

SPATIAL MODELLING

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SPATIAL MODELLING TOOLS

- The examples presented here use R
- Another excellent program with a nice GUI interface:
- Spatial Analysis in Macroecology
- <http://www.ecoevol.ufg.br/sam/>

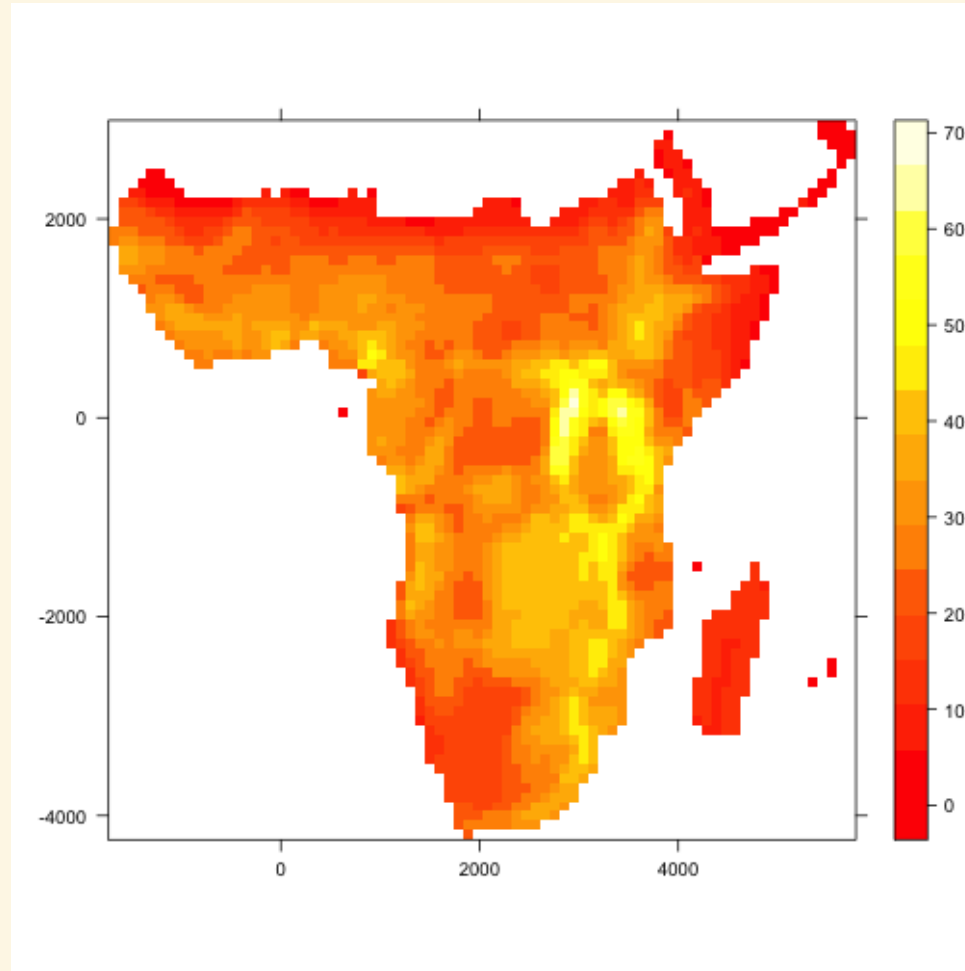


Samlogo

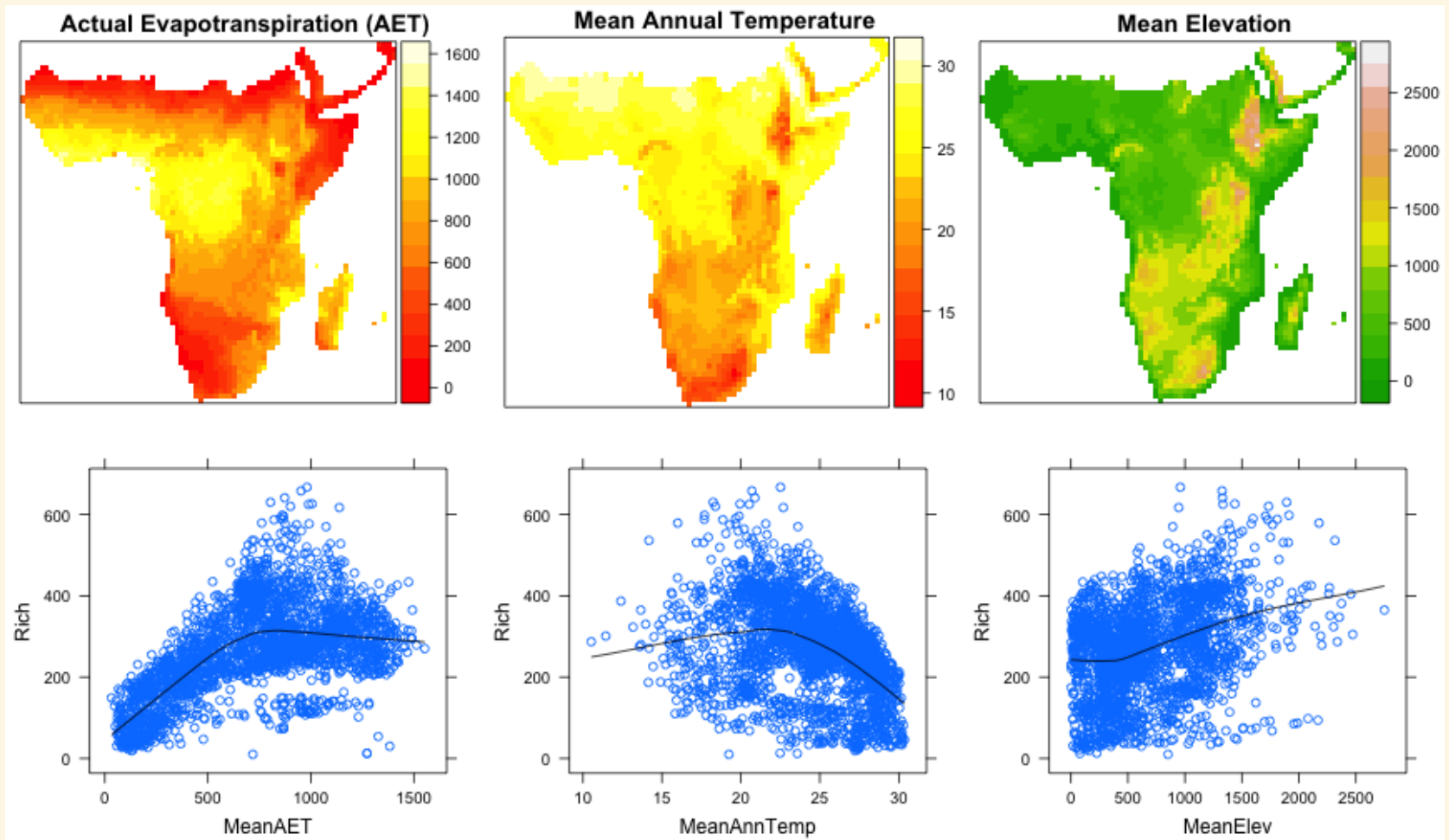
OVERVIEW

- Example data: Afrotropical bird diversity
- Naive models
- Describing spatial autocorrelation
- Accounting for spatial autocorrelation (degrees of freedom correction, SAR, GLS, eigenvector filtering, GWR)

AFROTROPICAL BIRD SPECIES RICHNESS



EXPLANATORY VARIABLES



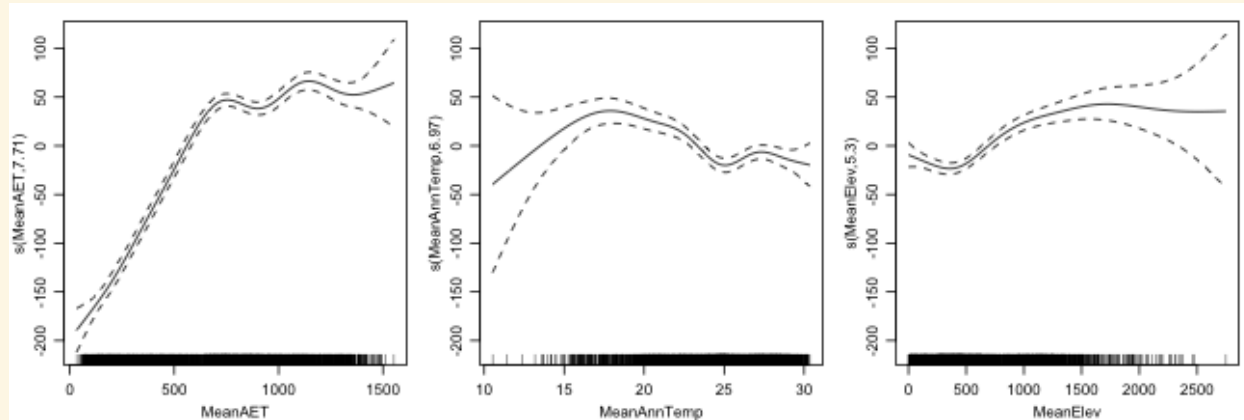
A SIMPLE LINEAR MODEL

Richness ~ AET + Temperature + Elevation

	Est	SE	t	p
(Intercept)	189.453	21.329	8.882	0
MeanAET	0.176	0.005	37.342	0
MeanAnnTemp	-4.178	0.722	-5.787	0
MeanElev	0.076	0.005	13.849	0

A SIMPLE GAM

Richness \sim s(AET) + s(Temperature) + s(Elevation)



s(MeanAET)

7.710335

8.584611

212.57750

s(MeanAnnTemp)

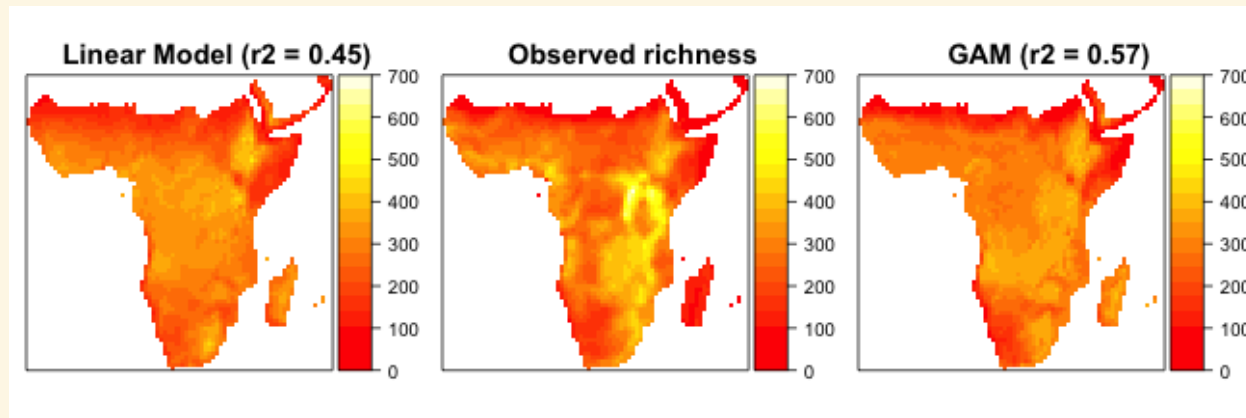
6.967881

8.078738

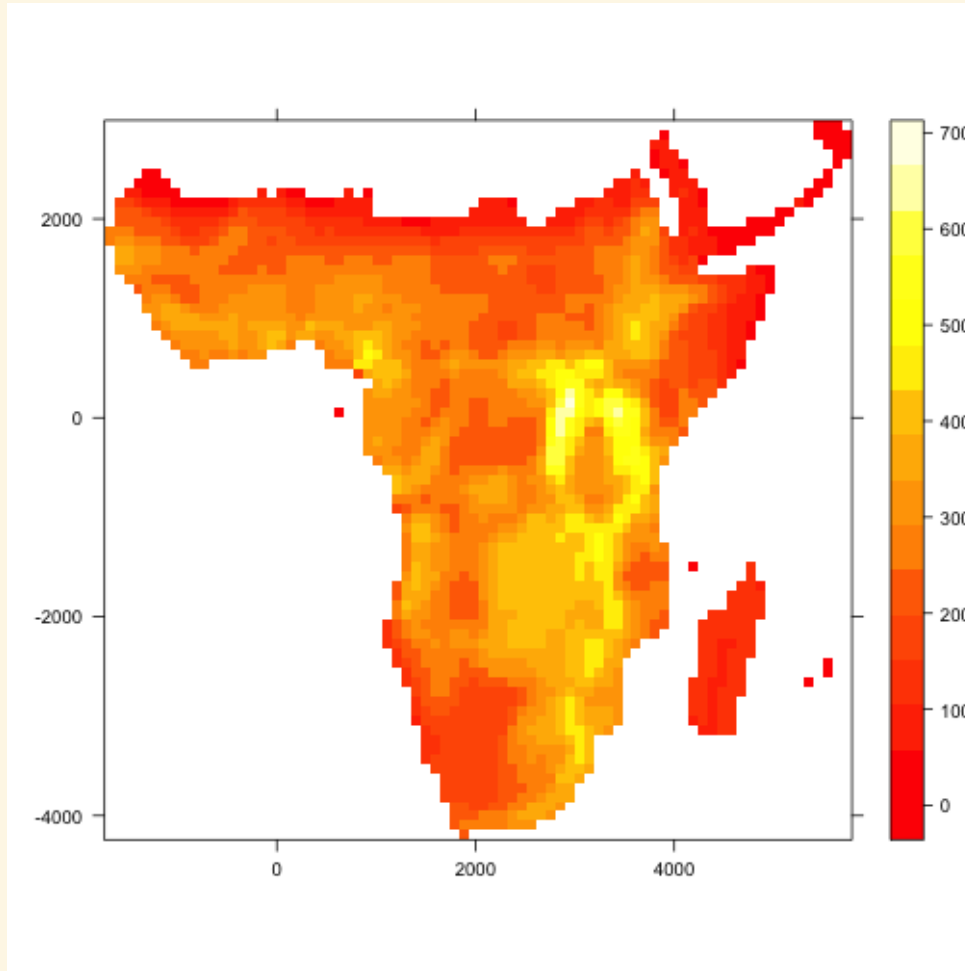
7.90674

	edf	Ref.df	
s(MeanElev)	5.302474	6.489696	12.05102

MODEL PREDICTIONS



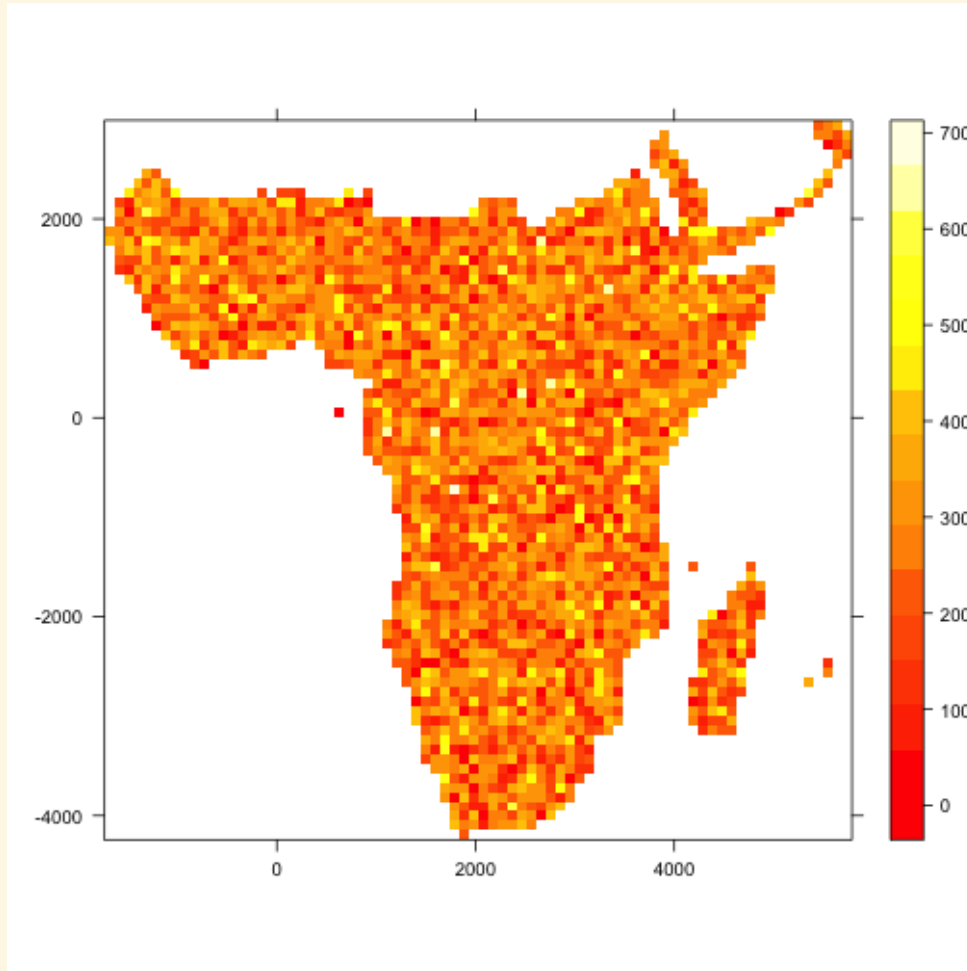
SPATIAL AUTOCORRELATION



Global Moran's I

- $I = 0.922$
- $p < 0.001$

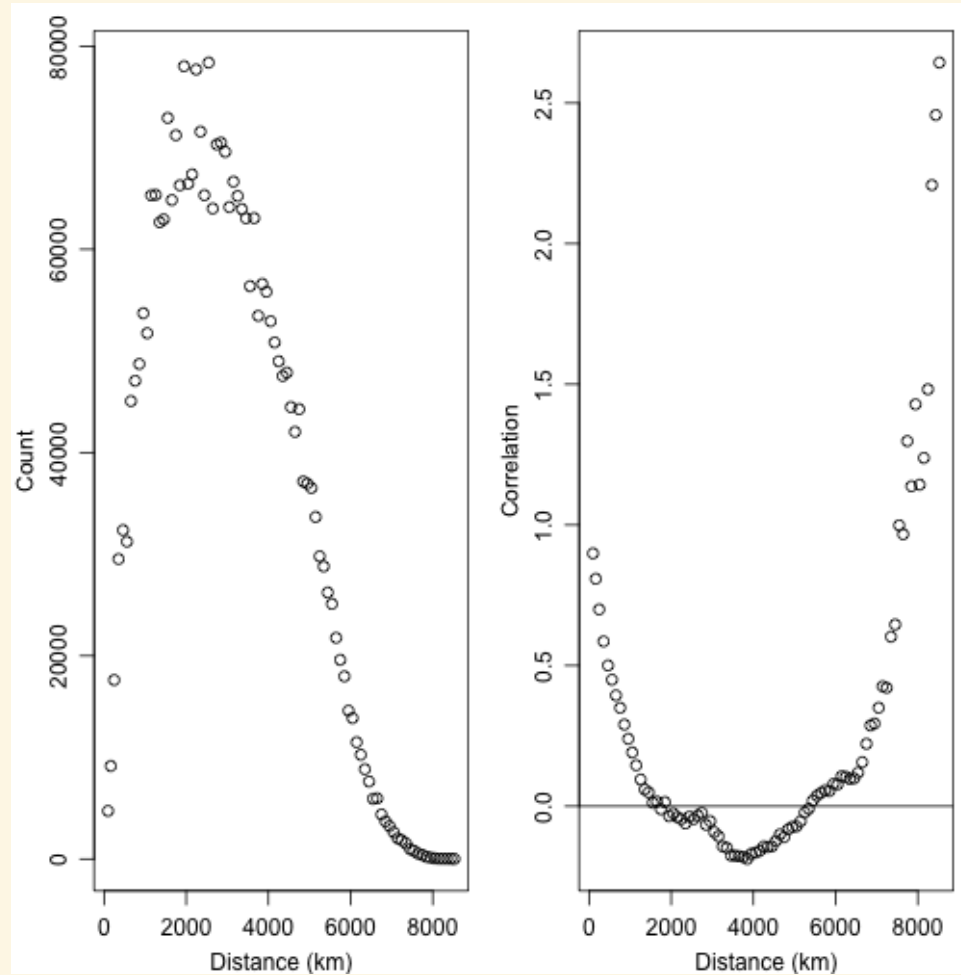
SPATIAL AUTOCORRELATION



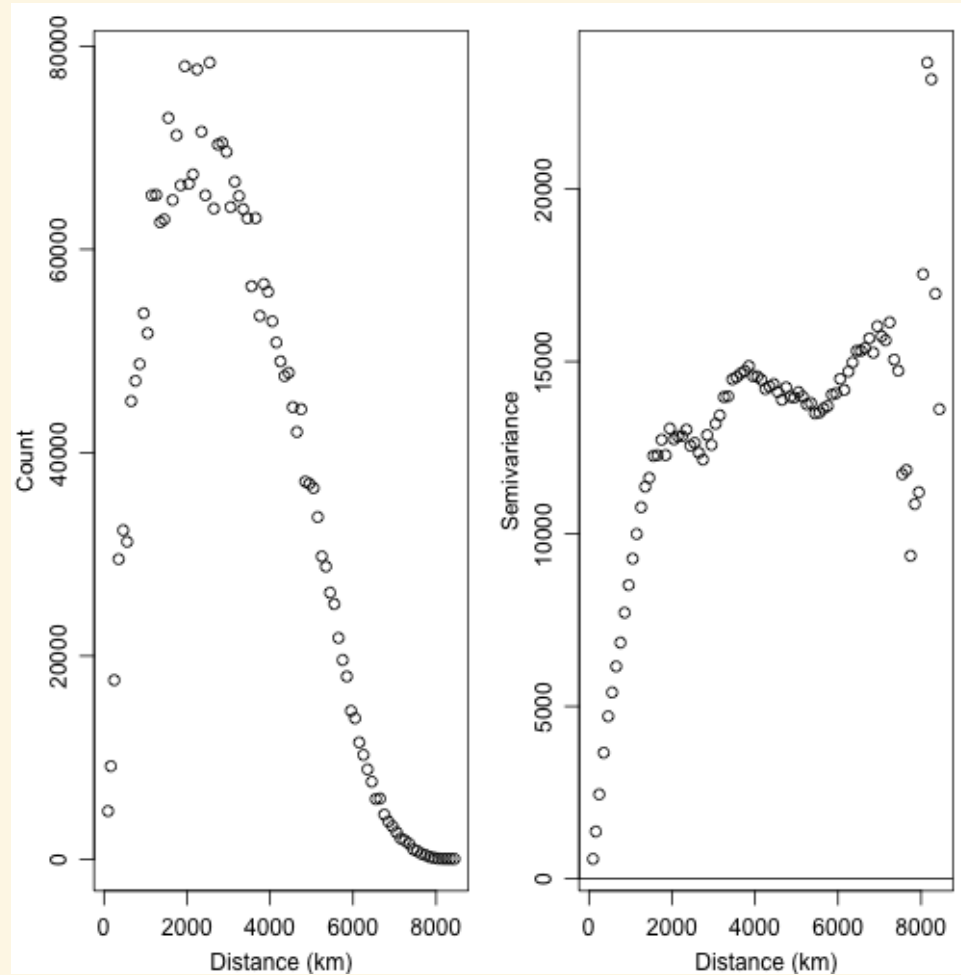
Global Moran's I

- $I = -0.010$
- $p = 0.821$

CORRELOGRAM

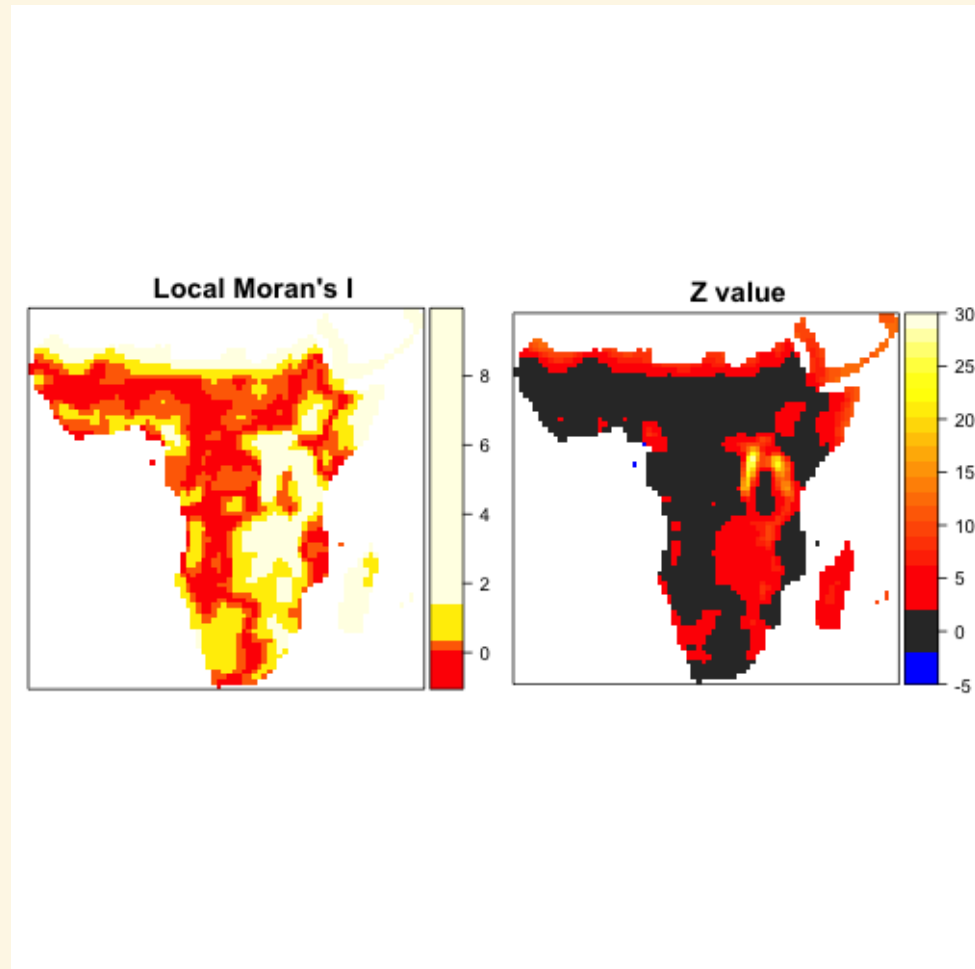


VARIOGRAM



LOCAL AUTOCORRELATION

Local indicators of spatial autocorrelation (LISA)



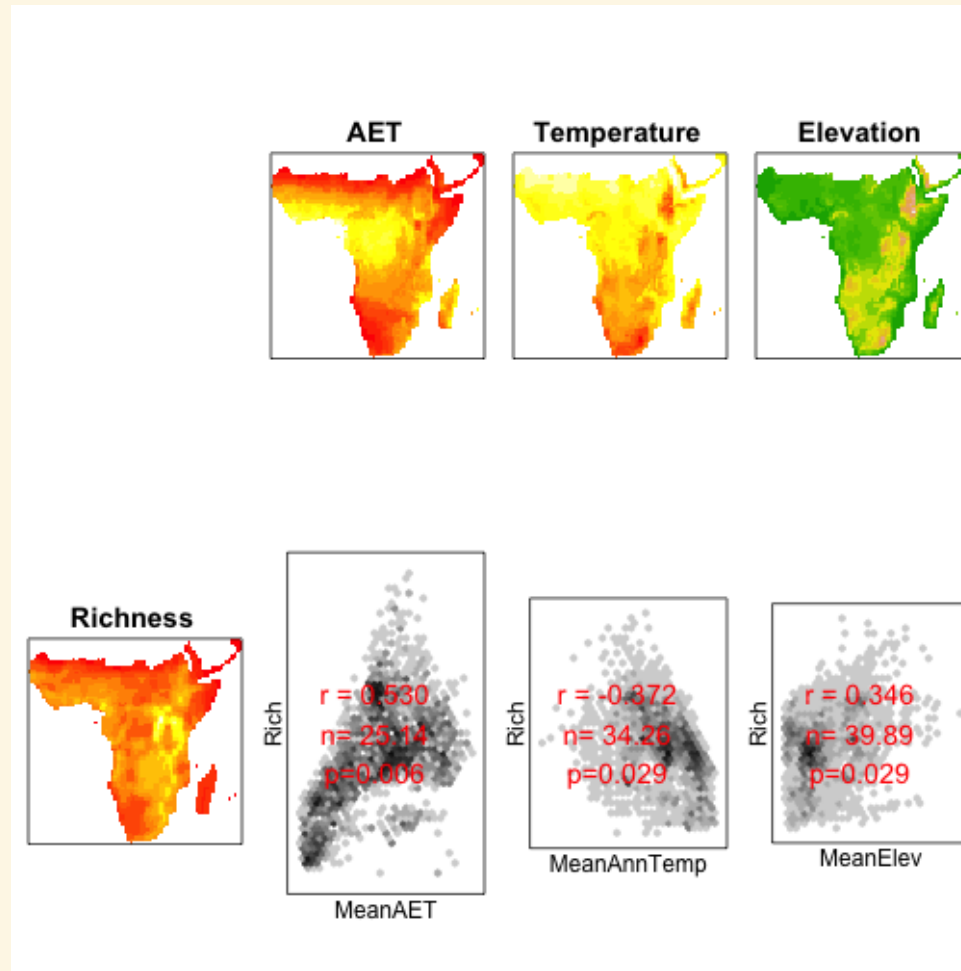
EFFECTS OF SPATIAL AUTOCORRELATION

- Violates assumption of independence between data points
- Degrees of freedom not equal to number of data points: **standard errors and significance testing affected**
- Data points do not contribute equally to determining the relationship between variables: **parameter estimation affected**

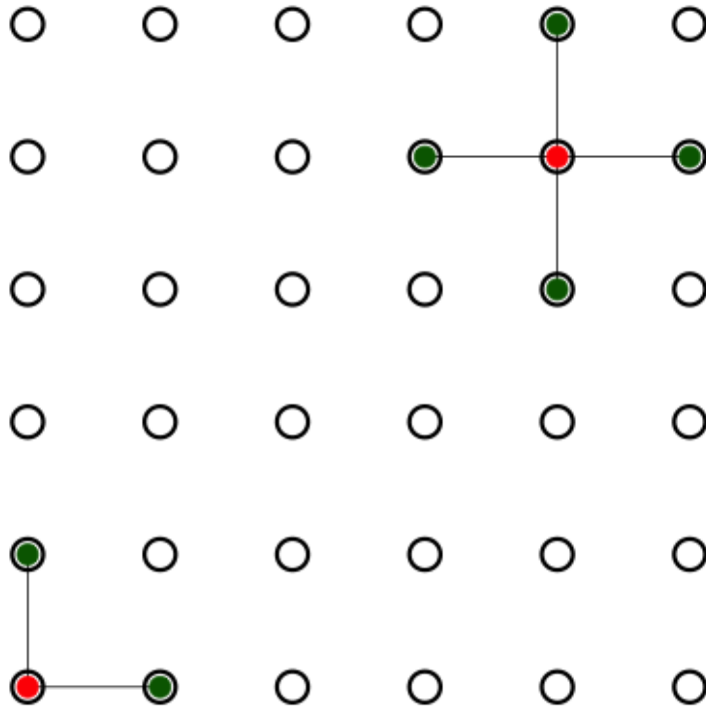
DEALING WITH SPATIAL AUTOCORRELATION

- Modify the degrees of freedom in significance testing
- Account for autocorrelation in models:
 - Simultaneous autoregressive models
 - Generalised least squares
 - Eigenvector filtering
 - Geographically weighted regression

DEGREES OF FREEDOM CORRECTION



NEIGHBOURHOODS

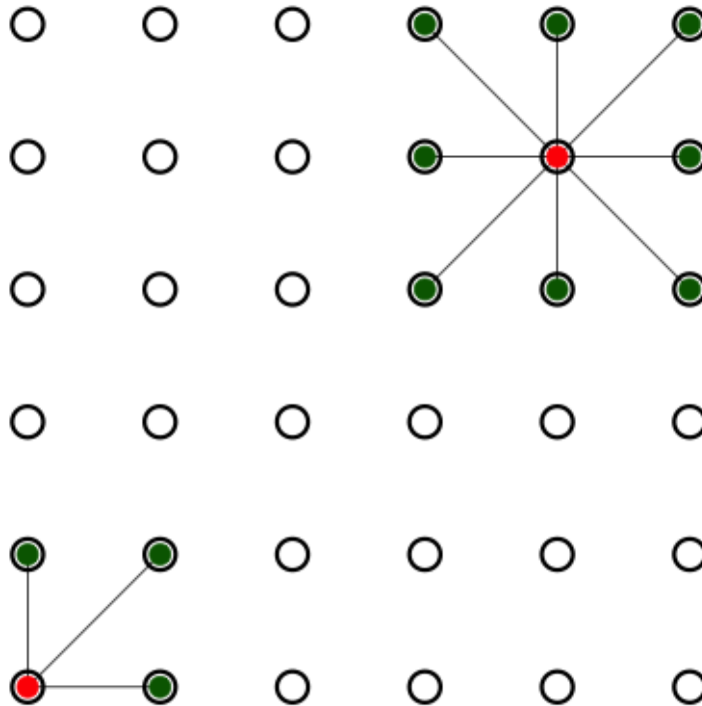


Rooks move

All cells within
one step:

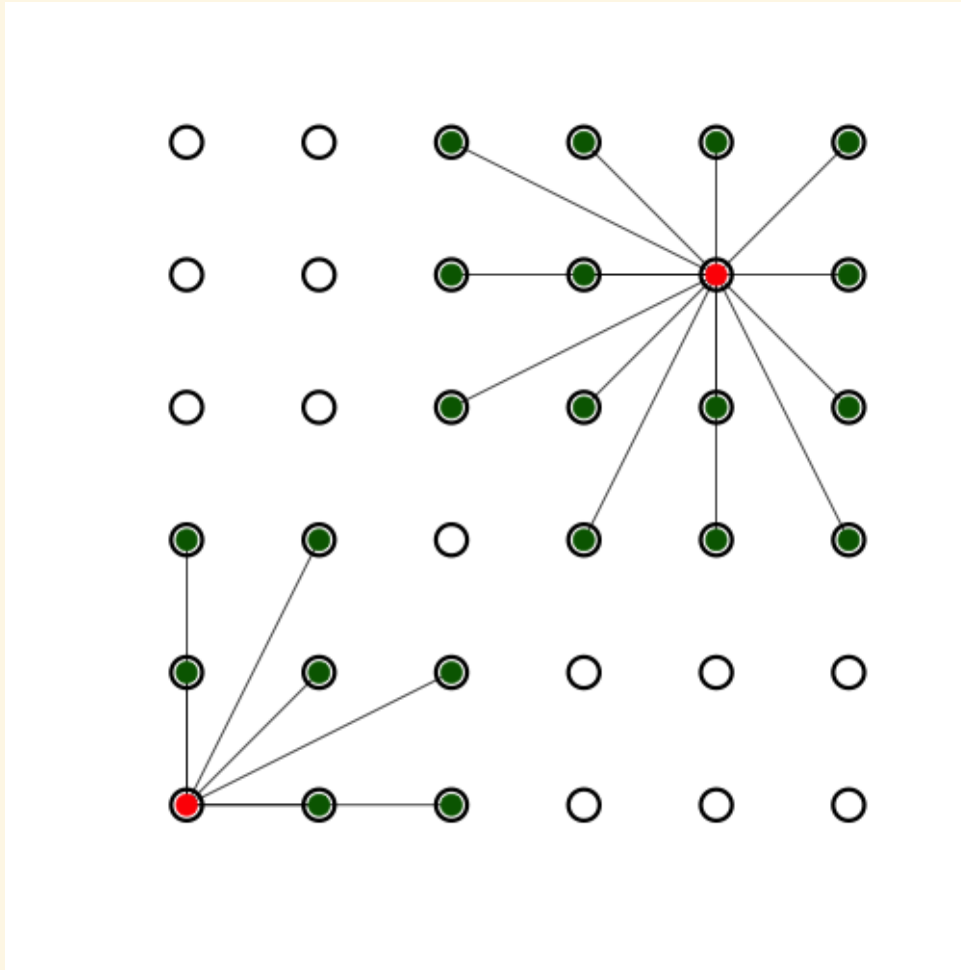
- vertically or
- horizontally

NEIGHBOURHOODS



- Queens move
- All cells within one step:
- vertically,
 - horizontally
 - or
 - diagonally

NEIGHBOURHOODS

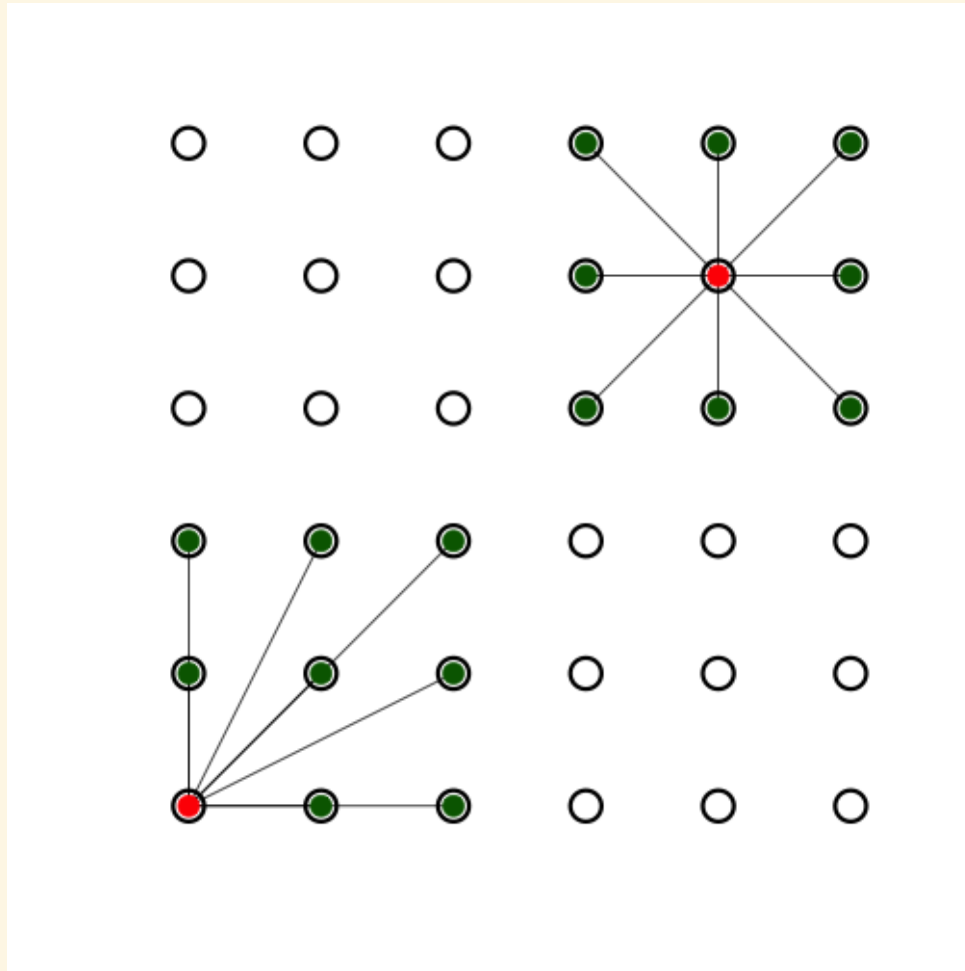


Distance based

All cells within:

- 2.4 units

NEIGHBOURHOODS



k nearest

The closest k cells

SPATIAL AUTOREGRESSION

Solve for b :



$$bx_1 + \frac{1}{2}bx_2$$



$$\frac{1}{2}bx_1 + bx_2 + \frac{1}{2}bx_3$$



$$\frac{1}{2}bx_2 + bx_3 + \frac{1}{2}bx_4$$



$$\frac{1}{2}bx_3 + \frac{1}{2}bx_4$$

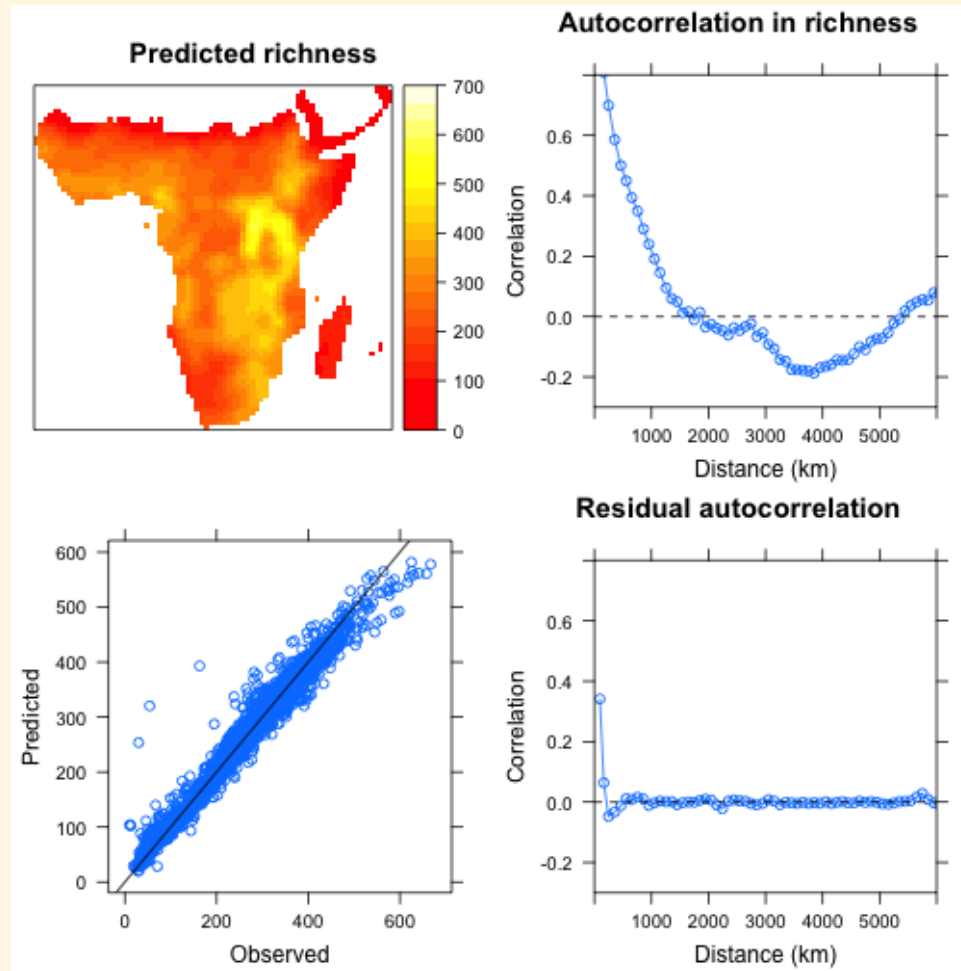
x_1

x_1

x_3

x_4

SPATIAL AUTOREGRESSION



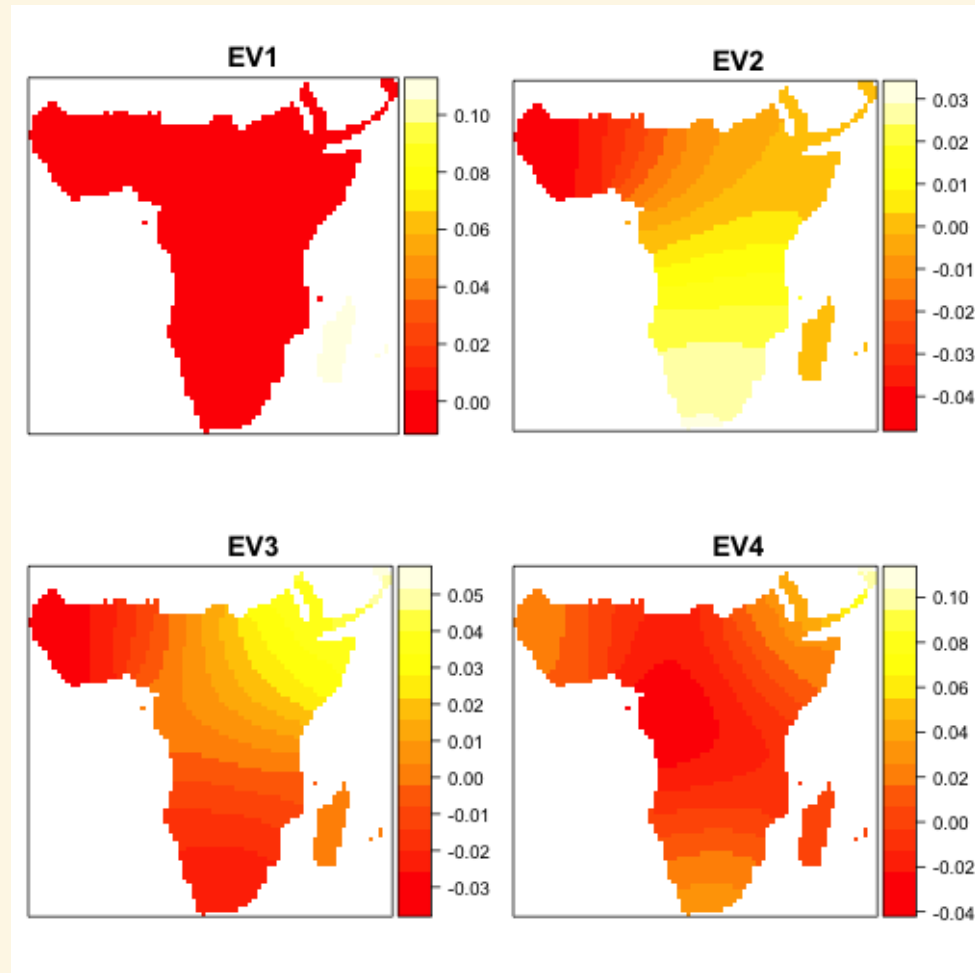
GENERALISED LEAST SQUARES

TODO - Slides!

EIGENVECTOR FILTERING

- Transform a spatial weights model into a series of eigenvectors
- Use eigenvectors as variables in the model
- Use a selection process to identify and include only important eigenvectors

EIGENVECTOR FILTERING



EIGENVECTOR FILTERING

`lm(Rich ~ MeanAET + MeanAnnTemp +
MeanElev`

	Est	SE	t	p
(Intercept)	189.453	21.329	8.882	0
MeanAET	0.176	0.005	37.342	0
MeanAnnTemp	-4.178	0.722	-5.787	0
MeanElev	0.076	0.005	13.849	0

EIGENVECTOR FILTERING

```
lm(Rich ~ MeanAET + MeanAnnTemp +  
MeanElev + Re(spEV1) + Re(spEV2) +  
Re(spEV3) + Re(spEV4))
```

	Est	SE	t	p
(Intercept)	80.231	33.003	2.431	0.015
MeanAET	0.182	0.006	31.432	0.000
MeanAnnTemp	0.099	1.141	0.087	0.931
MeanElev	0.078	0.006	12.703	0.000
Re(spEV1)	-1617.625	77.641	-20.835	0.000
Re(spEV2)	963.975	129.208	7.461	0.000
Re(spEV3)	-813.557	95.868	-8.486	0.000
Re(spEV4)	-150.378	100.280	-1.500	0.134

EIGENVECTOR FILTERING

$\text{lm}(\text{Rich} \sim \text{MeanAET} + \text{MeanAnnTemp} +$
 $\text{MeanElev} + \text{Re}(\text{spEV1}) + \text{Re}(\text{spEV2}) +$
 $\text{Re}(\text{spEV3}))$

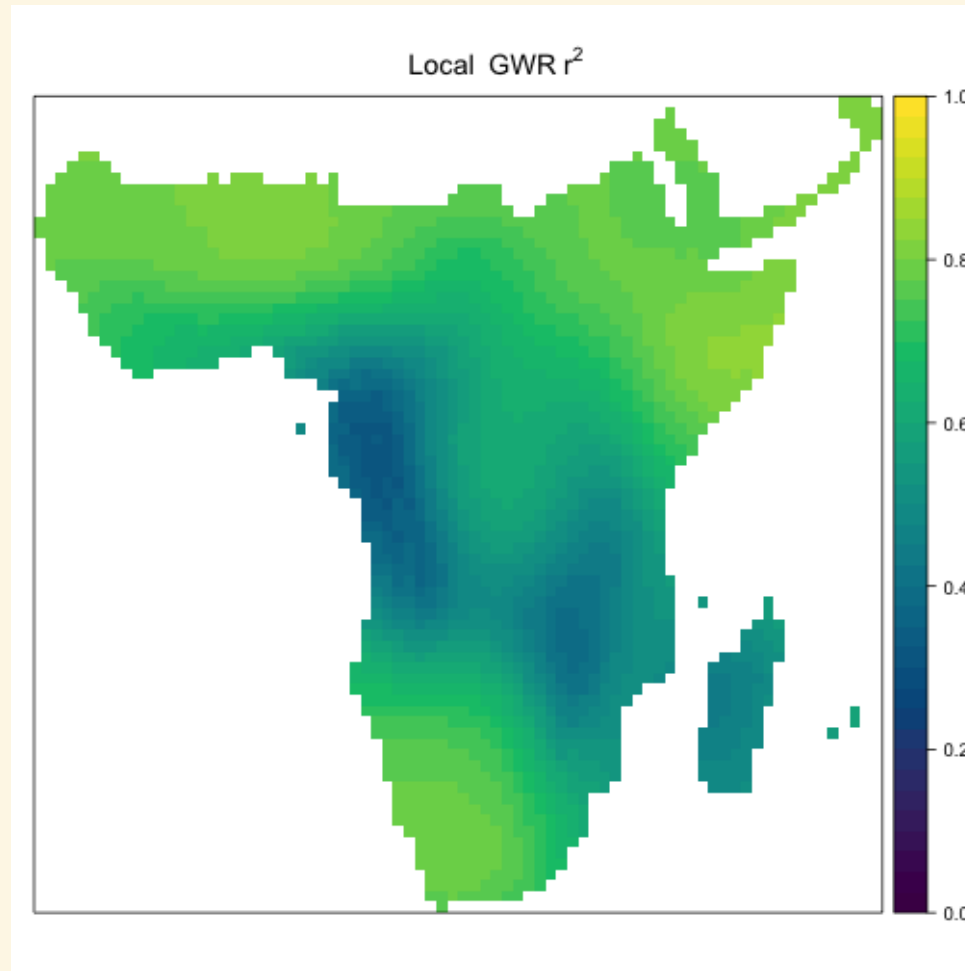
	Est	SE	t	p
(Intercept)	58.387	29.622	1.971	0.049
MeanAET	0.188	0.004	43.675	0.000
MeanAnnTemp	0.748	1.056	0.708	0.479
MeanElev	0.080	0.006	13.783	0.000
Re(spEV1)	-1610.754	77.525	-20.777	0.000
Re(spEV2)	1031.596	121.114	8.518	0.000
Re(spEV3)	-848.190	93.068	-9.114	0.000

GEOGRAPHICALLY WEIGHTED REGRESSION

```
## Warning in gwr(Rich ~ MeanAET + MeanAnnTemp + MeanElev, data =  
## 0.05, : standard errors set to NA, normalised RSS not availabl
```

```
##      user  system elapsed  
## 121.872   10.945  139.256
```

GEOGRAPHICALLY WEIGHTED REGRESSION



PROBLEMS

- Profusion of packages: sf, sp, spdep, mgcv, ncf, gstat, nlme, spgwr
- Different data structures
- Sometimes poor documentation
- Speed of calculation (= size of dataset)
- Memory hungry
- Too many options