Bio3018F Practical 2022

Biodiversity and Ecosystem Function in the Cape Floristic Region

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Introduction

Our understanding of and approach to studying the relationship between biodiversity and ecosystem function (B-EF) has evolved over the past few decades (Figure 1; van der Plas 2019). The historical view was one of biodiversity as the response variable, being determined by environmental and anthropogenic factors, with little feedback to ecosystem function. In the early 1990s, this shifted (and perhaps overcompensated) to focus on the causal effects of variation in biodiversity on ecosystem functioning, with little emphasis on the role of environmental variation. More recently, there is recognition that biodiversity both responds to the environment and partly drives ecosystem function in concert with environmental variation. The current focus of most B-EF research is on the relative importance of abiotic drivers (natural and anthropogenic) versus biotic variation in determining various ecosystem functions.

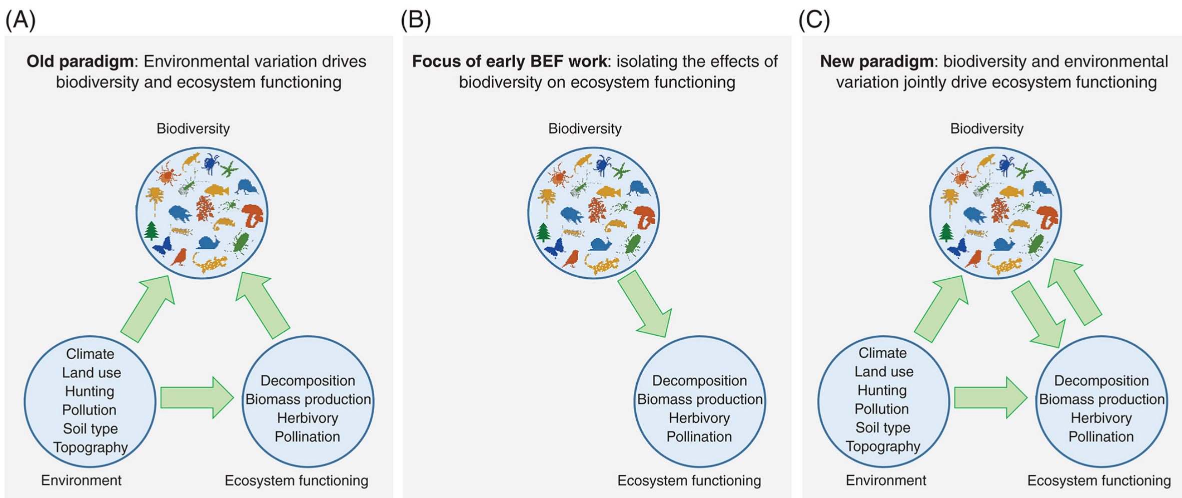


Figure 1: (from van der Plas 2019)

The Cape Floristic Region (CFR) of South Africa is one of the most botanically diverse areas on the planet. The indigenous flora of the CFR has several components with different evolutionary and biogeographic origins (Figure 2; Bergh et al. 2014), and distinct differences in a range of ecosystem functions. The CFR also has a long history of global change impacts, from direct anthropogenic disturbance (e.g. land use / land cover) to the introduction of invasive alien species. This provides a range of highly varied ecosystem types within close proximity, that often share or contrast in their biotic composition (species, functional and phylogenetic diversity) and abiotic conditions - climate, soils and disturbance regimes (fire, herbivory).

[Describe the measures of ecosystem function here… i.e. average and amplitude of seasonality of the Normalized Difference Vegetation Index (NDVI) recorded by the MODIS Terra satellite…]

In this practical, we will explore how variation in a set of measures of biodiversity (species, functional and

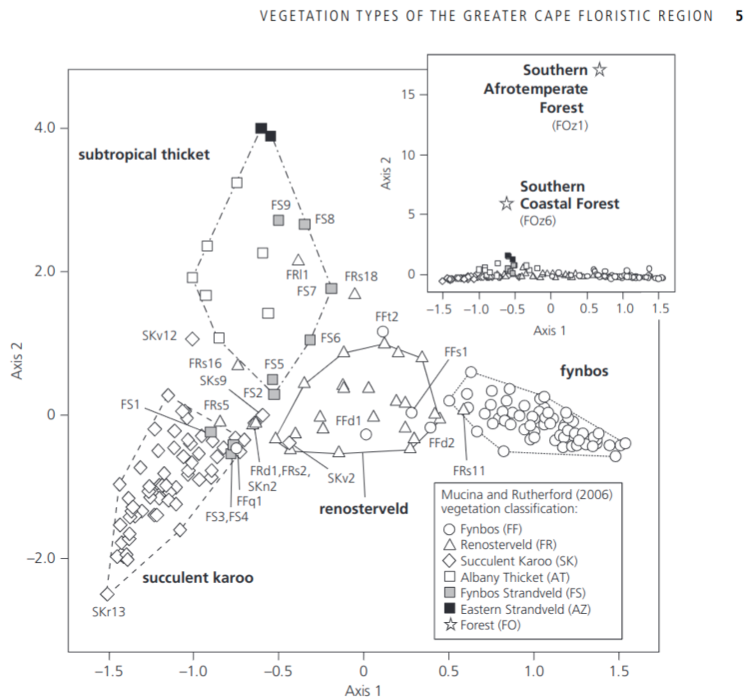


Figure 2: Ordination of genus-level floristic similarities of GCFR vegetation units sensu Mucina and Rutherford (2006), as inferred on the basis of the 'important species' lists provided in The vegetation of South Africa, Lesotho and Swaziland (Mucina and Rutherford 2006). Figure from Bergh et al. 2014.

phylogenetic α and β diversity) and environmental conditions relate to a set of metrics of ecosystem function derived from satellite timeseries.

The questions are:

- Does the variation in environmental conditions potentially explain the observed variation in biodiversity (species, functional and phylogenetic α and β diversity)?
- To what degree does the variation in functional and phylogenetic diversity potentially explain the observed variation in our measures of ecosystem function?
- What is the relative role of the environment versus biodiversity in determining the observed variation in ecosystem function?

Finally, consider this practical a descriptive study. In your discussion, describe a follow-up study that you would perform to discern cause from correlation and partition the relative influence of environmental conditions versus biodiversity on our measures of ecosystem function.

Methods:

The sites are selected to represent contrasting vegetation, but to all be the same (or similar) post-fire age (time since last fire). We will split into 4 teams of 2 or 3. Each pair will survey a point location (towards the corners) within the 250 by 250m MODIS pixel that makes up each site.

Each team will need:

- One or more smartphones
- 2 x 10m measuring tape (or longer)
- 1 x clipboard, paper and pen or pencil

- 1 x densiometer
- 1 x metre rule
- 1 x Vernier calipers
- 8 x large plastic bags for carrying soil and plant samples for each point location
- 8 x soil sample bags
- 2 x masking tape
- 2 x marker pen

At each site, navigate to your team's point location, lay out the two tapes at 90 degrees, crossing at 3.2m and ending at 6.4m. Consider this your guide for a 3.2m radius (~20m2) circle. Within the circle we will measure:

1. *Environmental conditions:*

- Estimate % projected cover (think the area you would see from above) bare soil
- Take a densiometer reading at ground level. To do this, hold the densiometer level on the soil surface. Pick a spot close to the centre, but try not to pick an obviously open (or closed) patch, it should be representative of the location. To take a reading, split each square into quarters and score them for the amount of light visible - a value from 0 (complete canopy cover) to 4 (no vegetation visible) - counting up these values for all 24 squares (to a maximum of 96), and write this down. We will convert this to canopy cover later, applying the formula $100 - 1.04 * X$, where X is your reading.
- Take a **soil sample** (as per Mike's prac, but it can be smaller as we are going to pool the 4 samples per site). These we will process for soil colour and pH as per Mike's prac.
- Do a **dung count**, scoring dung for the point location by the number of quarters where you find dung (i.e. a single score from 0-4 for the point location). Try to avoid scoring obvious single scat ("dung creation") events in more than one quadrat, unless it's an impressive pile.
- Take a few notes (and photos) on any other features that you think may be important or interesting (slope, rockiness, whatever).

2. *Diversity sampling:*

- First, make sure your smartphone is fully charged and set to record GPS location with your photographs!
- With your team, decide on which are the top 5 species by % projected cover. If your site is dominated by fewer than 5 species, count up as many species as make up 80% of the vegetation.
  - Take diagnostic photos for the 5 species (habit (whole plant), leaf, base, flowers and/or fruits).
  - For each of three individuals of your 5 target species, measure the height and collect a shoots for measuring leaf length and leaf width (mark with masking tape and put in sample bag for the site).
- Finally, set a timer and take as many photos of new species (other than your 5 target species) within or near your plot as you can before the alarm goes off. Make sure to take a photo of your site label on your sample bag between sites so you know which photos were collected at which sites. When we get back to base you will upload the photos to folders in the intranet labeled by site.

Analyses

Species Diversity

For this I have just taken the count of species encountered at each point, and the aggregated set of unique species for each site. i.e. no rarefaction etc. Do you think this is an issue for the method we used?

Site	Species Number
grass	13
invasion	13

Site	Species Number
sandstone	24

Functional Diversity

Here I've estimated Functional Diversity (FD) according to the method of Petchey and Gaston (2002) for each of the points, sites and functional turnover between points and between sites using the method of Bryant et al. 2008.

Sites:

	FD	SR
invasion	12.181	11
limestone	5.815	11
sandstone	6.964	9
grass	7.369	9
renosterveld	7.483	11
sand	6.876	9

By point sample:

	FD	SR
grass_SE	3.200	2
renosterveld_SE	4.181	5
invasion_SE	7.422	4
sand_SE	4.650	5
sandstone_SE	5.231	5
limestone_SE	4.599	5
grass_NE	3.729	3
renosterveld_NE	4.756	4
invasion_NE	5.856	5
sand_NE	4.136	4
sandstone_NE	4.344	3
limestone_NE	4.193	5
grass_SW	4.778	5
renosterveld_SW	5.410	5
invasion_SW	7.150	4
sand_SW	4.873	4
limestone_SW	4.599	5
sandstone_SW	4.344	3
grass_NW	4.680	3
renosterveld_NW	4.018	5
invasion_NW	6.413	3
sand_NW	2.713	1
sandstone_NW	5.840	5
limestone_NW	4.193	5

And functional turnover between sites:

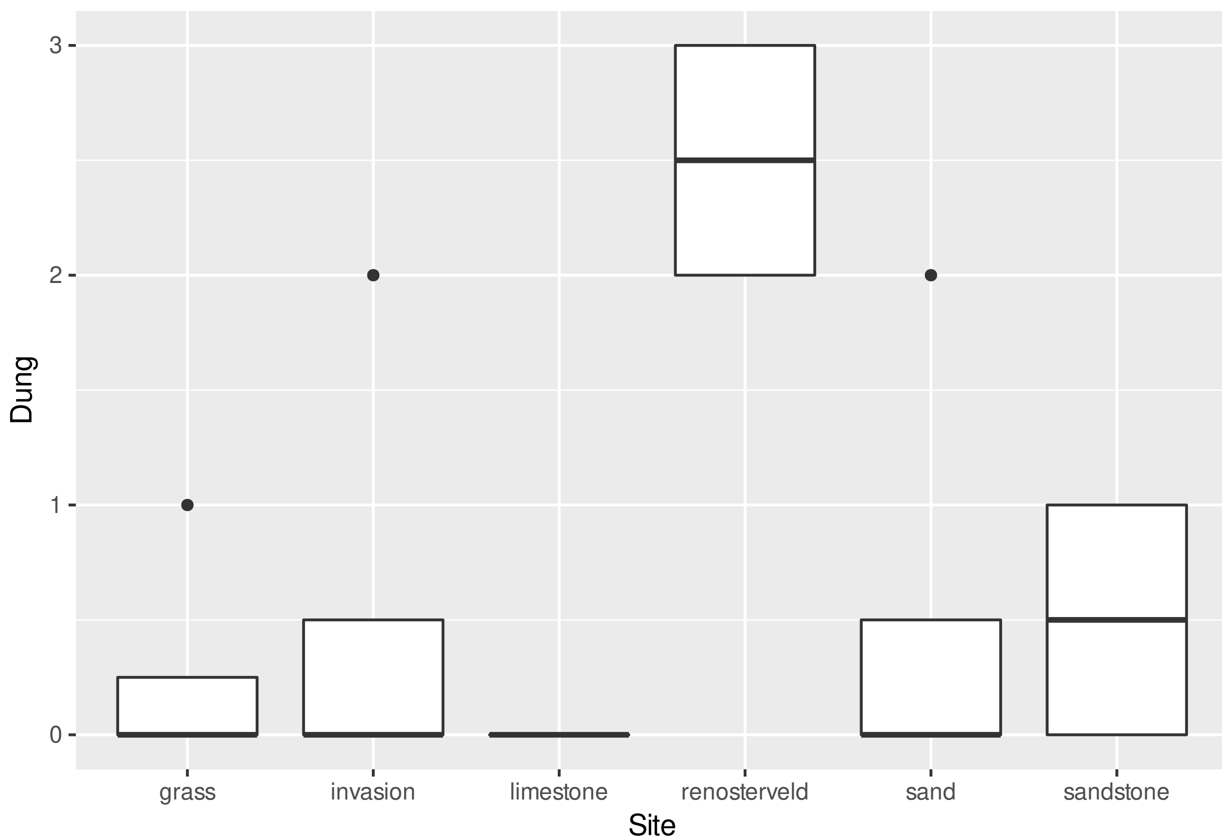
	invasion	limestone	sandstone	grass	renosterveld	sand
invasion						
limestone	0.401					
sandstone	0.431	0.487				
grass	0.487	0.481	0.643			
renosterveld	0.378	0.412	0.560	0.603		
sand	0.460	0.504	0.800	0.647	0.564	

See help file `?picante::phylosor` in R for details to help know how to interpret. Note that while the function was written for phylogenetic turnover, we've used it for functional turnover.

Environmental Similarity among sites

Here I provide a table and an ordination of the site-level environmental measurements we took relating to various aspects of soil conditions, canopy coverage and herbivory.

```
## [1] "Site"            "Point"           "PercentBareSoil" "SoilPH"
## [5] "SoilColour"      "Dung"            "Densiometer"
```




```
##
##  Kruskal-Wallis rank sum test
##
## data:  Dung by Site
## Kruskal-Wallis chi-squared = 12.73, df = 5, p-value = 0.02604
```

```
## Warning: Site was coerced to a factor.
```

```
##                  Comparison          Z     P.unadj      P.adj
## 1         grass - invasion -0.2020726 0.839859973 0.89984997
## 2        grass - limestone  0.5196152 0.603331772 0.90499766
## 3     invasion - limestone  0.7216878 0.470486422 0.88216204
## 4     grass - renosterveld -2.7135463 0.006656727 0.04992545
## 5  invasion - renosterveld -2.5114737 0.012022825 0.04508560
## 6 limestone - renosterveld -3.2331615 0.001224283 0.01836425
## 7             grass - sand -0.2020726 0.839859973 0.96906920
## 8          invasion - sand  0.0000000 1.000000000 1.00000000
## 9         limestone - sand -0.7216878 0.470486422 1.00000000
## 10     renosterveld - sand  2.5114737 0.012022825 0.06011413
## 11       grass - sandstone -0.5196152 0.603331772 1.00000000
## 12    invasion - sandstone -0.3175426 0.750831884 0.93853986
## 13   limestone - sandstone -1.0392305 0.298697556 0.74674389
## 14 renosterveld - sandstone  2.1939310 0.028240369 0.08472111
## 15        sand - sandstone -0.3175426 0.750831884 1.00000000
```

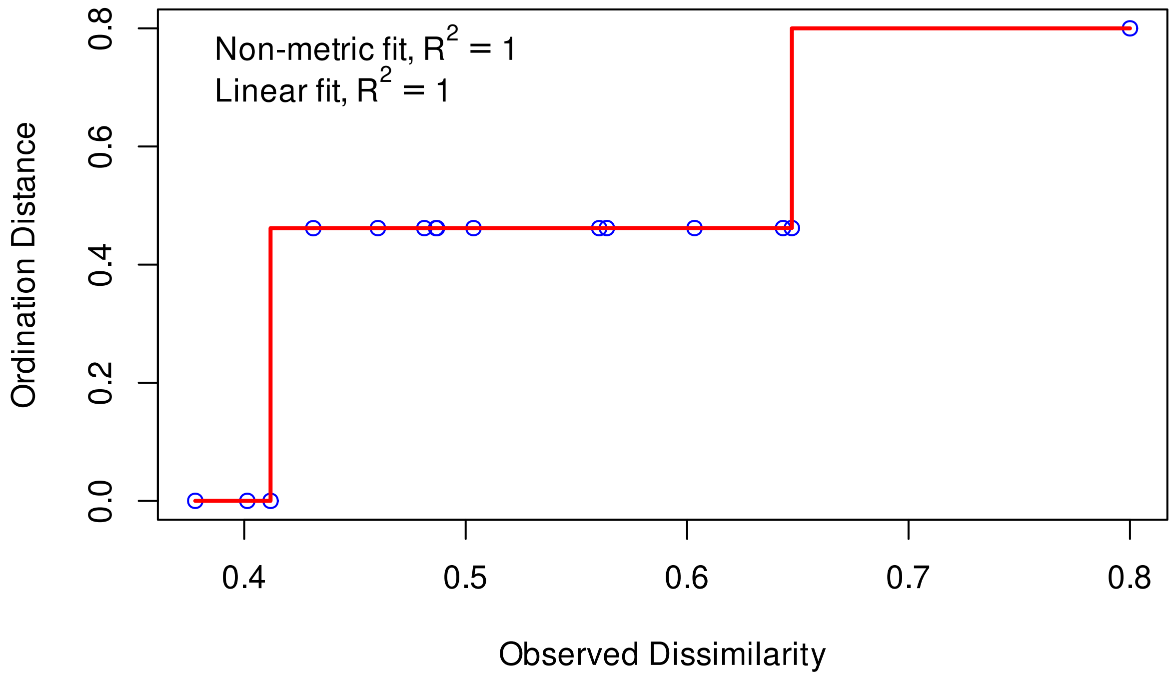
Ordination…

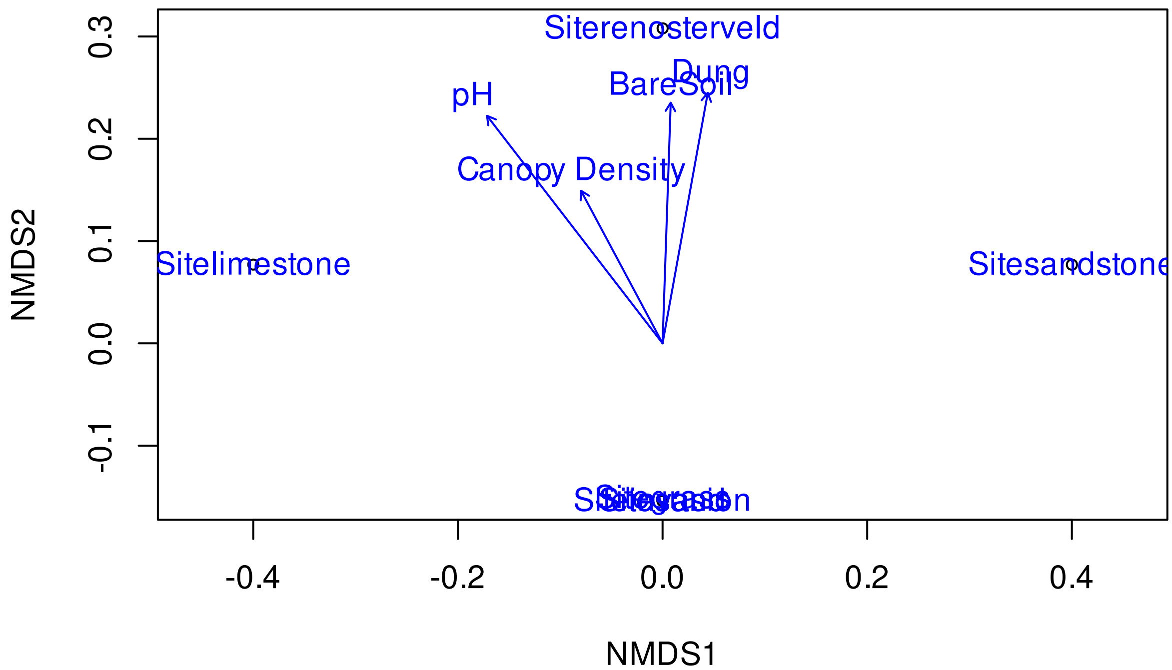
```
## Run 0 stress 9.939348e-05
## Run 1 stress 9.229059e-05
## ... New best solution
## ... Procrustes: rmse 0.152521  max resid 0.2402487
## Run 2 stress 9.165236e-05
## ... New best solution
## ... Procrustes: rmse 0.1555425  max resid 0.2394464
## Run 3 stress 8.801217e-05
## ... New best solution
## ... Procrustes: rmse 0.131448  max resid 0.1888766
## Run 4 stress 9.775185e-05
## ... Procrustes: rmse 0.1443894  max resid 0.2412048
## Run 5 stress 9.839421e-05
## ... Procrustes: rmse 0.1314856  max resid 0.1966632
## Run 6 stress 9.920224e-05
## ... Procrustes: rmse 0.03671988  max resid 0.05189537
## Run 7 stress 9.086215e-05
## ... Procrustes: rmse 0.07702215  max resid 0.1124543
## Run 8 stress 9.570185e-05
## ... Procrustes: rmse 0.09254966  max resid 0.1674672
## Run 9 stress 8.630562e-05
## ... New best solution
## ... Procrustes: rmse 0.1312554  max resid 0.196305
## Run 10 stress 9.478468e-05
## ... Procrustes: rmse 0.1554305  max resid 0.2561566
## Run 11 stress 7.170048e-05
## ... New best solution
## ... Procrustes: rmse 0.178655  max resid 0.3154978
## Run 12 stress 9.936715e-05
## ... Procrustes: rmse 0.1051276  max resid 0.1544445
## Run 13 stress 7.774408e-05
## ... Procrustes: rmse 0.08525769  max resid 0.1322613
## Run 14 stress 9.816235e-05
## ... Procrustes: rmse 0.1788391  max resid 0.3084478
## Run 15 stress 9.022062e-05
## ... Procrustes: rmse 0.09746161  max resid 0.1511601
```

```
## Run 16 stress 9.813139e-05
## ... Procrustes: rmse 0.03927617  max resid 0.06612115
## Run 17 stress 8.543164e-05
## ... Procrustes: rmse 0.09746463  max resid 0.1511497
## Run 18 stress 8.835862e-05
## ... Procrustes: rmse 0.08985547  max resid 0.1519959
## Run 19 stress 4.811685e-05
## ... New best solution
## ... Procrustes: rmse 0.1548195  max resid 0.2681385
## Run 20 stress 9.77609e-05
## ... Procrustes: rmse 0.1708986  max resid 0.2367236
## Run 21 stress 9.522657e-05
## ... Procrustes: rmse 0.1237572  max resid 0.170197
## Run 22 stress 9.793716e-05
## ... Procrustes: rmse 0.2393867  max resid 0.3712622
## Run 23 stress 9.645057e-05
## ... Procrustes: rmse 0.2063707  max resid 0.3233063
## Run 24 stress 7.580064e-05
## ... Procrustes: rmse 0.2671766  max resid 0.3779047
## Run 25 stress 9.659377e-05
## ... Procrustes: rmse 0.2671778  max resid 0.3779072
## Run 26 stress 9.505235e-05
## ... Procrustes: rmse 0.05317855  max resid 0.08811386
## Run 27 stress 8.903787e-05
## ... Procrustes: rmse 0.2393629  max resid 0.3712473
## Run 28 stress 8.64248e-05
## ... Procrustes: rmse 0.2393717  max resid 0.3712196
## Run 29 stress 9.858883e-05
## ... Procrustes: rmse 0.2657537  max resid 0.3756144
## Run 30 stress 9.025589e-05
## ... Procrustes: rmse 0.2667573  max resid 0.3772161
## Run 31 stress 9.7973e-05
## ... Procrustes: rmse 0.2393876  max resid 0.3712646
## Run 32 stress 9.583453e-05
## ... Procrustes: rmse 0.2595033  max resid 0.3752324
## Run 33 stress 8.434884e-05
## ... Procrustes: rmse 0.2427334  max resid 0.3775689
## Run 34 stress 0.1211354
## Run 35 stress 9.93365e-05
## ... Procrustes: rmse 0.1376237  max resid 0.2056461
## Run 36 stress 9.797424e-05
## ... Procrustes: rmse 0.09963804  max resid 0.1375433
## Run 37 stress 8.107154e-05
## ... Procrustes: rmse 0.2672104  max resid 0.3779201
## Run 38 stress 8.740278e-05
## ... Procrustes: rmse 0.2423174  max resid 0.3743636
## Run 39 stress 9.385085e-05
## ... Procrustes: rmse 0.239379  max resid 0.3712505
## Run 40 stress 6.918766e-05
## ... Procrustes: rmse 0.2669578  max resid 0.3776146
## Run 41 stress 7.023992e-05
## ... Procrustes: rmse 0.2393404  max resid 0.3711971
## Run 42 stress 9.385446e-05
## ... Procrustes: rmse 0.2672072  max resid 0.3779582
```

```
## Run 43 stress 6.759501e-05
## ... Procrustes: rmse 0.137517  max resid 0.1893376
## Run 44 stress 7.398783e-05
## ... Procrustes: rmse 0.2671908  max resid 0.3779068
## Run 45 stress 8.753539e-05
## ... Procrustes: rmse 0.239376  max resid 0.3712352
## Run 46 stress 7.388714e-05
## ... Procrustes: rmse 0.2636221  max resid 0.3777573
## Run 47 stress 7.101114e-05
## ... Procrustes: rmse 0.2672065  max resid 0.3779326
## Run 48 stress 9.786847e-05
## ... Procrustes: rmse 0.07317298  max resid 0.1016931
## Run 49 stress 9.781778e-05
## ... Procrustes: rmse 0.2670602  max resid 0.3777228
## Run 50 stress 9.526573e-05
## ... Procrustes: rmse 0.2393772  max resid 0.3712485
## Run 51 stress 9.824353e-05
## ... Procrustes: rmse 0.09250158  max resid 0.1293953
## Run 52 stress 8.91389e-05
## ... Procrustes: rmse 0.2393732  max resid 0.3712391
## Run 53 stress 8.934872e-05
## ... Procrustes: rmse 0.2391299  max resid 0.3745786
## Run 54 stress 0.1211358
## Run 55 stress 8.314523e-05
## ... Procrustes: rmse 0.008798515  max resid 0.01306918
## Run 56 stress 6.862563e-05
## ... Procrustes: rmse 0.2394814  max resid 0.3754971
## Run 57 stress 9.412624e-05
## ... Procrustes: rmse 0.230909  max resid 0.359968
## Run 58 stress 7.719491e-05
## ... Procrustes: rmse 0.2671782  max resid 0.3779083
## Run 59 stress 8.479855e-05
## ... Procrustes: rmse 0.2671457  max resid 0.3778473
## Run 60 stress 6.950524e-05
## ... Procrustes: rmse 0.2393472  max resid 0.3711776
## Run 61 stress 9.460367e-05
## ... Procrustes: rmse 0.239353  max resid 0.3711841
## Run 62 stress 9.303188e-05
## ... Procrustes: rmse 0.2393736  max resid 0.3712548
## Run 63 stress 9.196194e-05
## ... Procrustes: rmse 0.2390309  max resid 0.3738427
## Run 64 stress 0.1211361
## Run 65 stress 7.9389e-05
## ... Procrustes: rmse 9.676953e-05  max resid 0.0001687287
## ... Similar to previous best
## *** Solution reached
```

```
## Warning in metaMDS(msampBFD, trymax = 999): stress is (nearly) zero: you may
## have insufficient data
```


Non-metric fit, R^2 = 1
Linear fit, R^2 = 1
Ordination Distance
0.0
0.2
0.4
0.6
0.8
0.4
0.5
0.6
0.7
0.8
Observed Dissimilarity



Mike has shown you how to explore soil colour. Feel free to explore and add it in...

Ecosystem function

To explore ecosystem function we looked at the 20-year time series of the Normalized Difference Vegetation Index (NDVI) recorded by the MODIS satellite mission. From these we used the post-fire recovery trajectory modelling framework developed by Wilson et al (2015) to derive estimates of the mean maximum NDVI (alpha + gamma), and the amplitude and timing of seasonality (big alpha and phi) as our measures of ecosystem function. Here I've provided a table of these parameters by site and plots of the model fits. Are the models good fits? Do they miss anything? Is it relevant to the questions we're asking?

Explore relationship between EF and measures of diversity

- Mantel tests? ?mantel

Test relationships using a null model?

References

Bergh et al

Mucina and Rutherford

Slingsby et al. 2020

van der Plas

Wilson et al