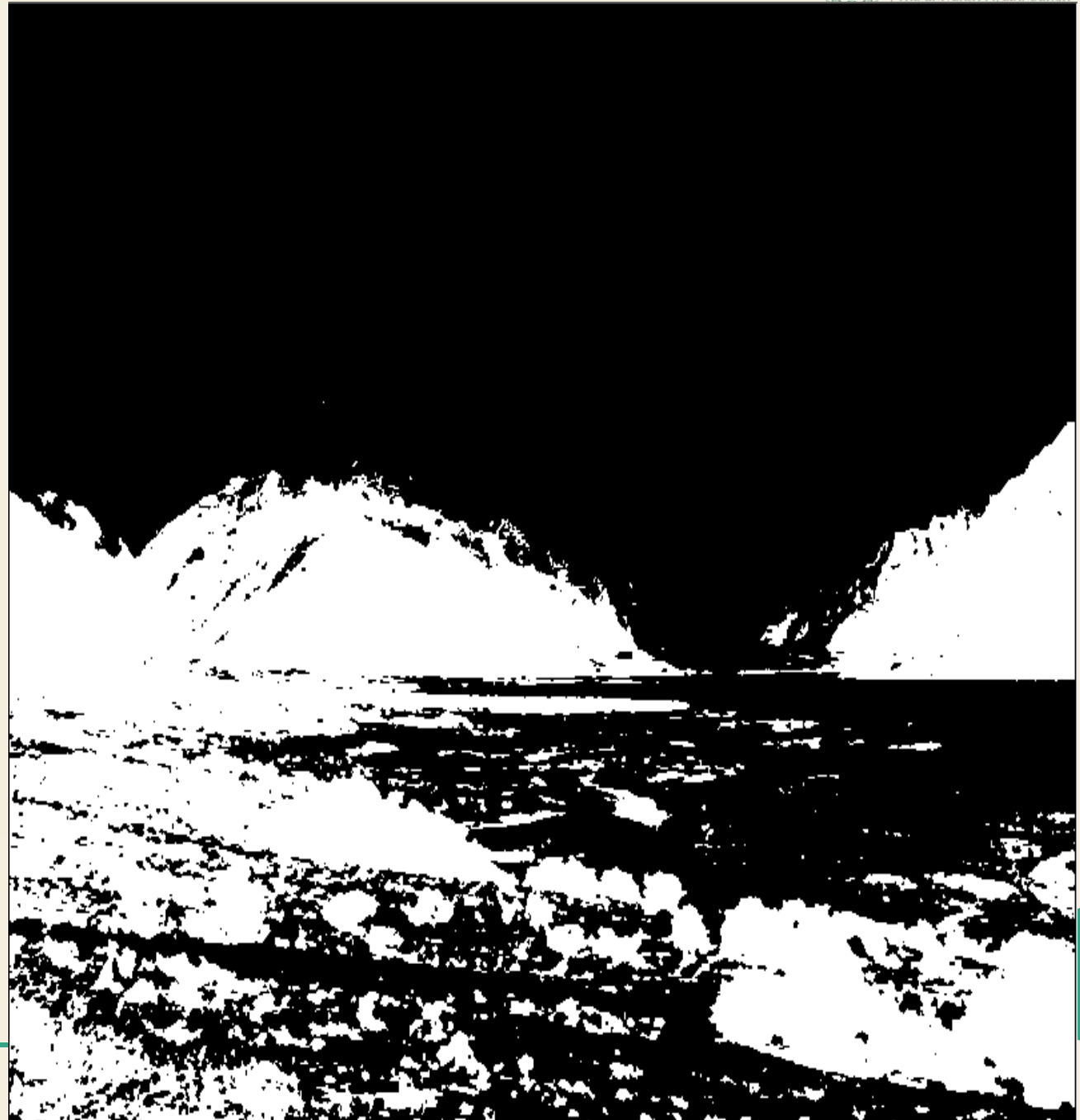


Image segmentation

$I = 70$

$D = 1.58$

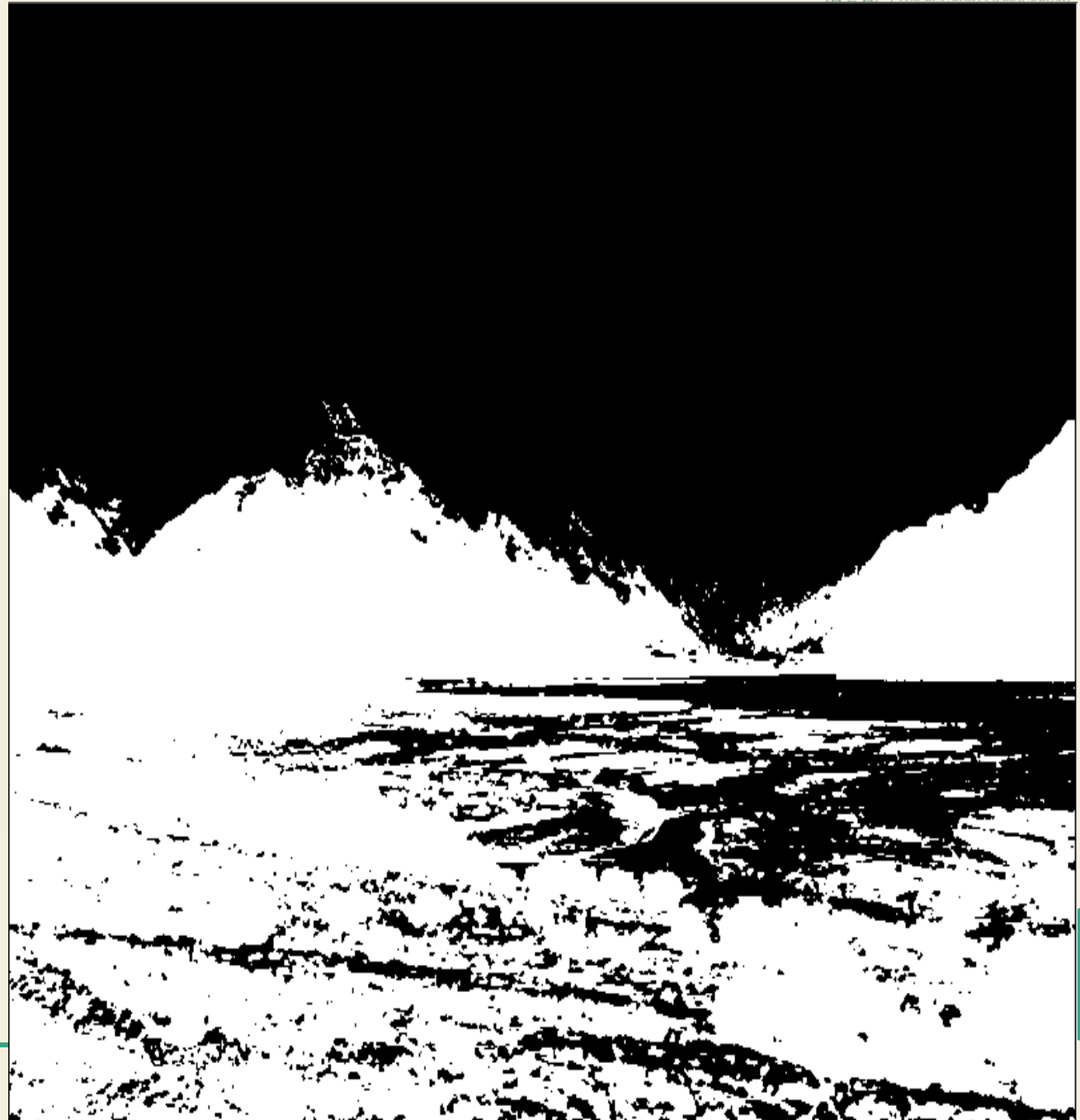


Image segmentation

I= 80

D=1.45

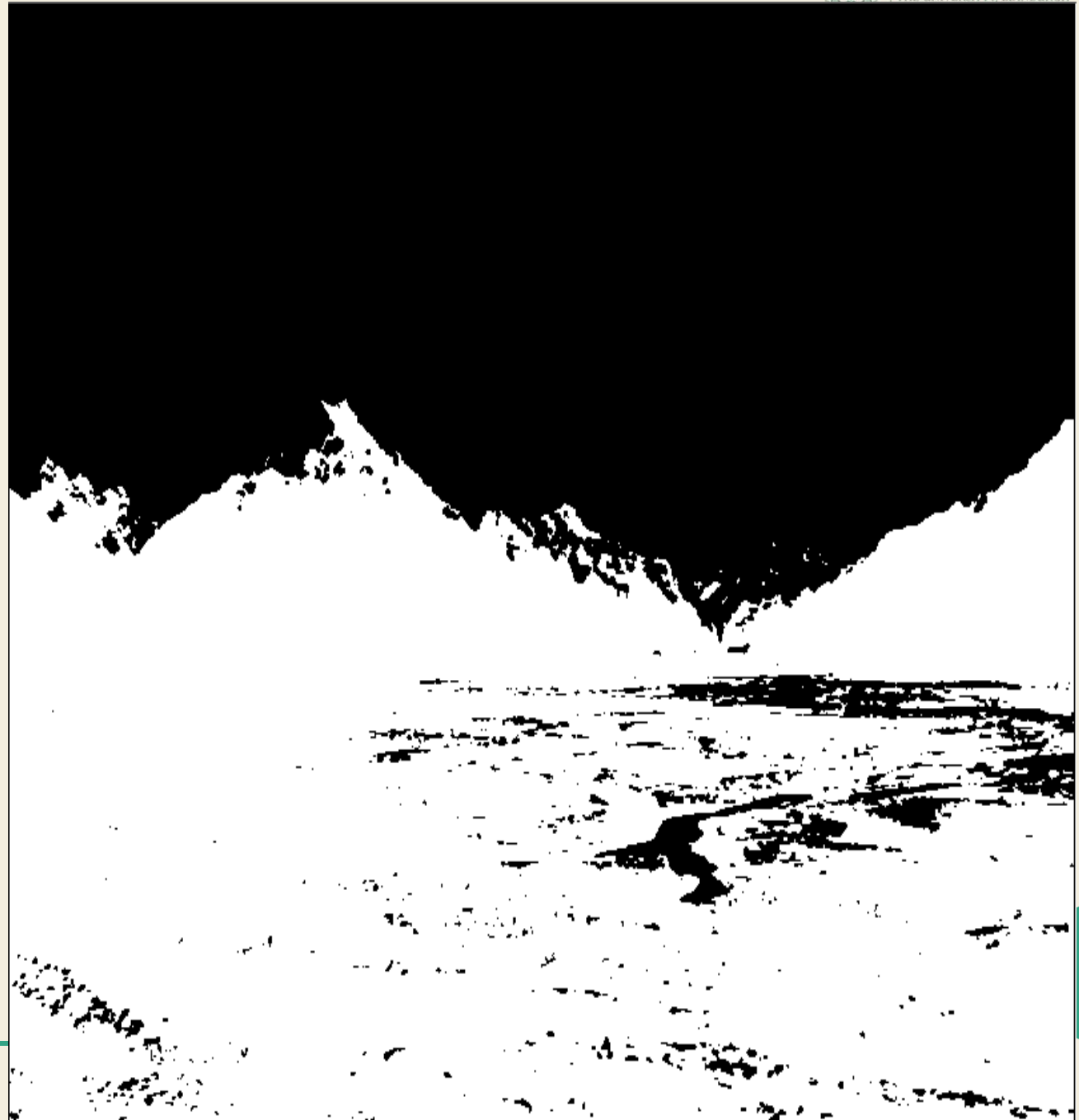


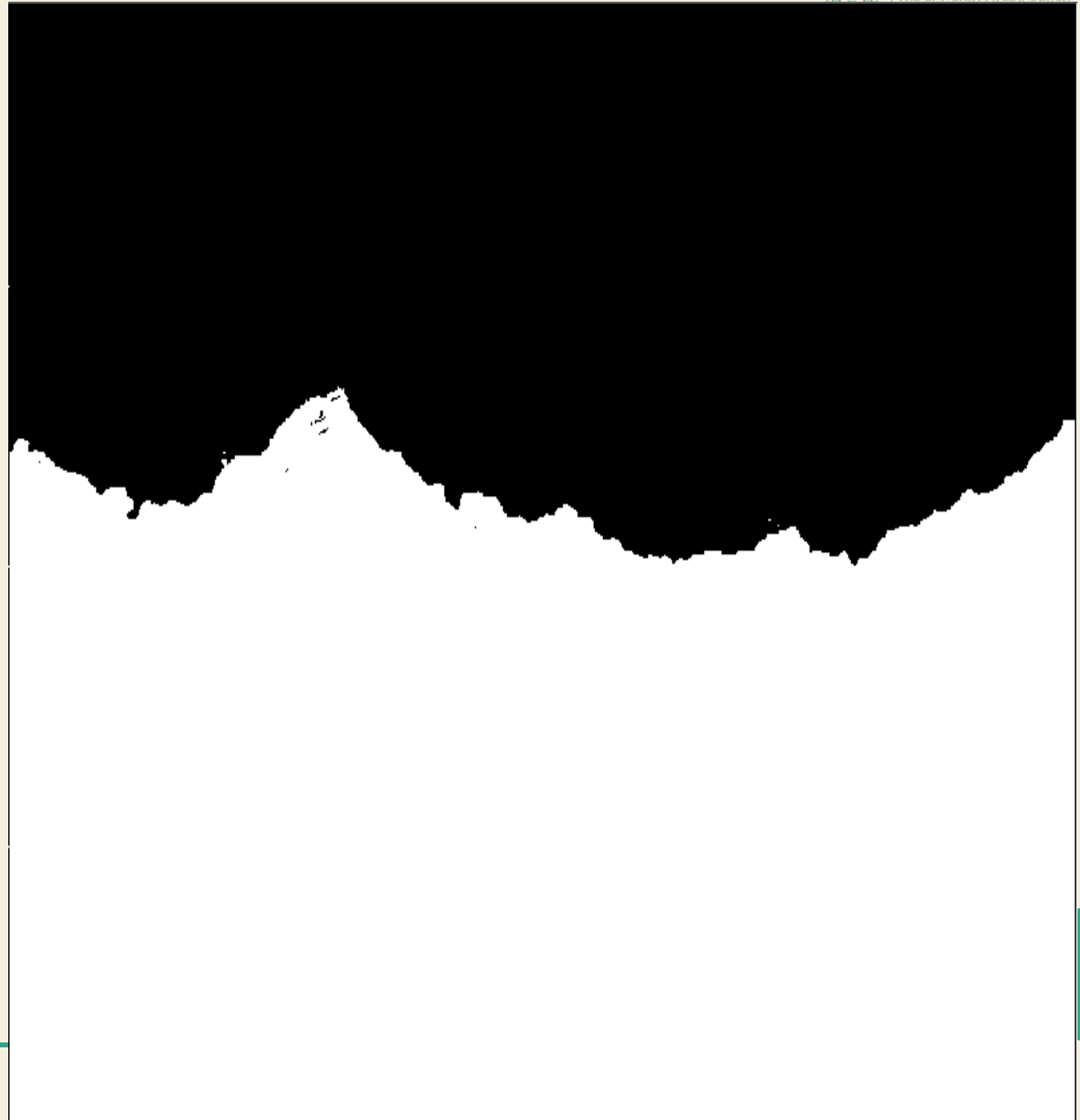
Image segmentation

$I = 90$

$D = 1.25$



Image segmentation



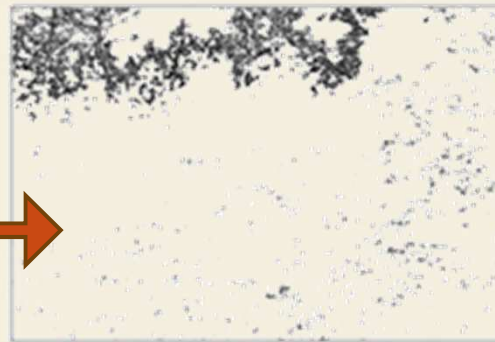
I= 95

D=1.09

Methodology



Original image



Extracted edges: $D=1.39$



Silhouette outline: $D=1.35$



Image 1a: Threshold at intensity: 94
 $D= 1.31$



Image 1b : Threshold at intensity: 44
 $D= 1.72$



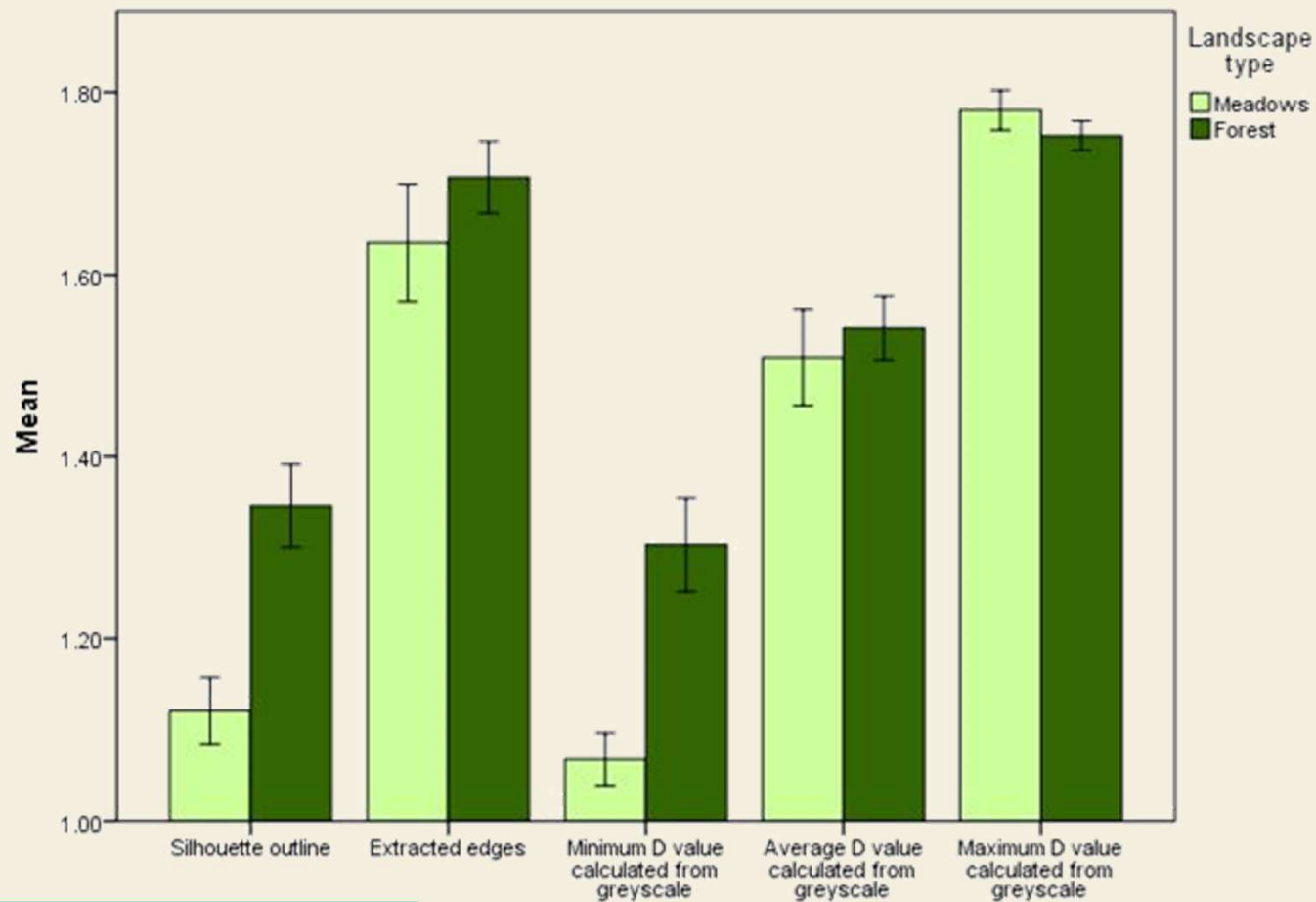
Image 1c : Threshold at intensity: 61
 $D= 1.561$

The three greyscale components



Results: Characterizing landscape type

Comparison of D values of Forests and Meadows calculated by five methods



Results: Viewpoints

Outline: [46]: $D = 1.00$; [47]: $D = 1.32$

Edges: [46]: $D = 1.73$; [47]: $D = 1.74$

Outline: [54]: $D = 0.99$; [55]: $D = 1.00$

Edges: [54]: $D = 1.46$; [55]: $D = 1.61$

Two pairs of landscape images with different values of D .



[46]



[47]



[54]



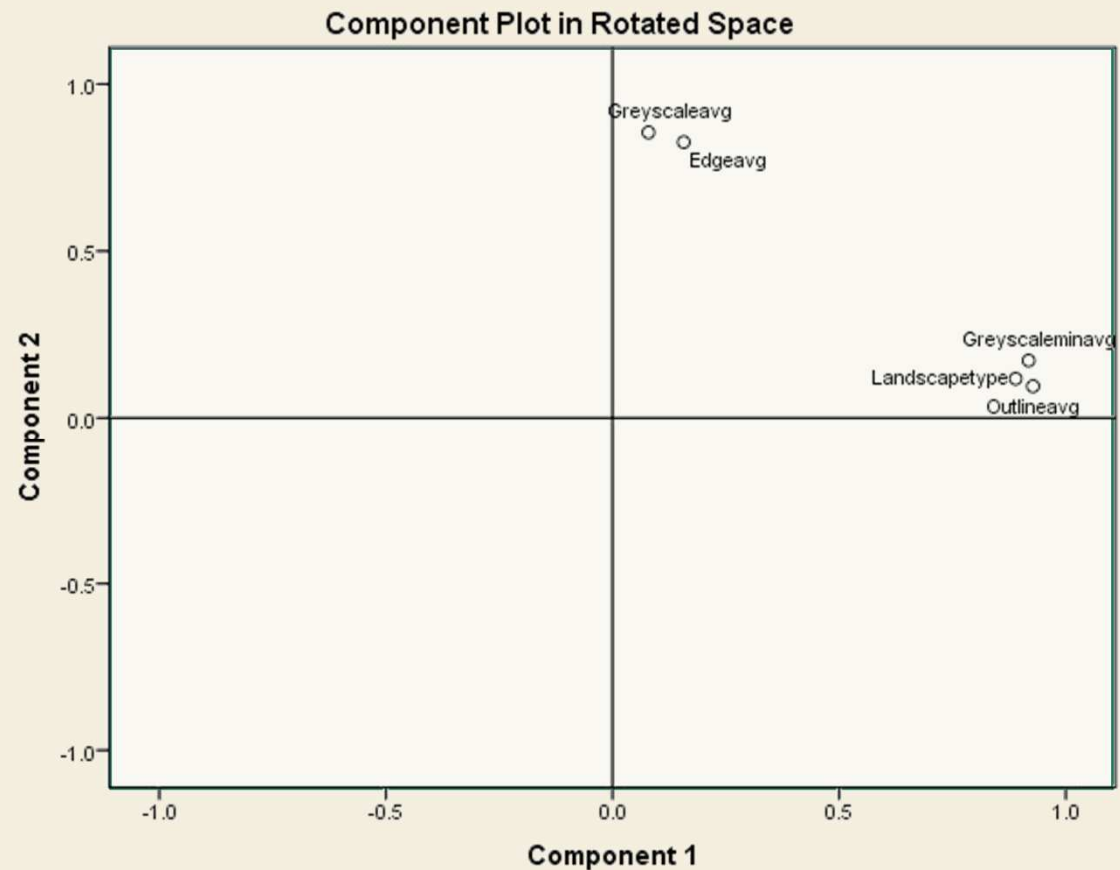
[55]



Results: Factor Analysis

Component 1: Fractal
Dimension of the Edges,
file size -> *Complexity*

Component 2: Fractal
Dimension of the
Silhouette Outline,
landscape type ->
Naturalness



Summary of Results

- Different image structures yield different fractal dimensions.
- There is no single fractal dimension of landscapes

Forests

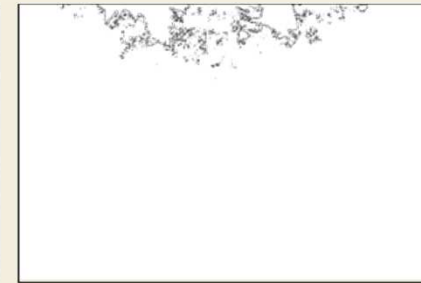


Edges



$D = 1.71$

Outlines

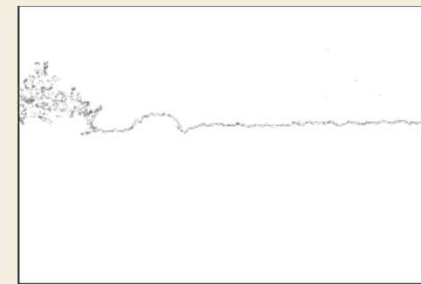


$D = 1.36$

Fields



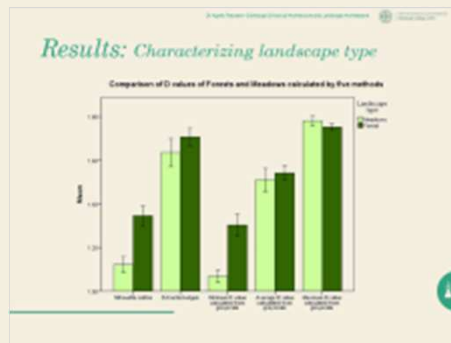
$D = 1.43$



$D = 1.18$



Summary of Results



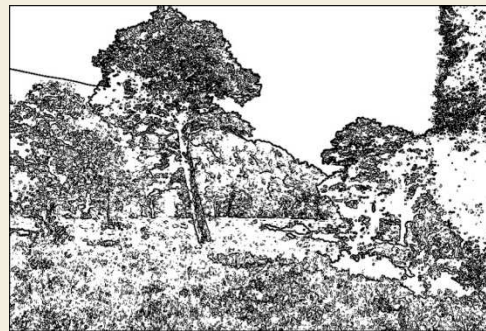
- **Forests:**

- Higher height of vegetation
- Higher D for outlines but not edges
- Forests equally complex as fields?

- **Meadows/Fields**

- Lower height of vegetation
- Not as natural as forests?

(a) & (b) : $D = 1.76$



(a)



(b)





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Discussion

What is Nature /naturalness for you?

