Remote Sensing And Predicting Shifts In Biome Distribution And Resilience Using NDVI Data

UNIVERSITETET I BERGEN

Universitetet i Bergen, Ecological and Environmental Change Research Group

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How can resilience be assessed and measured?

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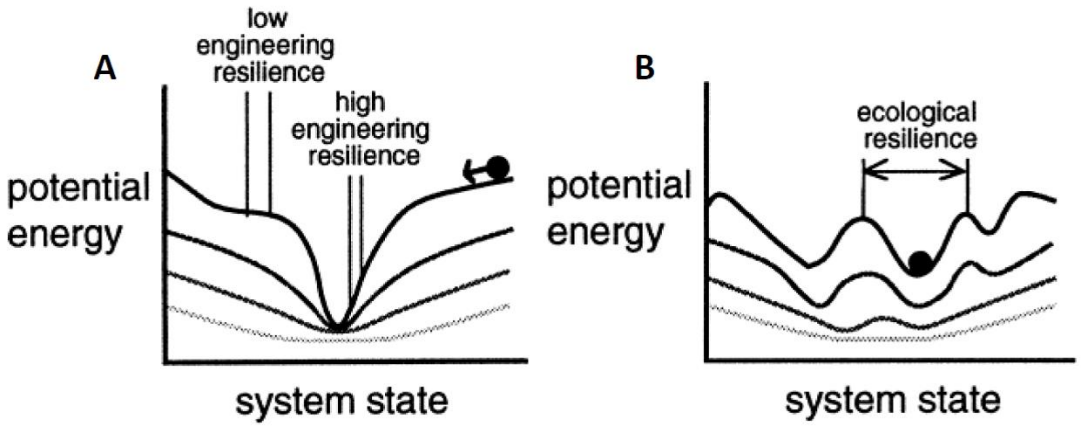

Figure 1: **Stability Landscapes according to Engineering and Ecological Resilience** [5].

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   The world is a linear environment. Each system only has one distinct state.
3. **Specified resilience** [6]
   Resilience of a system is assessed through some of its aspects in relation to perturbing forces.

What has been done? II

Alternative stable states... are established and maintained through *feedback mechanisms*

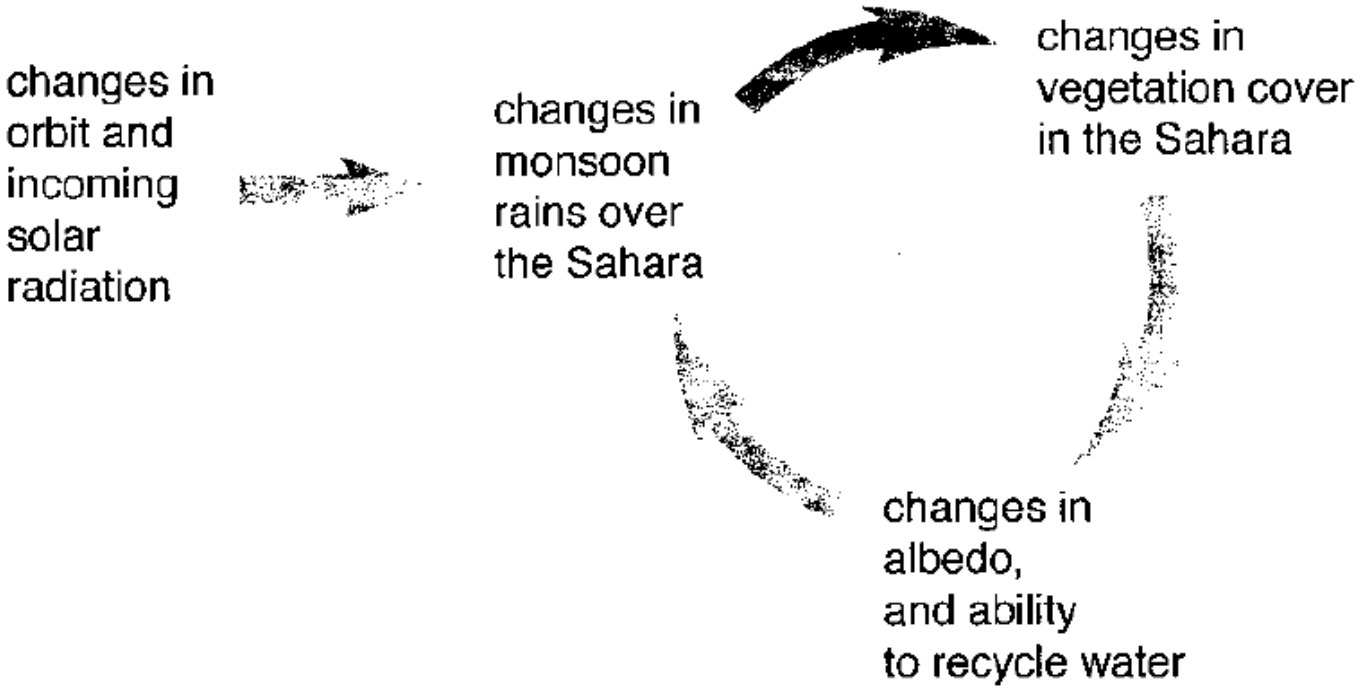

Figure 2: **Atmosphere-Vegetation Feedbacks** [7].

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1. *What and how many alternative stable states are present in a given focal system and have their distributions changed over time?*
2. *How are the observed alternative stable states related to the climate?*

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1. *What and how many alternative stable states are present in a given focal system and have their distributions changed over time?*
2. *How are the observed alternative stable states related to the climate?*
3. *How are the results of the ecosystem classification and vegetation-climate modelling linked to resilience?*

2 Conceptual Framework And Methods

- Quantity and qualitative properties of alternative stable states
- Vegetation-climate relationships
- Quantifying resilience

The 1st step: identifying alternative stable states

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$$\textbf{Biome} \simeq \textbf{stable state}^{[9,10]}$$

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- Data based clustering process
- Mixed effect modelling approach
- Carried out in R using the mclust-package[11]

The 2nd step: assessing vegetation-climate relationships

- Have been assessed using various approaches:
  - Tree cover and mean July temperature [9]
  - Tree cover and mean annual precipitation [10]

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- All approaches use:
  - *Parameters*
    1. Response variables
    2. Explanatory variables
  - *Modelling procedures*

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- GAMs employ smoothing curves which allow for non-linear relationships
- Assess relations of explanatory to response variables
- Carried out in R using the mgcv-package[12]

The 3rd step: measuring resilience

- Hodgson et. al's resilience framework [2]:
  1. *Resistance*
  2. *Recovery*

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- Low resilience in empirical analyses and modelling approaches:
  1. is accompanied by fluctuations in state dominance
  2. manifests in mixed environments
  3. allows for multiple alternative stable states to dominate under the same circumstances

The 3rd step: what did we do?

- Used to link results of the first two steps to the resilience framework

- Low resilience identified as:
  1. Low assignment confidence resulting from the mclust algorithm
  2. Loss of spatial coverage over time
  3. Potential for multiple alternative stable states to occur in the same location given the current climate regimes using GAM predictions and the ROC method

3 Parameters

- Response variables
- Explanatory variables
  - Temperature data
  - Precipitation data
  - Elevation data

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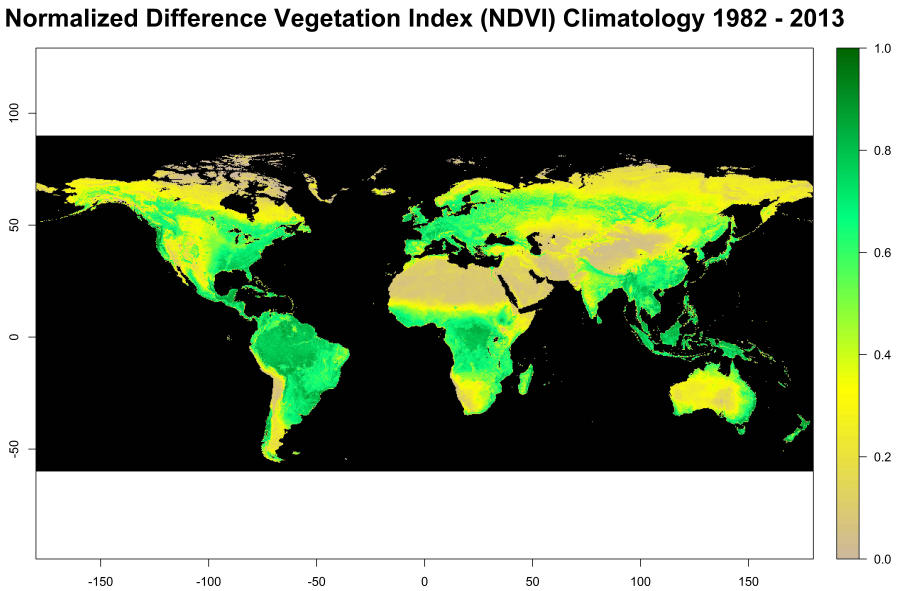
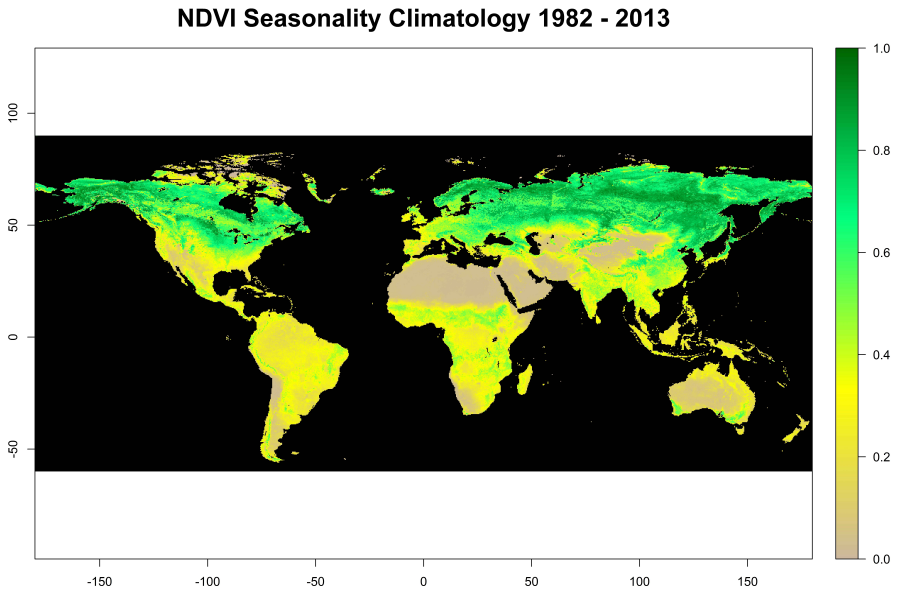
- *Data source?* GIMMS

The Normalized Difference Vegetation Index (NDVI) II



(a) NDVI 1982-2013



(b) NDVI Seasonality 1982-2013

Figure 3: **NDVI Climatologies:** Average composites of mean annual NDVI scores and annual NDVI seasonality.

Climate data

- **Explanatory variables**

- Climate effects have been proposed to affect biome distributions
- Two different descriptors of climate regimes have been incorporated

Temperature data

- *What?* Mean annual temperature

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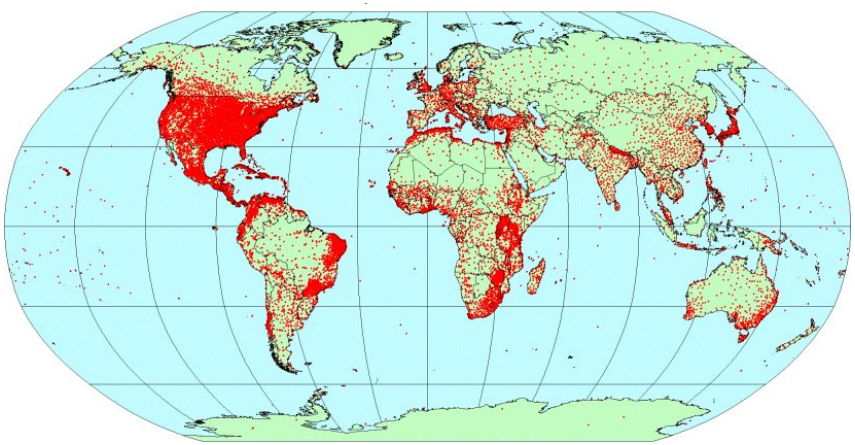

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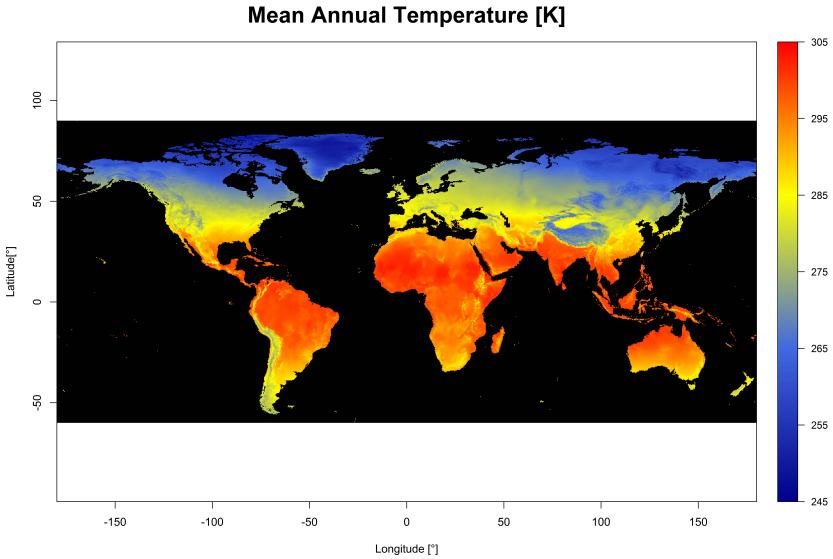

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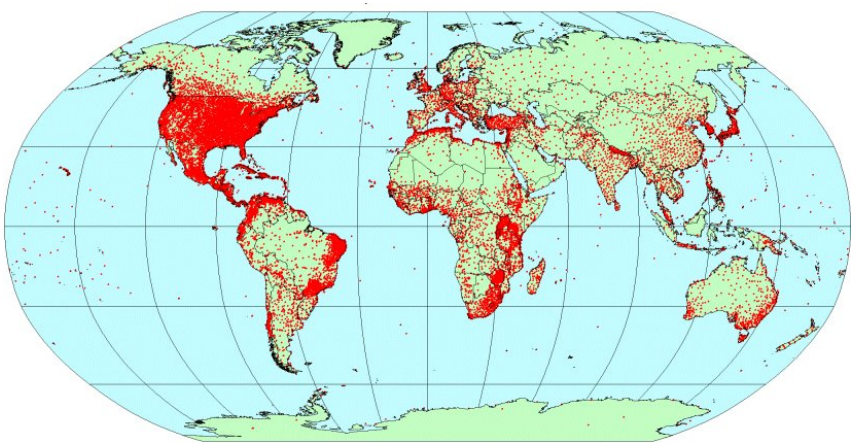

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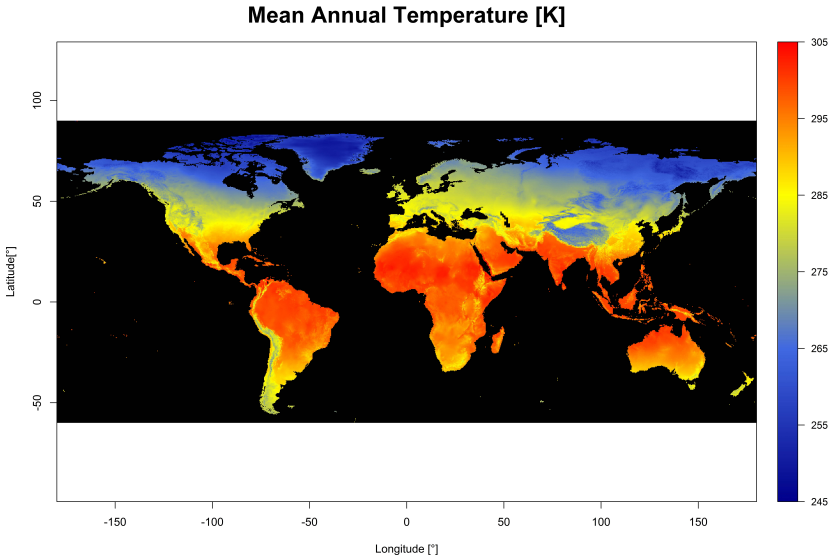

(b) Mean Annual Temperature

- *Data source?* WorldClim

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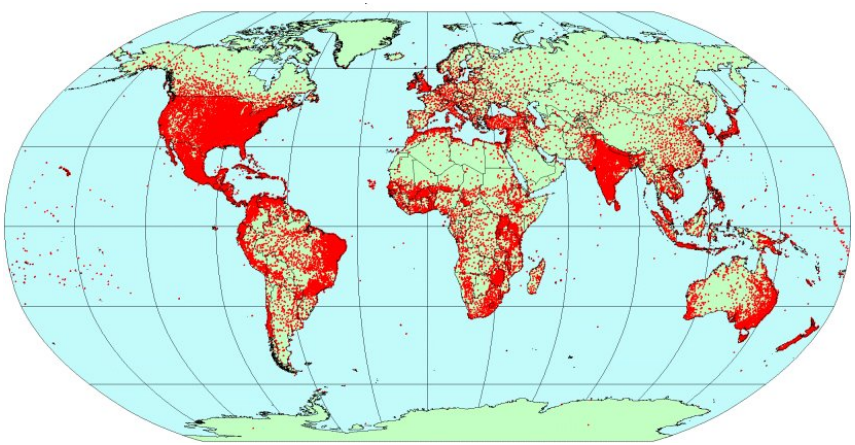

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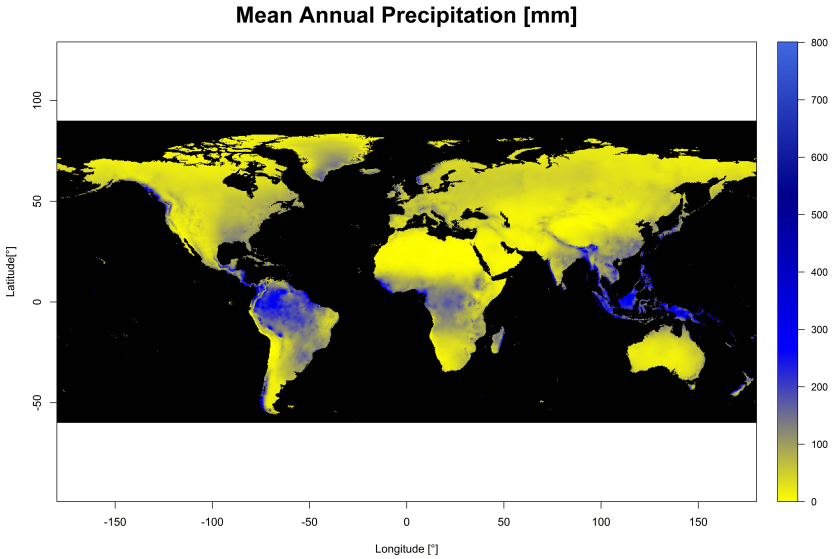

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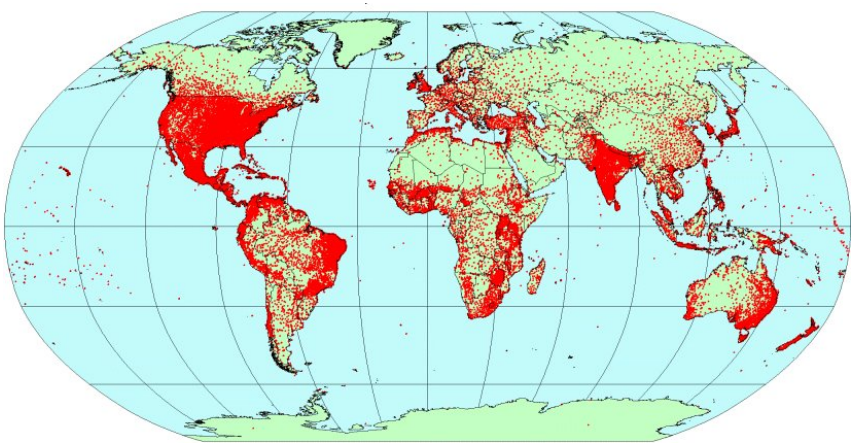

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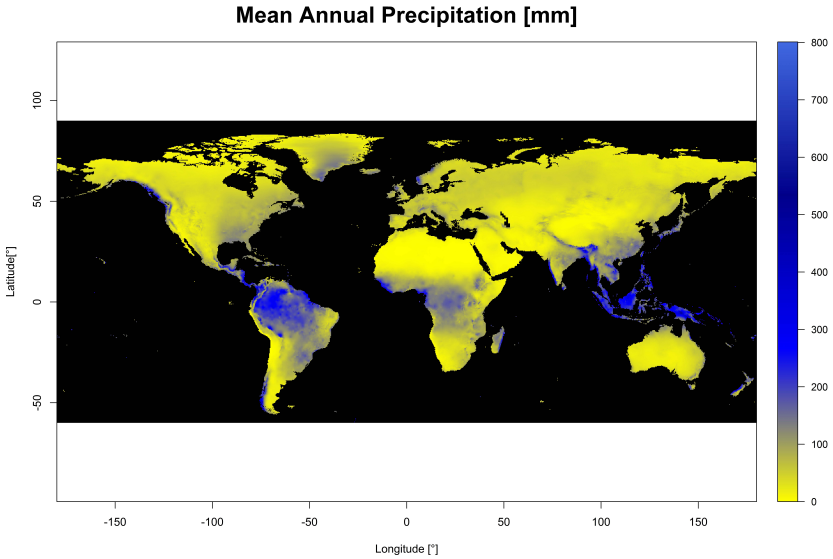

(b) Mean Annual Precipitation

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Elevation data I

- **Explanatory variable**

- *What?* Global Multi-resolution Terrain Elevation Data 2010
- *Data source?* U.S. Geological Survey

Elevation data II

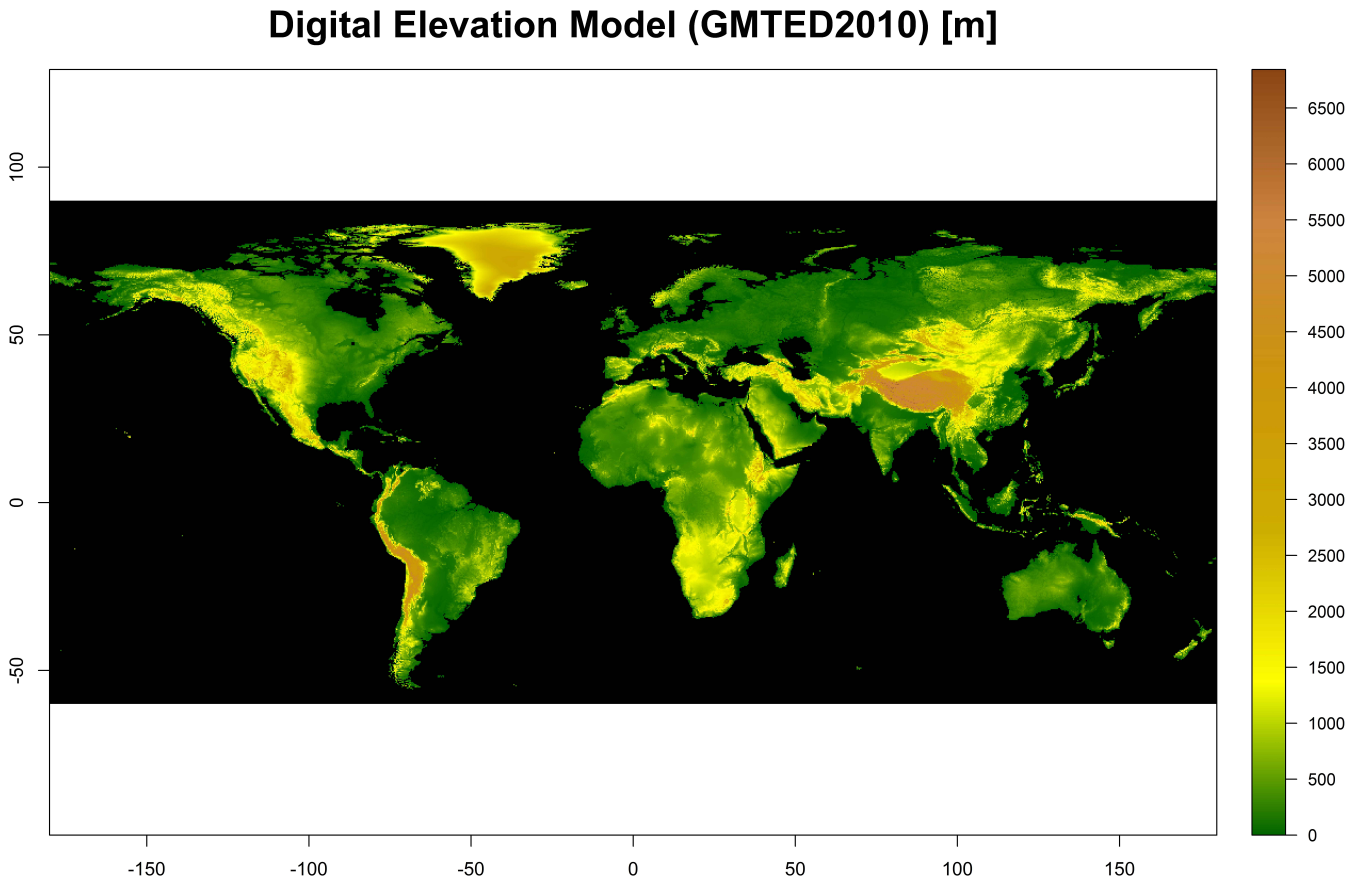

Figure 6: **Digital Elevation Model:** A digital elevation model contains altitude data. This study incorporates the use of the GMTED2010 mean elevation product.

4 Study site

- Resilience in the Arctic
- Alaska

Change in Arctic systems

- Areas in northern latitudes have been proposed to be under major influence by climate change

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- **Special interest and concern on areas of northern latitudes.**

Alaska

Excellent remote sensing study region:

1. Large extent (over 1,000,000 km^2)
2. Topographical variety
3. Low anthropogenic impact (except for severe deforestation in several regions)
4. Established land cover classification schemes are available (can be used for evaluation)
5. Ecological Relevance (warming rates twice the global average have been reported for the boreal region)

5 Results

- Initial biome delineation
- Biome contingency
- Resilience assessment

Identified alternative stable states

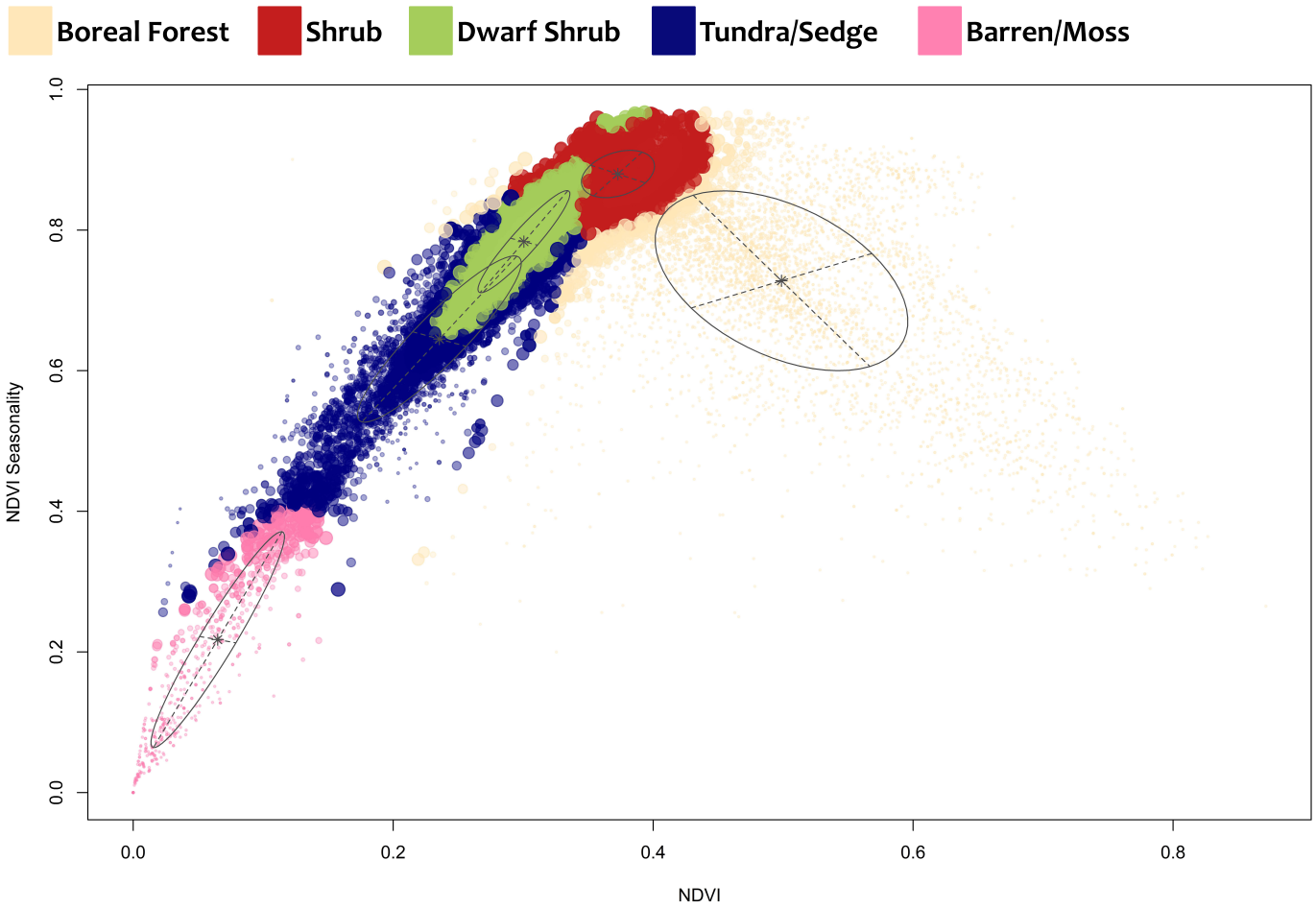
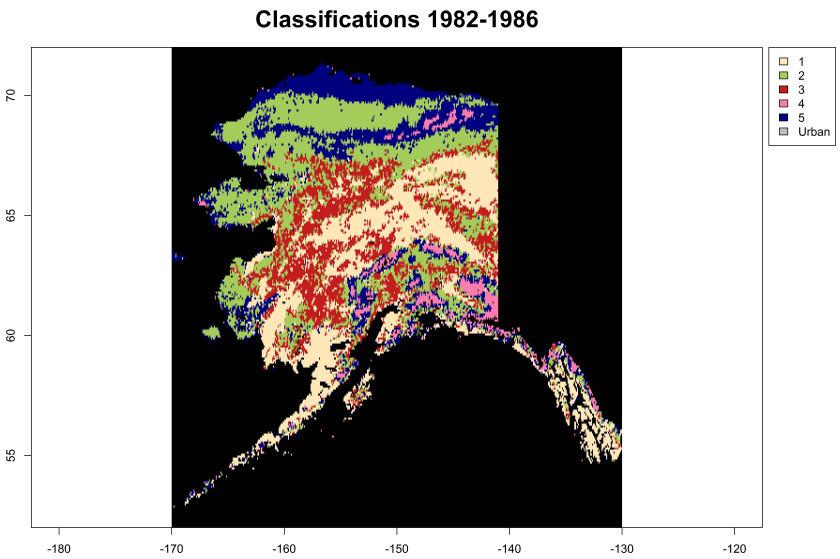
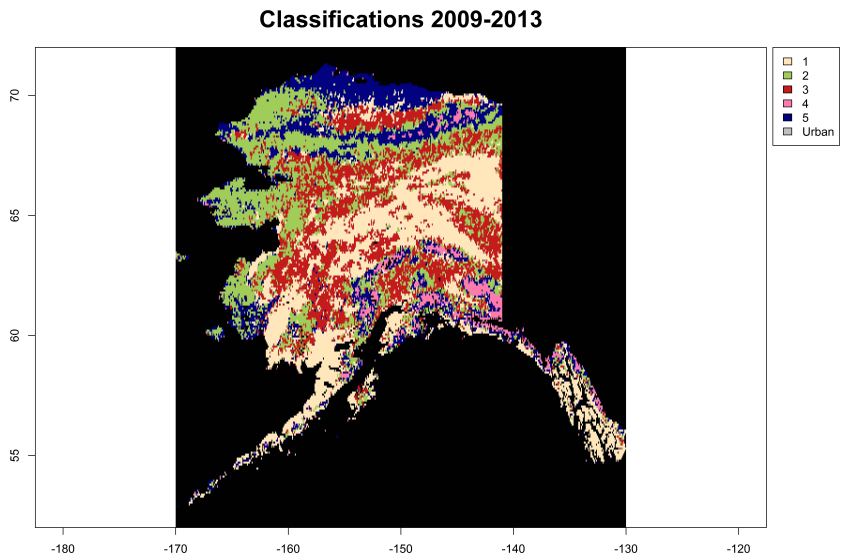


Figure 7: **Mclust Uncertainties Of Vegetation Clustering** (Alaska): Spectral data sets for 1982 - 2013 have been clustered using the mclust algorithm. The resulting data clusters have been visualized as an uncertainty plot.

Identified alternative stable states



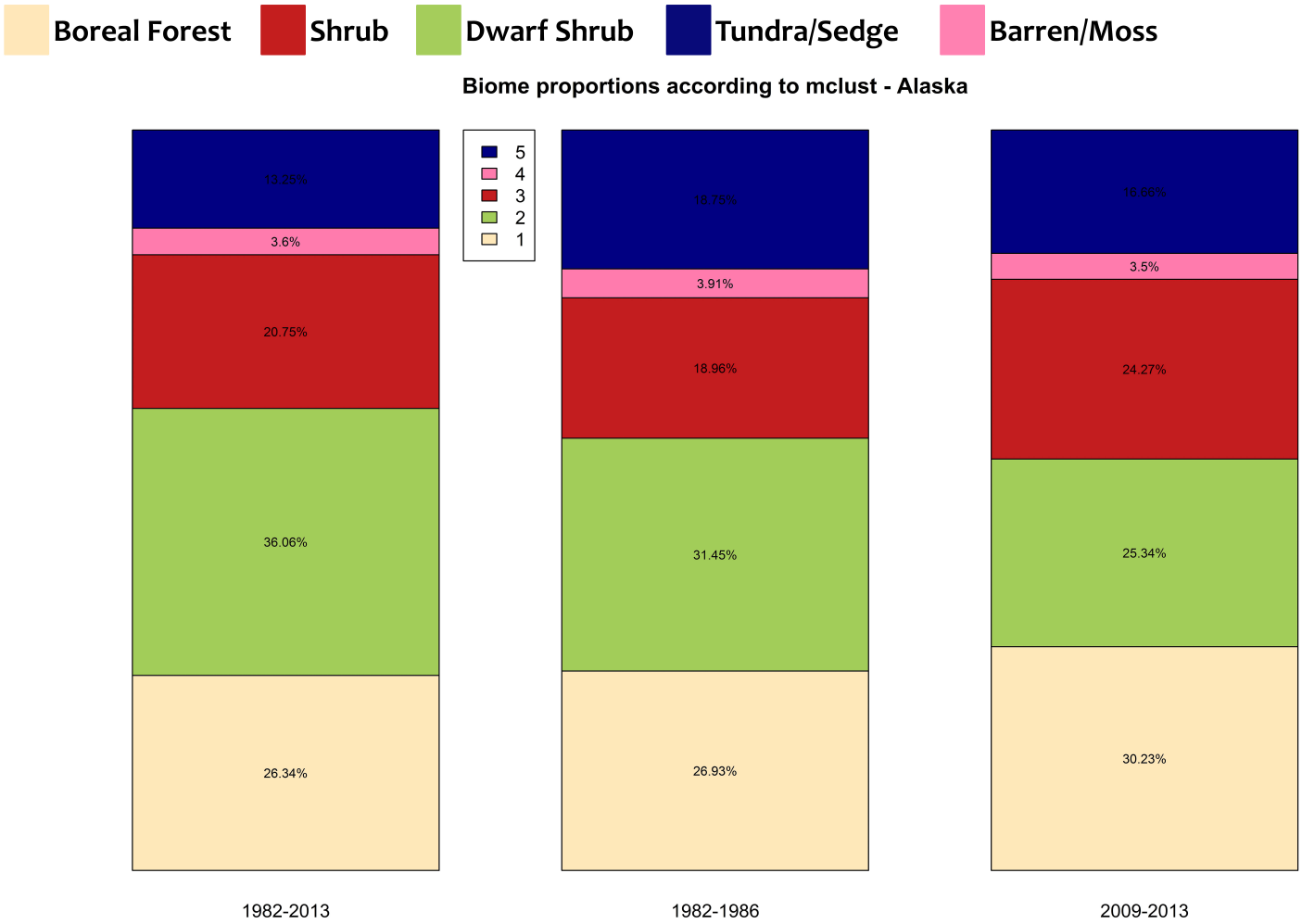
(a) Biome distributions (1982-1986)



(b) Biome distributions (2009-2013)

Figure 7: **Biome classifications via mclust** (Alaska): Spectral data sets for 1982 - 2013 have been clustered using the mclust algorithm. The resulting model has been used to cluster spectral data from 1982-1986 and 2009-2013 respectively.

Contingency of alternative stable states

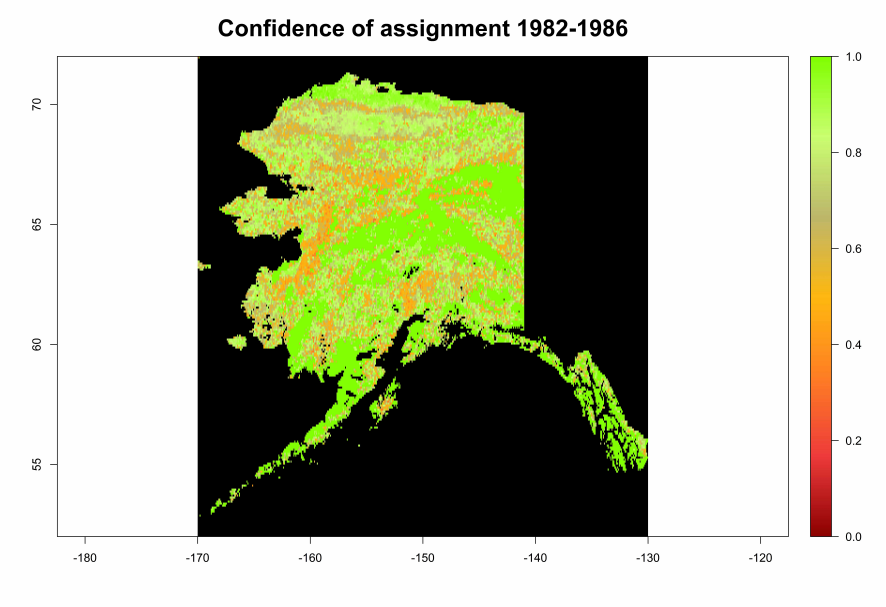


Contingency of alternative stable states

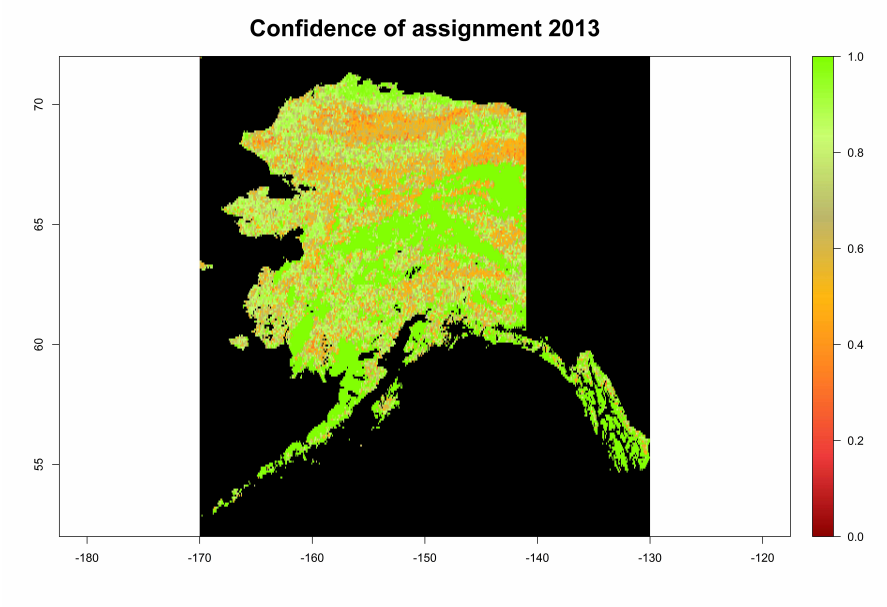
Table 1: **Biome Contingency** (Alaska): The similarity of stable state distributions obtained by analysing spectral data of 1982-1986 (past) and spectral data of 2009-2013 (present) has been calculated to assess the transitioning of stable states of vegetation in Alaska. Change from past to present state have been assessed as percentages relative to the initial proportion of the past state.

	Present State				
Past State	Boreal Forest	Dwarf Shrub	Shrub	Barren/Moss	Tundra/Sedge
Boreal Forest	93.39%	0.78%	4.56%	0.06%	1.21%
Dwarf Shrub	5.53%	53.5%	29.55%	0.02%	11.4%
Shrub	12.12%	17.85%	68.51%	0%	1.53%
Barren/Moss	1.23%	0.19%	0%	76.8%	21.77%
Tundra/Segde	5.3%	26.18%	4.1%	2.52%	61.89%

Resilience of alternative stable states



(a) Assignment confidence (1982-1986)



(b) Assignment confidence (2009-2013)

Figure 8: **Biome classifications via mclust** (Alaska): Spectral data sets for 1982 - 2013 have been clustered using the mclust algorithm. The resulting model has been used to cluster spectral data from 1982-1986 and 2009-2013 respectively. The respective assignment confidence scores for each data point have been mapped out.

Resilience of alternative stable states

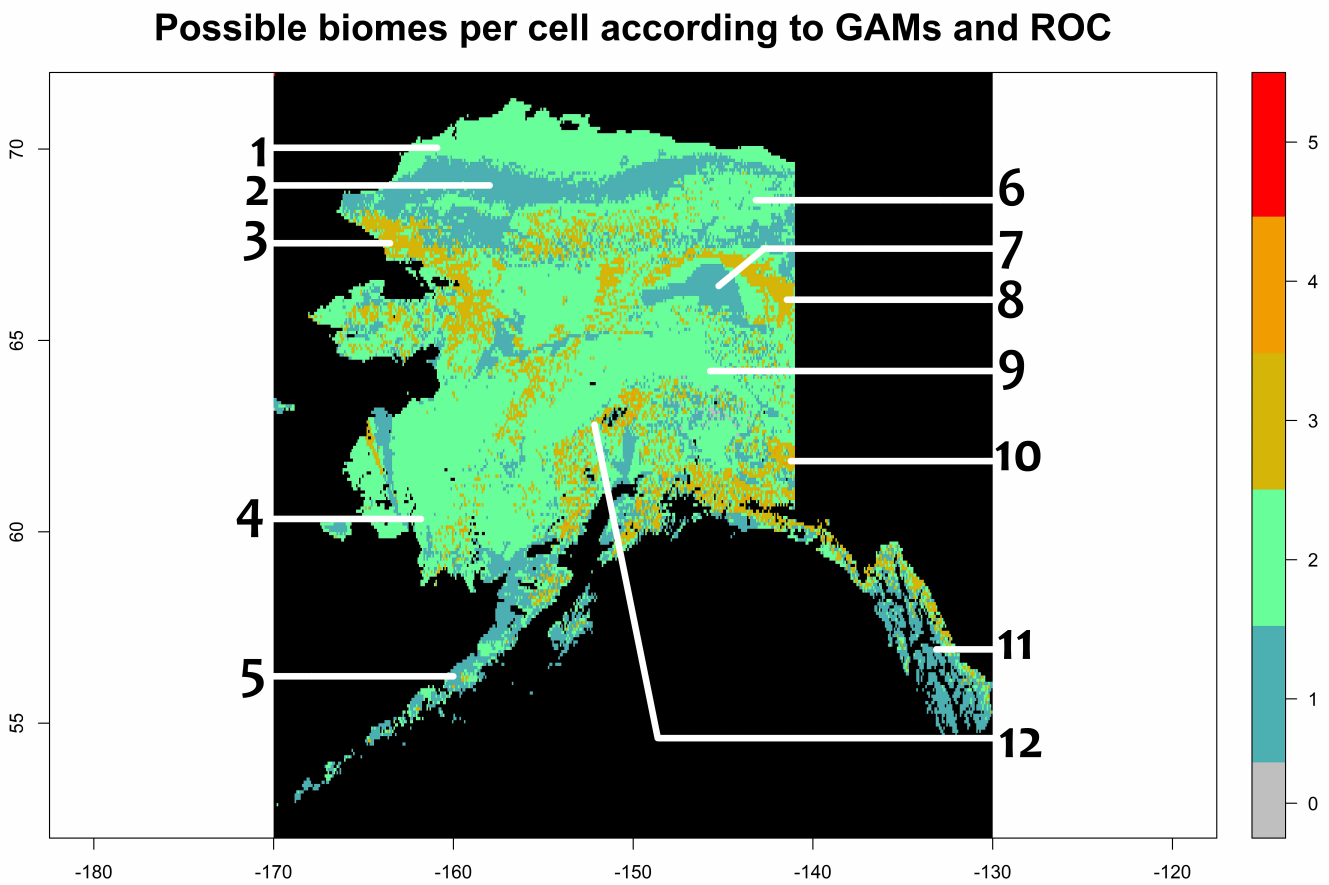


Figure 8: **ROC prediction of presence of alternative stable states** (Alaska): The ROC thresholding method has been used in combination with the GAMs to assess the possibility for multiple stable states to occur in the same place.

6 Conclusion

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- Flexible, three step framework
- Resilience assessments via biome contingency and potential for multiple stale states useful

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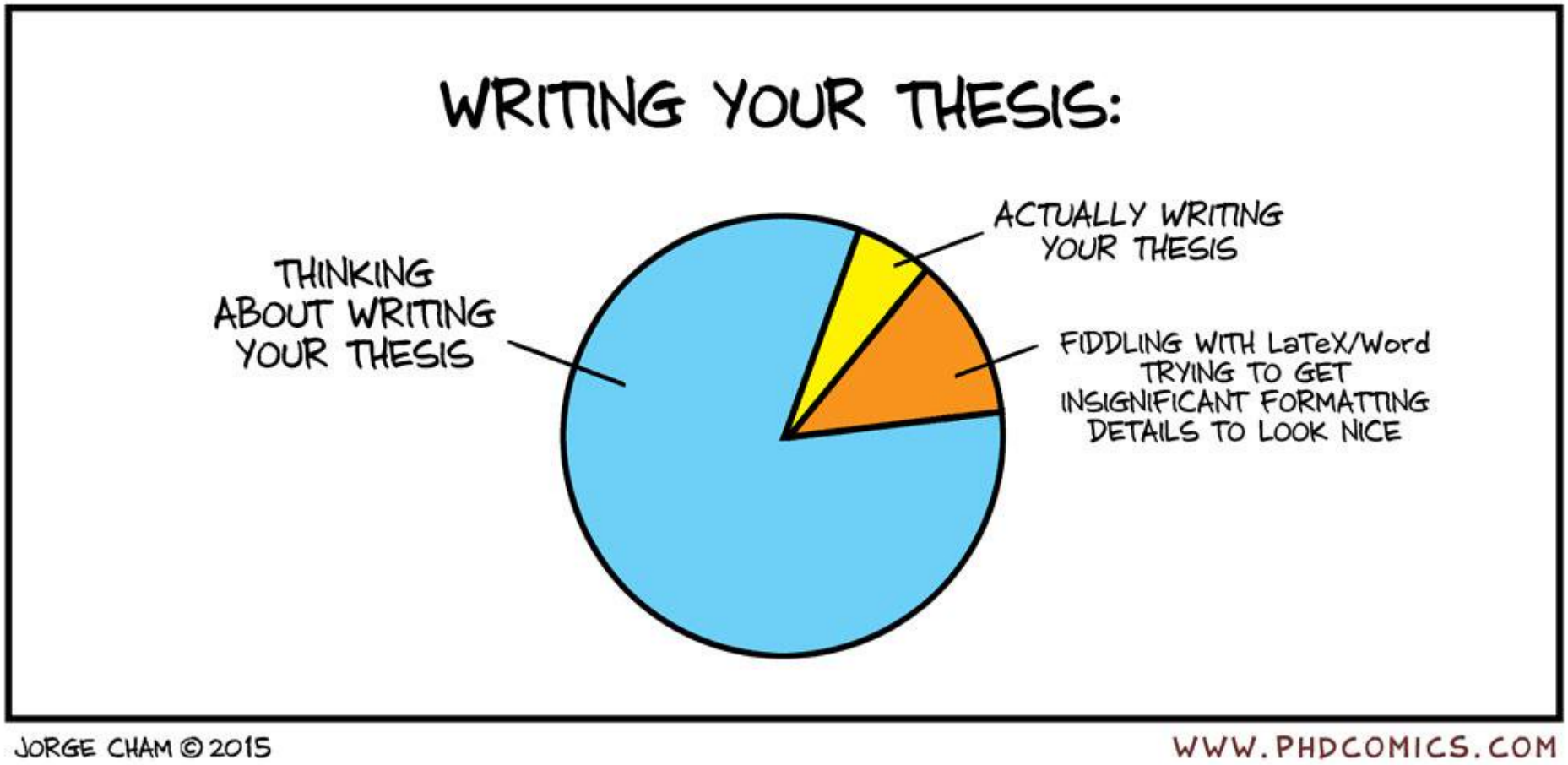
- More research needed:
  - Incorporation of more variables
  - Enhancement of GAMs
  - Focussing on areas of ecological uncertainty

Thank you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ACTUALLY WRITING YOUR THESIS
THINKING ABOUT WRITING YOUR THESIS
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