Global Nectar Distribution

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Evaluating biogeographical trends among floral nectar-producing plant communities

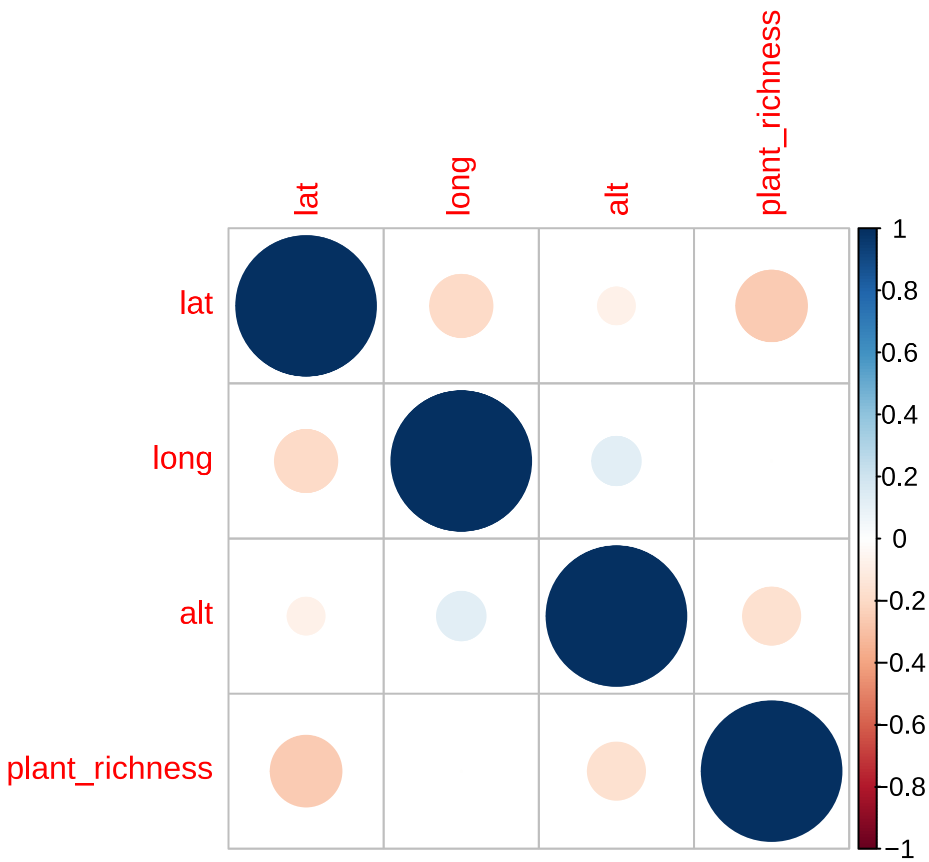
This file contains the code to reproduce the statistical analyses presented in the paper.

1. Relationship among the proportion of nectar-producing plants in communities worldwide and biogeographical variables

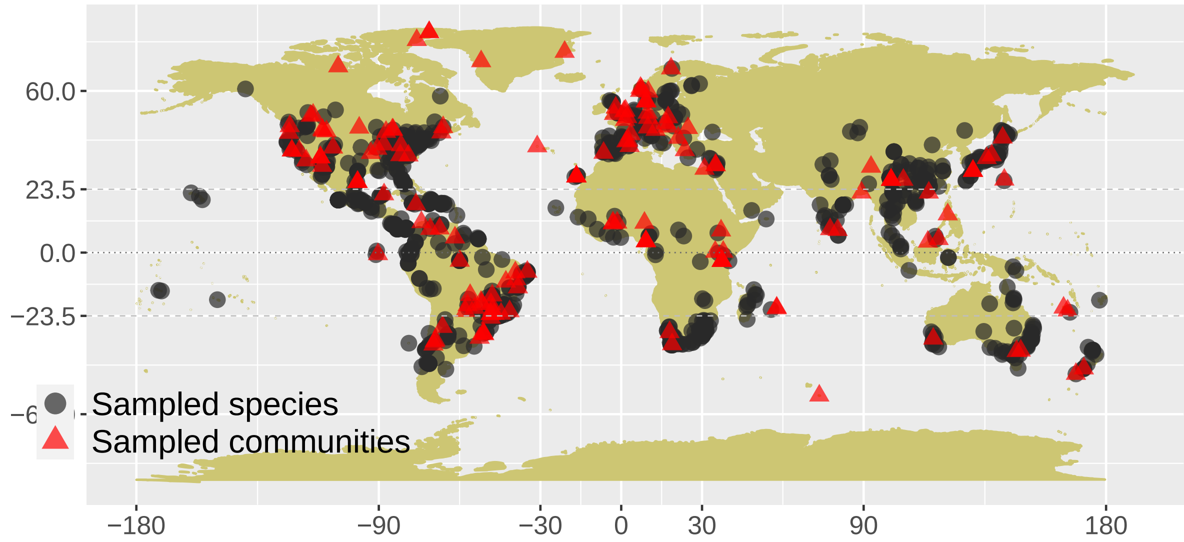
Correlation among response variables

First we will check if there is correlation between the numeric independent variables

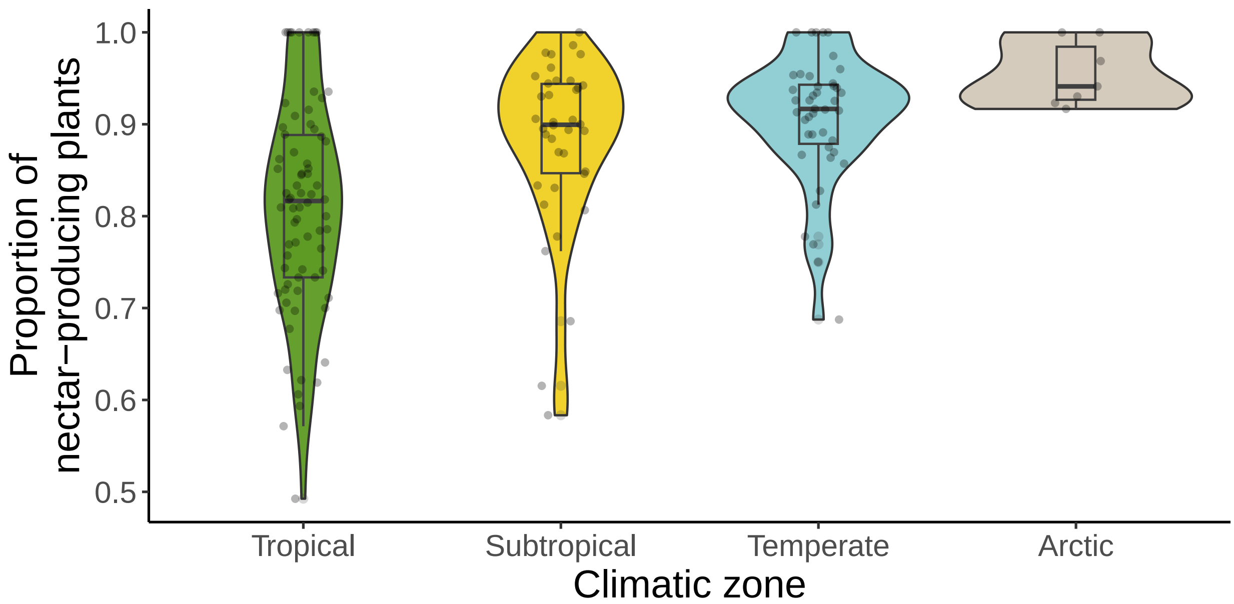
They are: Latitude, Longitude, Altitude and Plant richness (how many plant species in each plant community sampled)



As can be seen here, there are low levels of both negative and positive correlation between these variables. It should be expected, since we sampled several plant communities around the world not following any pre-established gradient. See the map:



Before running the models, let's check how the proportion of nectar-producing plants in communities worldwide is expressed by dividing plant communities into climatic zones.



It looks like tropical communities have a lower proportion of nectar-producing plants. Also it seems that there is a trend of increasing the proportion of nectar-producing plants following high latitudes.

Models

Now, we will check if some biogeographical variables are related with the proportion of nectar-producing plants in natural plant communities.

For these purpose we used the following variables

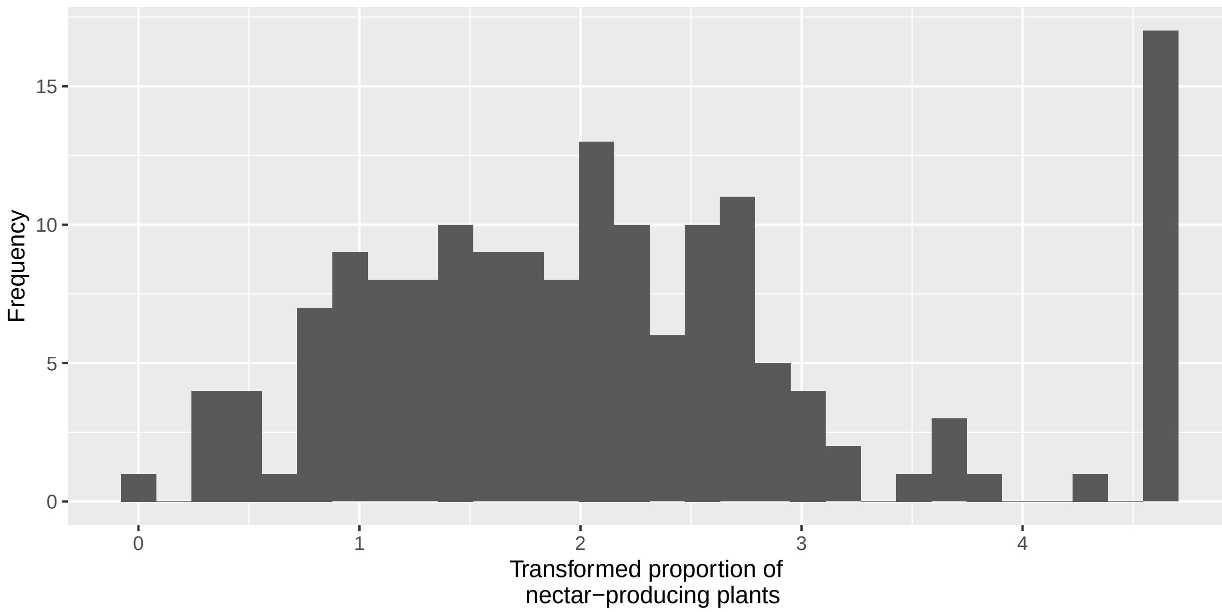
Latitude, Altitude, Plant richness, Insularity, Biome (according to Whittaker, 1962) and Sampling effort

GAMM models

We will use Generalized Aditive Mixed Models (GAMM) with the function `gamm4`.

We made 105 candidates models by combining the fixed factor, namely, Latitude, Altitude, Insularity and Biome and also combining the random effects, namely, Plant richness, Biome and Sampling effort

Transformation We first transformed our response variable (proportion of nectar-producing plants) to conform to a normal distribution



Multi-model inference

We ran seven possible models for 15 model structures, giving a total of 105 candidate models (not shown in the output).

Then, we ranked those models using the corrected Akaike Information Criterion `AICc` to determine the best model(s):

```
##           df     AICc
## m5g$mer    9 444.9128
## m5d$mer    8 445.5560
## m5f$mer    8 445.6881
## m5b$mer    7 446.4966
## m11f$mer   9 447.7971
## m11g$mer  10 447.8707
## m11d$mer   9 448.4890
## m11b$mer   8 448.6611
## m5e$mer    8 449.8485
## m5c$mer    7 450.9609
## m11c$mer   8 451.1055
## m5a$mer    7 451.3300
## m11e$mer   9 451.4056
## m12b$mer  15 451.5442
## m12d$mer  16 451.8488
## m11a$mer   8 453.2303
## m12f$mer  16 454.0083
## m12g$mer  17 454.3438
## m15b$mer  16 454.4059
## m9b$mer   13 455.2435
## m15d$mer  17 455.2994
## m12a$mer  15 455.8068
## m9d$mer   14 456.7746
## m9f$mer   14 457.6412
```

```
## m15f$mer 17 457.8087
## m15g$mer 18 457.8326
## m15a$mer 16 457.9557
## m12c$mer 15 458.0749
## m12e$mer 16 458.2709
## m14b$mer 14 458.6821
## m2f$mer   6 459.1631
## m9g$mer  15 459.2051
## m15c$mer 16 459.2415
## m9a$mer  13 459.3702
## m9c$mer  13 460.3630
## m2g$mer   7 460.4309
## m14d$mer 15 460.4456
## m15e$mer 17 460.4539
## m4d$mer  12 460.4947
## m14f$mer 15 461.1126
## m9e$mer  14 461.7679
## m8f$mer   7 461.9887
## m14a$mer 14 462.2188
## m2c$mer   5 462.2298
## m4b$mer  11 462.6183
## m14c$mer 14 462.7214
## m4g$mer  13 462.8602
## m14g$mer 16 462.9096
## m2e$mer   6 463.4083
## m1g$mer   7 463.4762
## m8g$mer   8 463.5817
## m8c$mer   6 463.6909
## m10d$mer 13 464.2100
## m7d$mer  14 464.4572
## m14e$mer 15 464.6494
## m4f$mer  12 464.9523
## m4a$mer  11 465.3004
## m8e$mer   7 465.4170
## m10b$mer 12 466.2080
## m10g$mer 14 466.6077
## m7g$mer  15 466.8878
## m1f$mer   6 466.9344
## m7b$mer  13 467.0895
## m6g$mer   8 467.1228
## m4e$mer  12 467.6343
## m13d$mer 15 468.2358
## m10f$mer 13 468.5735
## m3g$mer   6 468.6818
## m10a$mer 12 468.8031
## m1d$mer   6 469.4450
## m7f$mer  14 469.5442
## m6f$mer   7 470.3125
## m4c$mer  11 470.3900
## m7a$mer  13 470.5441
## m3f$mer   5 470.5511
## m13g$mer 16 470.6998
## m13b$mer 14 470.7541
## m1e$mer   6 471.1162
```

```
## m10e$mer 13 471.1686
## m1b$mer   5 471.9785
## m7e$mer  14 472.9418
## m10c$mer 12 473.1243
## m6d$mer   7 473.1262
## m13f$mer 15 473.1846
## m3e$mer   5 473.5160
## m13a$mer 14 474.1198
## m6e$mer   7 474.4091
## m3c$mer   4 475.3486
## m1c$mer   5 475.4623
## m6b$mer   6 475.5611
## m7c$mer  13 476.0922
## m13e$mer 15 476.5503
## m6c$mer   6 477.5743
## m1a$mer   5 478.1978
## m13c$mer 14 478.8101
## m6a$mer   6 481.7958
## m8b$mer   6 493.0393
## m8a$mer   6 493.6464
## m8d$mer   7 494.3632
## m2b$mer   5 495.8191
## m2d$mer   6 496.4036
## m2a$mer   5 496.7460
## m3b$mer   4 507.8607
## m3d$mer   5 507.8825
## m3a$mer   4 509.5573
```

It can be seen that models with Latitude and Altitude received the lowest AIC scores.

Models **m5g**, **m5d** , **m5f** and **m5b** are within the ΔAIC < 2 subset, therefore we must examine them.

Latitude + Altitude with Sampling effort, Plant richness and Biome as random effects

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## propC ~ s(lat) + s(alt)
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   2.2580     0.2665   8.473 1.72e-14 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##          edf Ref.df      F  p-value
## s(lat) 4.724  4.724  9.774 4.68e-07 ***
## s(alt) 1.000  1.000 29.831 7.17e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## R-sq.(adj) =  0.379
## lmer.REML = 425.73  Scale est. = 0.60827   n = 162
```

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## propC ~ s(lat) + s(alt)
##
## Approximate significance of smooth terms:
##          edf Ref.df      F  p-value
## s(lat) 4.724  4.724  9.774 4.68e-07
## s(alt) 1.000  1.000 29.831 7.17e-07
```

Latitude + Altitude with Sampling effort and Plant richness as random effects

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## propC ~ s(lat) + s(alt)
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   2.2411     0.2607   8.597 8.32e-15 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##          edf Ref.df     F p-value
## s(lat) 4.803  4.803 17.46  <2e-16 ***
## s(alt) 1.000  1.000 35.76  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.386
## lmer.REML = 428.61  Scale est. = 0.64635   n = 162
```

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## propC ~ s(lat) + s(alt)
##
## Approximate significance of smooth terms:
##          edf Ref.df     F p-value
## s(lat) 4.803  4.803 17.46  <2e-16
## s(alt) 1.000  1.000 35.76  <2e-16
```

Latitude + Altitude with Sampling effort and Biome as random effects

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## propC ~ s(lat) + s(alt)
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)    2.265      0.271   8.357 3.39e-14 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##          edf Ref.df      F  p-value
## s(lat) 4.748  4.748  8.911 1.25e-06 ***
## s(alt) 1.000  1.000 32.065  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.383
## lmer.REML = 428.75  Scale est. = 0.70459   n = 162
```

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## propC ~ s(lat) + s(alt)
##
## Approximate significance of smooth terms:
##          edf Ref.df      F  p-value
## s(lat) 4.748  4.748  8.911 1.25e-06
## s(alt) 1.000  1.000 32.065  < 2e-16
```

Latitude + Altitude with Sampling effort as random effect

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## propC ~ s(lat) + s(alt)
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   2.2470     0.2673   8.406 2.56e-14 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
```

```
##          edf Ref.df     F p-value
## s(lat) 4.812  4.812 16.98  <2e-16 ***
## s(alt) 1.000  1.000 37.36  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.388
## lmer.REML = 431.77  Scale est. = 0.74718   n = 162
```

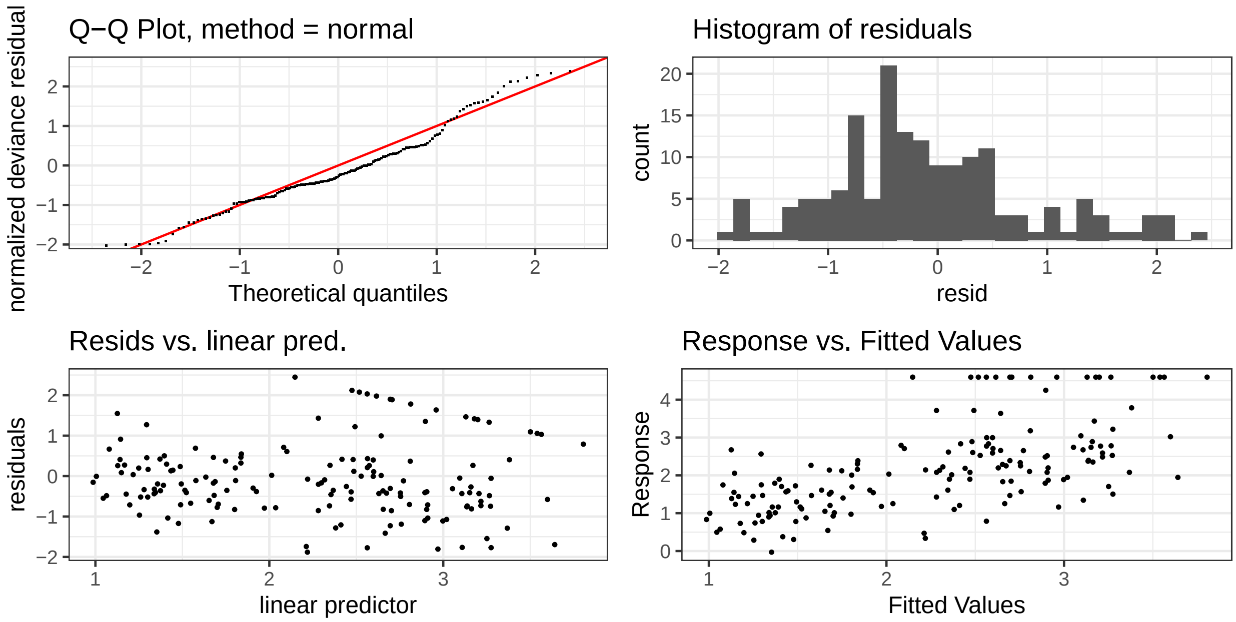
```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## propC ~ s(lat) + s(alt)
##
## Approximate significance of smooth terms:
##          edf Ref.df     F p-value
## s(lat) 4.812  4.812 16.98  <2e-16
## s(alt) 1.000  1.000 37.36  <2e-16
```

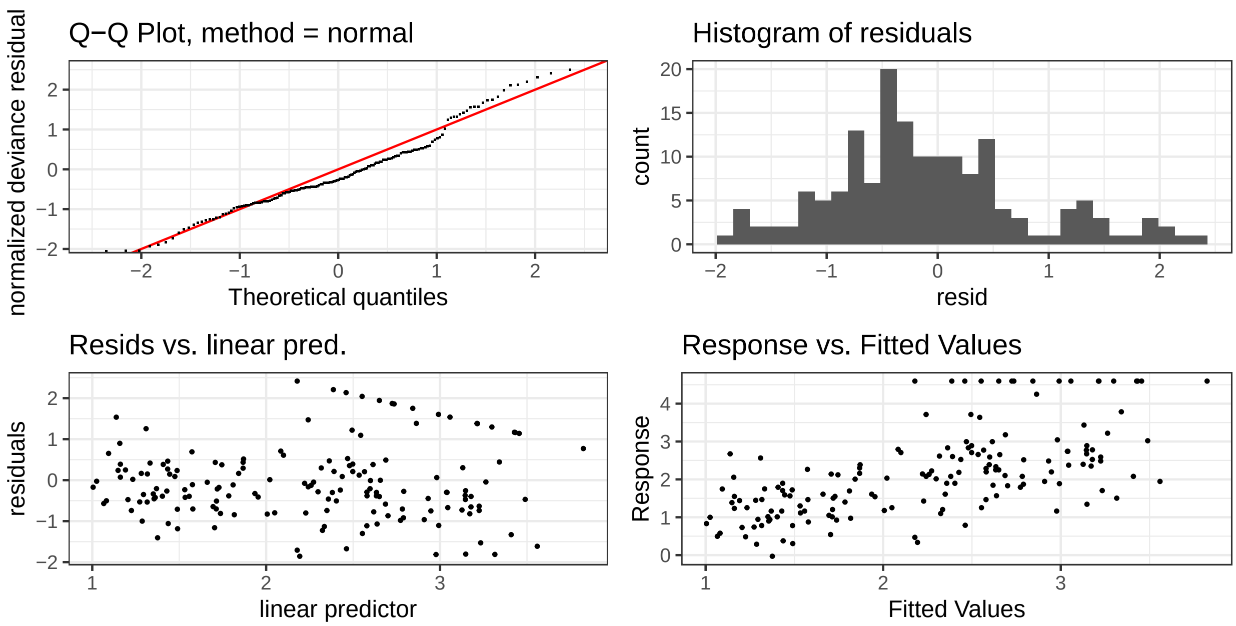
Results are quite similar among these four models.

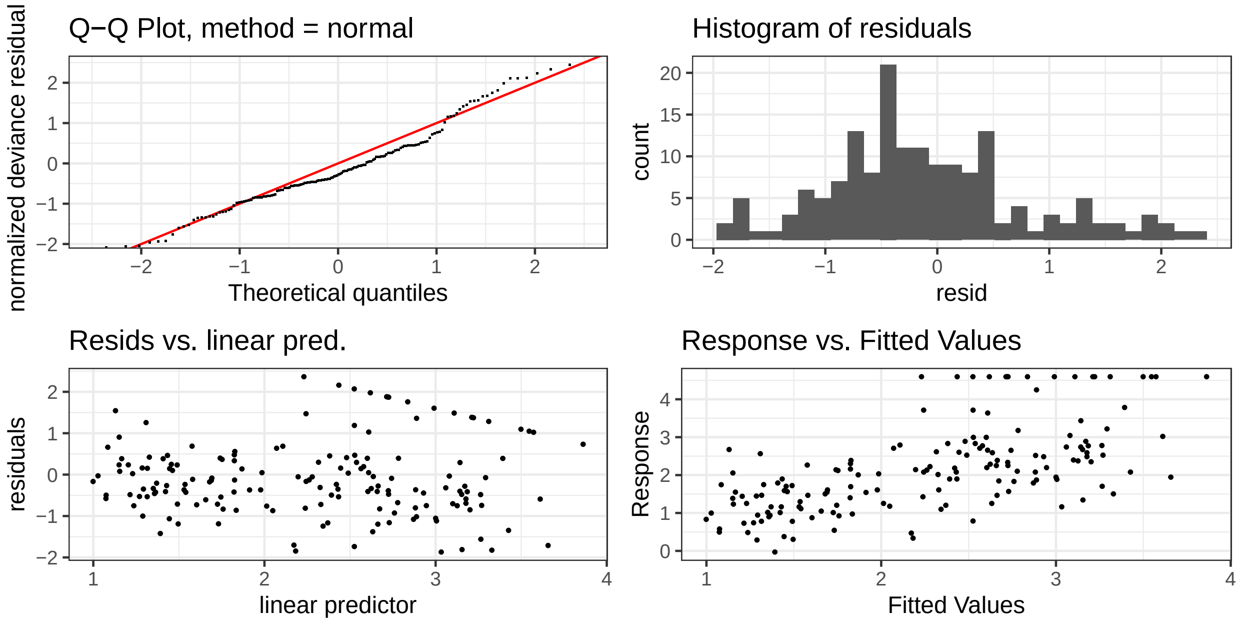
Evaluating the performance of variables in explaining the diversity of floral resources

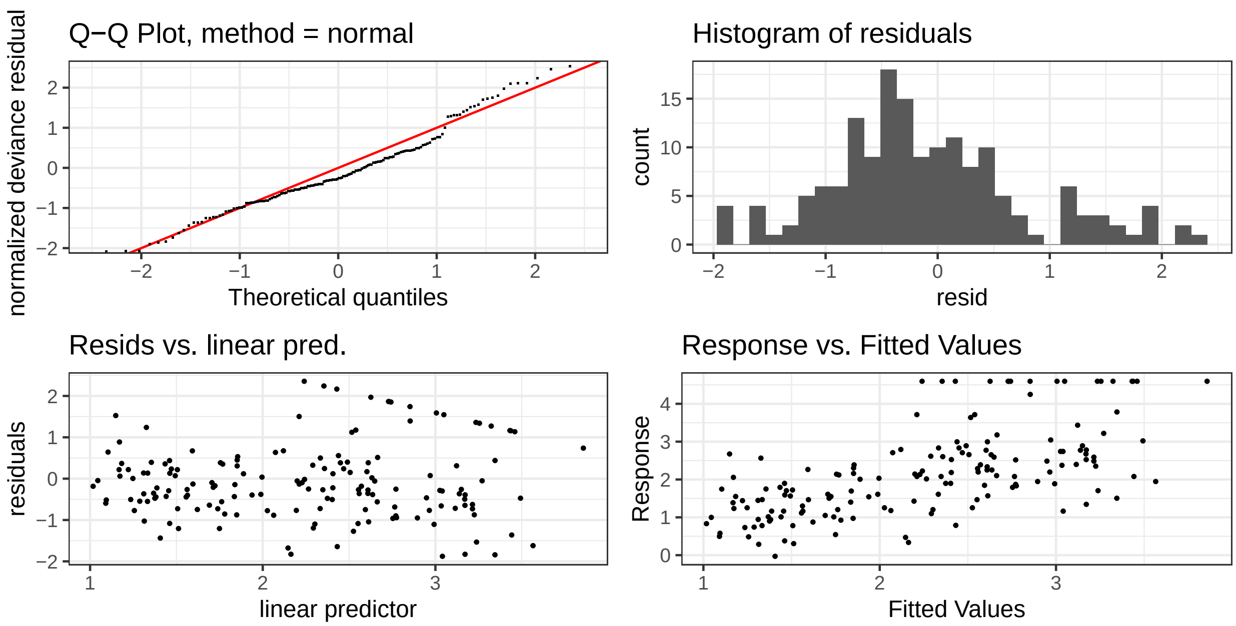
```
## Model selection table
##          X        random df   logLik  AICc delta weight
## m5g$mer  + X+X.0+p_r+e+b  9 -212.864 444.9  0.00  0.806
## m11g$mer + X+X.0+p_r+e+b 10 -213.207 447.9  2.96  0.184
## m12g$mer + X+X.0+p_r+e+b 17 -208.047 454.3  9.43  0.007
## m15g$mer + X+X.0+p_r+e+b 18 -208.525 457.8 12.92  0.001
## m9g$mer  +     X+p_r+e+b 15 -212.959 459.2 14.29  0.001
## m2g$mer  +     X+p_r+e+b  7 -222.852 460.4 15.52  0.000
## m4g$mer  +       p_r+e+b 13 -217.200 462.9 17.95  0.000
## m14g$mer +     X+p_r+e+b 16 -213.579 462.9 18.00  0.000
## m1g$mer  +     X+p_r+e+b  7 -224.374 463.5 18.56  0.000
## m8g$mer  +     X+p_r+e+b  8 -223.320 463.6 18.67  0.000
## m10g$mer +       p_r+e+b 14 -217.875 466.6 21.69  0.000
## m7g$mer  +     X+p_r+e+b 15 -216.800 466.9 21.97  0.000
## m6g$mer  +     X+p_r+e+b  8 -225.091 467.1 22.21  0.000
## m3g$mer  +       p_r+e+b  6 -228.070 468.7 23.77  0.000
## m13g$mer +     X+p_r+e+b 16 -217.474 470.7 25.79  0.000
## Models ranked by AICc(x)
## Random terms:
##  X  : 1 | Xr
##  X.0: 1 | Xr.0
##  p_r: 1 | plant_richness
##  e  : 1 | effort
##  b  : 1 | biome
```

Visual inspection of these models









All models seem to have a fair residual distribution

Assessing multicollinearity

To be sure that our results are not influenced by strong multicollinearity, we performed two tests:

1) estimating confidence intervals,

2) concurvity analysis, using `concurvity`

Latitude + Altitude with Sampling effort, Plant richness and Biome as random effect

```
##                      2.5 %        97.5 %
## (Intercept)  1.735654e+00  2.780308e+00
## s(lat).1    -2.852729e+00 -7.340535e-01
## s(lat).2    -1.109829e+00  2.531679e+00
## s(lat).3    -7.198948e-01  1.412388e-01
## s(lat).4    -8.538383e-01  1.799487e+00
## s(lat).5    -1.781256e-01  7.127530e-01
## s(lat).6    -6.351780e-01  1.524712e+00
## s(lat).7    -2.642694e-01  2.419817e-01
## s(lat).8    -5.910619e+00  1.328157e+00
## s(lat).9    -2.603413e+00 -2.711823e-02
## s(alt).1    -3.859692e-06  3.859692e-06
## s(alt).2    -9.509295e-06  9.509295e-06
## s(alt).3    -1.778929e-06  1.778929e-06
## s(alt).4    -5.904357e-06  5.904357e-06
## s(alt).5    -1.961996e-06  1.961996e-06
## s(alt).6    -5.331226e-06  5.331226e-06
## s(alt).7    -1.847231e-06  1.847231e-06
## s(alt).8    -1.993902e-05  1.993902e-05
## s(alt).9     2.730092e-01  5.786150e-01
```

```
##                  para     s(lat)    s(alt)
## worst    2.713528e-24 0.29806500 0.2980650
## observed 2.713528e-24 0.09579912 0.2083209
## estimate 2.713528e-24 0.09973733 0.1946390
```

Latitude + Altitude with Sampling effort and Plant richness as random effects

```
##                      2.5 %        97.5 %
## (Intercept)  1.730129e+00  2.751991e+00
## s(lat).1    -2.733830e+00 -7.587918e-01
## s(lat).2    -7.571183e-01  2.736691e+00
## s(lat).3    -6.609704e-01  1.791692e-01
## s(lat).4    -7.122846e-01  1.867173e+00
## s(lat).5    -1.240388e-01  7.458819e-01
## s(lat).6    -5.049338e-01  1.587512e+00
## s(lat).7    -2.552449e-01  2.431466e-01
## s(lat).8    -6.128071e+00  8.015048e-01
## s(lat).9    -2.502019e+00  1.945240e-02
## s(alt).1    -1.703308e-05  1.703323e-05
## s(alt).2    -4.196598e-05  4.196472e-05
## s(alt).3    -7.850505e-06  7.850631e-06
## s(alt).4    -2.605677e-05  2.605612e-05
## s(alt).5    -8.658585e-06  8.658338e-06
## s(alt).6    -2.352752e-05  2.352681e-05
## s(alt).7    -8.152127e-06  8.151858e-06
## s(alt).8    -8.799418e-05  8.799106e-05
## s(alt).9     2.887750e-01  5.703856e-01
```

```
##                  para     s(lat)    s(alt)
## worst    2.713528e-24 0.29806500 0.2980650
```

```
## observed 2.713528e-24 0.09716841 0.2083209
## estimate 2.713528e-24 0.09973733 0.1946390
```

Latitude + Altitude with Sampling effort as random effect

```
##                      2.5 %        97.5 %
## (Intercept)  1.733586e+00  2.795816e+00
## s(lat).1    -2.839777e+00 -6.876447e-01
## s(lat).2    -1.139213e+00  2.562222e+00
## s(lat).3    -7.647136e-01  1.085399e-01
## s(lat).4    -9.237563e-01  1.780376e+00
## s(lat).5    -1.843694e-01  7.234611e-01
## s(lat).6    -6.713616e-01  1.529279e+00
## s(lat).7    -2.663785e-01  2.490234e-01
## s(lat).8    -5.914219e+00  1.457941e+00
## s(lat).9    -2.663216e+00 -4.823080e-02
## s(alt).1    -4.154084e-06  4.154084e-06
## s(alt).2    -1.023460e-05  1.023460e-05
## s(alt).3    -1.914614e-06  1.914614e-06
## s(alt).4    -6.354703e-06  6.354703e-06
## s(alt).5    -2.111645e-06  2.111645e-06
## s(alt).6    -5.737857e-06  5.737857e-06
## s(alt).7    -1.988126e-06  1.988126e-06
## s(alt).8    -2.145983e-05  2.145983e-05
## s(alt).9     2.920595e-01  6.012592e-01
```

```
##                  para     s(lat)    s(alt)
## worst    2.713528e-24 0.29806500 0.2980650
## observed 2.713528e-24 0.09645287 0.2083209
## estimate 2.713528e-24 0.09973733 0.1946390
```

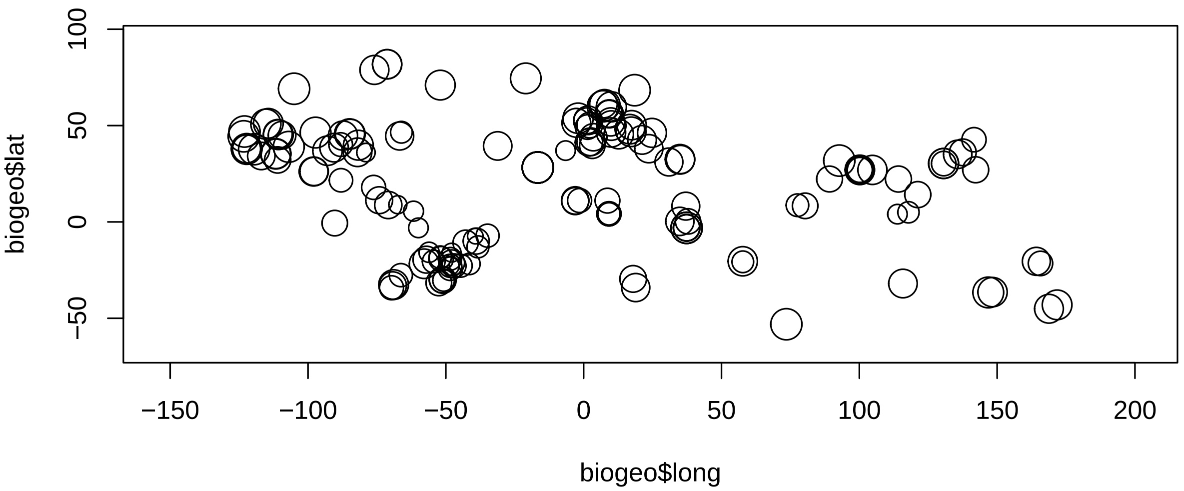
Latitude + Altitude with Sampling effort, Plant richness and Biome as random effects

```
##                      2.5 %        97.5 %
## (Intercept)  1.723103e+00  2.770991e+00
## s(lat).1    -2.718916e+00 -7.203126e-01
## s(lat).2    -7.659750e-01  2.766001e+00
## s(lat).3    -6.935672e-01  1.546674e-01
## s(lat).4    -7.565950e-01  1.857459e+00
## s(lat).5    -1.358611e-01  7.452216e-01
## s(lat).6    -5.303111e-01  1.588854e+00
## s(lat).7    -2.542298e-01  2.498215e-01
## s(lat).8    -6.148693e+00  8.642894e-01
## s(lat).9    -2.538970e+00  1.210991e-02
## s(alt).1    -4.277771e-06  4.277771e-06
## s(alt).2    -1.053933e-05  1.053933e-05
## s(alt).3    -1.971621e-06  1.971621e-06
## s(alt).4    -6.543913e-06  6.543913e-06
## s(alt).5    -2.174518e-06  2.174518e-06
## s(alt).6    -5.908701e-06  5.908701e-06
## s(alt).7    -2.047322e-06  2.047322e-06
## s(alt).8    -2.209879e-05  2.209879e-05
## s(alt).9     3.015531e-01  5.862338e-01
```

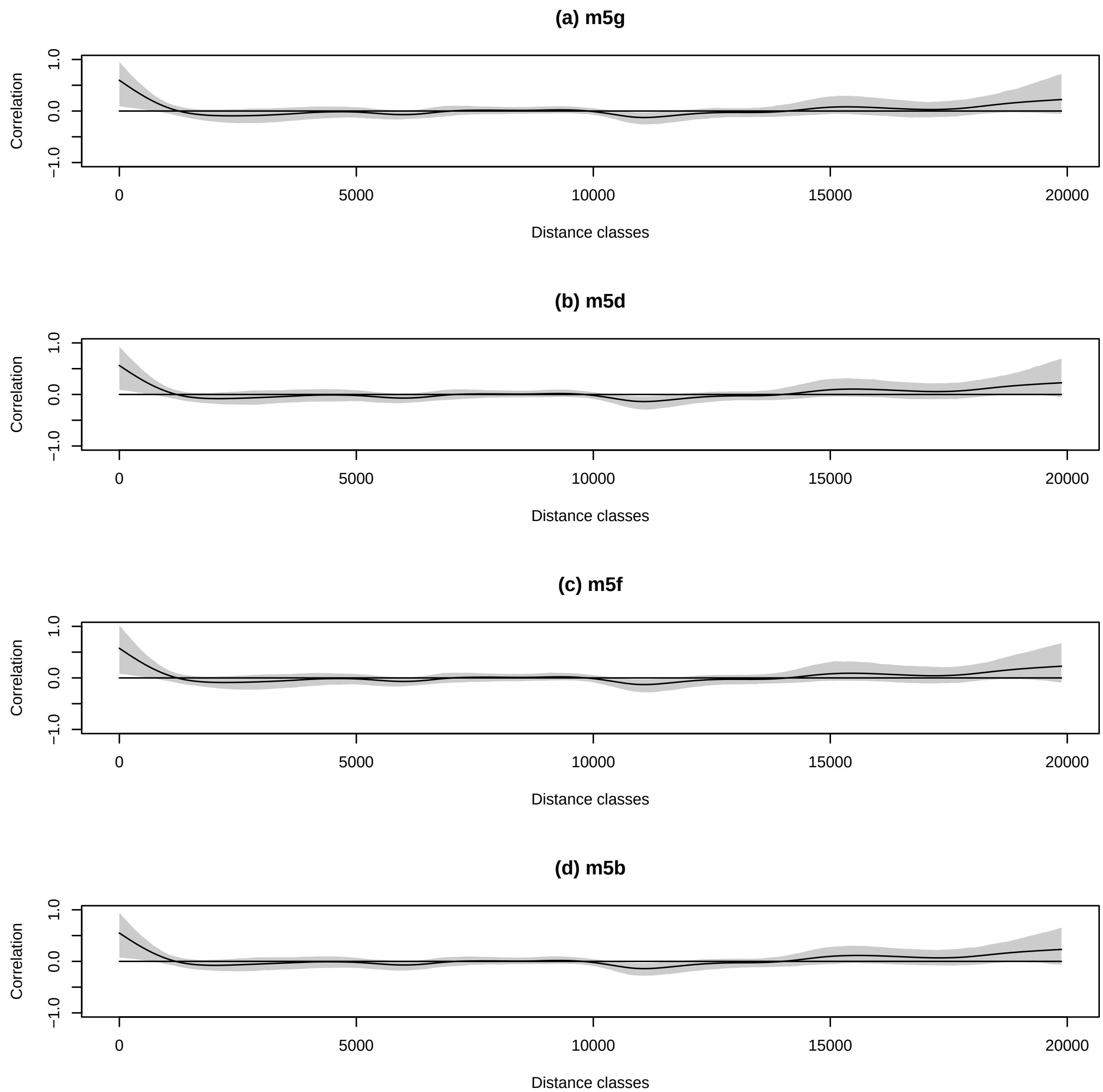
```
##                    para     s(lat)    s(alt)
## worst    2.713528e-24 0.29806500 0.2980650
## observed 2.713528e-24 0.09695454 0.2083209
## estimate 2.713528e-24 0.09973733 0.1946390
```

Confidence intervals seems reasonable. Also, estimate concurvity is lower than 0.8 which is acceptable.

Evaluating spatial autocorrelation

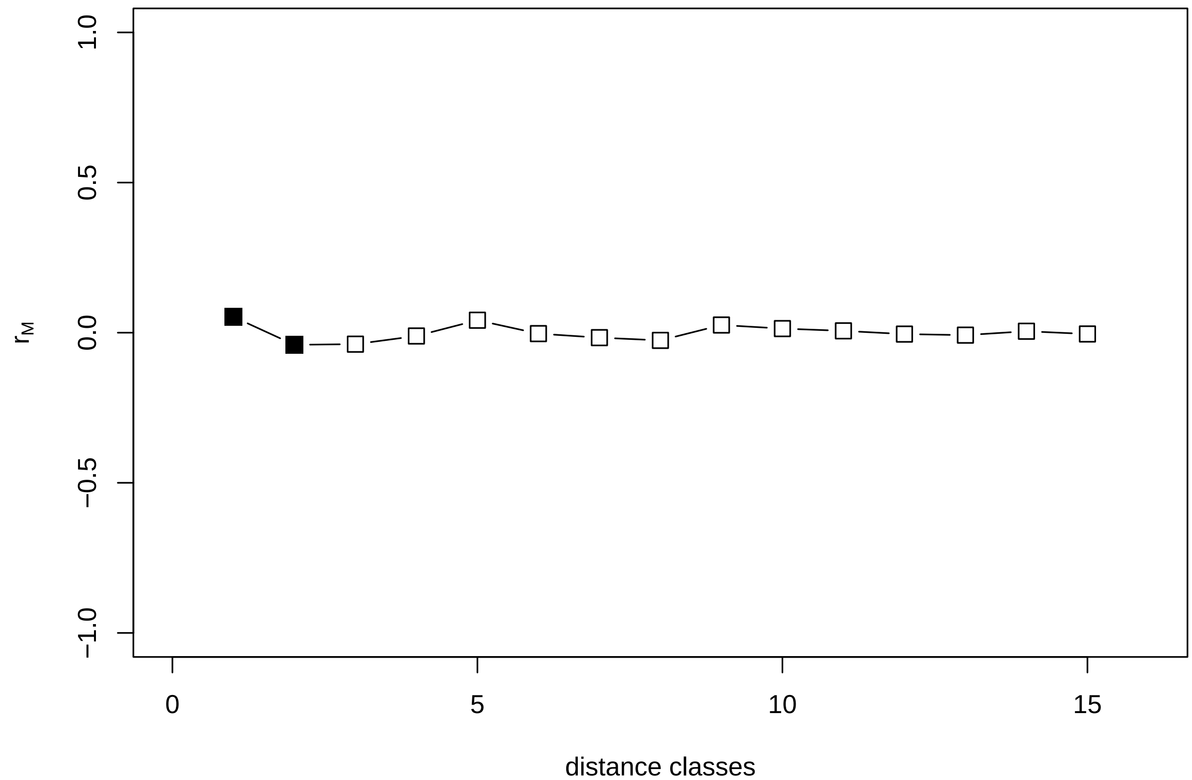



```
## 100  of  1000 200  of  1000 300  of  1000 400  of  1000 500  of  1000 600  of  1000 700  of  1000 80

## 100  of  1000 200  of  1000 300  of  1000 400  of  1000 500  of  1000 600  of  1000 700  of  1000 80

## 100  of  1000 200  of  1000 300  of  1000 400  of  1000 500  of  1000 600  of  1000 700  of  1000 80

## 100  of  1000 200  of  1000 300  of  1000 400  of  1000 500  of  1000 600  of  1000 700  of  1000 80
```



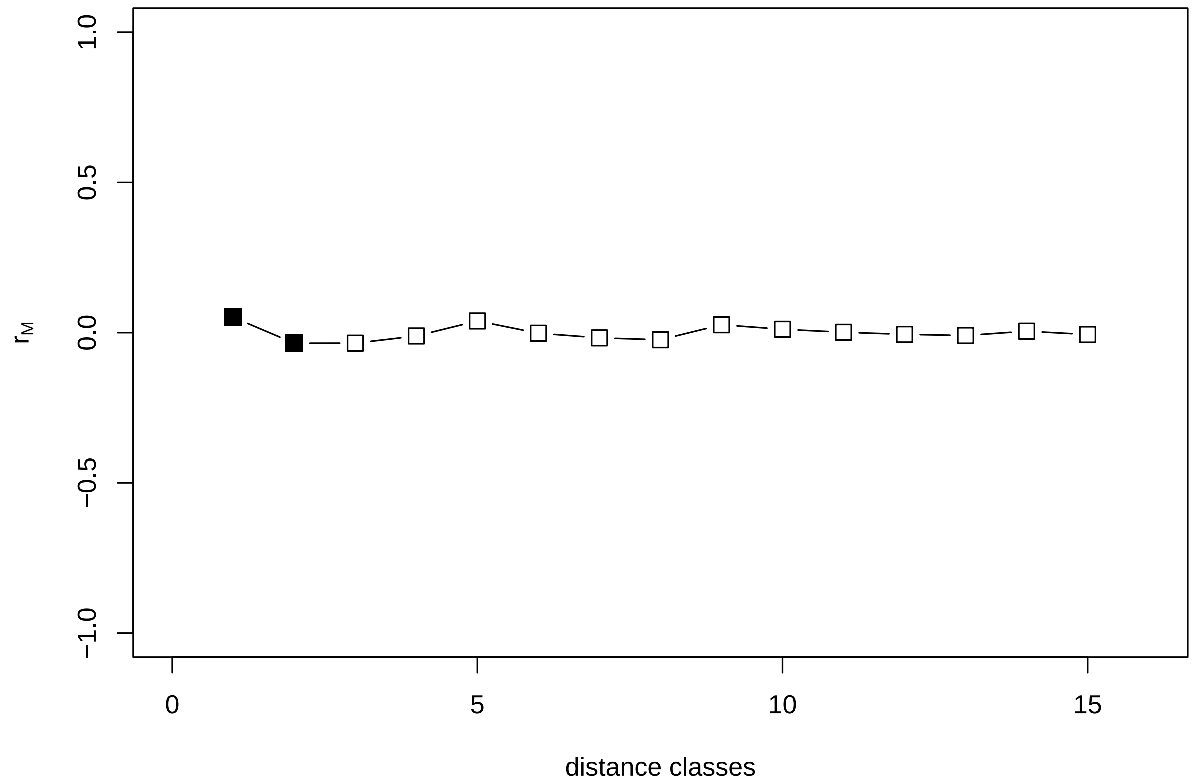
Mantel partial correlogram

```
## evaluating distance class 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15,
```

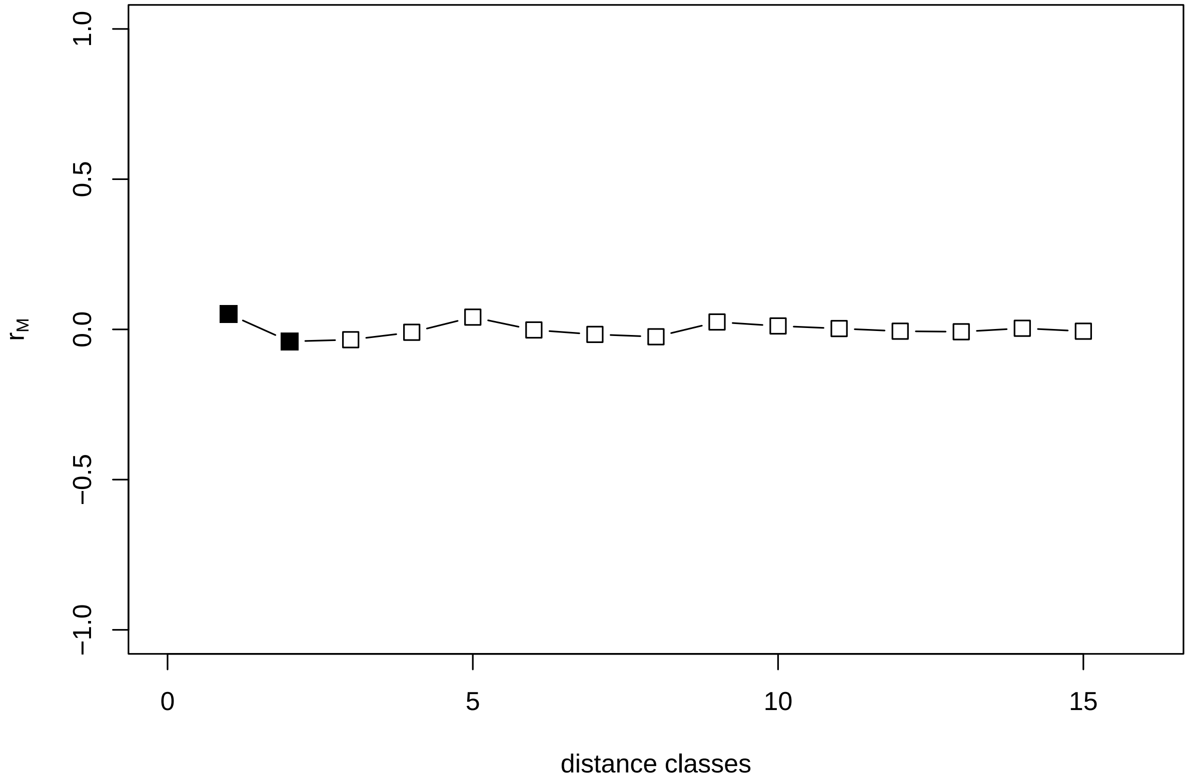



```
##    class      distance.range            rM          p p.Bonferroni
## 1      1        0  -  20.547  0.052731717 0.00139986   0.00139986
## 2      2   20.547  -  41.095 -0.040348683 0.00529947   0.01059894
## 3      3   41.095  -  61.642 -0.038216924 0.03539646   0.10618938
## 4      4    61.642  -  82.19 -0.011009024 0.27157284   1.08629137
## 5      5   82.19  -  102.737  0.041542903 0.01189881   0.05949405
## 6      6 102.737  -  123.285 -0.003136951 0.42835716   2.57014299
## 7      7 123.285  -  143.832 -0.016497714 0.16818318   1.17728227
## 8      8  143.832  -  164.38 -0.025662086 0.04959504   0.39676032
## 9      9  164.38  -  184.927  0.025542187 0.05139486   0.46255374
## 10    10 184.927  -  205.475  0.013633003 0.22197780   2.21977802
## 11    11 205.475  -  226.022  0.006098748 0.37156284   4.08719128
## 12    12  226.022  -  246.57 -0.004704394 0.38926107   4.67113289
## 13    13  246.57  -  267.117 -0.008157260 0.31166883   4.05169483
## 14    14 267.117  -  287.665  0.004804774 0.42275772   5.91860814
## 15    15 287.665  -  309.212 -0.004363976 0.35656434   5.34846515
```

```
## evaluating distance class 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15,
```

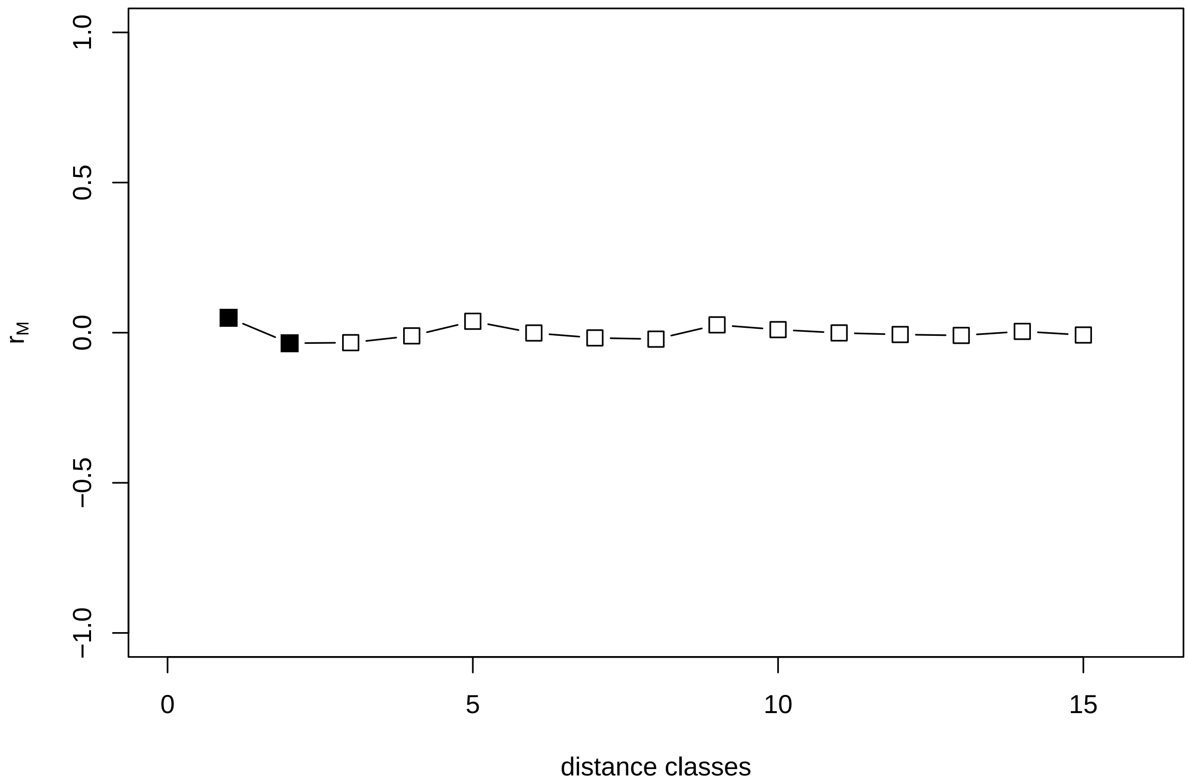



```
##    class      distance.range           rM          p p.Bonferroni
## 1      1        0  -  20.547  0.050982611 0.00129987   0.00129987
## 2      2   20.547  -  41.095 -0.035190436 0.01519848   0.03039696
## 3      3   41.095  -  61.642 -0.034946819 0.04359564   0.13078692
## 4      4    61.642  -  82.19 -0.011044938 0.26297370   1.05189481
## 5      5   82.19  -  102.737  0.038959801 0.01479852   0.07399260
## 6      6 102.737  -  123.285 -0.001901880 0.45795420   2.74772523
## 7      7 123.285  -  143.832 -0.017373851 0.14588541   1.02119788
## 8      8  143.832  -  164.38 -0.023662848 0.06269373   0.50154985
## 9      9  164.38  -  184.927  0.026255991 0.04609539   0.41485851
## 10    10 184.927  -  205.475  0.011223371 0.27207279   2.72072793
## 11    11 205.475  -  226.022  0.001265562 0.49285071   5.42135786
## 12    12  226.022  -  246.57 -0.005685846 0.36106389   4.33276672
## 13    13  246.57  -  267.117 -0.009510820 0.28817118   3.74622538
## 14    14 267.117  -  287.665  0.004877496 0.43535646   6.09499050
## 15    15 287.665  -  309.212 -0.006221260 0.33666633   5.04999500

## evaluating distance class 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15,
```




```
##    class      distance.range           rM          p p.Bonferroni
## 1      1        0  -  20.547  0.050998942 0.00209979   0.00209979
## 2      2   20.547  -  41.095 -0.040033000 0.00619938   0.01239876
## 3      3   41.095  -  61.642 -0.034360985 0.04359564   0.13078692
## 4      4    61.642  -  82.19 -0.009631460 0.30536946   1.22147785
## 5      5   82.19  -  102.737  0.040842222 0.01119888   0.05599440
## 6      6 102.737  -  123.285 -0.001911532 0.44835516   2.69013099
## 7      7 123.285  -  143.832 -0.016721928 0.15968403   1.11778822
## 8      8  143.832  -  164.38 -0.024491155 0.05619438   0.44955504
## 9      9  164.38  -  184.927  0.024622688 0.05759424   0.51834817
## 10    10 184.927  -  205.475  0.011430228 0.26147385   2.61473853
## 11    11 205.475  -  226.022  0.002817841 0.44145585   4.85601440
## 12    12  226.022  -  246.57 -0.006022840 0.36236376   4.34836516
## 13    13  246.57  -  267.117 -0.007839314 0.32056794   4.16738326
## 14    14 267.117  -  287.665  0.003709168 0.44145585   6.18038196
## 15    15 287.665  -  309.212 -0.006094716 0.34306569   5.14598540
```

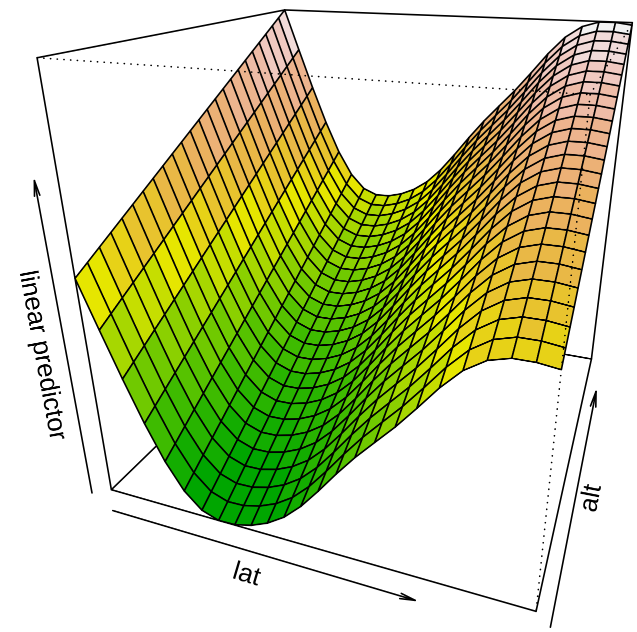
```
## evaluating distance class 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15,
```



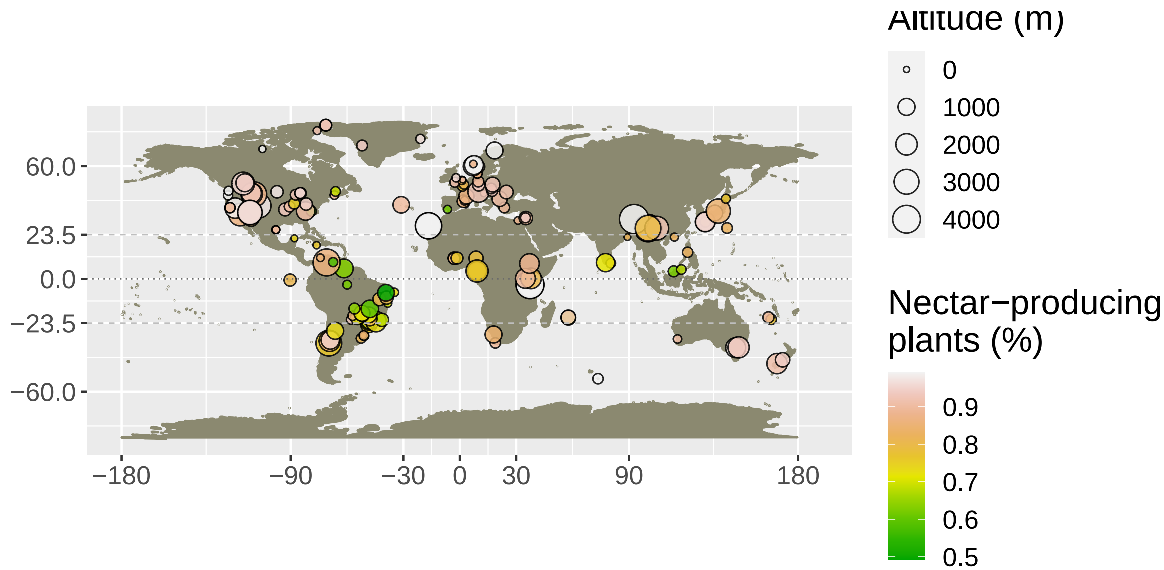

```
##    class      distance.range            rM          p p.Bonferroni
## 1      1        0  -  20.547  0.0500410441 0.00179982   0.00179982
## 2      2   20.547  -  41.095 -0.0350356016 0.01399860   0.02799720
## 3      3   41.095  -  61.642 -0.0332473294 0.05229477   0.15688431
## 4      4    61.642  -  82.19 -0.0105834177 0.28277172   1.13108689
## 5      5   82.19  -  102.737  0.0380119806 0.01759824   0.08799120
## 6      6 102.737  -  123.285 -0.0011077987 0.46925307   2.81551845
## 7      7 123.285  -  143.832 -0.0173934881 0.14988501   1.04919508
## 8      8  143.832  -  164.38 -0.0214850471 0.08059194   0.64473553
## 9      9  164.38  -  184.927  0.0260035078 0.05039496   0.45355464
## 10    10 184.927  -  205.475  0.0101299824 0.28947105   2.89471053
## 11    11 205.475  -  226.022 -0.0007895952 0.47645235   5.24097590
## 12    12  226.022  -  246.57 -0.0061404846 0.35416458   4.24997500
## 13    13  246.57  -  267.117 -0.0091433189 0.30026997   3.90350965
## 14    14 267.117  -  287.665  0.0042762418 0.43865613   6.14118588
## 15    15 287.665  -  309.212 -0.0077847647 0.31186881   4.67803220
```

Conclusion: correlograms show no major spatial autocorrelation Since model are similar to each other. Let's visualize it.

Plotting the model in 3D



Results in the global map



We discuss that the biogeographical trend observed for nectar production in flowering plants across the globe may be a result of the presented resource diversity among global communities. Therefore, **temperate communities** may present lower richness and diversity of floral resources than **tropical communities**.

2. Relationship among the Shannon diversity of floral resources in communities worldwide and biogeographical variables

To test this assumption we used a subsample* of our sampled communities and tested whether resource diversity may be a result of the same biogeographical factors

We used a subsample (n=87) because we were able to track the floral resources richness in only a portion of our sample

Models

We used the same analytical procedure that was used for the proportion of nectar-producing plants. This time, our response variable was Shannon diversity of floral resources *(H')*. To assess Shannon diversity of floral resources *(H')*, e considered each type of floral resource (e.g. nectar, oil, pollen, resin, fragrance) as a different "species" following the regular taxonomical use of the Shannon diversity.

We also used the same procedure to check multicollinearity and spatial autocorrelation.

Multi-model inference

We ran seven possible models for 15 model structures, giving a total of 105 candidate models (not shown in the output).

Then, we ranked those models using the corrected Akaike Information Criterion `AICc` to determine the best model(s):

```
##              df        AICc
## m1bSH$mer    5 -36.91604979
## m6bSH$mer    6 -35.02104157
## m1aSH$mer    5 -34.91955903
## m1cSH$mer    5 -34.91955901
## m1fSH$mer    6 -34.60679047
## m1dSH$mer    6 -34.60678822
## m5bSH$mer    7 -33.84016002
## m6dSH$mer    7 -32.66185352
## m6fSH$mer    7 -32.65331998
## m1eSH$mer    6 -32.61029977
## m1gSH$mer    7 -32.23906888
## m5dSH$mer    8 -31.74085300
## m5aSH$mer    7 -31.66472938
## m5cSH$mer    7 -31.66240719
## m6aSH$mer    6 -31.50967176
## m6cSH$mer    6 -31.50967176
## m5fSH$mer    8 -31.41172768
## m6gSH$mer    8 -30.23342141
## m11bSH$mer   8 -29.65849206
## m5gSH$mer    9 -29.24934452
## m5eSH$mer    8 -29.23629706
## m6eSH$mer    7 -29.14195024
## m11dSH$mer   9 -27.54954634
## m11fSH$mer   9 -27.16698356
## m11aSH$mer   8 -26.50728688
## m11cSH$mer   8 -26.50728687
## m11gSH$mer 10 -24.99247185
## m11eSH$mer   9 -24.01577839
## m3cSH$mer    4 -12.99455855
## m3fSH$mer    5 -11.82320370
## m3eSH$mer    5 -10.74162269
## m2cSH$mer    5  -9.73022653
## m3gSH$mer    6  -9.51394444
## m2fSH$mer    6  -8.20232783
## m2eSH$mer    6  -7.42096727
## m2gSH$mer    7  -5.83460631
## m8cSH$mer    6  -4.02554621
## m8fSH$mer    7  -2.55387168
## m8eSH$mer    7  -1.65782469
## m4bSH$mer   11  -1.37839908
## m4cSH$mer   11  -0.74608609
## m4aSH$mer   11  -0.74608609
## m8gSH$mer    8  -0.12543971
## m7bSH$mer   13   0.09066189
## m4dSH$mer   12   1.31781713
## m4fSH$mer   12   1.31781717
## m7aSH$mer   13   1.36964904
## m7cSH$mer   13   1.36970963
## m4eSH$mer   12   1.95013013
## m7dSH$mer   14   2.87042776
## m7fSH$mer   14   2.93769385
## m13bSH$mer 14   3.34714837
## m10bSH$mer 12   3.82112572
```

```
## m4gSH$mer  13   4.08790229
## m7eSH$mer  14   4.21668100
## m10aSH$mer 12   4.81733385
## m10cSH$mer 12   4.81733385
## m13aSH$mer 14   5.60610207
## m13cSH$mer 14   5.60610211
## m7gSH$mer  15   5.79765781
## m13dSH$mer 15   6.25089063
## m13fSH$mer 15   6.27437841
## m10dSH$mer 13   6.59121088
## m10fSH$mer 13   6.59121088
## m12bSH$mer 15   7.33834183
## m10eSH$mer 13   7.58741900
## m9bSH$mer  13   8.49468819
## m13eSH$mer 15   8.53333212
## m12aSH$mer 15   8.71607407
## m12cSH$mer 15   8.81783394
## m9cSH$mer  13   9.12889735
## m9aSH$mer  13   9.12889735
## m13gSH$mer 16   9.26175582
## m10gSH$mer 14   9.43824284
## m12dSH$mer 16   9.79152564
## m12fSH$mer 16  10.34920719
## m9fSH$mer  14  11.34172015
## m9dSH$mer  14  11.34172015
## m12eSH$mer 16  11.72693927
## m9eSH$mer  14  11.97592932
## m15bSH$mer 16  12.27107673
## m12gSH$mer 17  12.88966227
## m9gSH$mer  15  14.26895027
## m14bSH$mer 14  14.28277232
## m15aSH$mer 16  14.39340751
## m15cSH$mer 16  14.41143358
## m15dSH$mer 17  14.96988147
## m14cSH$mer 14  15.13647594
## m14aSH$mer 14  15.13647594
## m15fSH$mer 17  15.36921338
## m14dSH$mer 15  17.21000237
## m14fSH$mer 15  17.21000237
## m15eSH$mer 17  17.49154416
## m14eSH$mer 15  18.06370599
## m15gSH$mer 18  18.15913978
## m14gSH$mer 16  20.22086756
## m3aSH$mer   4  37.16770269
## m3bSH$mer   4  37.49361577
## m3dSH$mer   5  39.42063855
## m2bSH$mer   5  40.92536349
## m2aSH$mer   5  40.92536349
## m2dSH$mer   6  43.23462275
## m8aSH$mer   6  44.18777524
## m8bSH$mer   6  44.20198468
## m8dSH$mer   7  46.55549676
```

It can be seen that models with Latitude or Latitude + Insularity received the lowest AIC scores

Models **m1bSH**, and **m6bSH** are within the ΔAIC < 2 subset, therefore we must examine them

Latitude with Sampling effort as random effect

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## Shan ~ s(lat)
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.44056    0.04325   10.19 3.95e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##          edf Ref.df     F p-value
## s(lat) 5.549  5.549 30.16  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.646
## lmer.REML = -47.657  Scale est. = 0.025637  n = 87
```

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## Shan ~ s(lat)
##
## Approximate significance of smooth terms:
##          edf Ref.df     F p-value
## s(lat) 5.549  5.549 30.16  <2e-16
```

Latitude + Insularity with Sampling effort as random effects

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## Shan ~ s(lat) + insularity
##
## Parametric coefficients:
##                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)       0.41839    0.05272   7.937 1.13e-11 ***
## insularityIsland  0.12976    0.06278   2.067    0.042 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

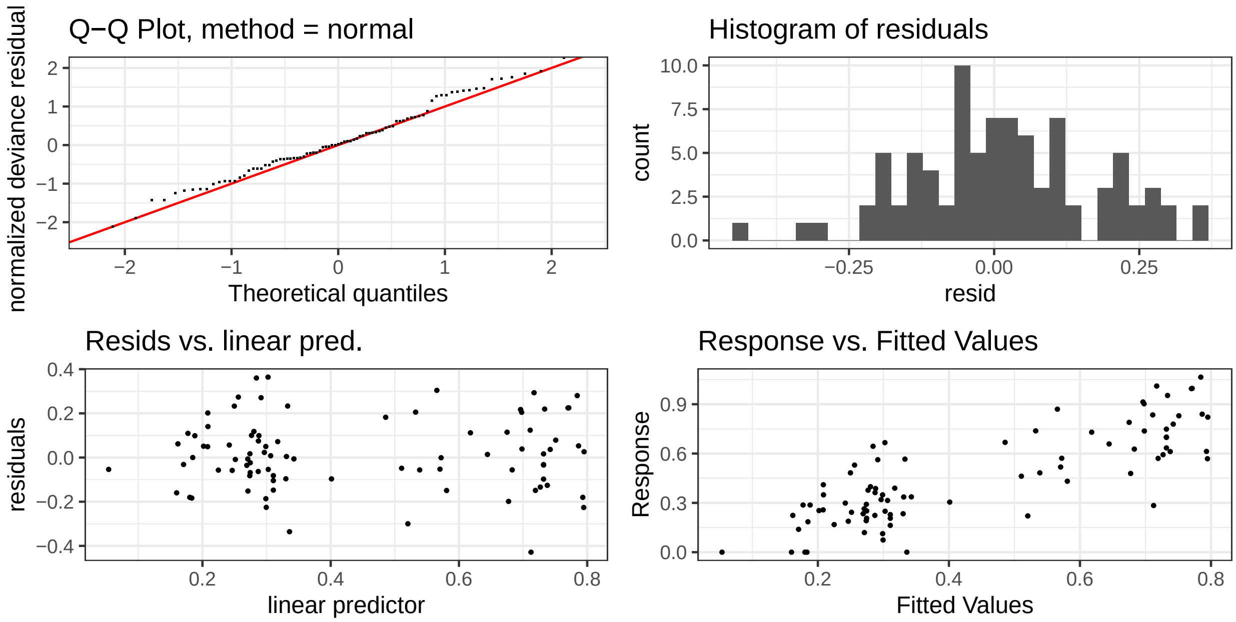
```
##
## Approximate significance of smooth terms:
##          edf Ref.df     F p-value
## s(lat) 5.653  5.653 31.41  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.652
## lmer.REML = -48.071  Scale est. = 0.024403  n = 87
```

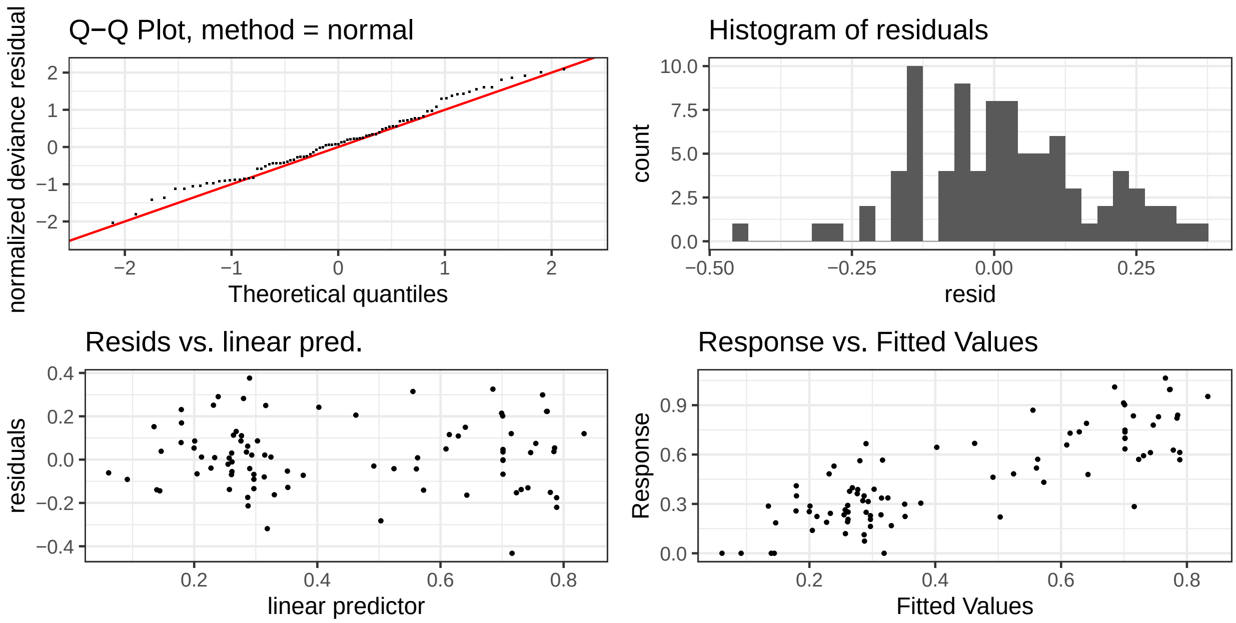
```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## Shan ~ s(lat) + insularity
##
## Parametric Terms:
##            df     F p-value
## insularity  1 4.271   0.042
##
## Approximate significance of smooth terms:
##          edf Ref.df     F p-value
## s(lat) 5.653  5.653 31.41  <2e-16
```

Evaluating the performance of variables in explaining the diversity of floral resources

```
## Model selection table
##             X  random df  logLik  AICc delta weight
## m1bSH$mer  +      X+e  5  23.828 -36.9  0.00  0.614
## m6bSH$mer  +      X+e  6  24.036 -35.0  1.90  0.238
## m5bSH$mer  + X+X.0+e  7  24.629 -33.8  3.08  0.132
## m11bSH$mer + X+X.0+e  8  23.752 -29.7  7.26  0.016
## m4bSH$mer  +        e 11  13.449  -1.4 35.54  0.000
## m7bSH$mer  +      X+e 13  15.448   0.1 37.01  0.000
## m13bSH$mer +      X+e 14  15.243   3.3 40.26  0.000
## m10bSH$mer +        e 12  12.198   3.8 40.74  0.000
## m12bSH$mer + X+X.0+e 15  14.711   7.3 44.25  0.000
## m9bSH$mer  +      X+e 13  11.246   8.5 45.41  0.000
## m15bSH$mer + X+X.0+e 16  13.750  12.3 49.19  0.000
## m14bSH$mer +      X+e 14   9.775  14.3 51.20  0.000
## m3bSH$mer  +        e  4 -14.503  37.5 74.41  0.000
## m2bSH$mer  +      X+e  5 -15.092  40.9 77.84  0.000
## m8bSH$mer  +      X+e  6 -15.576  44.2 81.12  0.000
## Models ranked by AICc(x)
## Random terms:
##  X  : 1 | Xr
##  e  : 1 | effort
##  X.0: 1 | Xr.0
```

Visual inspection of these models





All models seem to have a fair residual distribution

Assessing multicollinearity

Latitude with Sampling effort as random effect

```
##                     2.5 %     97.5 %
## (Intercept)  0.35579157  0.5253337
## s(lat).1    -1.03064066 -0.4197807
## s(lat).2    -0.34182457  0.7231775
## s(lat).3    -0.13606871  0.1278380
```

```
## s(lat).4    -0.49208103  0.3310474
## s(lat).5    -0.06710552  0.1802000
## s(lat).6    -0.46580309  0.2195573
## s(lat).7    -0.09660591  0.1832274
## s(lat).8    -0.45458854  1.6025297
## s(lat).9     0.07257241  0.8808313
```

```
##                  para       s(lat)
## worst    6.175505e-25 6.149835e-25
## observed 6.175505e-25 3.651900e-28
## estimate 6.175505e-25 1.260400e-27
```

Latitude + Insularity with Sampling effort as random effects

```
##                         2.5 %     97.5 %
## (Intercept)       0.315066125  0.5217136
## insularityIsland  0.006701704  0.2528099
## s(lat).1         -1.098826325 -0.4772788
## s(lat).2         -0.168070510  1.0045399
## s(lat).3         -0.110844081  0.1574963
## s(lat).4         -0.621960196  0.2480353
## s(lat).5         -0.088202917  0.1692715
## s(lat).6         -0.599209303  0.1396278
## s(lat).7         -0.073763236  0.2222101
## s(lat).8         -0.150947267  2.1014001
## s(lat).9          0.083278351  0.9011970
```

```
##               para     s(lat)
## worst    0.2246129 0.44766334
## observed 0.2246129 0.08317812
## estimate 0.2246129 0.04481488
```

Latitude + Altitude with Sampling effort as random effects

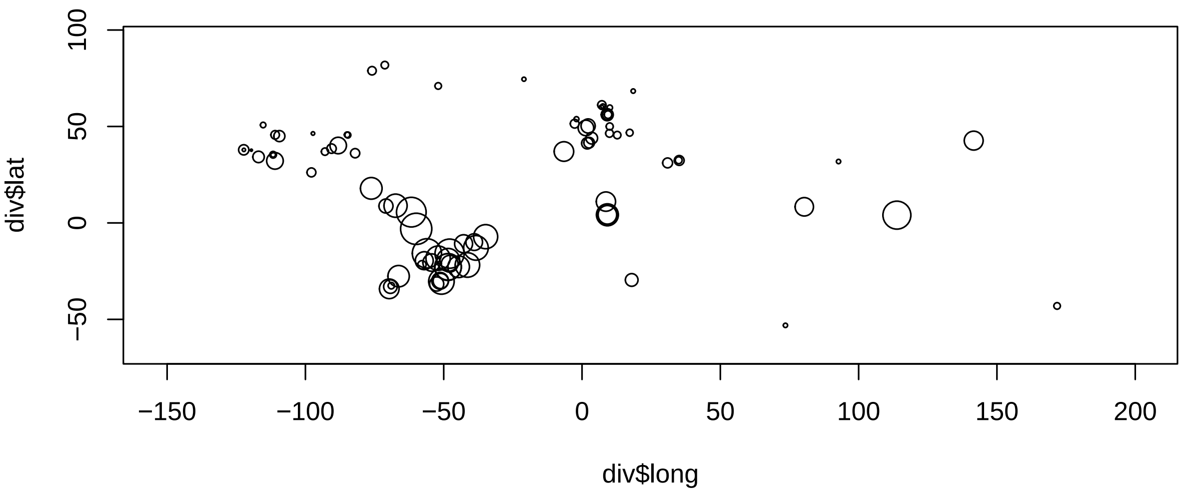
```
##                     2.5 %        97.5 %
## (Intercept)  3.569188e-01  5.242261e-01
## s(lat).1    -1.014403e+00 -4.322830e-01
## s(lat).2    -2.856329e-01  7.261789e-01
## s(lat).3    -1.132228e-01  1.393692e-01
## s(lat).4    -5.263276e-01  2.562569e-01
## s(lat).5    -6.668156e-02  1.669604e-01
## s(lat).6    -4.814597e-01  1.677863e-01
## s(lat).7    -7.908784e-02  1.847652e-01
## s(lat).8    -2.971607e-01  1.657360e+00
## s(lat).9     9.220229e-02  8.590583e-01
## s(alt).1    -5.787632e-07  5.787632e-07
## s(alt).2    -1.527278e-06  1.527278e-06
## s(alt).3    -2.945346e-07  2.945346e-07
## s(alt).4    -9.819326e-07  9.819326e-07
## s(alt).5    -1.735739e-07  1.735739e-07
## s(alt).6    -8.797243e-07  8.797243e-07
## s(alt).7    -7.165944e-07  7.165944e-07
```

```
## s(alt).8    -3.664788e-06  3.664788e-06
## s(alt).9    -8.229543e-02 -1.541494e-02
```

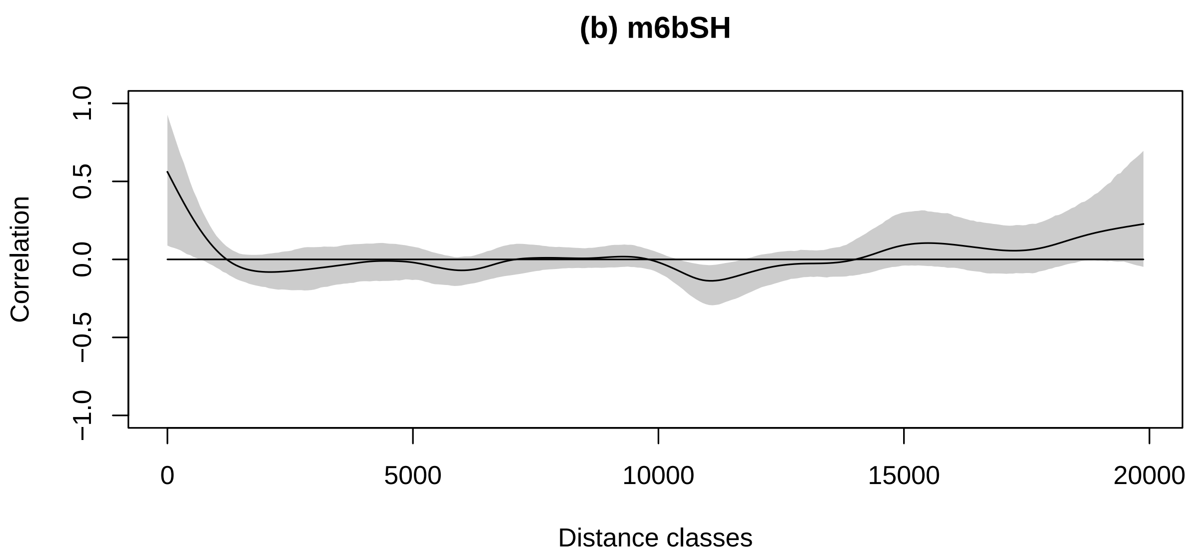
```
##                  para    s(lat)     s(alt)
## worst    8.050626e-25 0.2516938 0.25169378
## observed 8.050626e-25 0.1519827 0.09199860
## estimate 8.050626e-25 0.1276181 0.09878631
```

Confidence intervals seems reasonable. Also, estimate concurvity is lower than 0.8 which is acceptable.

Evaluating spatial autocorrelation

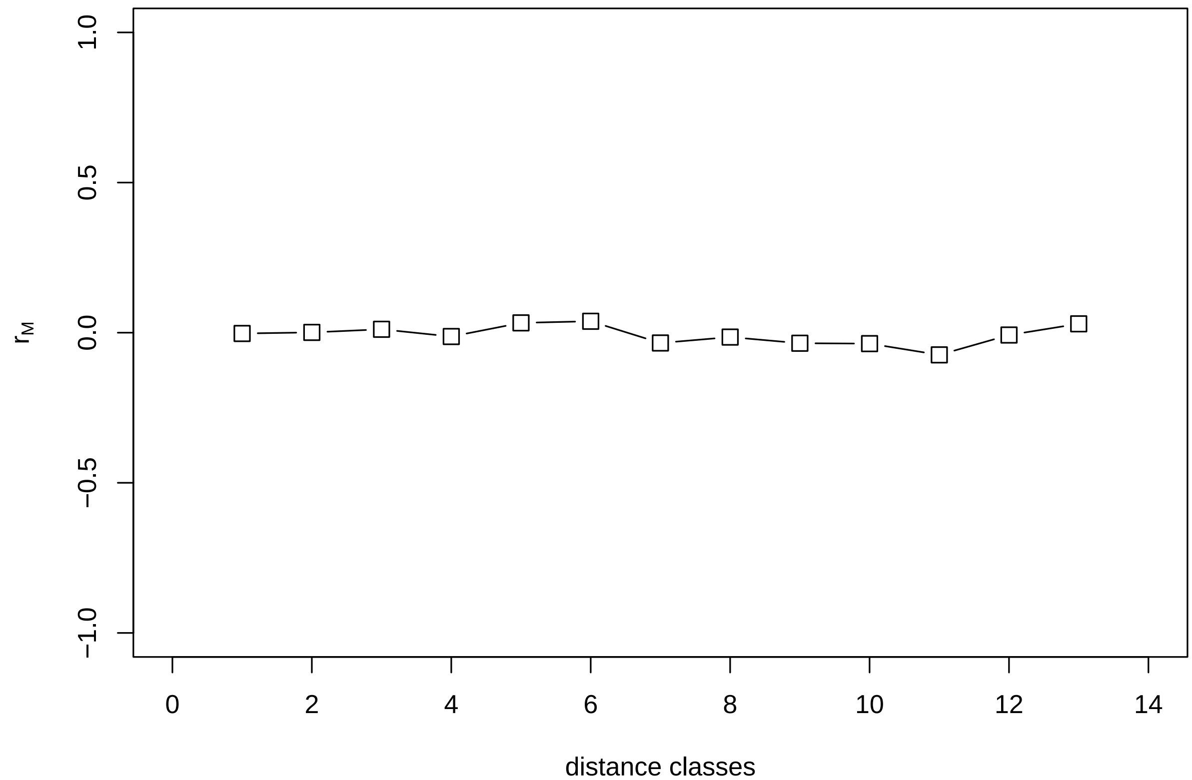



```
## 100  of  1000 200  of  1000 300  of  1000 400  of  1000 500  of  1000 600  of  1000 700  of  1000 800

## 100  of  1000 200  of  1000 300  of  1000 400  of  1000 500  of  1000 600  of  1000 700  of  1000 800
```



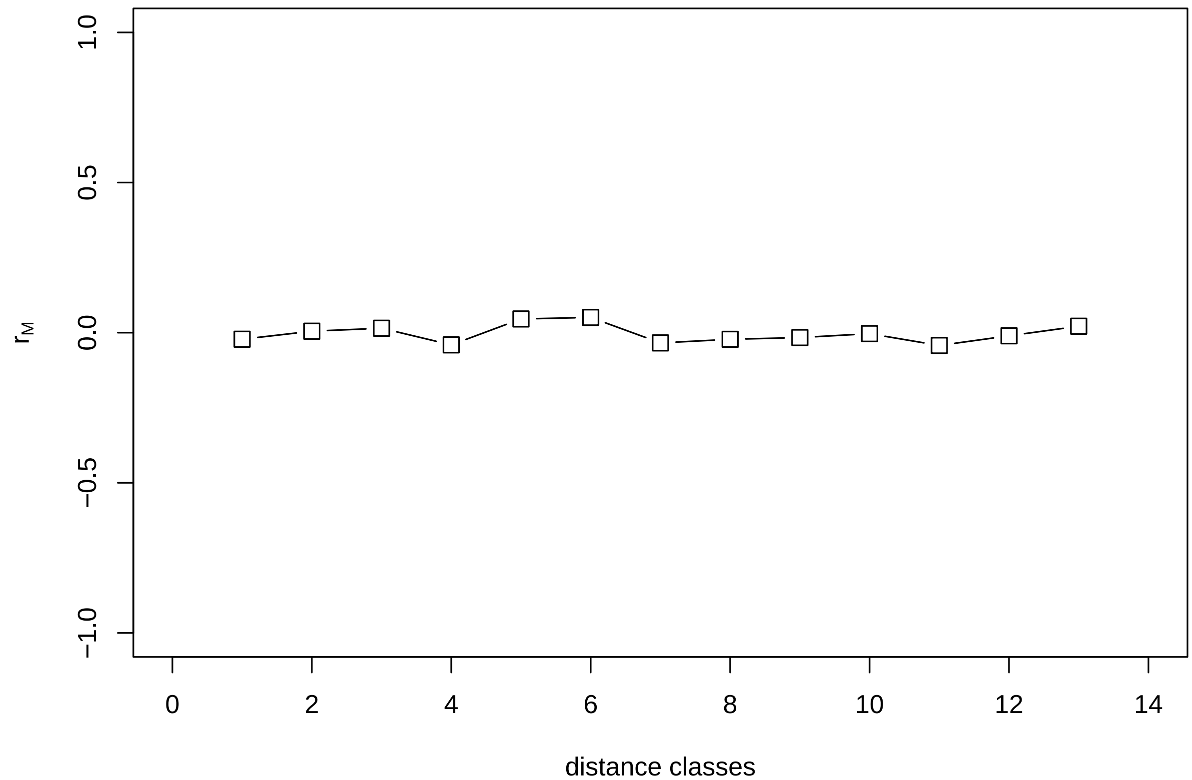
Mantel partial correlogram

```
## evaluating distance class 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13,
```




```
##    class    distance.range            rM          p p.Bonferroni
## 1      1       0  -  23.46 -0.0026786820 0.46995300    0.4699530
## 2      2   23.46  -  46.92  0.0009047313 0.51274873    1.0254975
## 3      3   46.92  -  70.38  0.0112994357 0.37416258    1.1224878
## 4      4   70.38  -  93.84 -0.0127918814 0.30936906    1.2374763
## 5      5   93.84  -  117.3  0.0326666226 0.10688931    0.5344466
## 6      6  117.3  -  140.76  0.0380345530 0.12618738    0.7571243
## 7      7 140.76  -  164.22 -0.0343149205 0.12488751    0.8742126
## 8      8 164.22  -  187.68 -0.0146163594 0.27787221    2.2229777
## 9      9 187.68  -  211.14 -0.0350992846 0.12568743    1.1311869
## 10    10  211.14  -  234.6 -0.0364344482 0.13008699    1.3008699
## 11    11  234.6  -  258.06 -0.0739144537 0.01219878    0.1341866
## 12    12 258.06  -  281.52 -0.0078229280 0.31136886    3.7364264
## 13    13 281.52  -  305.98  0.0295085333 0.10748925    1.3973603
```

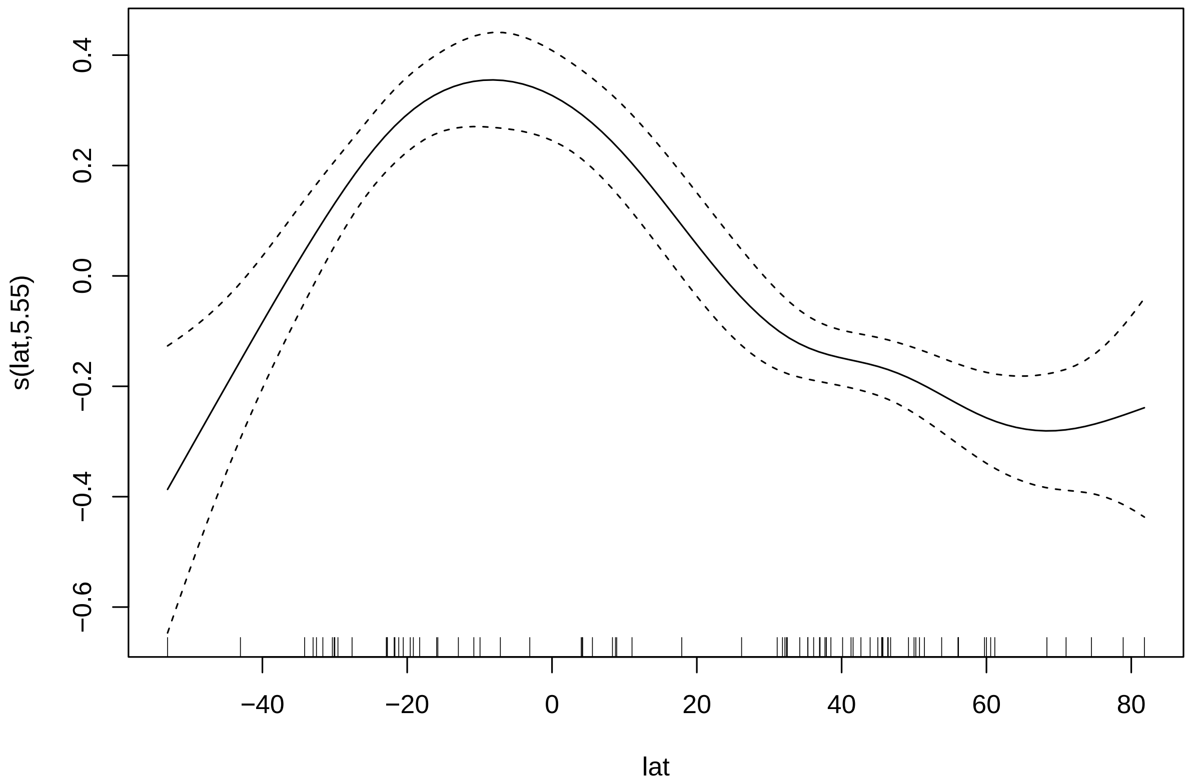
```
## evaluating distance class 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13,
```




```
##    class    distance.range           rM          p p.Bonferroni
## 1      1       0  -  23.46 -0.021818623 0.21517848    0.2151785
## 2      2   23.46  -  46.92  0.004956677 0.45175482    0.9035096
## 3      3   46.92  -  70.38  0.014861895 0.33136686    0.9941006
## 4      4   70.38  -  93.84 -0.040636849 0.04679532    0.1871813
## 5      5   93.84  -  117.3  0.045692942 0.03839616    0.1919808
## 6      6  117.3  -  140.76  0.050802009 0.05269473    0.3161684
## 7      7 140.76  -  164.22 -0.034078067 0.13068693    0.9148085
## 8      8 164.22  -  187.68 -0.022072872 0.21177882    1.6942306
## 9      9 187.68  -  211.14 -0.016301819 0.26597340    2.3937606
## 10    10  211.14  -  234.6 -0.003284652 0.38756124    3.8756124
## 11    11  234.6  -  258.06 -0.042531137 0.07409259    0.8150185
## 12    12 258.06  -  281.52 -0.010409217 0.28007199    3.3608639
## 13    13 281.52  -  305.98  0.021520818 0.23957604    3.1144886
```

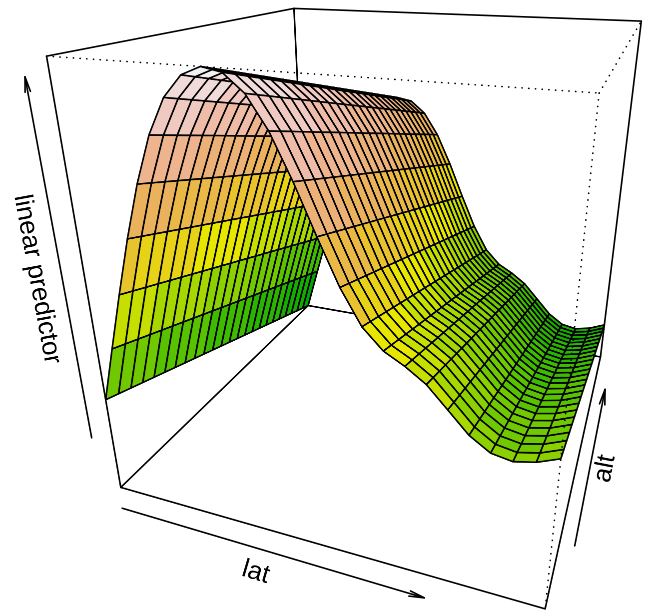
Conclusion: correlograms show no spatial autocorrelation Since model are similar to each other. Let's visualize it.

Let's plot it

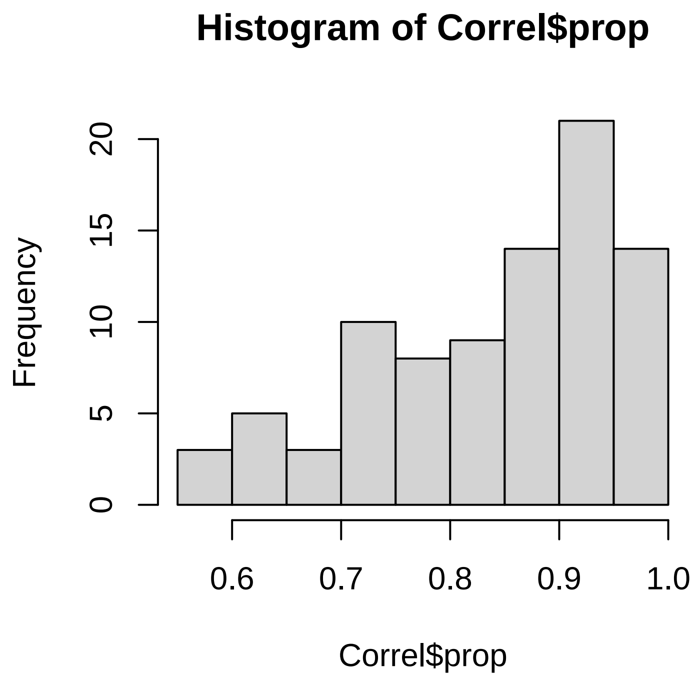


It behaves extremely contrary to the analysis of the proportion of nectar-producing plants!!

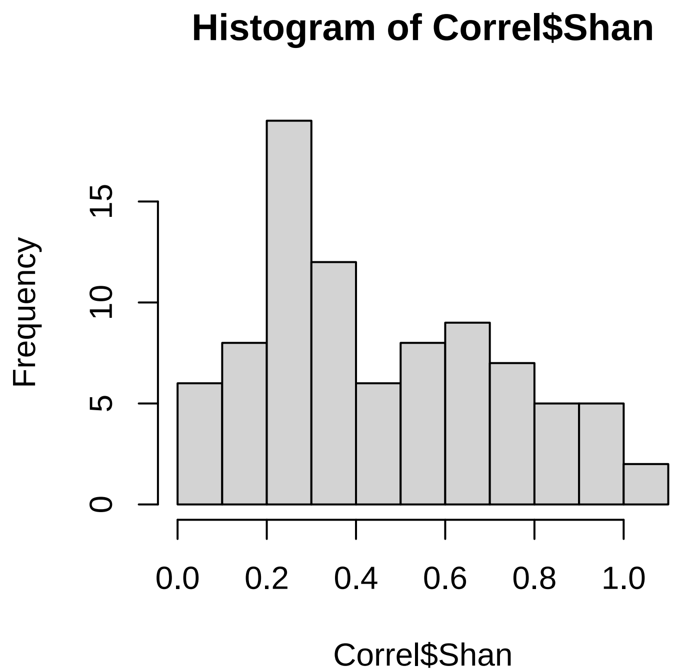
To visually evaluate let's plot the model also including the altitude as predictor variable



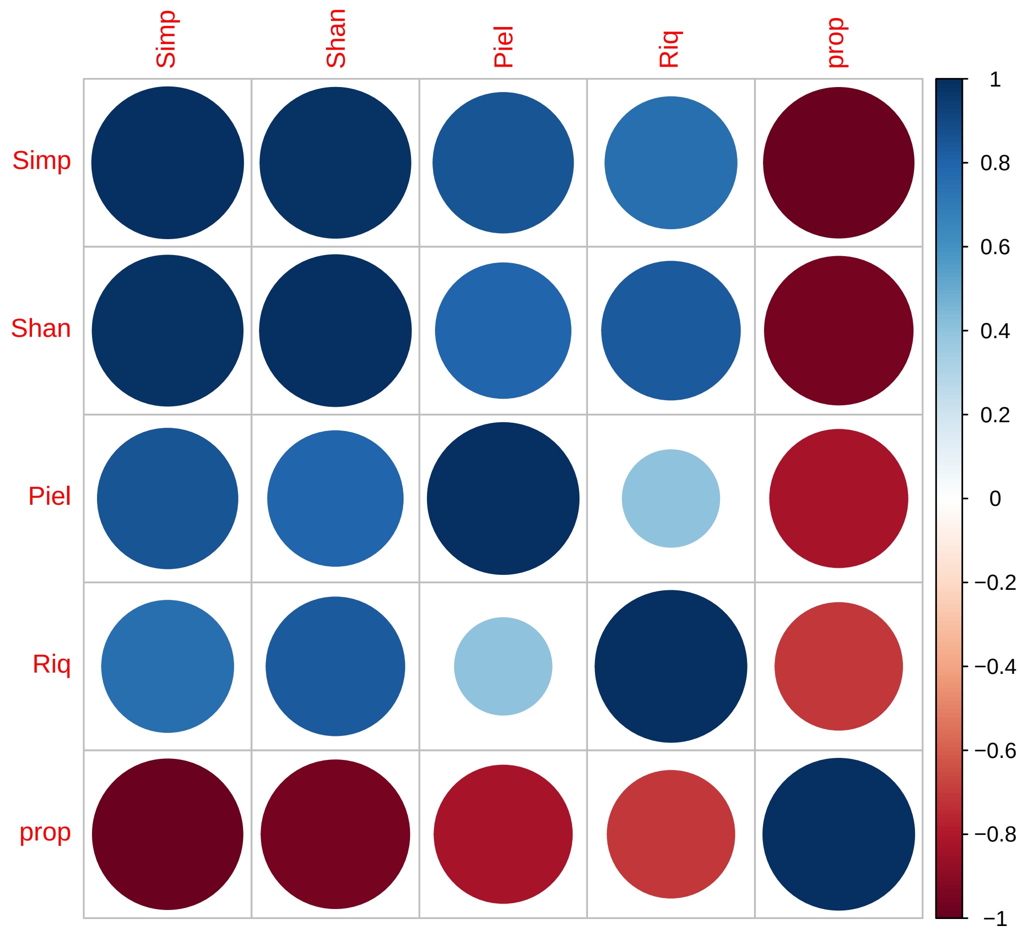
It seems that Shannon diversity of floral resources exhibit the opposite trend to that observed by the proportion of nectar producing plants. Let's evaluate if they are negative correlated.




```
##
##  Shapiro-Wilk normality test
##
## data:  Correl$prop
## W = 0.92762, p-value = 0.0001162
```



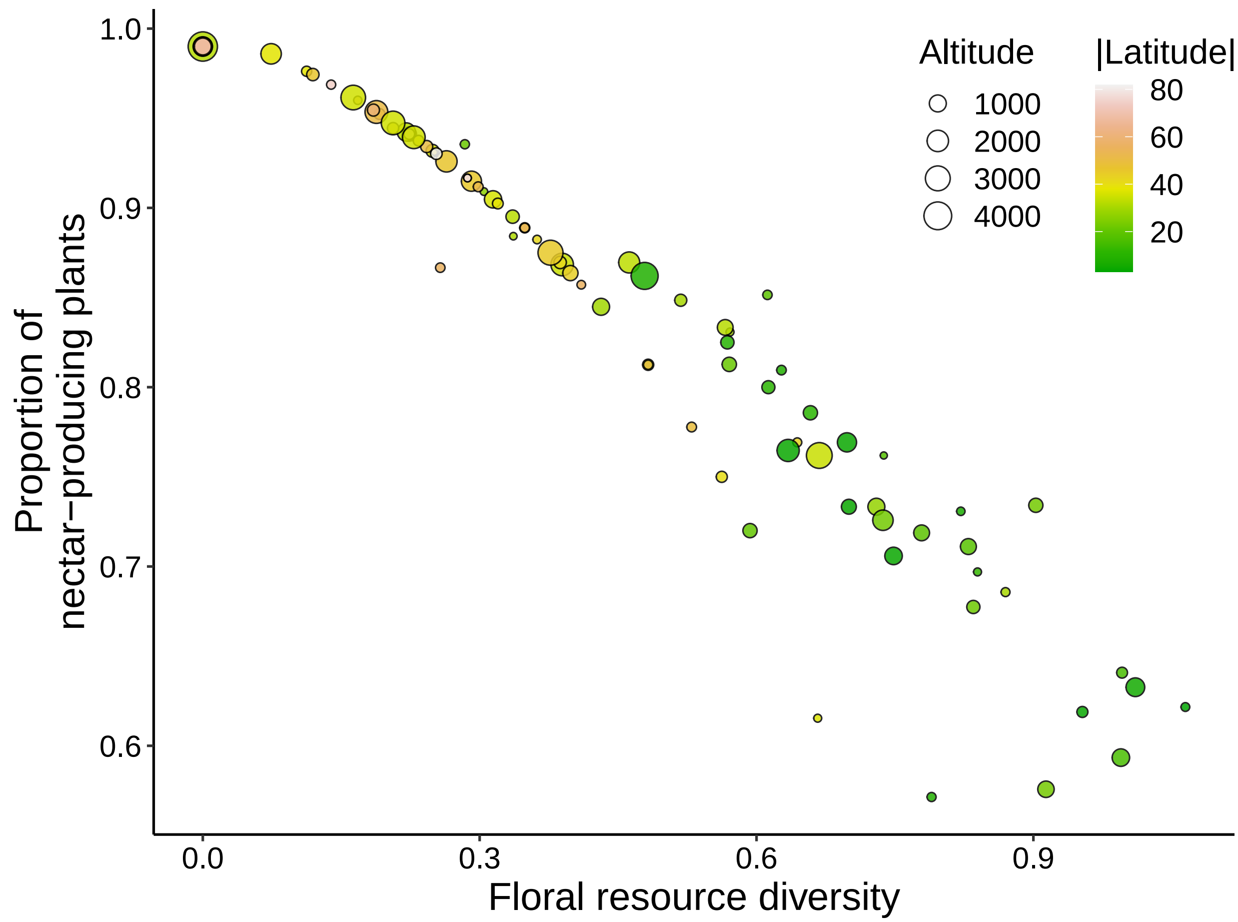

```
##
##  Shapiro-Wilk normality test
##
## data:  Correl$Shan
## W = 0.9599, p-value = 0.008637
```



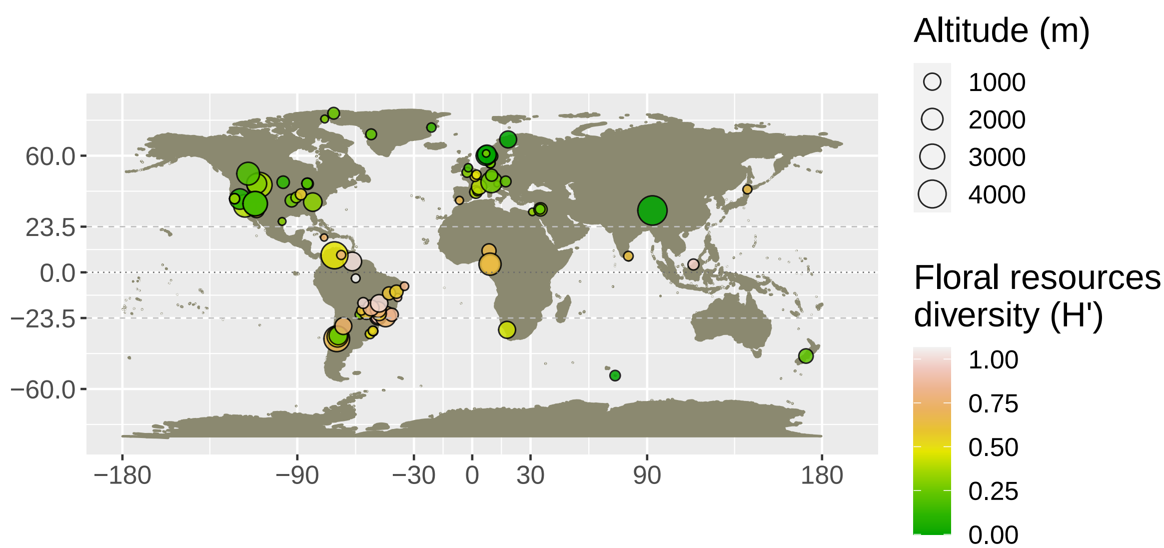
Well, it is ultra high negative correlated. Let's see the `rho` index through a Spearman correlation test.

```
##
##  Spearman's rank correlation rho
##
## data:  Correl$prop and Correl$Shan
## S = 217464, p-value < 2.2e-16
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##        rho
## -0.9817015
```

Lets visualize this.



Results in the global map



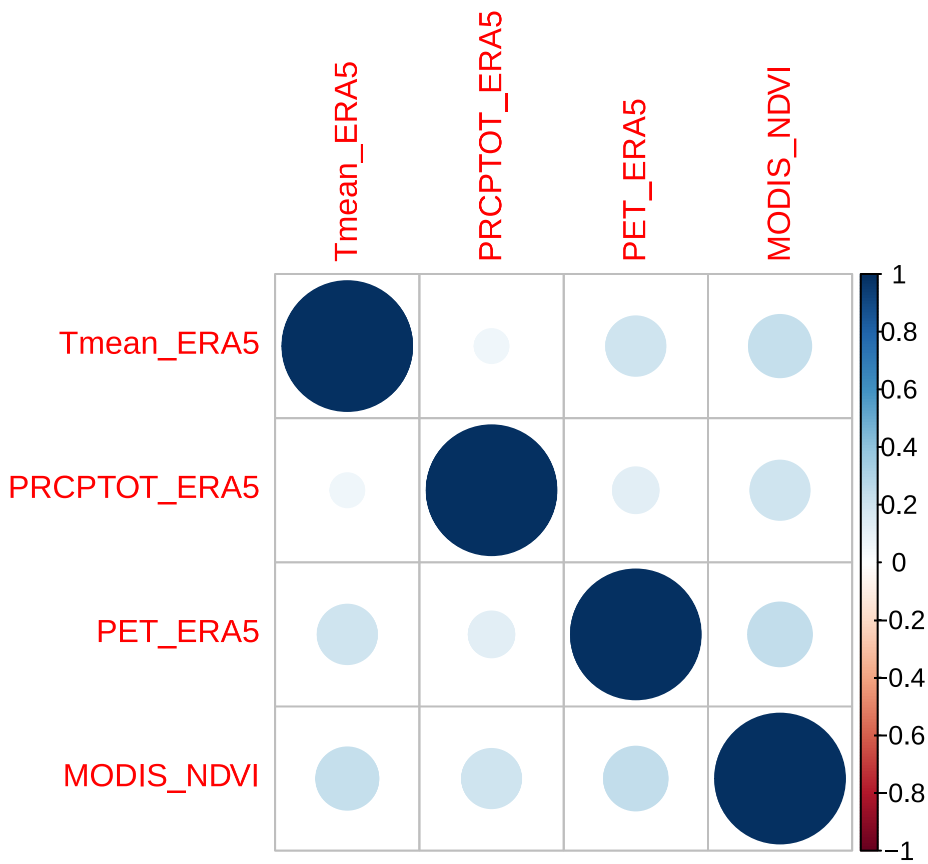
As biogeographical trends (e.g. diversity and distribution patterns following latitudinal gradients) may reflect Earth's climatic patterns, we also evaluated whether the proportion of nectar producing-plants in communities worldwide as well as their Shannon diversity of floral resources are influnced by climatic variables.

3. Relationship among the Proportion of nectar-producing plants in communities worldwide and environmental variables

Correlation among response variables

First we will check if there is correlation between the numeric independent variables

They are: Mean annual temperature (MAT), Annual precipitation (AP), Evapotranspiration (ET), and vegetation coverage (vegetation index - VI)



As can be seen here, there are low levels of positive correlation between these variables.

Models

Now, we will check if some environmental variables are related with the proportion of nectar-producing plants in natural plant communities.

We used the same analytical procedure that was used for the 2 abovementioned steps. However, we now are using different response variables:

Mean annual temperature (MAT), Annual precipitation (AP), Evapotranspiration (ET), and vegetation coverage (vegetation index - VI), Plant richness, Biome (according to Whittaker, 1962) and Sampling effort

GAMM models

We will use Generalized Aditive Mixed Models (GAMM) with the function `gamm4`.

As mentioned above, we made 105 candidates models by combining the fixed factor, namely, MAT, AP, ET and VI and also combining the random effects, namely, Plant richness, Biome and Sampling effort

We used the transformed version of our response variable (proportion of nectar-producing plants) to conform to a normal distribution

Multi-model inference

We ran seven possible models for 15 model structures, giving a total of 105 candidate models (not shown in the output).

Then, we ranked those models using the corrected Akaike Information Criterion `AICc` to determine the best model(s):

```
##            df     AICc
## em1f$mer   6 437.0420
## em1g$mer   7 438.4252
## em1c$mer   5 439.0170
## em1e$mer   6 440.1394
## em5f$mer   8 441.6913
## em5g$mer   9 442.8449
## em5c$mer   7 444.2890
## em5e$mer   8 445.1224
## em1b$mer   5 447.3886
## em5b$mer   7 447.8172
## em5d$mer   8 448.2044
## em1d$mer   6 448.3712
## em1a$mer   5 451.4523
## em5a$mer   7 451.9630
## em7f$mer   7 453.9054
## em7g$mer   8 455.2266
## em7c$mer   6 455.5473
## em7e$mer   7 456.5535
## em6f$mer   7 457.1475
## em12f$mer  9 458.1934
## em6g$mer   8 458.4242
## em12g$mer 10 459.2664
## em6c$mer   6 459.4902
## em12c$mer  8 460.4115
## em6e$mer   7 460.4884
## em11f$mer  9 461.0814
## em12e$mer  9 461.0940
## em11g$mer 10 461.8890
## em12b$mer  8 463.3750
## em11d$mer  9 463.6309
## em12d$mer  9 463.8095
```

```
## em11b$mer  8 463.8170
## em7b$mer   6 464.1259
## em11c$mer  8 464.3952
## em11e$mer  9 464.8749
## em6b$mer   6 464.9877
## em7d$mer   7 464.9966
## em6d$mer   7 465.4576
## em12a$mer  8 466.5764
## em2g$mer   7 467.1617
## em7a$mer   6 467.9299
## em11a$mer  8 468.0413
## em2f$mer   6 468.1280
## em6a$mer   6 469.1814
## em2e$mer   6 472.8444
## em13f$mer  8 474.1788
## em2c$mer   5 474.4271
## em13g$mer  9 475.4088
## em13c$mer  7 476.1545
## em4g$mer   6 476.6128
## em13e$mer  8 477.0567
## em15f$mer 10 477.8342
## em15g$mer 11 478.5764
## em4f$mer   5 478.6355
## em15d$mer 10 479.6679
## em15b$mer  9 479.8469
## em15c$mer  9 480.5105
## em3g$mer   6 480.5839
## em15e$mer 10 480.9754
## em13b$mer  7 482.0433
## em4e$mer   5 482.2200
## em13d$mer  8 482.4431
## em3f$mer   5 482.5906
## em15a$mer  9 482.9144
## em9g$mer   8 483.7927
## em9f$mer   7 484.9085
## em4c$mer   4 484.9815
## em13a$mer  7 485.6845
## em3e$mer   5 486.5084
## em8g$mer   8 487.7331
## em8f$mer   7 488.6720
## em3c$mer   4 489.0040
## em9e$mer   7 489.1006
## em9c$mer   6 490.8173
## em8e$mer   7 493.3824
## em8c$mer   6 494.6869
## em10g$mer  7 497.2944
## em10f$mer  6 499.2144
## em2d$mer   6 501.9383
## em2b$mer   5 502.4877
## em10e$mer  6 502.7409
## em14g$mer  9 504.4083
## em10c$mer  5 505.1330
## em2a$mer   5 505.2430
## em14f$mer  8 505.4725
```

```
## em14e$mer  8 509.6247
## em14c$mer  7 511.0638
## em4d$mer   5 517.7325
## em4b$mer   4 518.2595
## em9d$mer   7 518.9113
## em9b$mer   6 519.3519
## em4a$mer   4 520.2646
## em3d$mer   5 521.2179
## em8d$mer   7 521.8360
## em3b$mer   4 522.0500
## em9a$mer   6 522.1298
## em8b$mer   6 522.5203
## em3a$mer   4 523.8392
## em8a$mer   6 525.4378
## em10d$mer  6 537.8930
## em10b$mer  5 538.5287
## em14d$mer  8 538.7908
## em14b$mer  7 539.3727
## em10a$mer  5 540.5662
## em14a$mer  7 542.3269
```

It can be seen that models with MAT received the lowest AIC scores.

Model **m1f**, **m1g** and **m1c** are within the ΔAIC < 2 subset, we must examine them.

MAT with Sampling effort, and Biome as random effects

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## propC ~ s(Tmean_ERA5)
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   2.3152     0.2514    9.21 2.38e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##                 edf Ref.df    F p-value
## s(Tmean_ERA5) 6.277  6.277 8.48  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.369
## lmer.REML = 424.49  Scale est. = 0.67259   n = 160
```

```
##
## Family: gaussian
## Link function: identity
##
```

```
## Formula:
## propC ~ s(Tmean_ERA5)
##
## Approximate significance of smooth terms:
##                 edf Ref.df    F p-value
## s(Tmean_ERA5) 6.277  6.277 8.48  <2e-16
```

MAT with Sampling effort, Plant richness and Biome as random effects

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## propC ~ s(Tmean_ERA5)
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   2.3158     0.2492   9.295   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##                 edf Ref.df     F  p-value
## s(Tmean_ERA5) 6.045  6.045 8.249 1.73e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.366
## lmer.REML = 423.69  Scale est. = 0.62567   n = 160
```

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## propC ~ s(Tmean_ERA5)
##
## Approximate significance of smooth terms:
##                 edf Ref.df     F  p-value
## s(Tmean_ERA5) 6.045  6.045 8.249 1.73e-07
```

MAT with Biome as random effects

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## propC ~ s(Tmean_ERA5)
##
## Parametric coefficients:
```

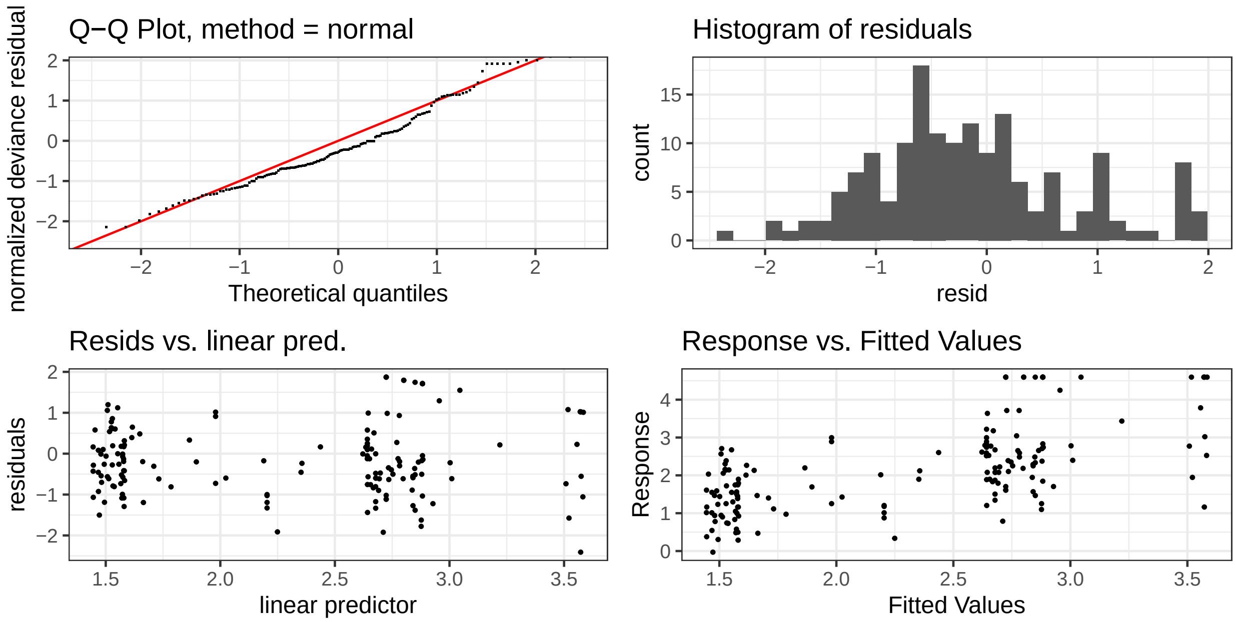
```
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   2.2277     0.1665   13.38   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##                 edf Ref.df     F p-value
## s(Tmean_ERA5) 6.51   6.51 9.673  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.377
## lmer.REML = 428.63  Scale est. = 0.69324   n = 160
```

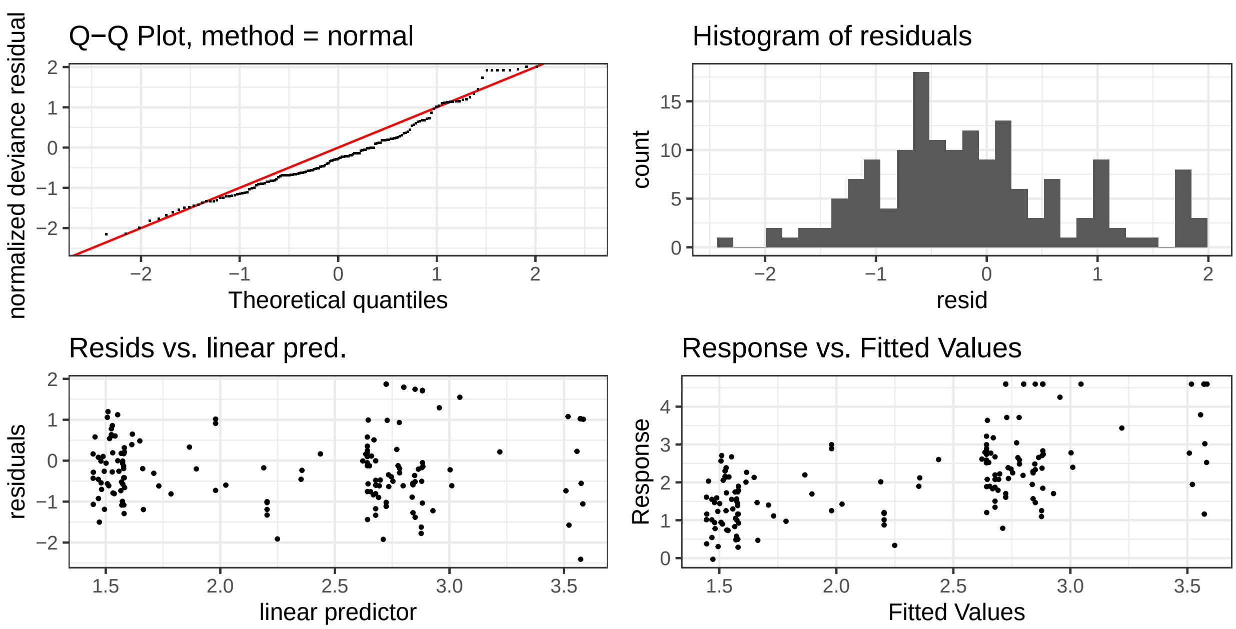
```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## propC ~ s(Tmean_ERA5)
##
## Approximate significance of smooth terms:
##                 edf Ref.df     F p-value
## s(Tmean_ERA5) 6.51   6.51 9.673  <2e-16
```

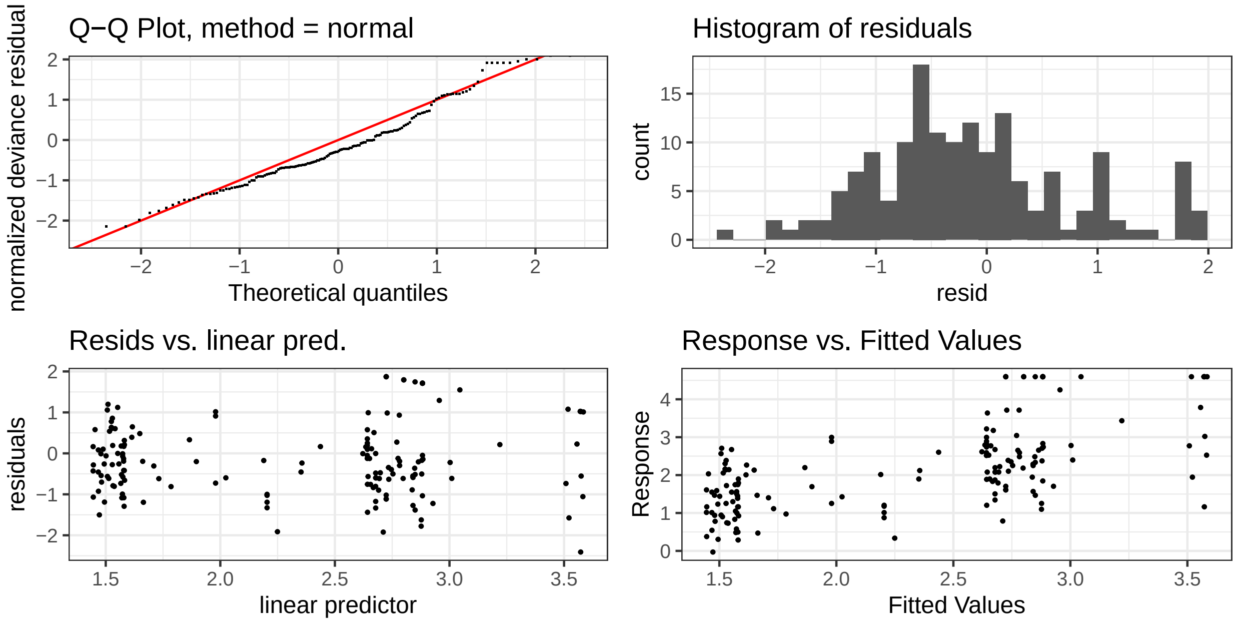
Evaluating the performance of variables in explaining the diversity of floral resources

```
## Model selection table
##            X    random df   logLik  AICc delta weight
## em1f$mer  +     X+e+b  6 -212.246 437.0  0.00  0.911
## em5f$mer  + X+X.0+e+b  8 -212.369 441.7  4.65  0.089
## em7f$mer  +     X+e+b  7 -219.584 453.9 16.86  0.000
## em6f$mer  +     X+e+b  7 -221.205 457.1 20.11  0.000
## em12f$mer + X+X.0+e+b  9 -219.497 458.2 21.15  0.000
## em11f$mer + X+X.0+e+b  9 -220.941 461.1 24.04  0.000
## em2f$mer  +     X+e+b  6 -227.790 468.1 31.09  0.000
## em13f$mer +     X+e+b  8 -228.613 474.2 37.14  0.000
## em15f$mer + X+X.0+e+b 10 -228.179 477.8 40.79  0.000
## em4f$mer  +       e+b  5 -234.123 478.6 41.59  0.000
## em3f$mer  +       e+b  5 -236.100 482.6 45.55  0.000
## em9f$mer  +     X+e+b  7 -235.086 484.9 47.87  0.000
## em8f$mer  +     X+e+b  7 -236.968 488.7 51.63  0.000
## em10f$mer +       e+b  6 -243.333 499.2 62.17  0.000
## em14f$mer +     X+e+b  8 -244.259 505.5 68.43  0.000
## Models ranked by AICc(x)
## Random terms:
##  X  : 1 | Xr
##  e  : 1 | effort
##  b  : 1 | biome
##  X.0: 1 | Xr.0
```

Visual inspection of the model







All models seem to have a fair residual distribution

Assessing multicollinearity

MAT with Sampling effort and Biome as random effect

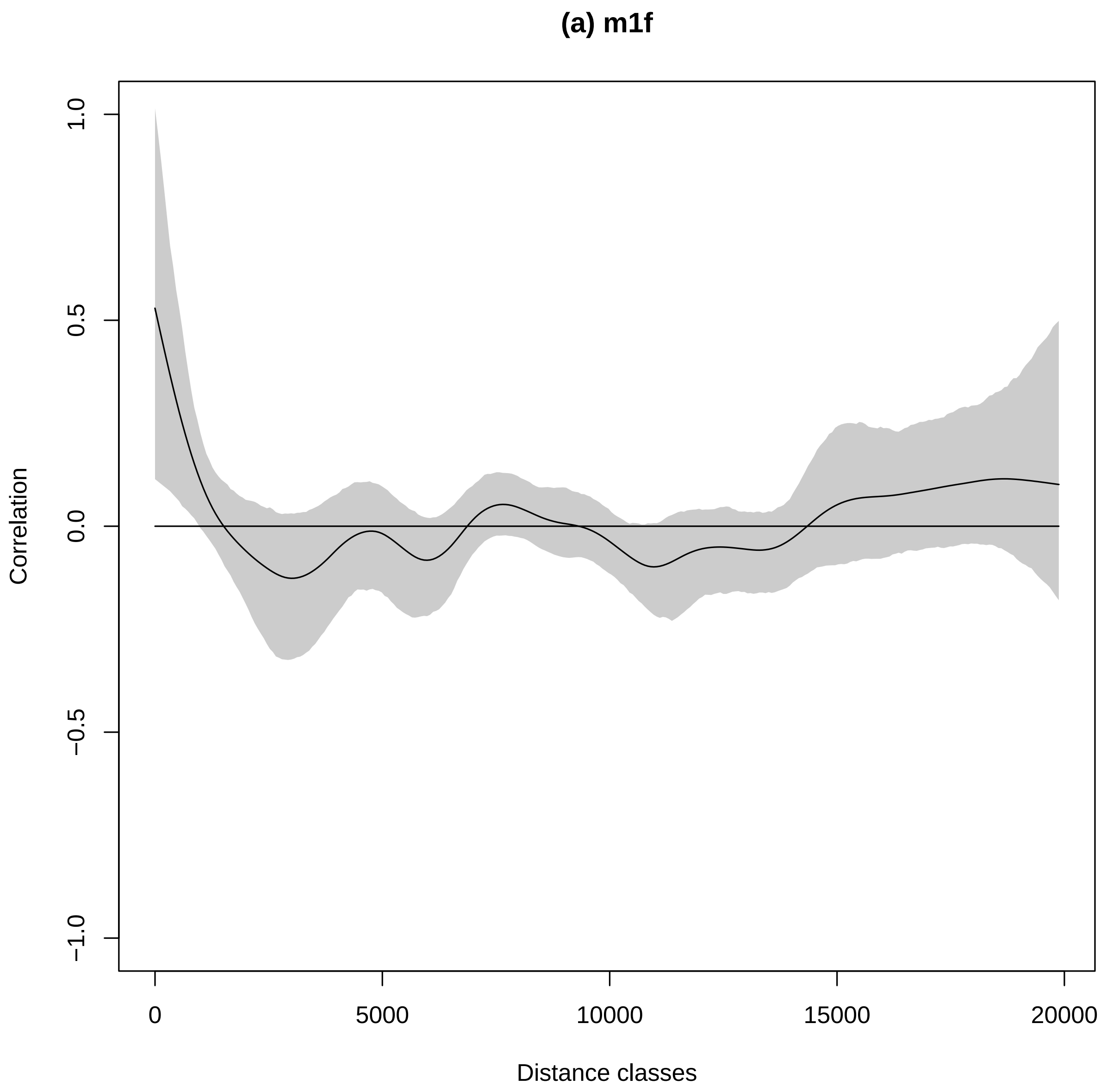
```
##                           2.5 %       97.5 %
## (Intercept)          1.803147e+00 2.791732e+00
## s(Tmean_ERA5).1     -1.507982e+00 8.865681e-02
## s(Tmean_ERA5).2     -2.260908e+00 2.061780e+00
## s(Tmean_ERA5).3      2.304880e-01 1.127842e+00
## s(Tmean_ERA5).4     -1.927591e+00 1.057736e+00
## s(Tmean_ERA5).5     -1.641002e+00 8.039769e-01
## s(Tmean_ERA5).6     -1.795499e+00 1.042477e+00
## s(Tmean_ERA5).7     -4.358097e-01 2.358523e-01
## s(Tmean_ERA5).8     -4.261162e+00 7.026057e+00
## s(Tmean_ERA5).9     -1.211872e+00 1.940269e+00
## s(PRCPTOT_ERA5).1 -8.436703e-06 8.436575e-06
## s(PRCPTOT_ERA5).2 -1.135586e-05 1.135595e-05
## s(PRCPTOT_ERA5).3 -2.529759e-06 2.529765e-06
## s(PRCPTOT_ERA5).4 -7.711258e-06 7.711227e-06
## s(PRCPTOT_ERA5).5 -1.919927e-06 1.919928e-06
## s(PRCPTOT_ERA5).6 -6.863126e-06 6.863100e-06
## s(PRCPTOT_ERA5).7 -1.839896e-06 1.839902e-06
## s(PRCPTOT_ERA5).8 -3.327322e-05 3.327327e-05
## s(PRCPTOT_ERA5).9 -3.101237e-01 1.790697e-02
```

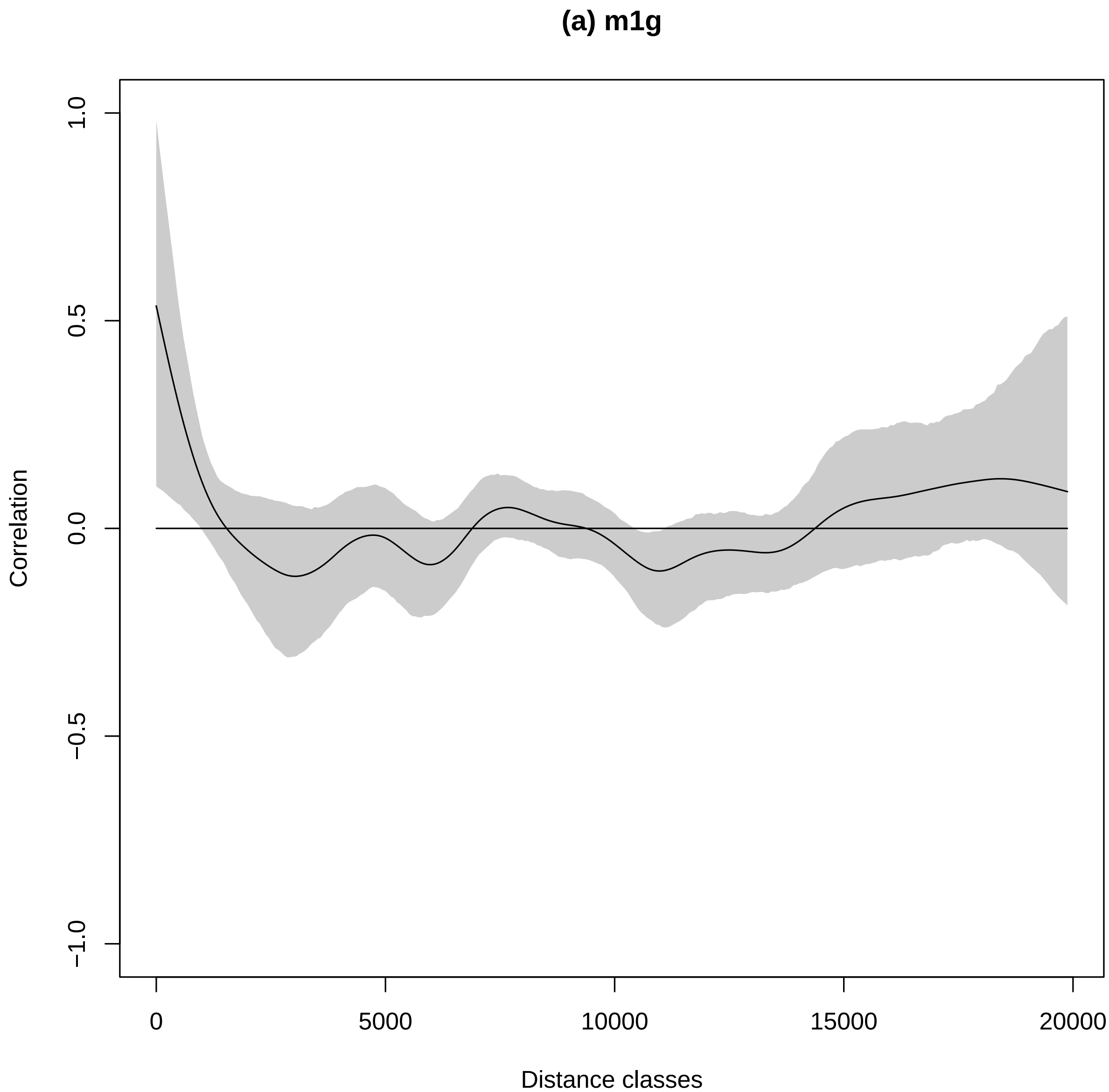
```
##                   para s(Tmean_ERA5) s(PRCPTOT_ERA5)
## worst    6.822315e-25     0.3621322       0.3621322
## observed 6.822315e-25     0.1696222       0.1664077
## estimate 6.822315e-25     0.1151200       0.1834979
```

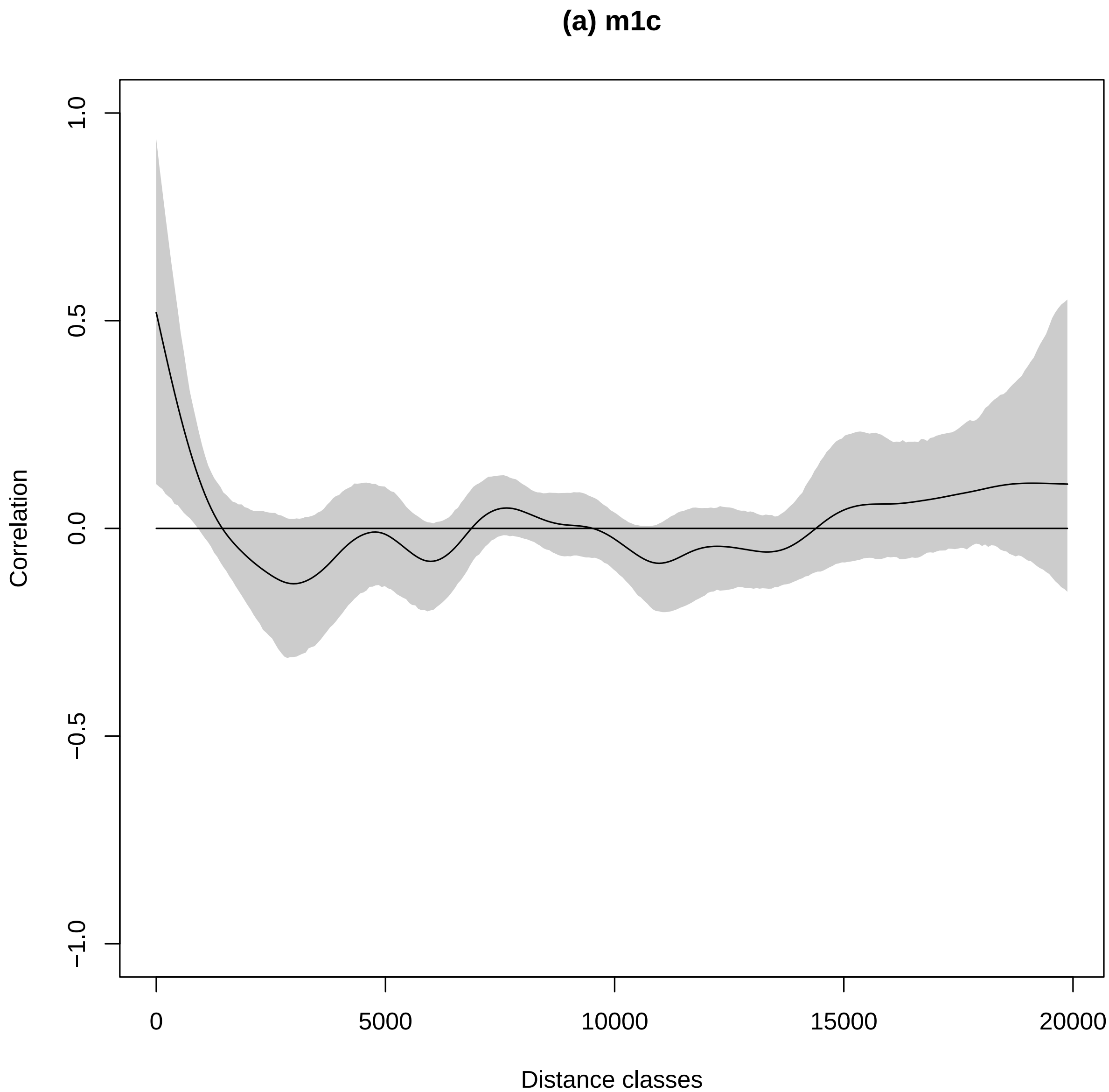
Confidence intervals seems reasonable. Also, estimate concurvity is lower than 0.8 which is acceptable.

Evaluating spatial autocorrelation

```
## 100  of  1000 200  of  1000 300  of  1000 400  of  1000 500  of  1000 600  of  1000 700  of  1000 800

## 100  of  1000 200  of  1000 300  of  1000 400  of  1000 500  of  1000 600  of  1000 700  of  1000 800

## 100  of  1000 200  of  1000 300  of  1000 400  of  1000 500  of  1000 600  of  1000 700  of  1000 800
```

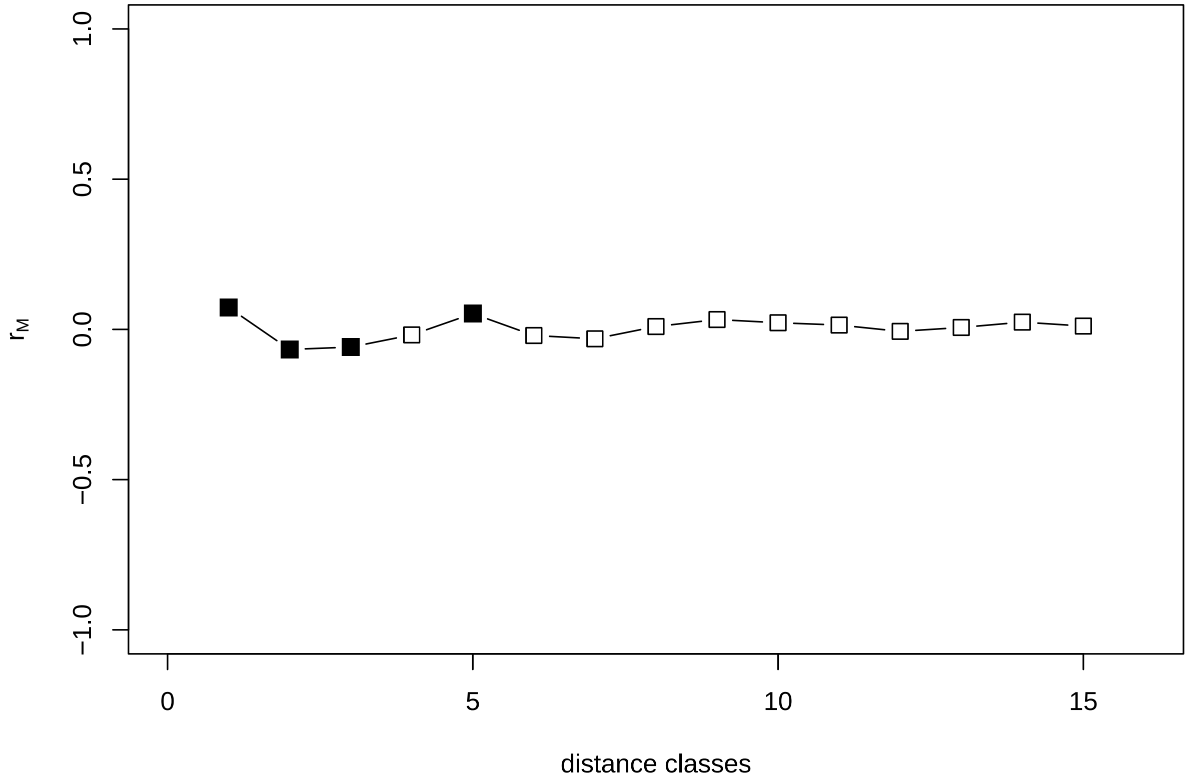



(a) m1g
Correlation
1.0
0.5
0.0
−0.5
−1.0
0
5000
10000
15000
20000
Distance classes



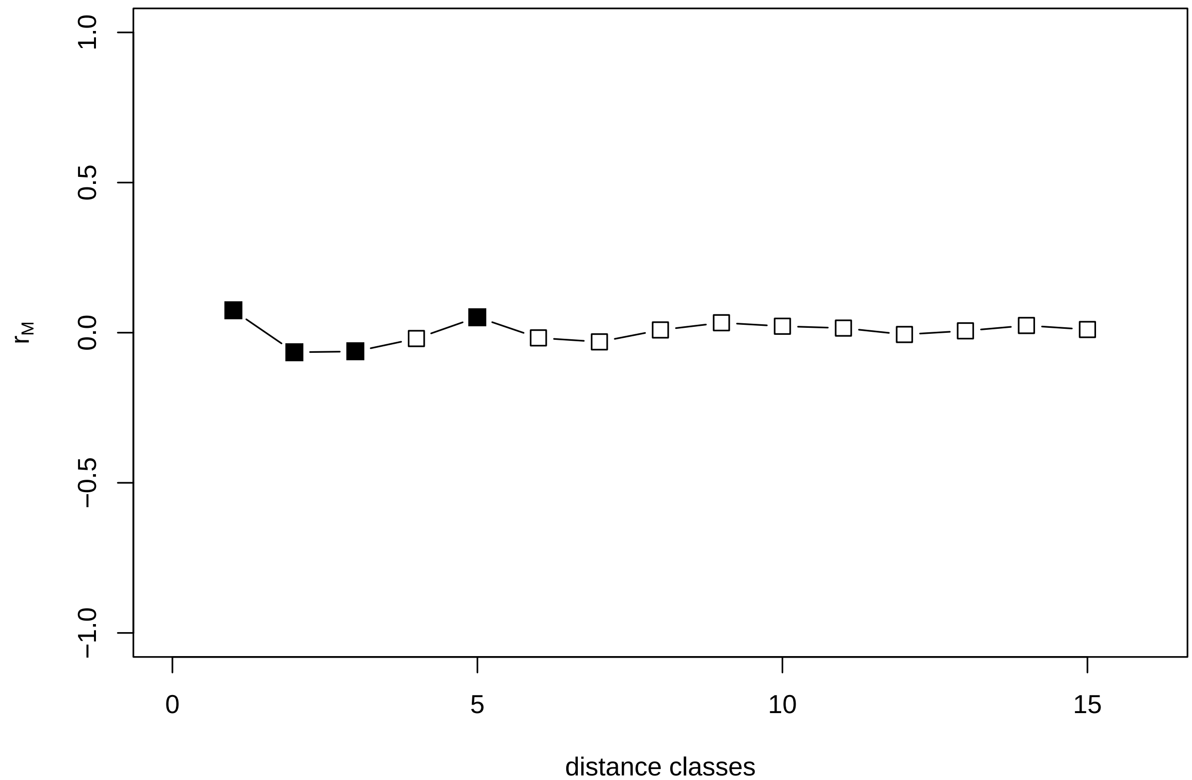
Mantel partial correlogram

```
## evaluating distance class 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15,
```



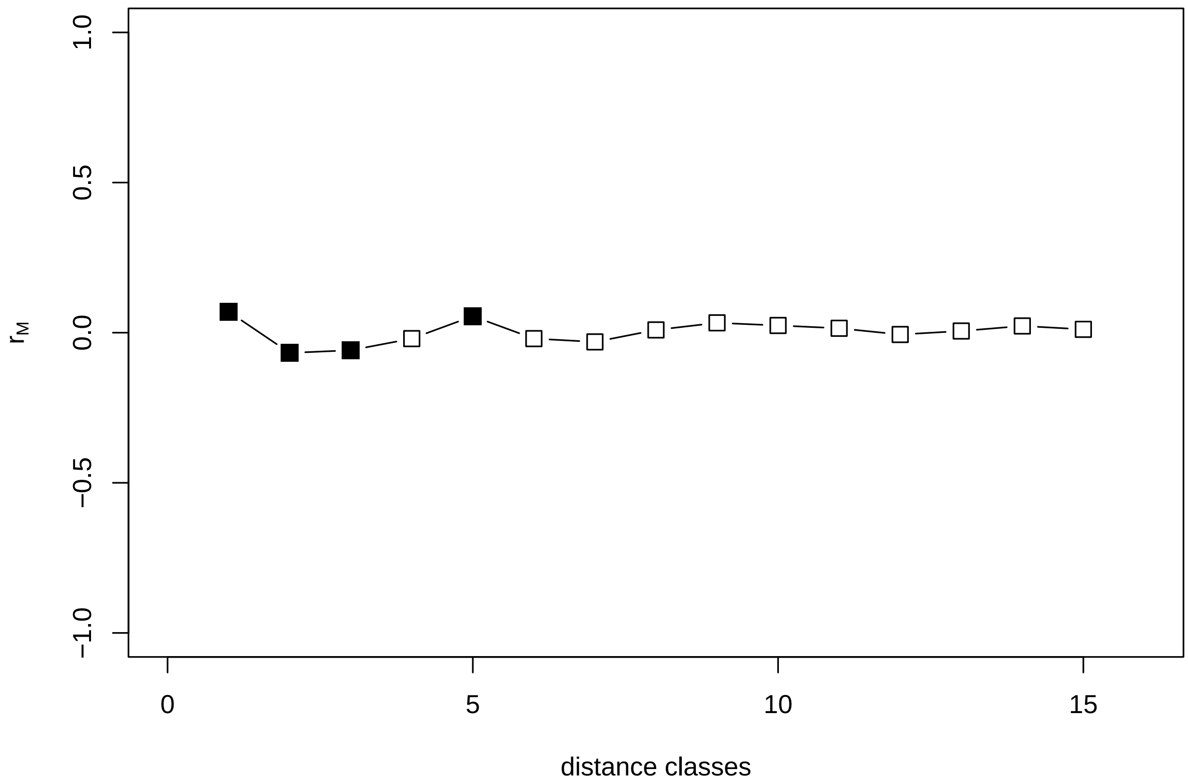

```
##    class      distance.range           rM          p p.Bonferroni
## 1      1        0  -  20.547  0.073069999 0.00009999   0.00009999
## 2      2   20.547  -  41.095 -0.066798747 0.00009999   0.00019998
## 3      3   41.095  -  61.642 -0.058840688 0.00179982   0.00539946
## 4      4    61.642  -  82.19 -0.018315460 0.15548445   0.62193781
## 5      5   82.19  -  102.737  0.052471144 0.00079992   0.00399960
## 6      6 102.737  -  123.285 -0.020308876 0.09209079   0.55254475
## 7      7 123.285  -  143.832 -0.031272277 0.02819718   0.19738026
## 8      8  143.832  -  164.38  0.009529153 0.26327367   2.10618938
## 9      9  164.38  -  184.927  0.032828681 0.01379862   0.12418758
## 10    10 184.927  -  205.475  0.022134131 0.09059094   0.90590941
## 11    11 205.475  -  226.022  0.014452663 0.20647935   2.27127287
## 12    12  226.022  -  246.57 -0.006601846 0.34626537   4.15518448
## 13    13  246.57  -  267.117  0.006443859 0.36056394   4.68733127
## 14    14 267.117  -  287.665  0.024190820 0.07499250   1.04989501
## 15    15 287.665  -  309.212  0.011070449 0.30196980   4.52954705
```

```
## evaluating distance class 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15,
```




```
##    class      distance.range           rM          p p.Bonferroni
## 1      1        0  -  20.547  0.073856347 0.00009999   0.00009999
## 2      2   20.547  -  41.095 -0.065125640 0.00009999   0.00019998
## 3      3   41.095  -  61.642 -0.062580303 0.00099990   0.00299970
## 4      4    61.642  -  82.19 -0.019445898 0.13218678   0.52874713
## 5      5   82.19  -  102.737  0.051671528 0.00159984   0.00799920
## 6      6 102.737  -  123.285 -0.017340892 0.12918708   0.77512249
## 7      7 123.285  -  143.832 -0.030591354 0.02789721   0.19528047
## 8      8  143.832  -  164.38  0.009069021 0.27567243   2.20537946
## 9      9  164.38  -  184.927  0.033128933 0.01429857   0.12868713
## 10    10 184.927  -  205.475  0.021461952 0.10148985   1.01489851
## 11    11 205.475  -  226.022  0.015277769 0.19118088   2.10298970
## 12    12  226.022  -  246.57 -0.006092465 0.35816418   4.29797020
## 13    13  246.57  -  267.117  0.006125673 0.37146285   4.82901710
## 14    14 267.117  -  287.665  0.023910072 0.08179182   1.14508549
## 15    15 287.665  -  309.212  0.010511129 0.30656934   4.59854015
```

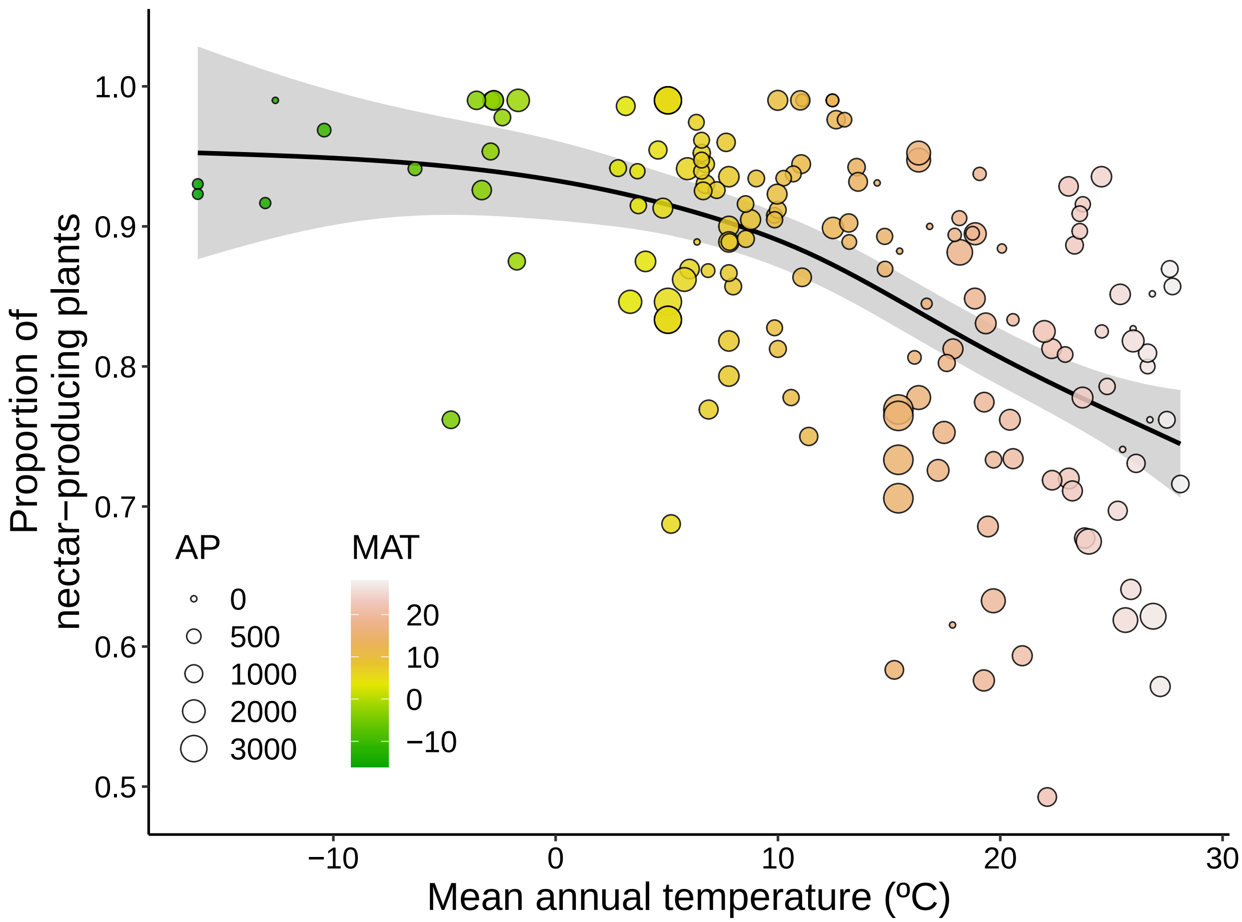
```
## evaluating distance class 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15,
```




```
##    class     distance.range           rM          p p.Bonferroni
## 1      1        0  -  20.547  0.070060753 0.00009999   0.00009999
## 2      2   20.547  -  41.095 -0.067366655 0.00009999   0.00019998
## 3      3   41.095  -  61.642 -0.058572266 0.00229977   0.00689931
## 4      4    61.642  -  82.19 -0.019797844 0.12578742   0.50314969
## 5      5   82.19  -  102.737  0.054947248 0.00129987   0.00649935
## 6      6 102.737  -  123.285 -0.019744646 0.10538946   0.63233677
## 7      7 123.285  -  143.832 -0.030741733 0.02969703   0.20787921
## 8      8  143.832  -  164.38  0.009128806 0.27437256   2.19498050
## 9      9  164.38  -  184.927  0.032836865 0.01399860   0.12598740
## 10    10 184.927  -  205.475  0.024037922 0.06939306   0.69393061
## 11    11 205.475  -  226.022  0.014693260 0.19538046   2.14918508
## 12    12  226.022  -  246.57 -0.006086996 0.35306469   4.23677632
## 13    13  246.57  -  267.117  0.005540799 0.38386161   4.99020098
## 14    14 267.117  -  287.665  0.022380262 0.09609039   1.34526547
## 15    15 287.665  -  309.212  0.011112941 0.29847015   4.47705229
```

Conclusion: correlograms show some spatial autocorrelation in the first distant classes, but not something big that affect our conclusions.

Let's plot it



4. Relationship among the Shannon diversity of floral resources in communities worldwide and environmental variables

We used the same analytical procedure that was used for the proportion of nectar-producing plants. This time, our response variable was Shannon diversity of floral resources *(H')*. To assess Shannon diversity of floral resources *(H')*, e considered each type of floral resource (e.g. nectar, oil, pollen, resin, fragrance) as a different "species" following the regular taxonomical use of the Shannon diversity.

We also used the same procedure to check multicollinearity and spatial autocorrelation.

Multi-model inference

We ran seven possible models for 15 model structures, giving a total of 105 candidate models (not shown in the output).

Then, we ranked those models using the corrected Akaike Information Criterion `AICc` to determine the best model(s):

```
##              df        AICc
## em5bSH$mer    7 -28.6577411
## em5aSH$mer    7 -27.6116589
```

```
## em5cSH$mer   7 -27.6116589
## em5dSH$mer   8 -26.2293088
## em5fSH$mer   8 -26.2293087
## em5eSH$mer   8 -25.1832266
## em1cSH$mer   5 -24.9260600
## em5gSH$mer   9 -23.7378003
## em1fSH$mer   6 -23.5427684
## em1eSH$mer   6 -22.6168006
## em1gSH$mer   7 -21.1750468
## em1bSH$mer   5 -20.1372280
## em1aSH$mer   5 -19.2502506
## em1dSH$mer   6 -17.8279687
## em2cSH$mer   5  -9.4357797
## em12bSH$mer  8  -9.0470361
## em12cSH$mer  8  -8.1721332
## em12aSH$mer  8  -8.1721332
## em2fSH$mer   6  -7.7005409
## em2eSH$mer   6  -7.1265205
## em12dSH$mer  9  -6.5555276
## em12fSH$mer  9  -6.5555276
## em12eSH$mer  9  -5.6806247
## em11bSH$mer  8  -5.6733601
## em7cSH$mer   6  -5.3422450
## em2gSH$mer   7  -5.3328194
## em11cSH$mer  8  -4.6094726
## em11aSH$mer  8  -4.6094726
## em12gSH$mer 10  -3.9984531
## em7fSH$mer   7  -3.7676100
## em11fSH$mer  9  -3.1818516
## em11dSH$mer  9  -3.1818516
## em7eSH$mer   7  -2.9745235
## em11eSH$mer  9  -2.1179641
## em6cSH$mer   6  -1.9965462
## em7gSH$mer   8  -1.3391777
## em11gSH$mer 10  -0.6247773
## em6fSH$mer   7  -0.5592021
## em7bSH$mer   6  -0.2926899
## em6eSH$mer   7   0.3711753
## em4cSH$mer   4   0.4066131
## em7aSH$mer   6   0.4719841
## em6gSH$mer   8   1.8691934
## em4fSH$mer   5   1.9463662
## em7dSH$mer   7   2.0750316
## em6bSH$mer   6   2.1352978
## em4eSH$mer   5   2.6595489
## em6aSH$mer   6   3.0405254
## em3cSH$mer   4   3.3310209
## em4gSH$mer   6   4.2556255
## em6dSH$mer   7   4.5030193
## em3fSH$mer   5   4.5335201
## em3eSH$mer   5   5.5839568
## em3gSH$mer   6   6.8427794
## em9cSH$mer   6   9.4860843
## em9fSH$mer   7  11.1574556
```

```
## em9eSH$mer   7  11.8538058
## em8cSH$mer   6  12.2924352
## em8fSH$mer   7  13.5726106
## em9gSH$mer   8  13.5858879
## em15bSH$mer  9  14.0947089
## em8eSH$mer   7  14.6601568
## em15cSH$mer  9  14.9974536
## em15aSH$mer  9  14.9974536
## em8gSH$mer   8  16.0010429
## em15dSH$mer 10  16.6517834
## em15fSH$mer 10  16.6517834
## em15eSH$mer 10  17.5545281
## em13cSH$mer  7  17.6628334
## em15gSH$mer 11  19.2770467
## em13fSH$mer  8  19.2865959
## em13eSH$mer  8  20.0912658
## em13gSH$mer  9  21.7779227
## em13bSH$mer  7  22.0865901
## em10cSH$mer  5  22.4232540
## em13aSH$mer  7  22.8845263
## em10fSH$mer  6  23.7771412
## em13dSH$mer  8  24.5150225
## em10eSH$mer  6  24.7325132
## em2bSH$mer   5  25.1644283
## em2aSH$mer   5  25.3563926
## em10gSH$mer  7  26.1448628
## em2dSH$mer   6  27.4736735
## em14cSH$mer  7  31.4493009
## em14fSH$mer  8  32.8668279
## em14eSH$mer  8  33.8777332
## em14gSH$mer  9  35.3583364
## em9bSH$mer   6  44.3802154
## em9aSH$mer   6  44.6081696
## em9dSH$mer   7  46.7479364
## em8bSH$mer   6  47.5321291
## em8aSH$mer   6  47.7485790
## em8dSH$mer   7  49.8998506
## em4aSH$mer   4  51.4017428
## em4bSH$mer   4  51.6818131
## em4dSH$mer   5  53.6546787
## em3aSH$mer   4  55.6015006
## em3bSH$mer   4  55.7353354
## em3dSH$mer   5  57.8544364
## em14bSH$mer  7  66.9138469
## em14aSH$mer  7  67.1495752
## em14dSH$mer  8  69.3422792
## em10aSH$mer  5  73.8934563
## em10bSH$mer  5  74.2017477
## em10dSH$mer  6  76.2027155
```

It can be seen that models with MAT received the lowest AIC scores.

Models **m5b**, **m5a**, and **m5c** received scores within the ΔAIC $<$ 2 subset, let's examine them.

MAT + AP with Sampling effort as random effect

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## Shan ~ s(Tmean_ERA5) + s(PRCPTOT_ERA5)
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.44378    0.03724   11.92   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##                   edf Ref.df     F  p-value
## s(Tmean_ERA5)   3.351  3.351 33.92  < 2e-16 ***
## s(PRCPTOT_ERA5) 1.440  1.440 13.96 5.79e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =   0.63
## lmer.REML = -44.075  Scale est. = 0.027285  n = 87
```

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## Shan ~ s(Tmean_ERA5) + s(PRCPTOT_ERA5)
##
## Approximate significance of smooth terms:
##                   edf Ref.df     F  p-value
## s(Tmean_ERA5)   3.351  3.351 33.92  < 2e-16
## s(PRCPTOT_ERA5) 1.440  1.440 13.96 5.79e-05
```

MAT + AP with Plant richness as random effect

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## Shan ~ s(Tmean_ERA5) + s(PRCPTOT_ERA5)
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.45521    0.01807    25.2   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
```

```
##                   edf Ref.df     F  p-value
## s(Tmean_ERA5)   3.207  3.207 33.68  < 2e-16 ***
## s(PRCPTOT_ERA5) 1.000  1.000 21.62 1.28e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.627
## lmer.REML = -43.029  Scale est. = 0.028395  n = 87
```

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## Shan ~ s(Tmean_ERA5) + s(PRCPTOT_ERA5)
##
## Approximate significance of smooth terms:
##                   edf Ref.df     F  p-value
## s(Tmean_ERA5)   3.207  3.207 33.68  < 2e-16
## s(PRCPTOT_ERA5) 1.000  1.000 21.62 1.28e-05
```

MAT + AP with Biome as random effect

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## Shan ~ s(Tmean_ERA5) + s(PRCPTOT_ERA5)
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.45521    0.01807    25.2   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##                   edf Ref.df     F  p-value
## s(Tmean_ERA5)   3.207  3.207 33.68  < 2e-16 ***
## s(PRCPTOT_ERA5) 1.000  1.000 21.62 1.28e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.627
## lmer.REML = -43.029  Scale est. = 0.028395  n = 87
```

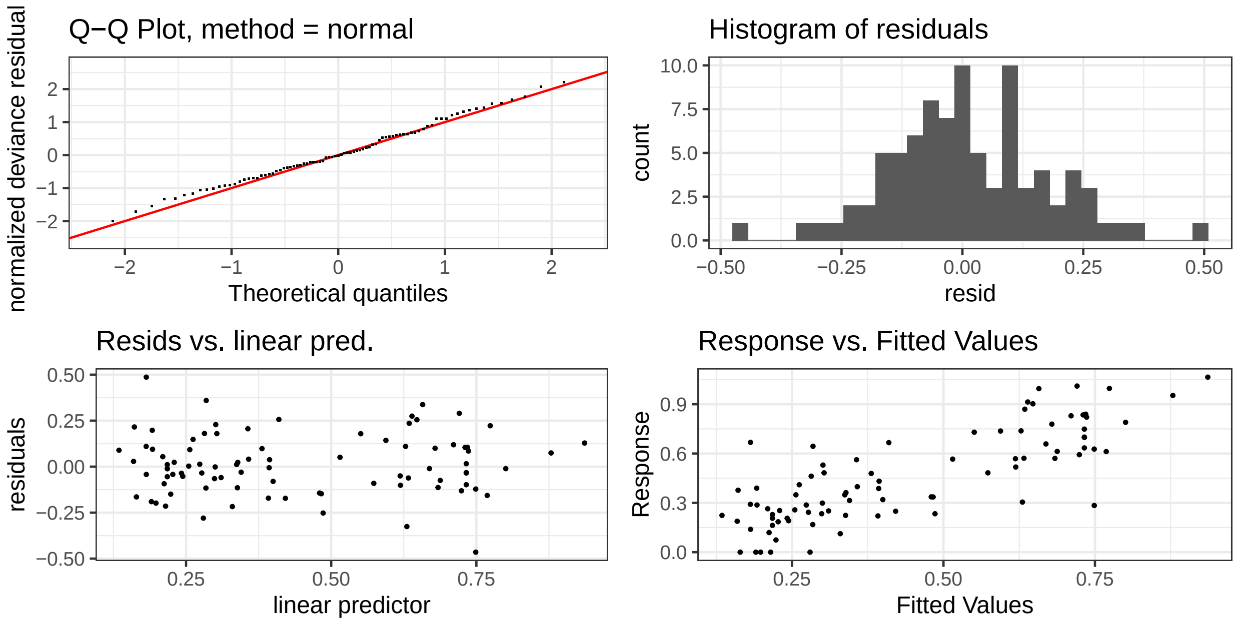
```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## Shan ~ s(Tmean_ERA5) + s(PRCPTOT_ERA5)
##
```

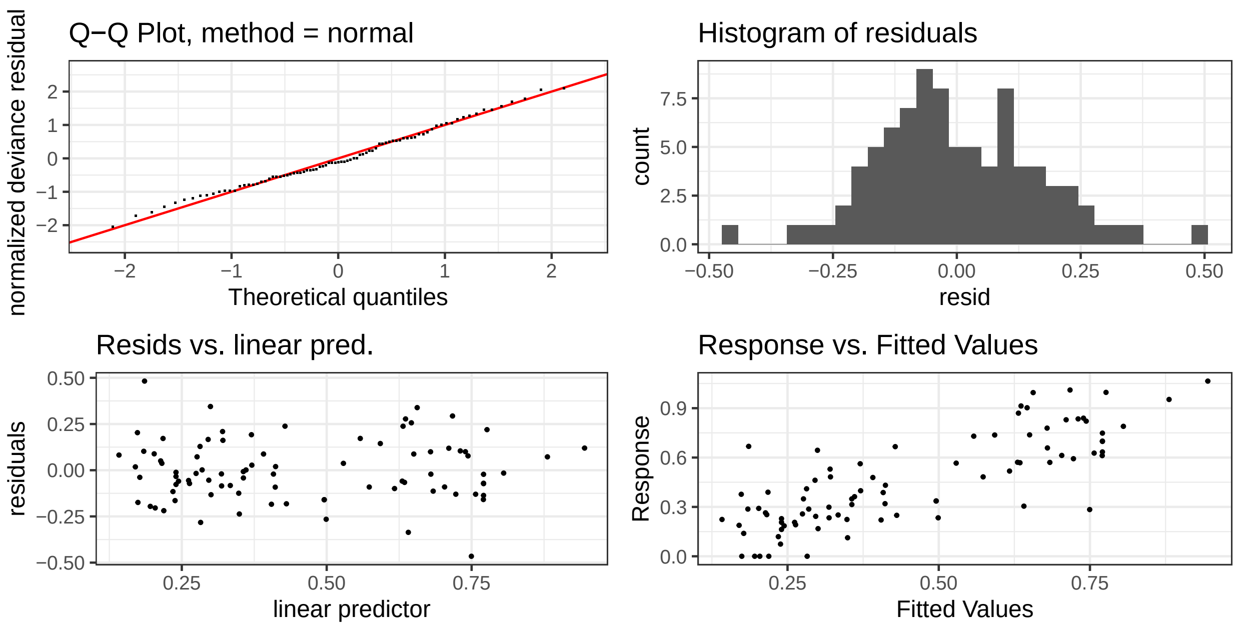
```
## Approximate significance of smooth terms:
##                   edf Ref.df     F  p-value
## s(Tmean_ERA5)   3.207  3.207 33.68  < 2e-16
## s(PRCPTOT_ERA5) 1.000  1.000 21.62 1.28e-05
```

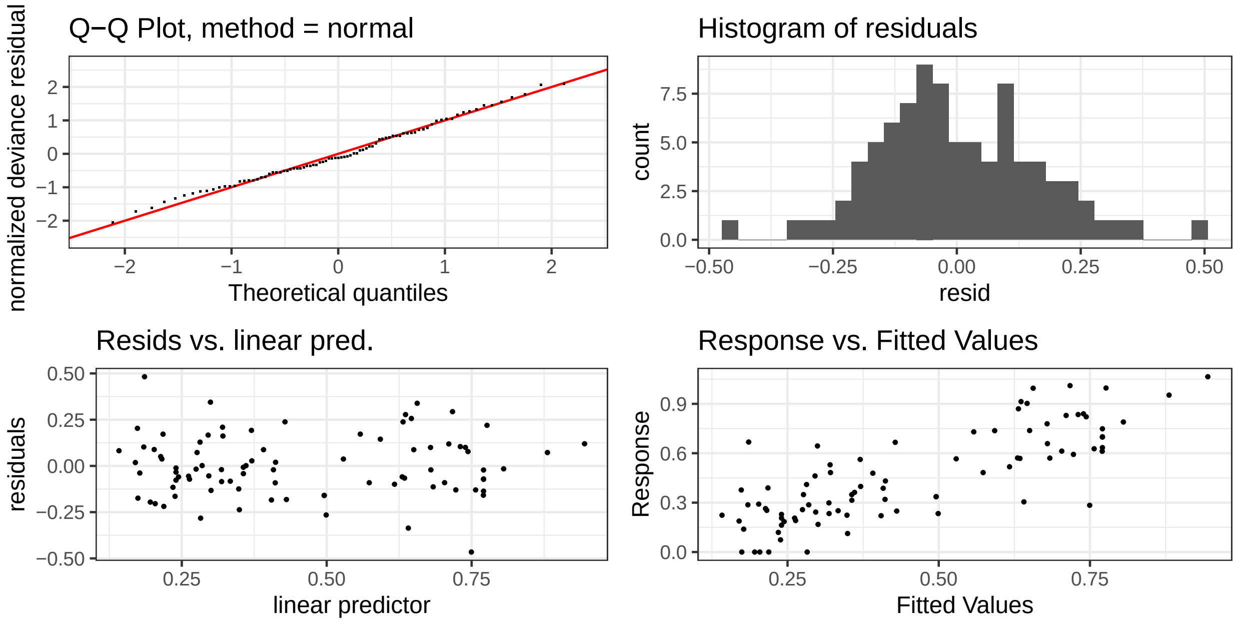
Evaluating the performance of variables in explaining the diversity of floral resources

```
## Model selection table
##              X  random df  logLik  AICc  delta weight
## em5bSH$mer   + X+X.0+e  7  22.038 -28.7   0.00  0.986
## em1bSH$mer   +     X+e  5  15.439 -20.1   8.52  0.014
## em12bSH$mer + X+X.0+e  8  13.447  -9.0  19.61  0.000
## em11bSH$mer + X+X.0+e  8  11.760  -5.7  22.98  0.000
## em7bSH$mer   +     X+e  6   6.671  -0.3  28.37  0.000
## em6bSH$mer   +     X+e  6   5.457   2.1  30.79  0.000
## em15bSH$mer + X+X.0+e  9   3.121  14.1  42.75  0.000
## em13bSH$mer +     X+e  7  -3.334  22.1  50.74  0.000
## em2bSH$mer   +     X+e  5  -7.212  25.2  53.82  0.000
## em9bSH$mer   +     X+e  6 -15.665  44.4  73.04  0.000
## em8bSH$mer   +     X+e  6 -17.241  47.5  76.19  0.000
## em4bSH$mer   +       e  4 -21.597  51.7  80.34  0.000
## em3bSH$mer   +       e  4 -23.624  55.7  84.39  0.000
## em14bSH$mer +     X+e  7 -25.748  66.9  95.57  0.000
## em10bSH$mer +       e  5 -31.731  74.2 102.86  0.000
## Models ranked by AICc(x)
## Random terms:
##  X  : 1 | Xr
##  X.0: 1 | Xr.0
##  e  : 1 | effort
```

Visual inspection of the model







All models seem to have a fair residual distribution

Assessing multicollinearity

MAT + AP with Sampling effort as random effect

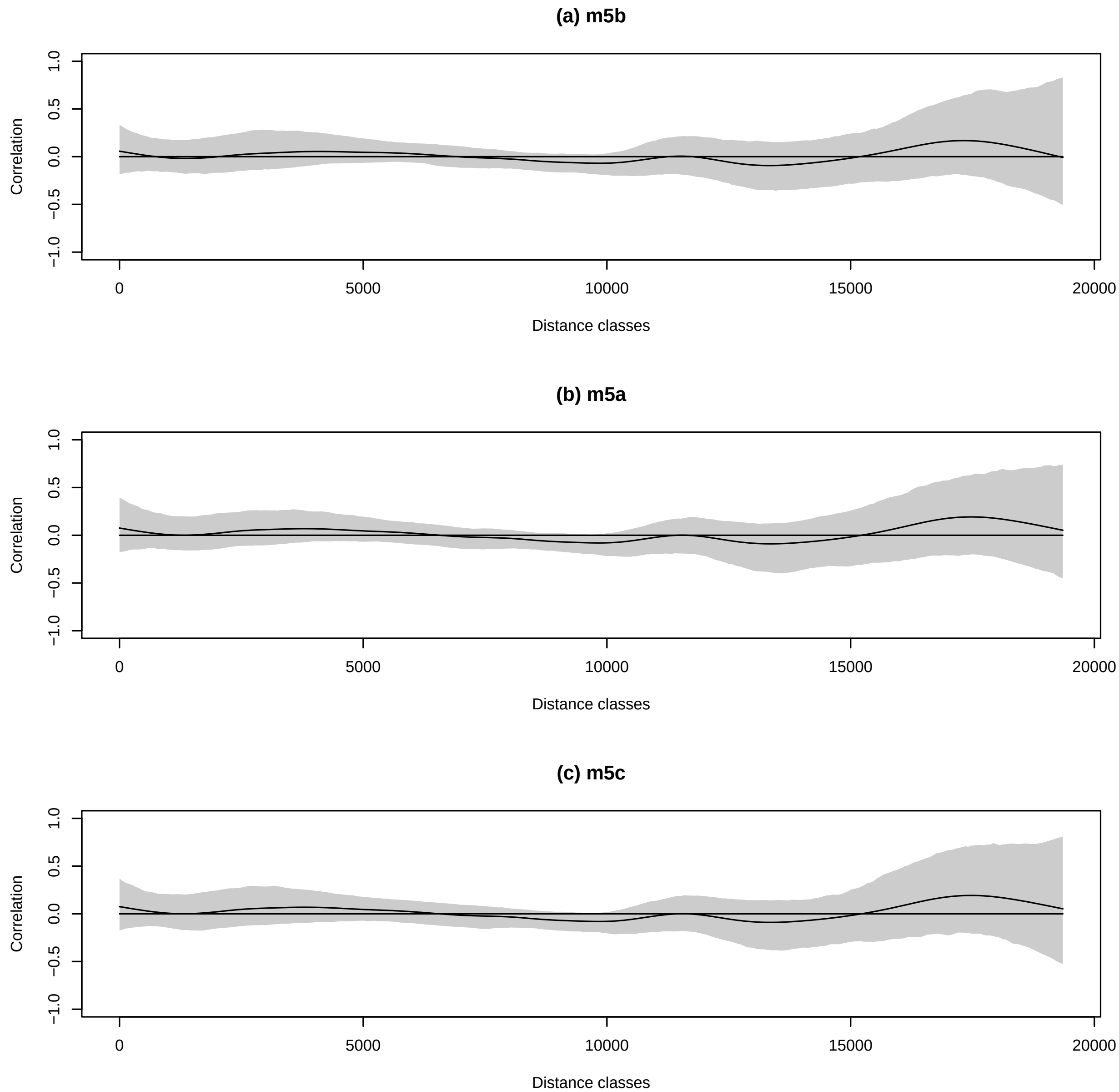
```
##                          2.5 %      97.5 %
## (Intercept)         0.37079396 0.516760331
## s(Tmean_ERA5).1    -0.23956810 0.050927269
## s(Tmean_ERA5).2    -0.30908562 0.225935961
## s(Tmean_ERA5).3    -0.06282578 0.054739188
## s(Tmean_ERA5).4    -0.14418905 0.242020355
## s(Tmean_ERA5).5    -0.07922063 0.061957572
## s(Tmean_ERA5).6    -0.19209186 0.070632251
## s(Tmean_ERA5).7    -0.03183676 0.022616127
## s(Tmean_ERA5).8    -0.93418276 0.242871621
## s(Tmean_ERA5).9    -0.15107703 0.248805160
## s(PRCPTOT_ERA5).1 -0.04056437 0.028974427
## s(PRCPTOT_ERA5).2 -0.05632862 0.043676303
## s(PRCPTOT_ERA5).3 -0.01242359 0.015176953
## s(PRCPTOT_ERA5).4 -0.03918368 0.025313678
## s(PRCPTOT_ERA5).5 -0.01097506 0.008030577
## s(PRCPTOT_ERA5).6 -0.02050056 0.034193213
## s(PRCPTOT_ERA5).7 -0.02064368 0.012282928
## s(PRCPTOT_ERA5).8 -0.09564293 0.177218174
## s(PRCPTOT_ERA5).9  0.02710862 0.130324901
```

```
##                  para s(Tmean_ERA5) s(PRCPTOT_ERA5)
## worst    2.487691e-25     0.5488504       0.5488504
## observed 2.487691e-25     0.2982248       0.1398582
## estimate 2.487691e-25     0.2139522       0.2371270
```

Confidence intervals seems reasonable. Also, estimate concurvity is lower than 0.8 which is acceptable.

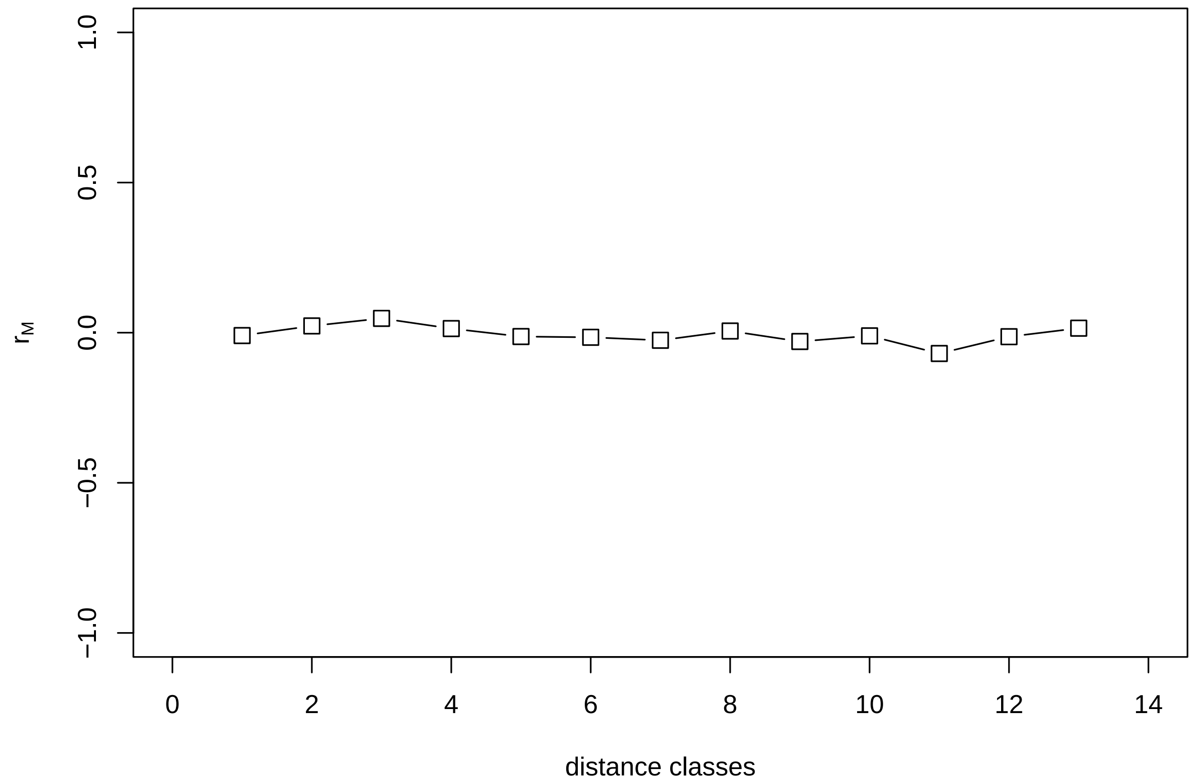
Evaluating spatial autocorrelation

```
## 100  of  1000 200  of  1000 300  of  1000 400  of  1000 500  of  1000 600  of  1000 700  of  1000 80

## 100  of  1000 200  of  1000 300  of  1000 400  of  1000 500  of  1000 600  of  1000 700  of  1000 80

## 100  of  1000 200  of  1000 300  of  1000 400  of  1000 500  of  1000 600  of  1000 700  of  1000 80
```



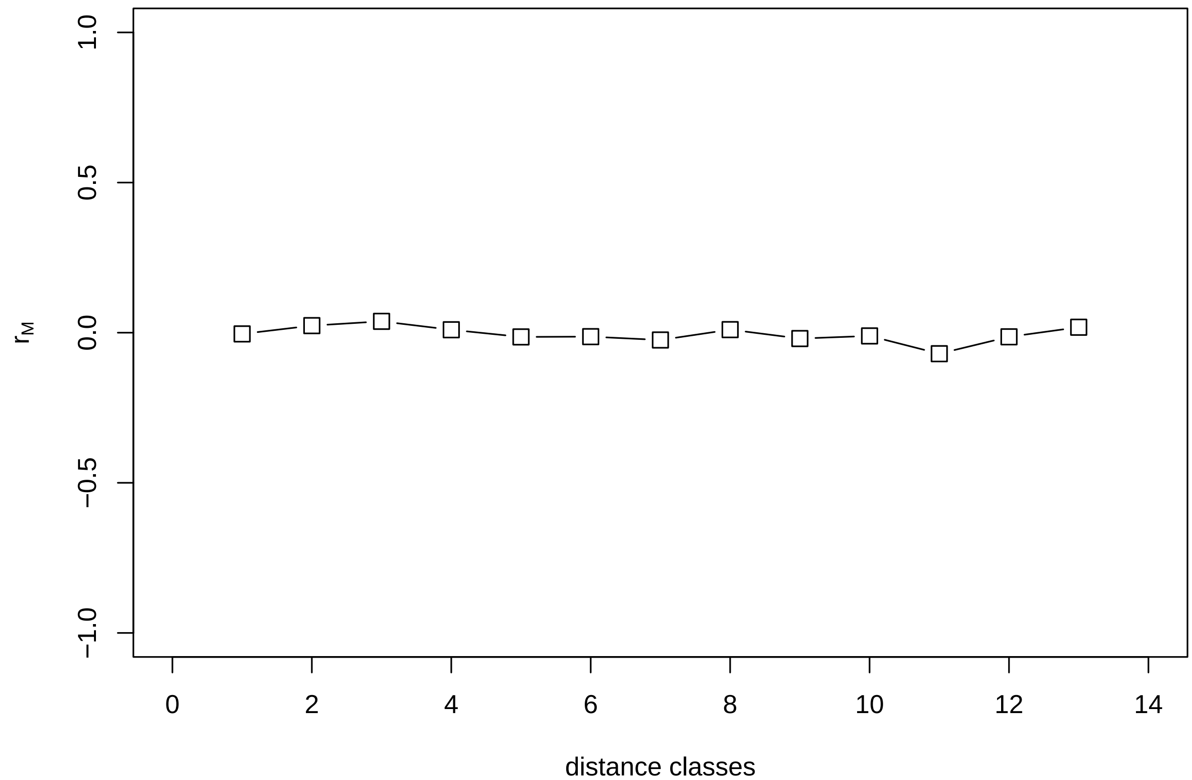
Mantel partial correlogram

```
## evaluating distance class 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13,
```



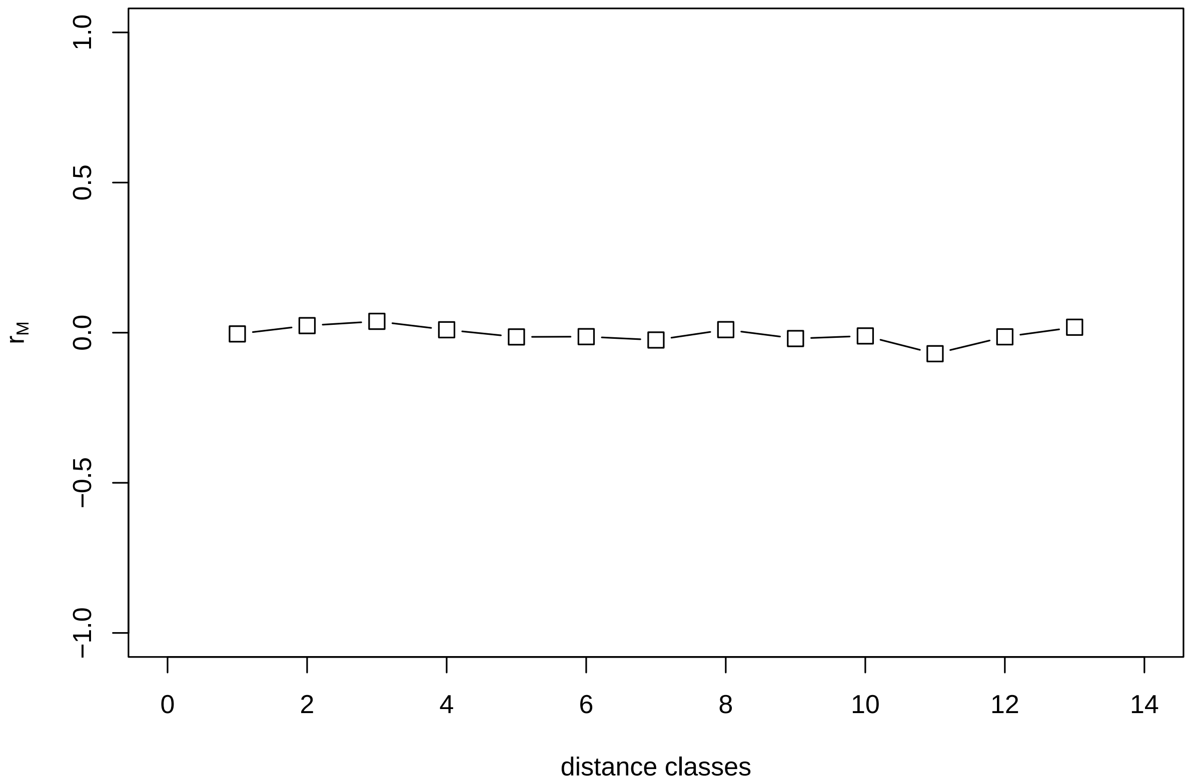

```
##    class    distance.range           rM          p p.Bonferroni
## 1      1       0  -  23.46 -0.009593145 0.38076192    0.3807619
## 2      2   23.46  -  46.92  0.022489259 0.23197680    0.4639536
## 3      3   46.92  -  70.38  0.047603905 0.04999500    0.1499850
## 4      4   70.38  -  93.84  0.013688889 0.29107089    1.1642836
## 5      5   93.84  -  117.3 -0.012859890 0.32196780    1.6098390
## 6      6  117.3   -  140.76 -0.015396130 0.31416858    1.8850115
## 7      7 140.76   -  164.22 -0.025352154 0.19388061    1.3571643
## 8      8 164.22   -  187.68  0.005527990 0.48865113    3.9092091
## 9      9 187.68   -  211.14 -0.029326909 0.16438356    1.4794521
## 10    10  211.14  -  234.6 -0.010554549 0.29927007    2.9927007
## 11    11  234.6   -  258.06 -0.069334196 0.02559744    0.2815718
## 12    12 258.06   -  281.52 -0.013357863 0.23367663    2.8041196
## 13    13 281.52   -  305.98  0.014991796 0.36316368    4.7211279
```

```
## evaluating distance class 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13,
```




```
##    class    distance.range           rM         p p.Bonferroni
## 1      1       0  -  23.46 -0.004088107 0.4582542    0.4582542
## 2      2   23.46  -  46.92  0.023497367 0.2148785    0.4297570
## 3      3   46.92  -  70.38  0.037765092 0.1032897    0.3098690
## 4      4   70.38  -  93.84  0.009726523 0.3528647    1.4114589
## 5      5   93.84  -  117.3 -0.014134816 0.2985701    1.4928507
## 6      6  117.3   -  140.76 -0.013221532 0.3405659    2.0433957
## 7      7 140.76   -  164.22 -0.024362486 0.1894811    1.3263674
## 8      8 164.22   -  187.68  0.010158243 0.4202580    3.3620638
## 9      9 187.68   -  211.14 -0.019530580 0.2392761    2.1534847
## 10    10  211.14  -  234.6 -0.010827985 0.2954705    2.9547045
## 11    11  234.6   -  258.06 -0.070016990 0.0229977    0.2529747
## 12    12 258.06   -  281.52 -0.013778197 0.2242776    2.6913309
## 13    13 281.52   -  305.98  0.018163539 0.2967703    3.8580142
```

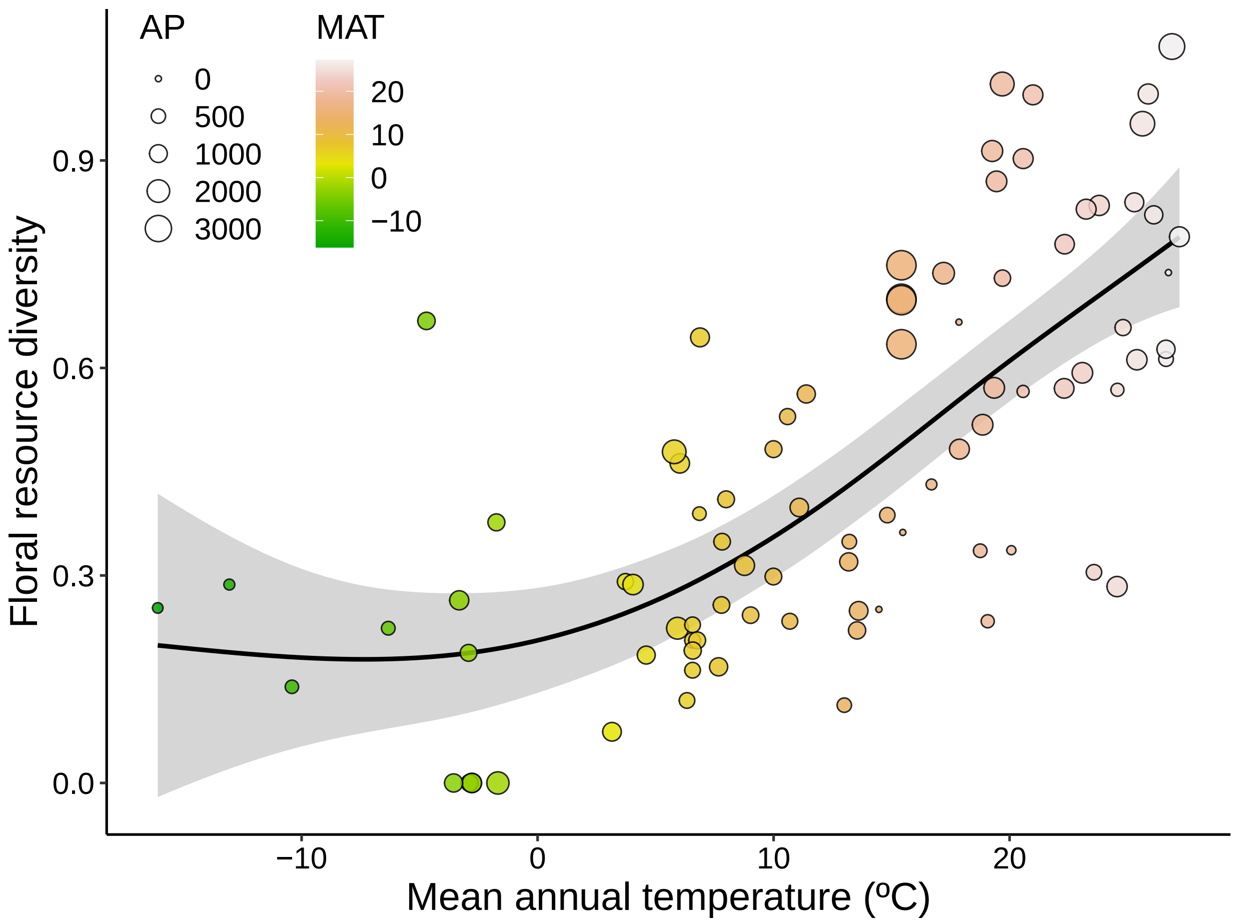
```
## evaluating distance class 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13,
```




```
##    class    distance.range           rM         p p.Bonferroni
## 1      1       0  -  23.46 -0.004088232 0.4595540    0.4595540
## 2      2   23.46  -  46.92  0.023497127 0.2259774    0.4519548
## 3      3   46.92  -  70.38  0.037765305 0.1009899    0.3029697
## 4      4   70.38  -  93.84  0.009726648 0.3398660    1.3594641
## 5      5   93.84  -  117.3 -0.014134785 0.2982702    1.4913509
## 6      6  117.3  -  140.76 -0.013221570 0.3374663    2.0247975
## 7      7 140.76  -  164.22 -0.024362493 0.1986801    1.3907609
## 8      8 164.22  -  187.68  0.010158355 0.4273573    3.4188581
## 9      9 187.68  -  211.14 -0.019530651 0.2357764    2.1219878
## 10    10  211.14  -  234.6 -0.010828028 0.2979702    2.9797020
## 11    11  234.6  -  258.06 -0.070016977 0.0229977    0.2529747
## 12    12 258.06  -  281.52 -0.013778101 0.2378762    2.8545145
## 13    13 281.52  -  305.98  0.018163494 0.2982702    3.8775122
```

Conclusion: correlograms show NO spatial autocorrelation

Let’s plot it



Session

```r
sessionInfo()
```

```
## R version 4.3.1 (2023-06-16 ucrt)
## Platform: x86_64-w64-mingw32/x64 (64-bit)
## Running under: Windows 10 x64 (build 19045)
##
## Matrix products: default
##
##
## locale:
## [1] LC_COLLATE=English_United States.utf8
## [2] LC_CTYPE=English_United States.utf8
## [3] LC_MONETARY=English_United States.utf8
## [4] LC_NUMERIC=C
## [5] LC_TIME=English_United States.utf8
##
## time zone: Europe/Paris
## tzcode source: internal
##
```

```
## attached base packages:
## [1] stats4    stats     graphics  grDevices utils     datasets  methods
## [8] base
##
## other attached packages:
##  [1] maps_3.4.1          knitr_1.43          mpmcorrelogram_0.1-4
##  [4] vegan_2.6-4         lattice_0.21-8      permute_0.9-7
##  [7] ncf_1.3-2           mgcViz_0.1.9        qgam_1.3.4
## [10] car_3.1-2           carData_3.0-5       ggplot2_3.4.2
## [13] MuMIn_1.47.5        cAIC4_1.0           gamm4_0.2-6
## [16] mgcv_1.8-42         nlme_3.1-162        lme4_1.1-33
## [19] Matrix_1.5-4.1      corrplot_0.92
##
## loaded via a namespace (and not attached):
##  [1] gtable_0.3.3       xfun_0.39          GGally_2.1.2       vctrs_0.6.3
##  [5] tools_4.3.1        generics_0.1.3     parallel_4.3.1     tibble_3.2.1
##  [9] fansi_1.0.4        highr_0.10         cluster_2.1.4      pkgconfig_2.0.3
## [13] KernSmooth_2.23-21 RColorBrewer_1.1-3 lifecycle_1.0.3    farver_2.1.1
## [17] compiler_4.3.1     munsell_0.5.0      codetools_0.2-19   httpuv_1.6.11
## [21] htmltools_0.5.5    yaml_2.3.7         pillar_1.9.0       later_1.3.1
## [25] nloptr_2.0.3       MASS_7.3-60        ellipsis_0.3.2     viridis_0.6.3
## [29] iterators_1.0.14   boot_1.3-28.1      abind_1.4-5        foreach_1.5.2
## [33] mime_0.12          tidyselect_1.2.0   digest_0.6.32      mvtnorm_1.2-2
## [37] dplyr_1.1.2        labeling_0.4.2     splines_4.3.1      fastmap_1.1.1
## [41] grid_4.3.1         colorspace_2.1-0   RLRsim_3.1-8       cli_3.6.1
## [45] magrittr_2.0.3     utf8_1.2.3         withr_2.5.0        scales_1.2.1
## [49] promises_1.2.0.1   rmarkdown_2.23     matrixStats_1.0.0  gridExtra_2.3
## [53] shiny_1.7.4.1      evaluate_0.21      doParallel_1.0.17  viridisLite_0.4.2
## [57] miniUI_0.1.1.1     rlang_1.1.1        Rcpp_1.0.10        xtable_1.8-4
## [61] glue_1.6.2         rstudioapi_0.15.0  minqa_1.2.5        reshape_0.8.9
## [65] R6_2.5.1           plyr_1.8.8
```