Drought intensity and species distribution

Richard Condit
Smithsonian Tropical Research Institute

University of Turku
August 2008

Drought intensity and species distribution

Richard Condit
Smithsonian Tropical Research Institute

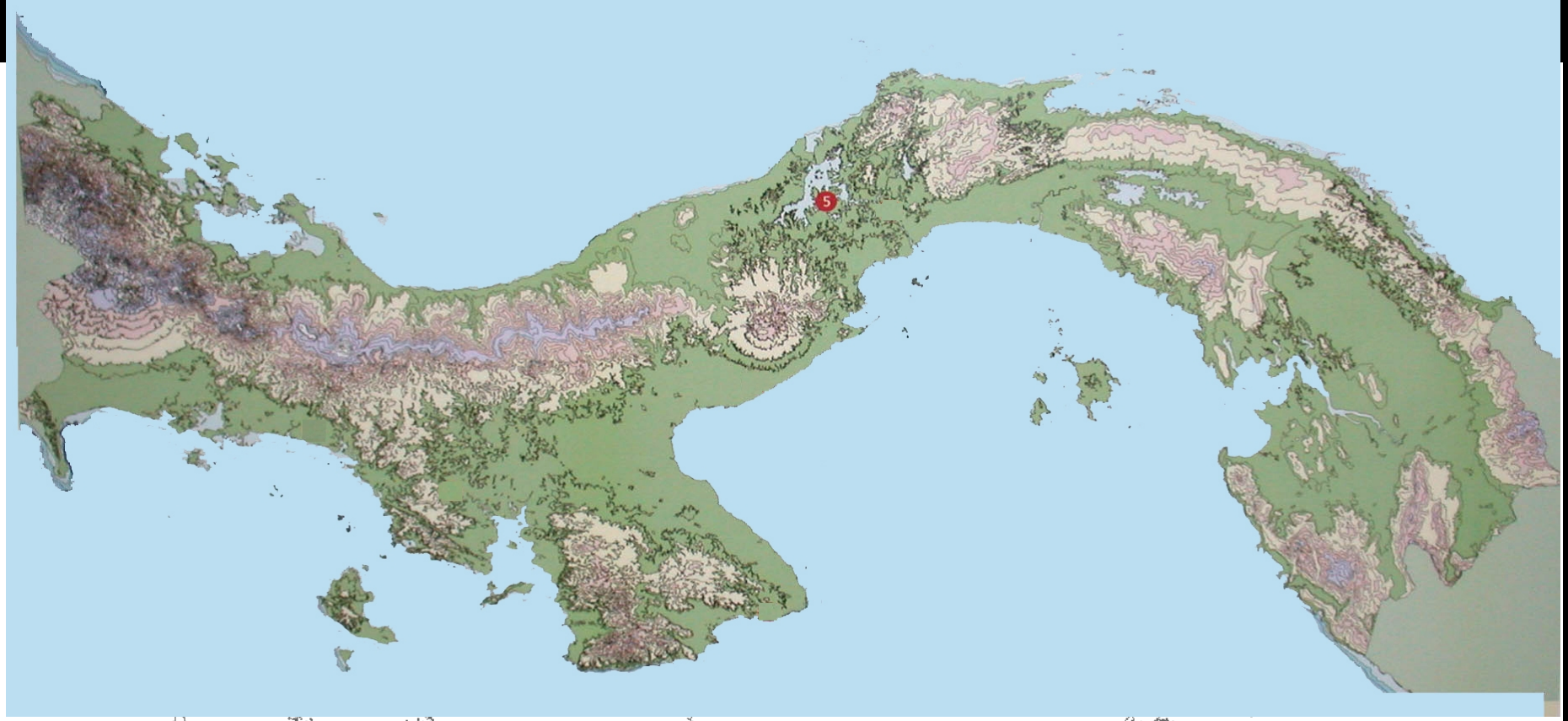
University of Turku
August 2008

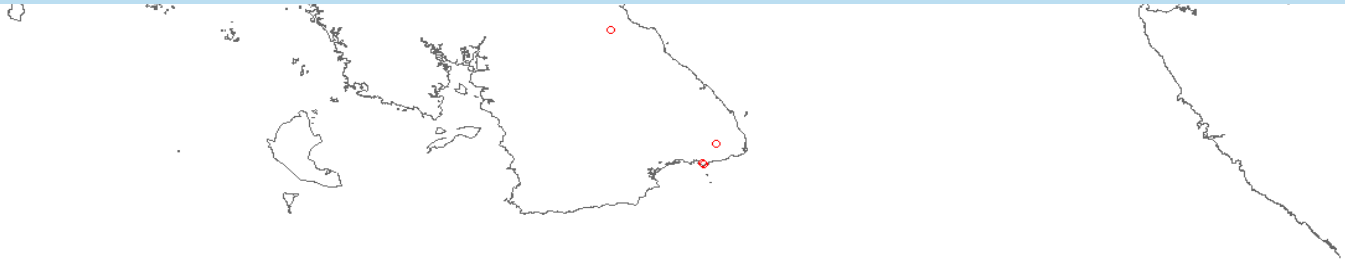
The dry season as driver of forest patterns:

- Most trees reproduce annually, with peaks Mar-Jun
- Leaf flushing tied to seasonal cycle
- Herbivore populations limited by dry season loss of food
- Fruit failures attributed to altered dry season
- Mast events follow ENSO following a weak dry season
- Bird & mammal populations track fruit failures & masts
- 1983 drought had conspicuous effect on ~10% of tree species

Central America and the Caribbean

802107 (R00769) 8-93

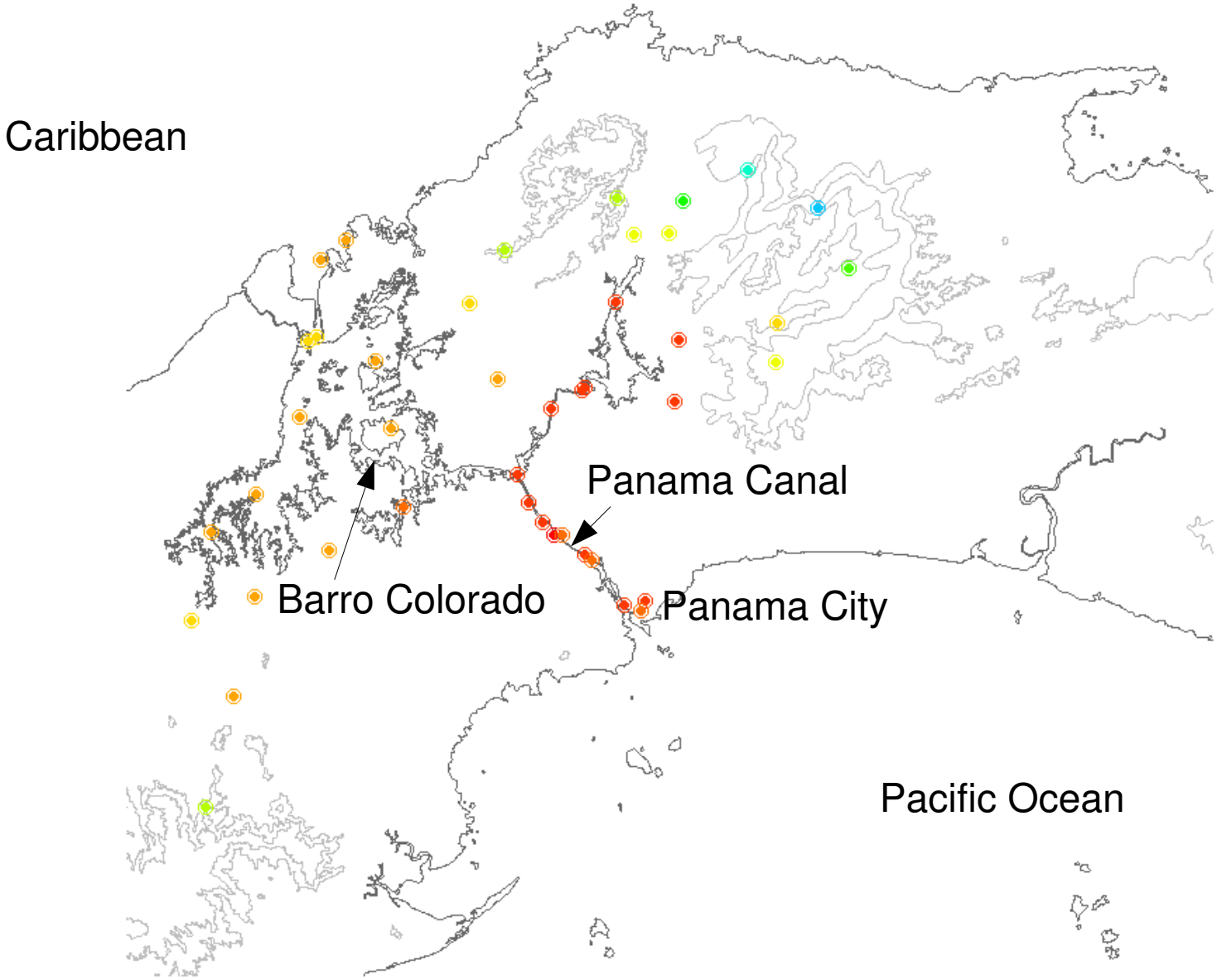




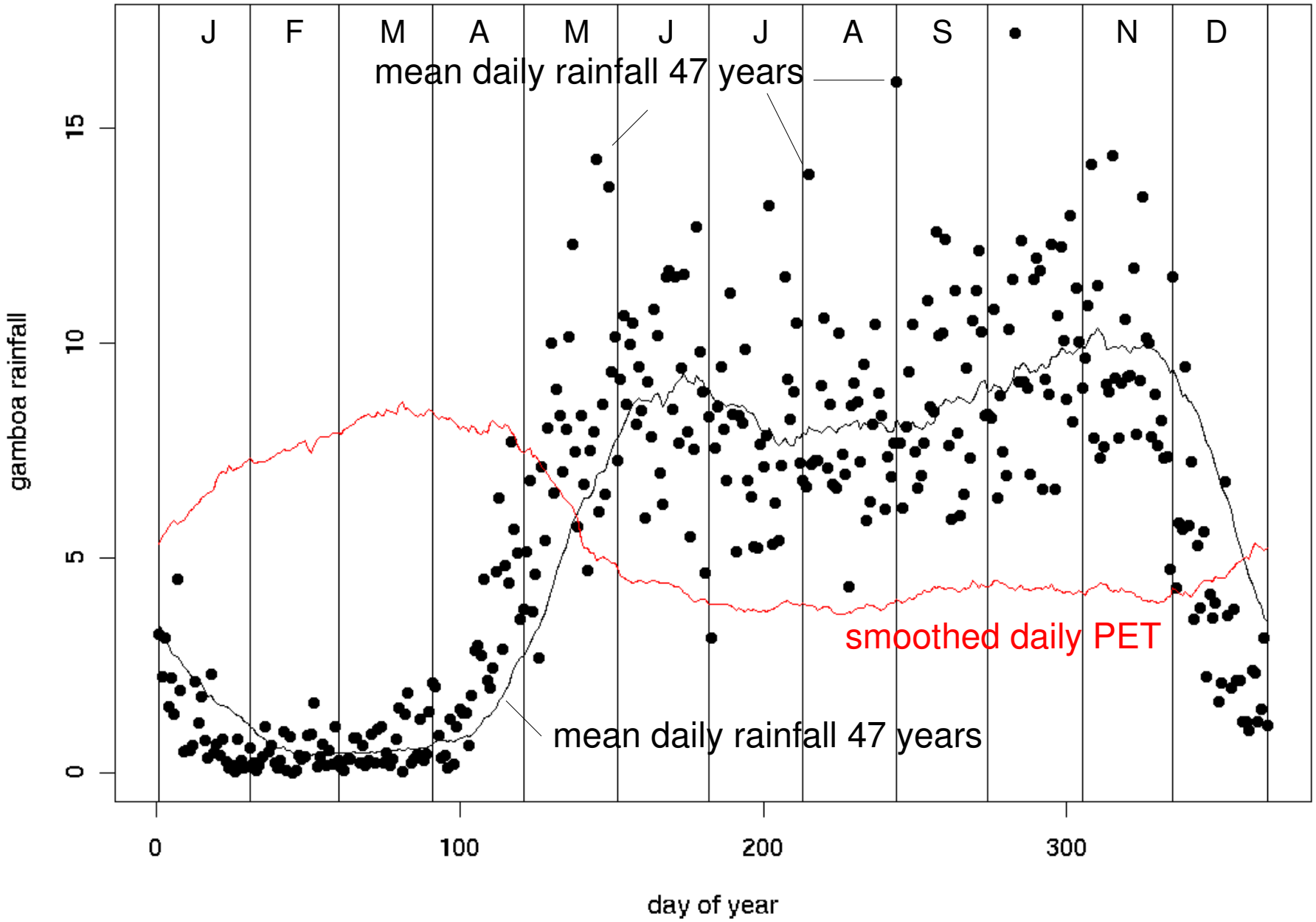
forest cover

Dry season intensity...

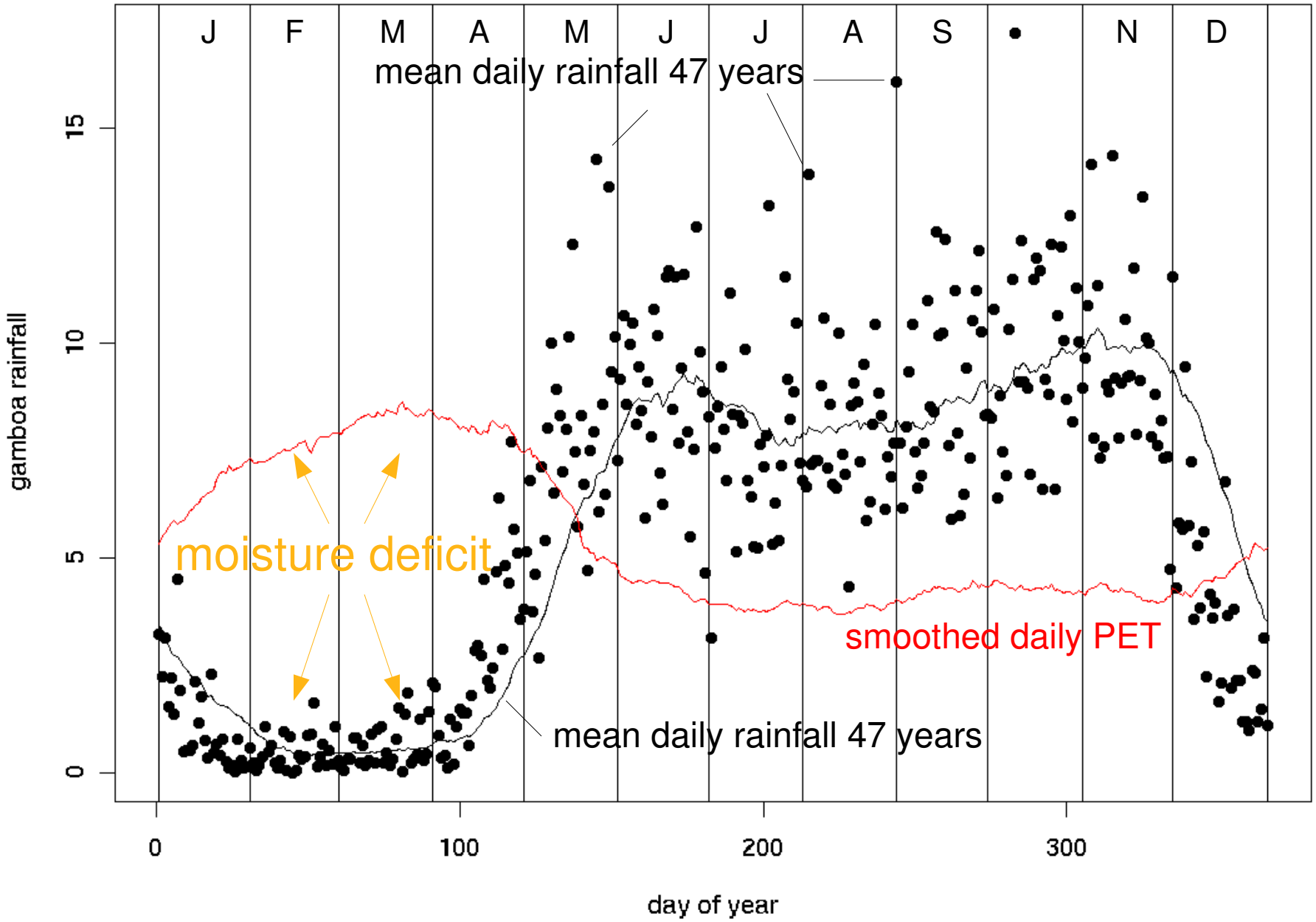
Panama Canal Authority rainfall gauges
3-100 year records

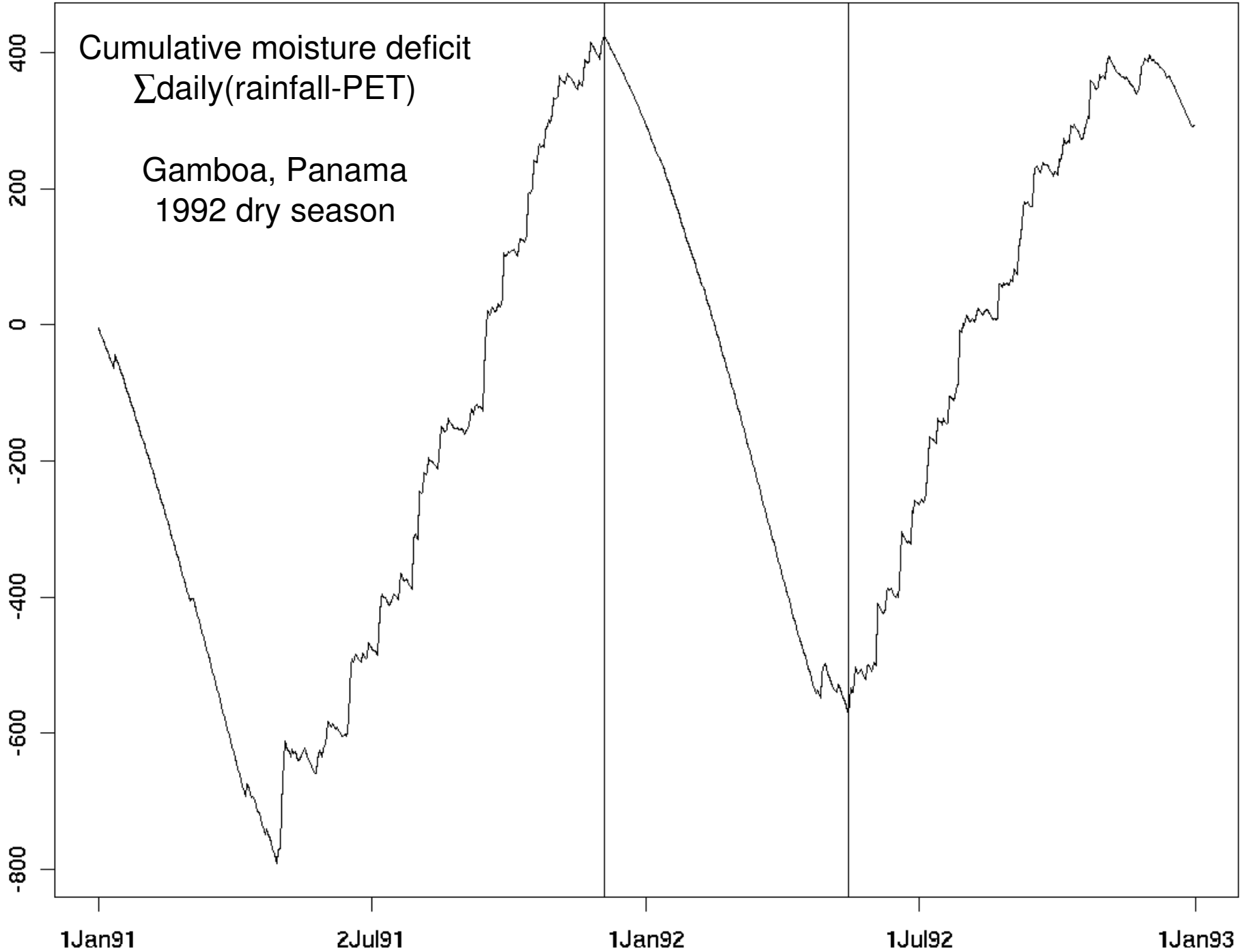


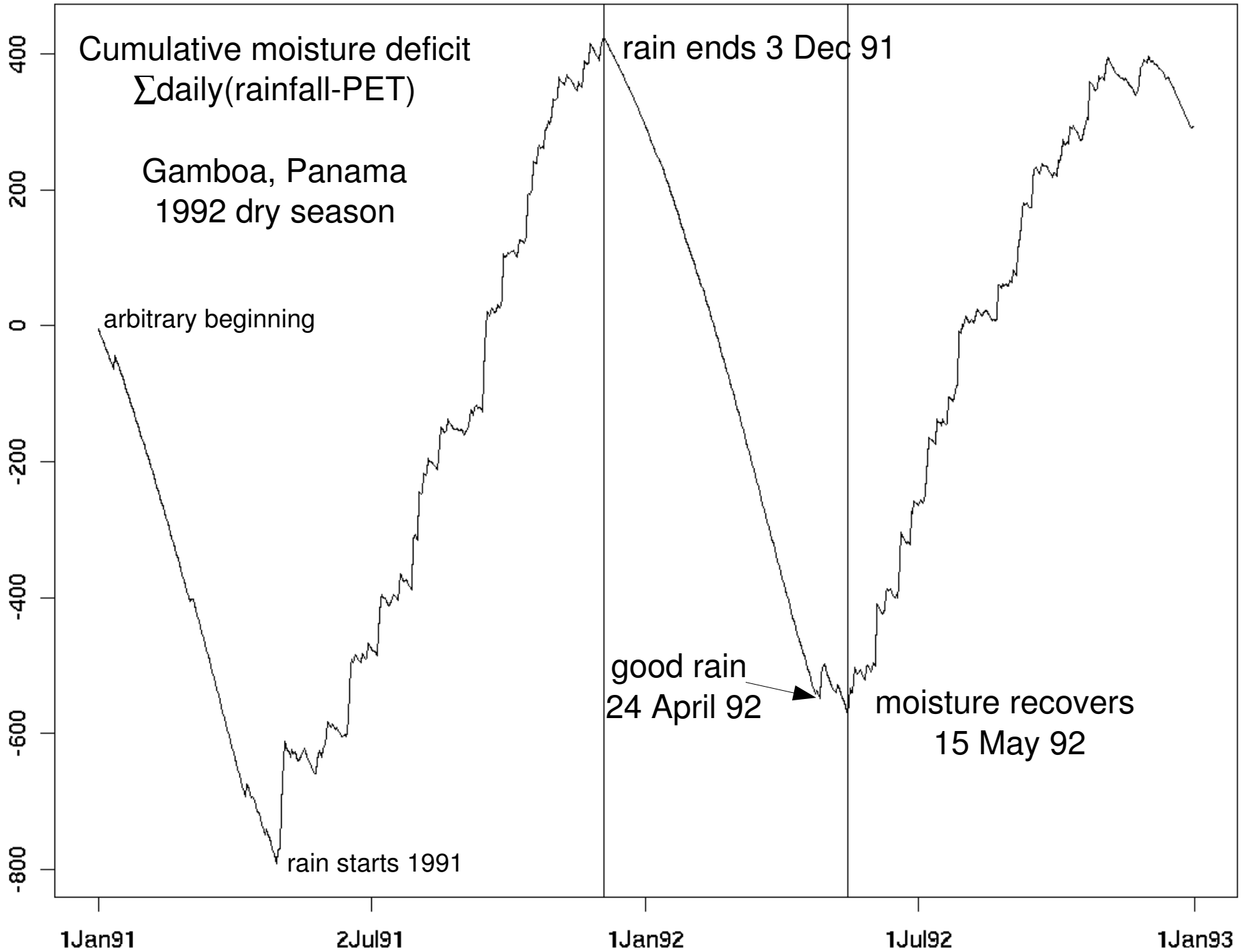
Defining dry season intensity

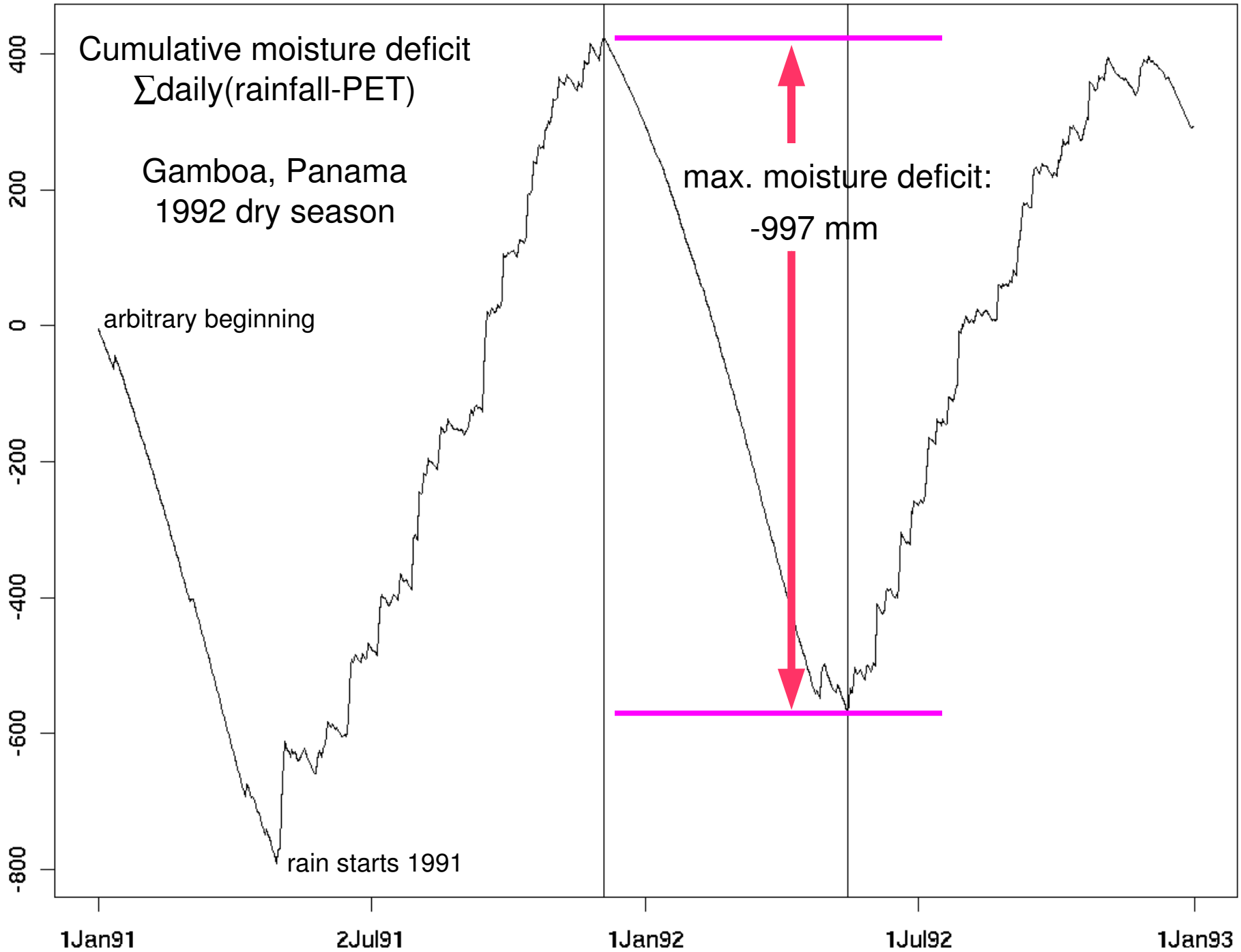


Defining dry season intensity

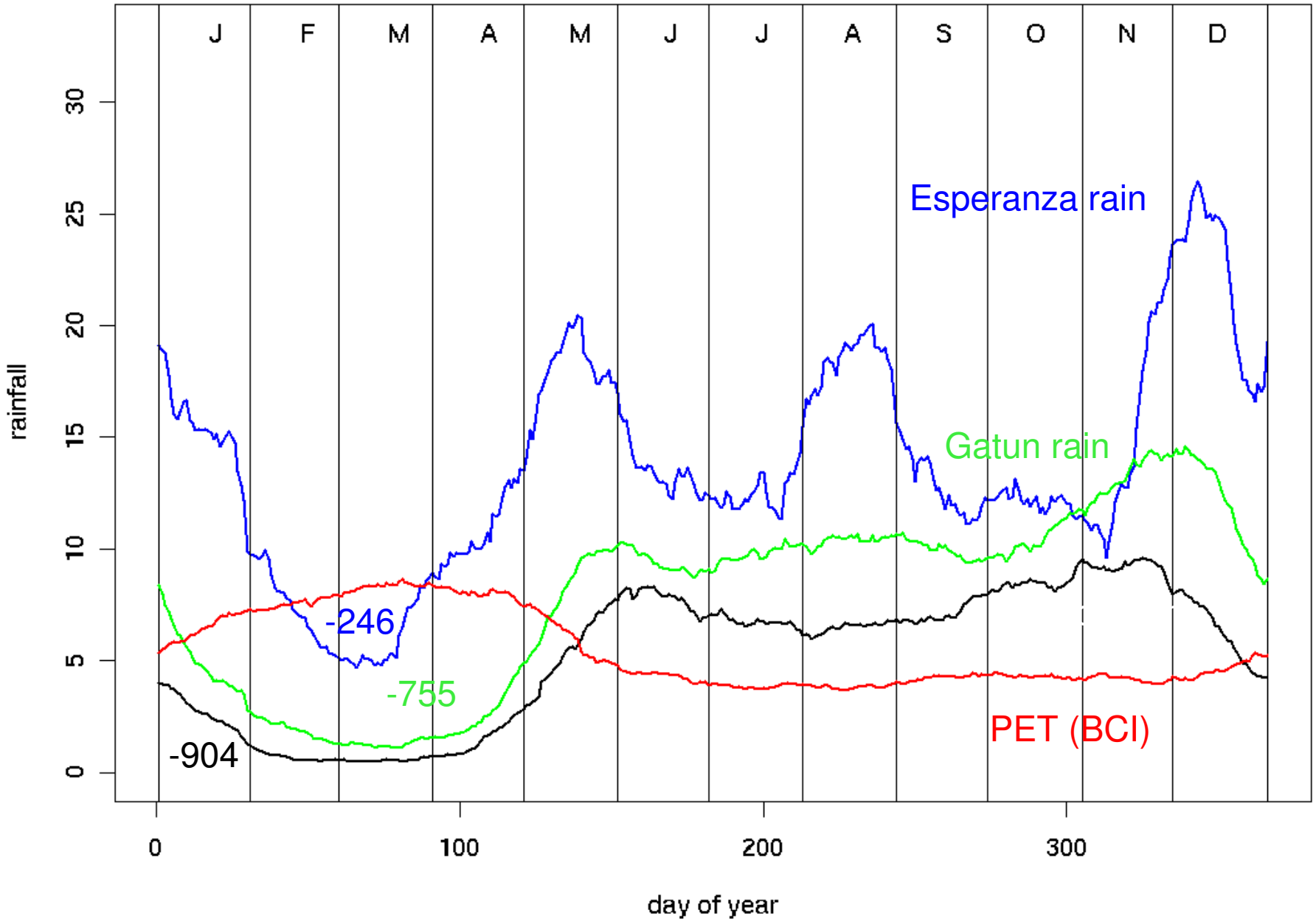



Cumulative moisture deficit
∑daily(rainfall-PET)
Gamboa, Panama
1992 dry season
400
200
0
-200
-400
-600
-800
1Jan91
2Jul91
1Jan92
1Jul92
1Jan93

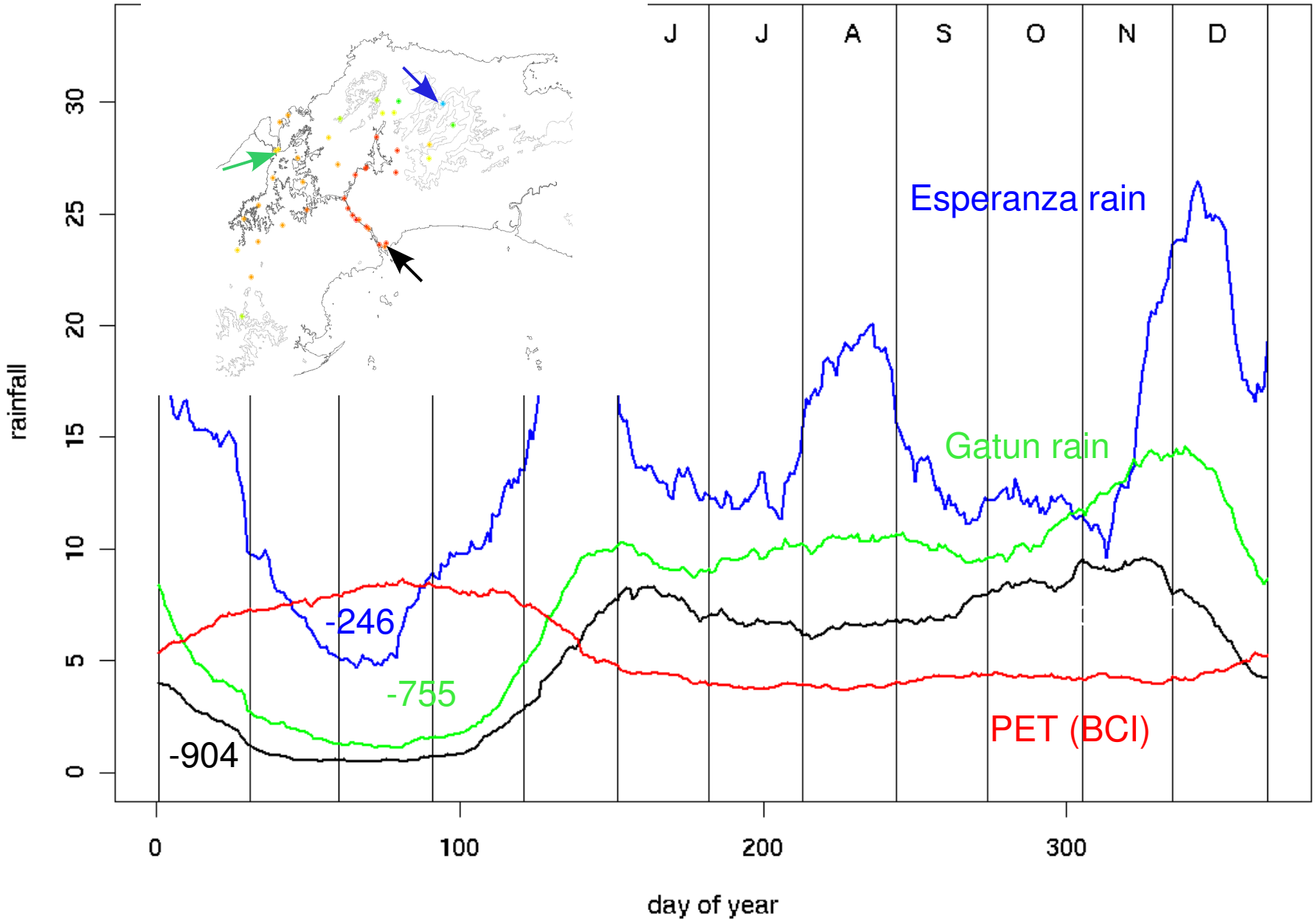

Cumulative moisture deficit
∑daily(rainfall-PET)
Gamboa, Panama
1992 dry season
arbitrary beginning
rain starts 1991
rain ends 3 Dec 91
good rain
24 April 92
moisture recovers
15 May 92
400
200
0
-200
-400
-600
-800
1Jan91
2Jul91
1Jan92
1Jul92
1Jan93

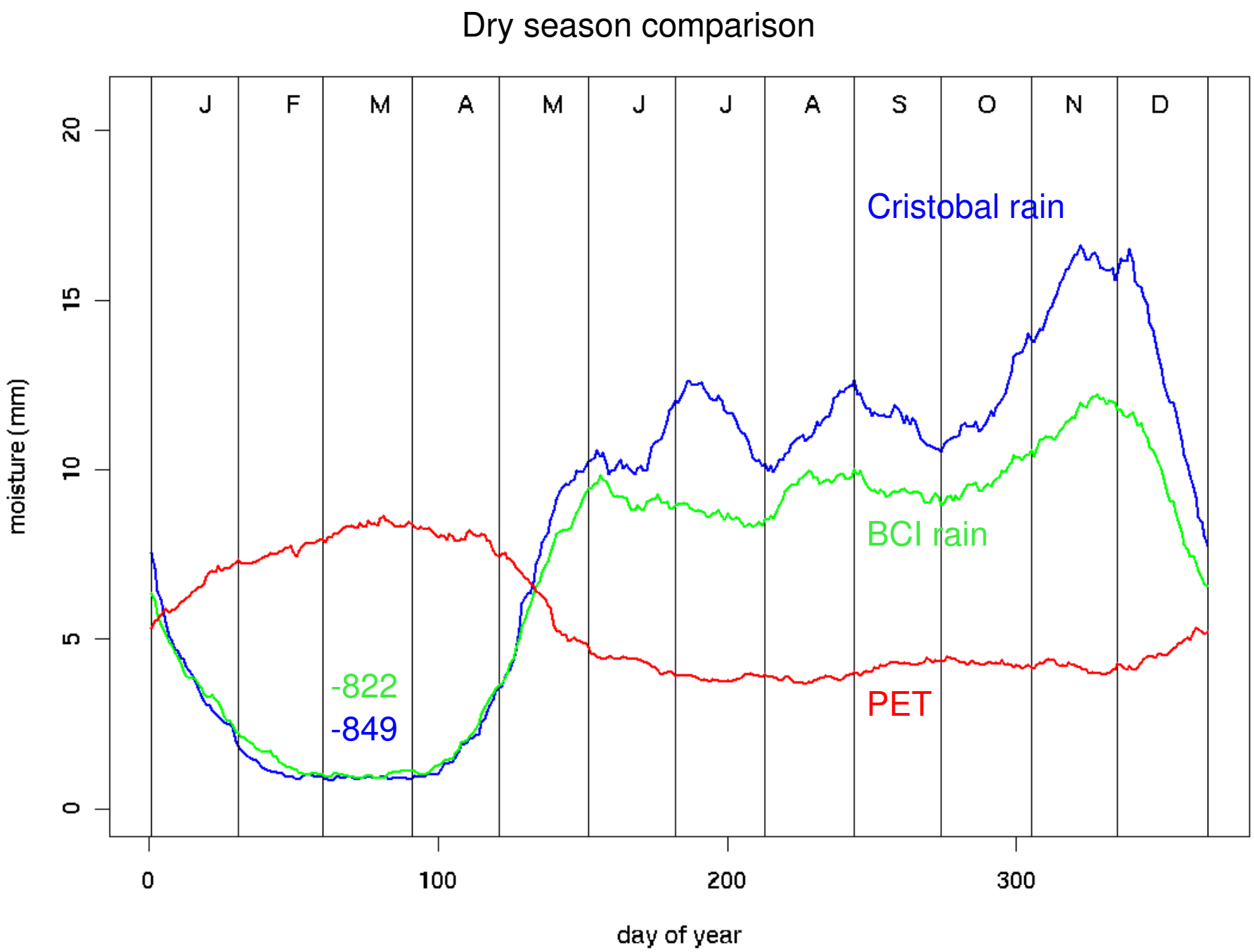

Cumulative moisture deficit
∑daily(rainfall-PET)
Gamboa, Panama
1992 dry season
arbitrary beginning
rain starts 1991
max. moisture deficit:
-997 mm
400
200
0
-200
-400
-600
-800
1Jan91
2Jul91
1Jan92
1Jul92
1Jan93

Dry season comparison

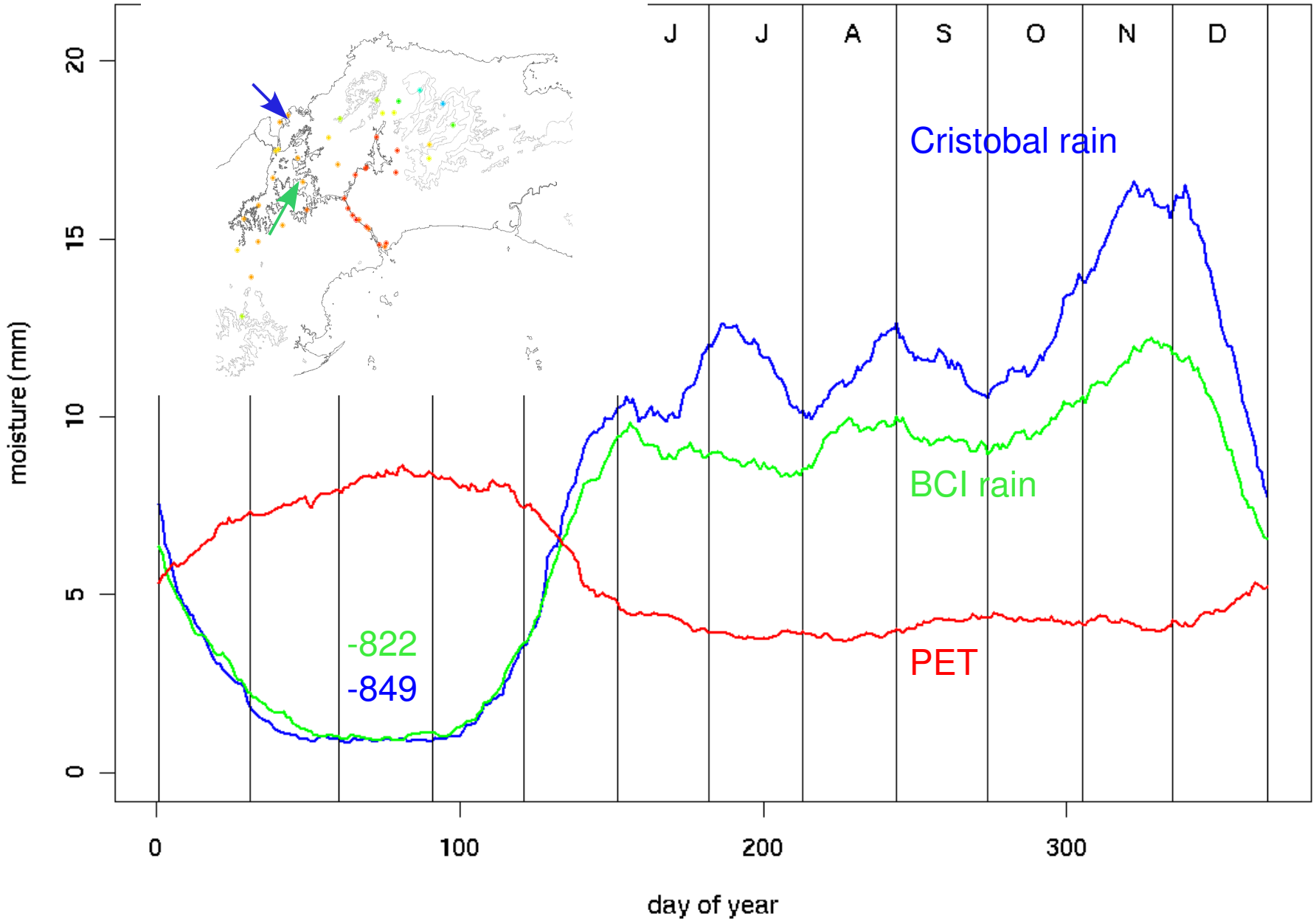


Dry season comparison

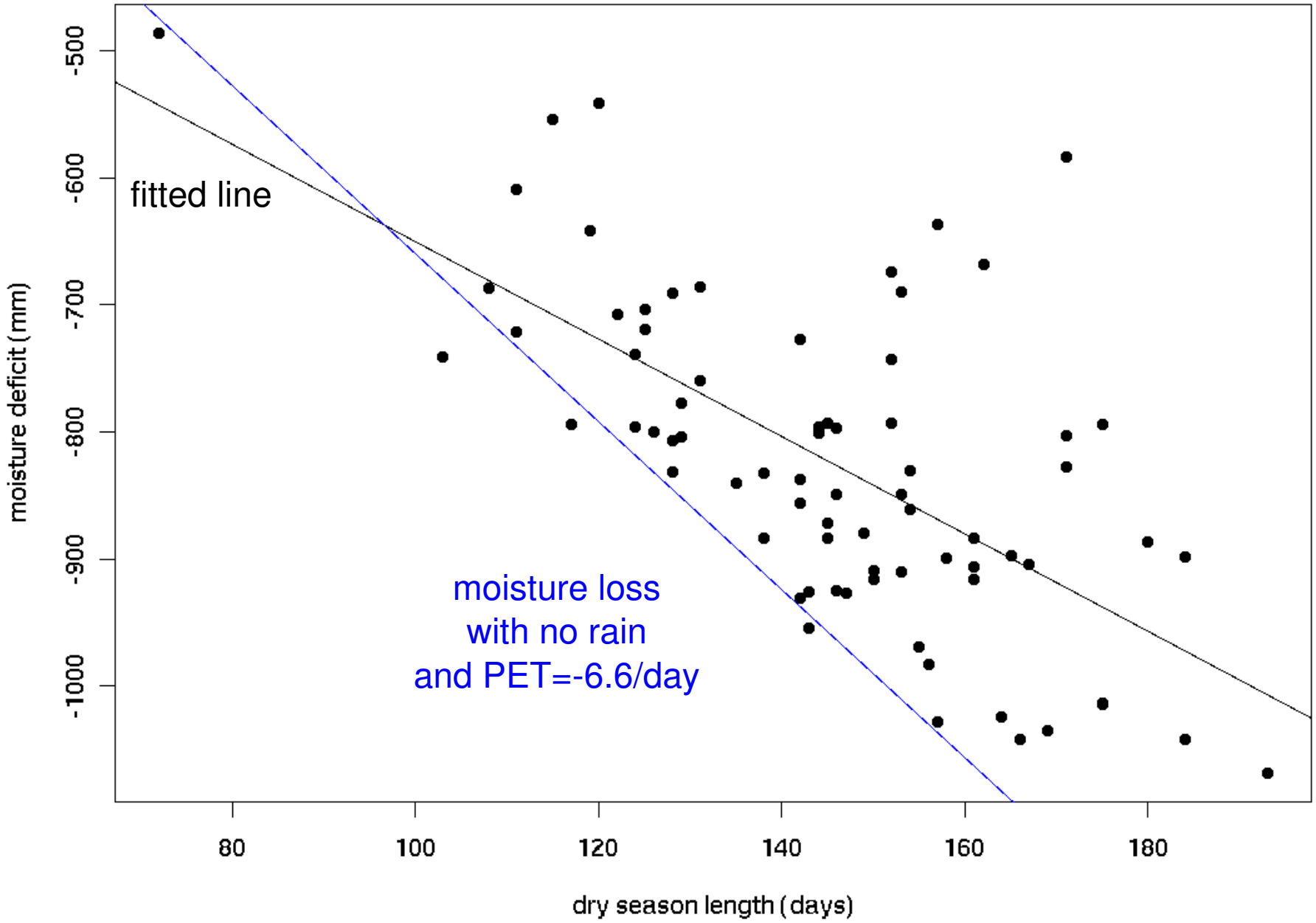



Dry season comparison
J
F
M
A
M
J
J
A
S
O
N
D
Cristobal rain
BCI rain
PET
-822
-849
moisture (mm)
0
5
10
15
20
0
100
200
300
day of year

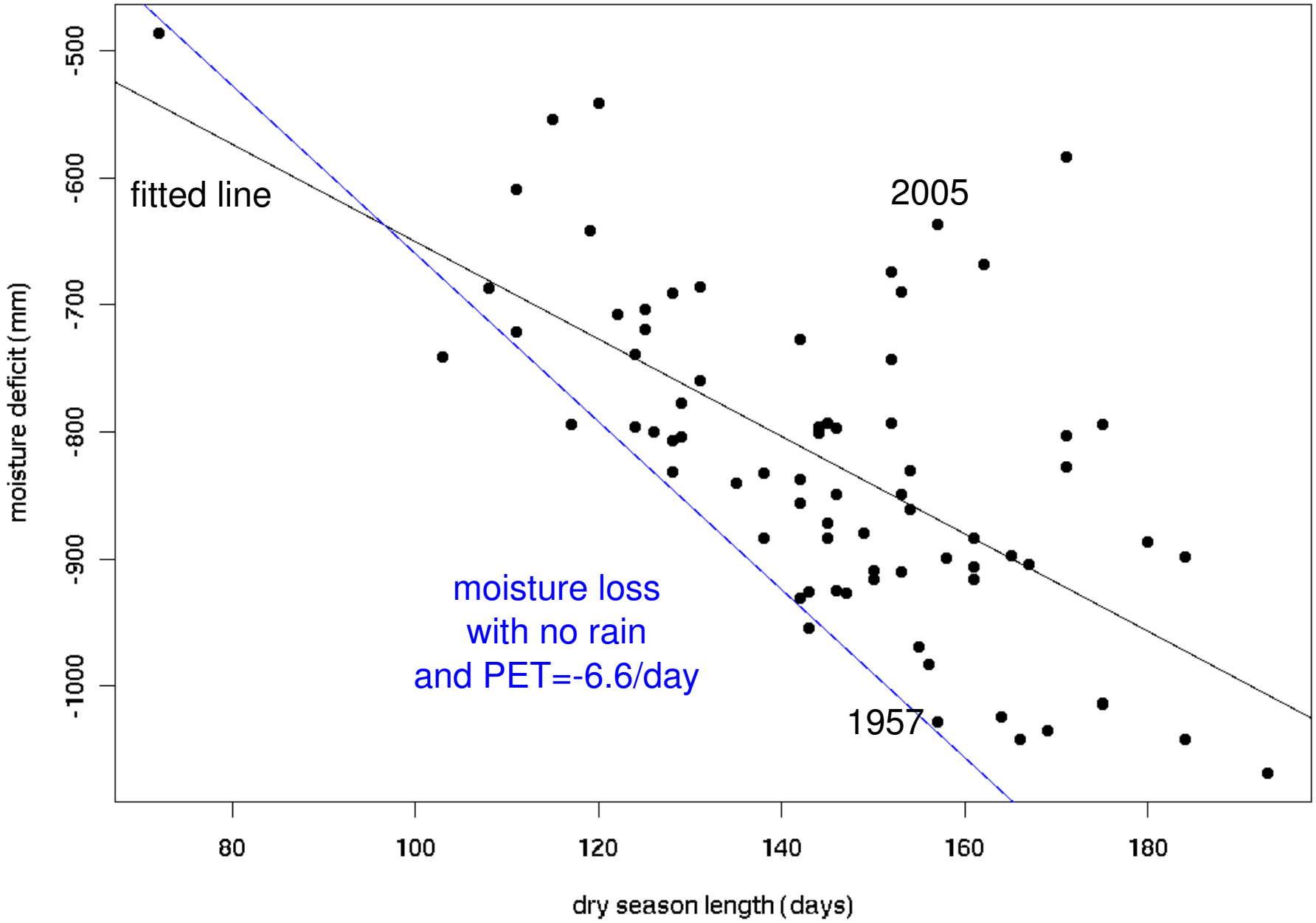
Dry season comparison



Dry season duration (days) & dry season intensity (moisture deficit)
BCI 1931-2006

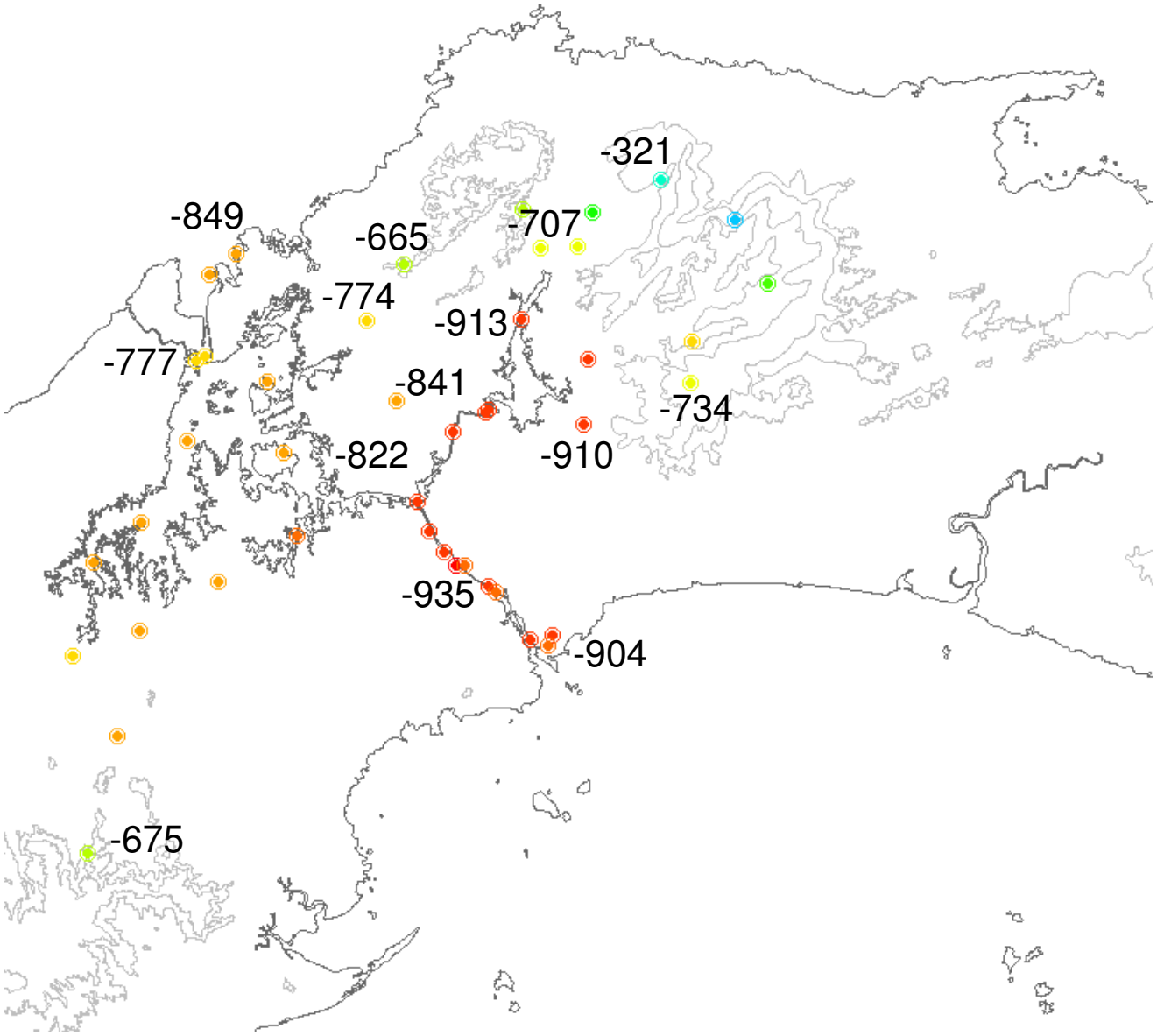


Dry season duration (days) & dry season intensity (moisture deficit)
BCI 1931-2006

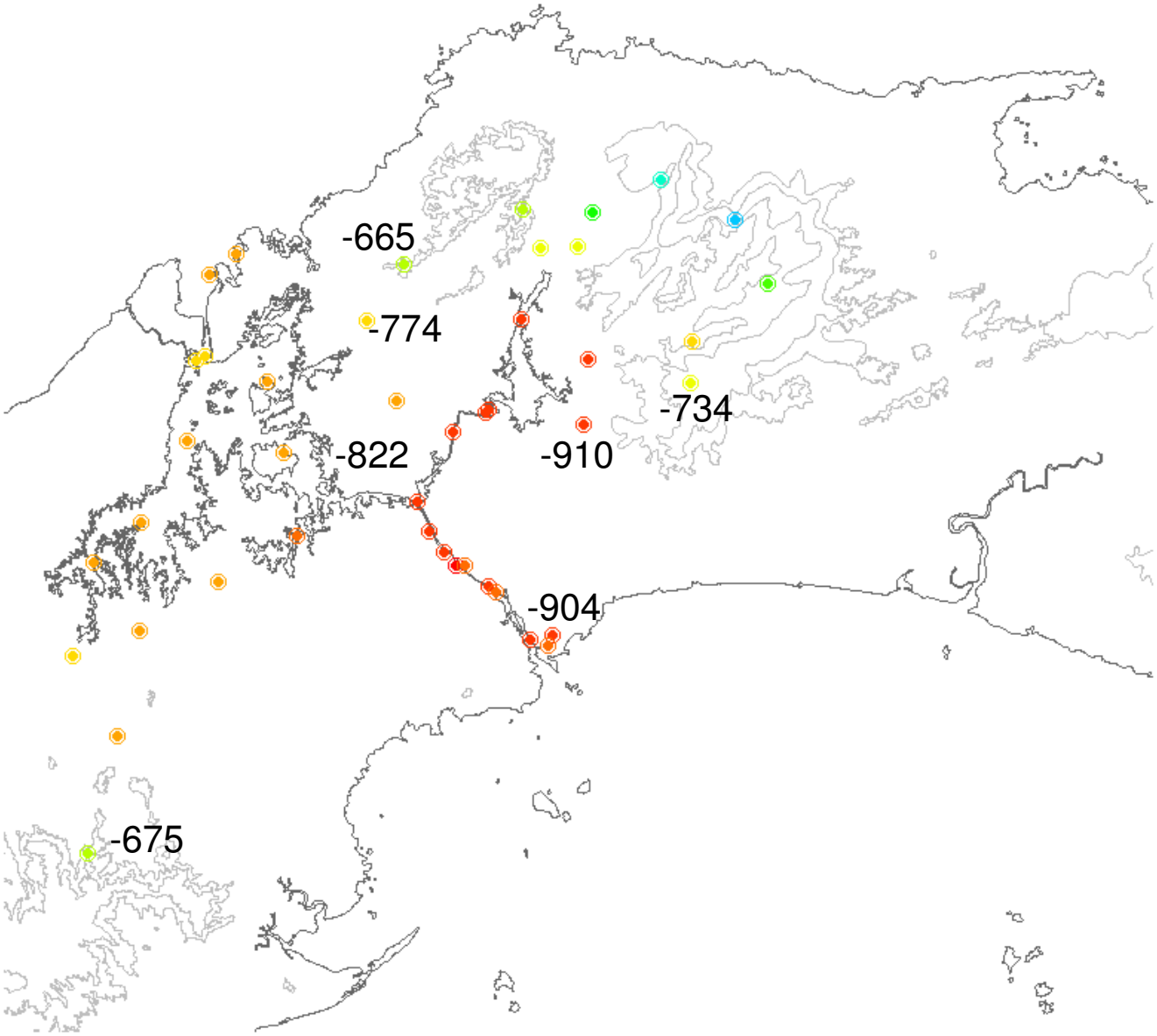


dry season length vs. moisture deficit

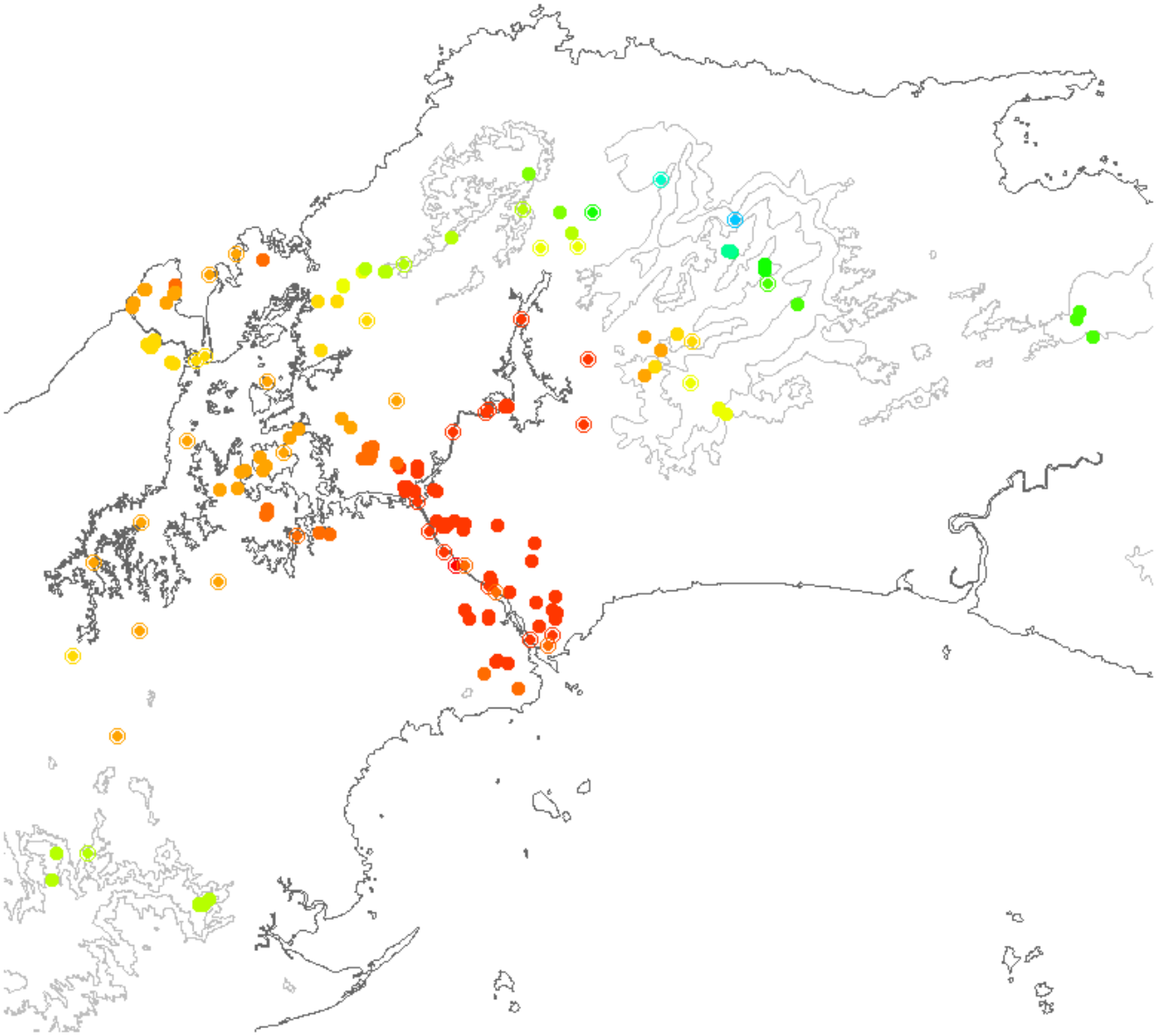
Panama Canal Authority rainfall gauges
Dry season intensity



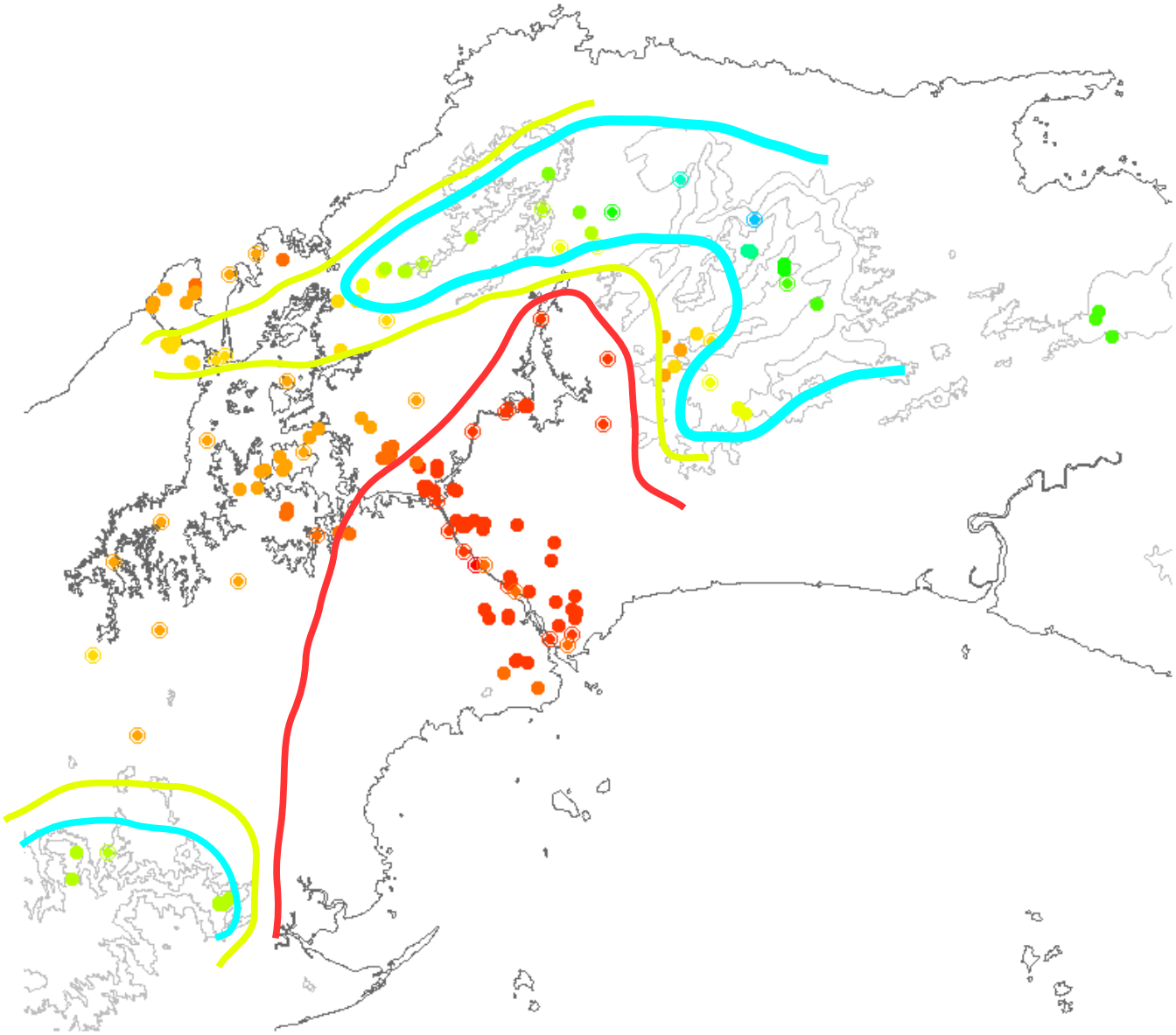
Panama Canal Authority rainfall gauges
Dry season intensity



Tree inventories
Estimated dry season intensity at each



Tree inventories
Estimated dry season intensity at each

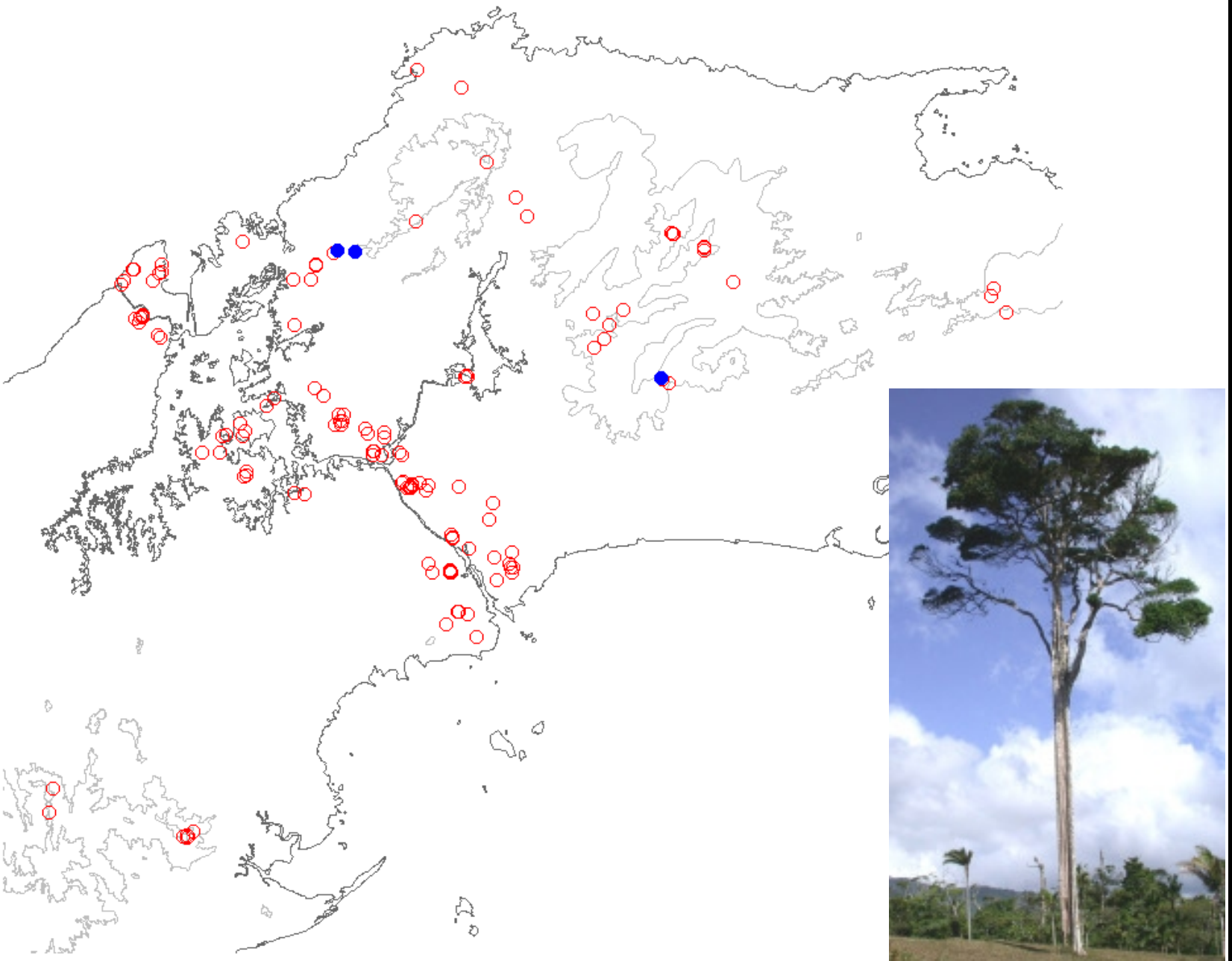


Tree distributions across the gradient in drought

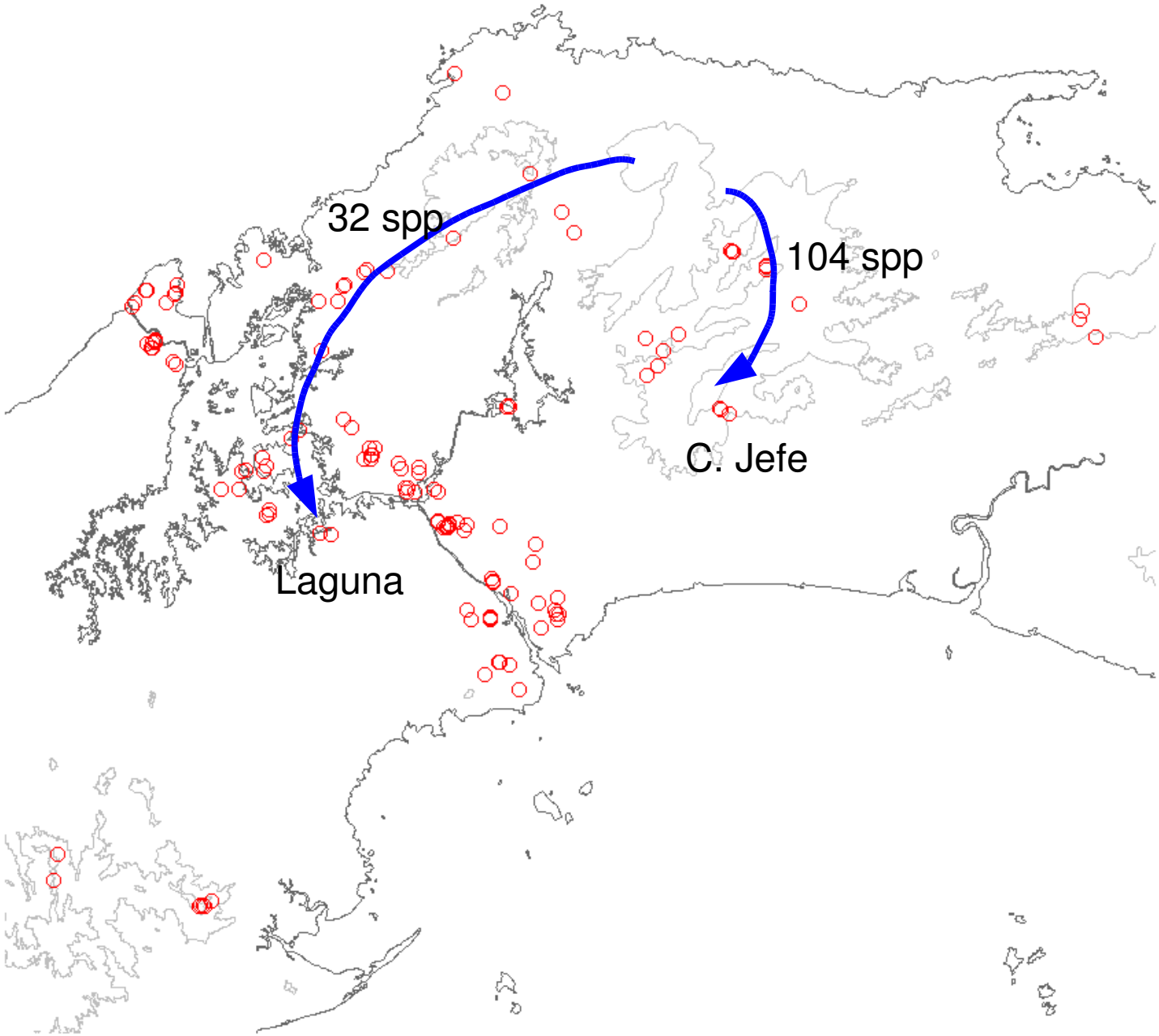
Faramea occidentalis plots and inventories

87 Pacific species reach C. Campana
but not the very wet sites

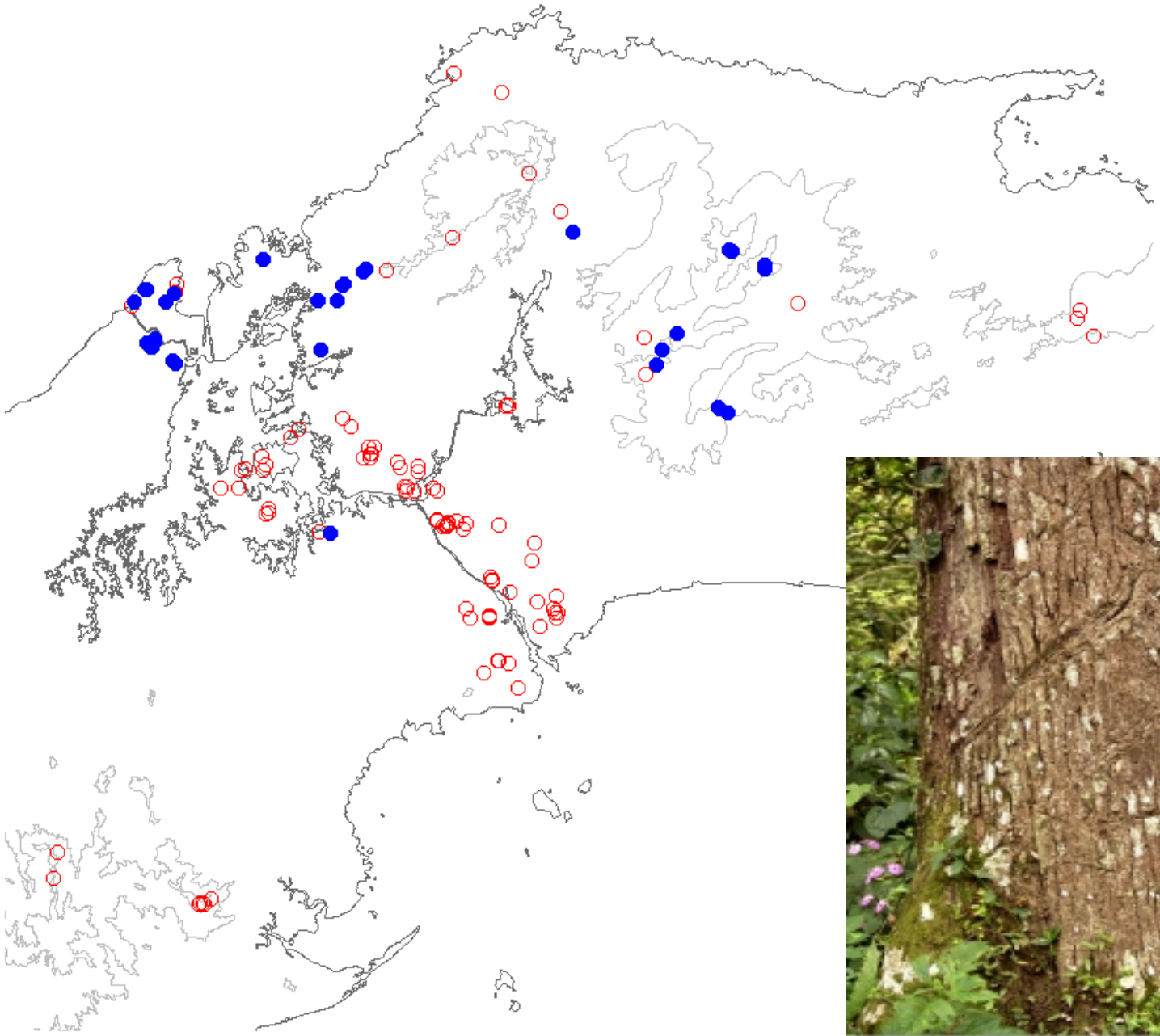
Lecointea amazonica plots and inventories



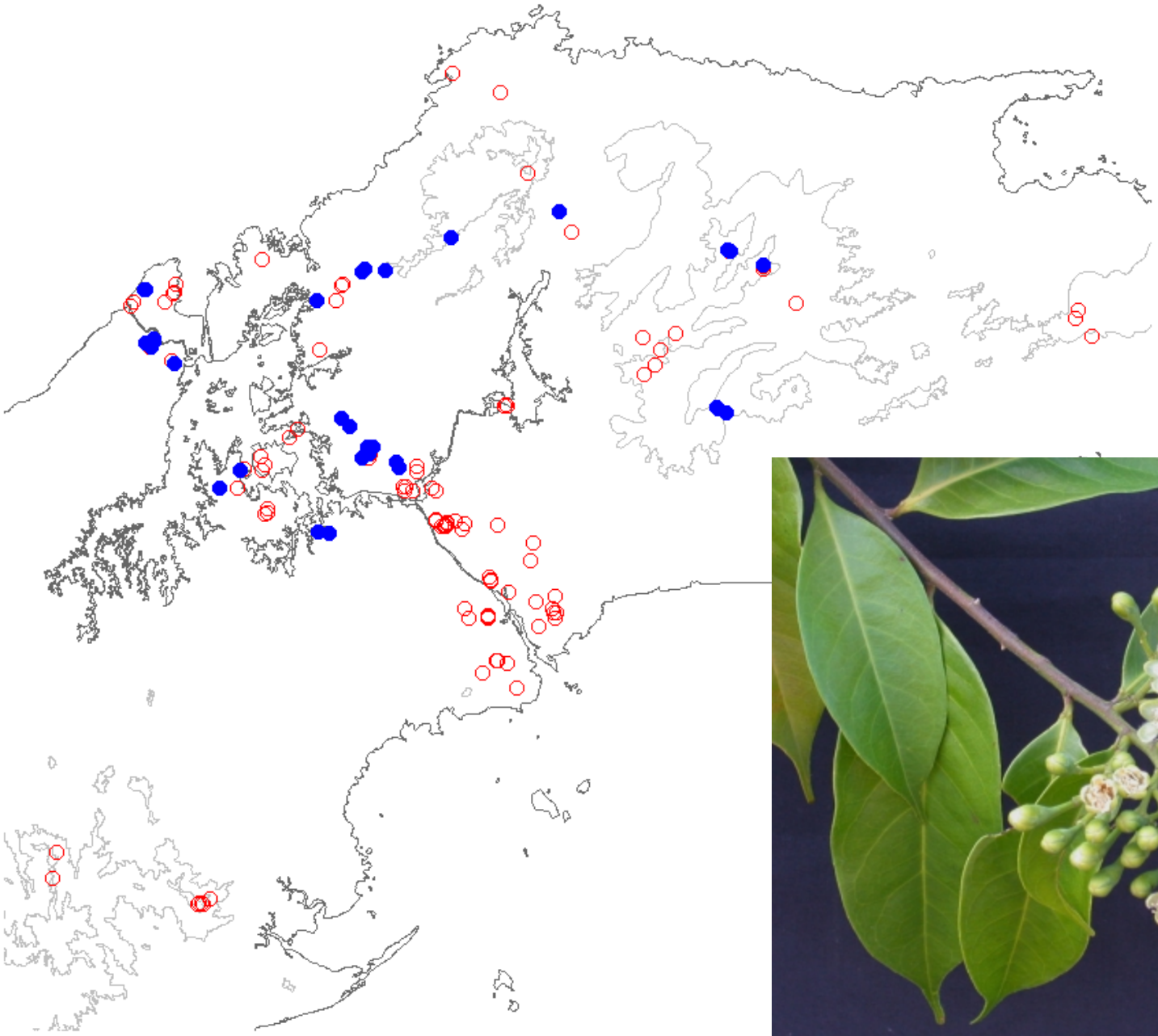
Frequent climatic limits of wet forest species



Manilkara bidentata plots and inventories

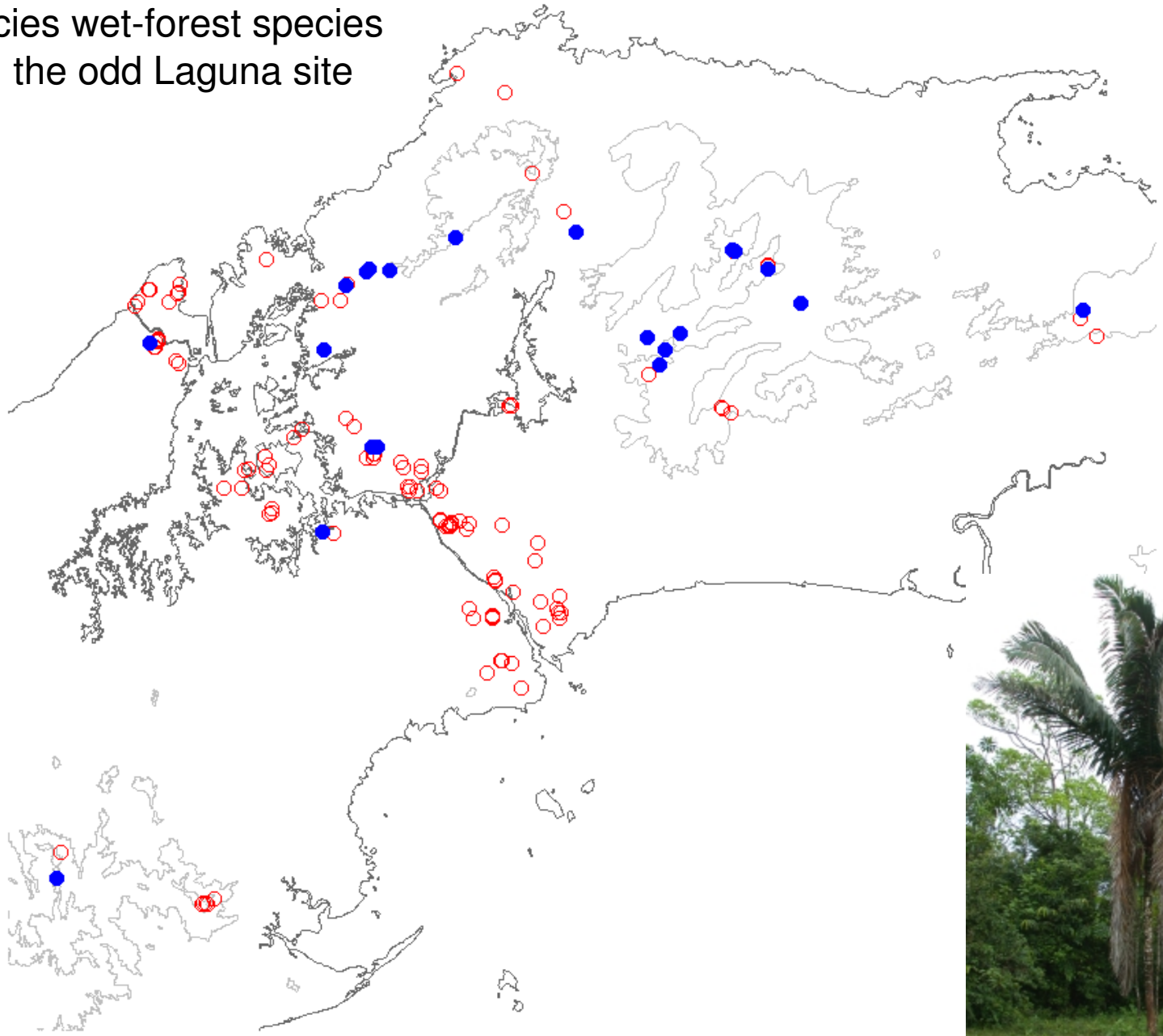


Maranthes panamensis plots and inventories

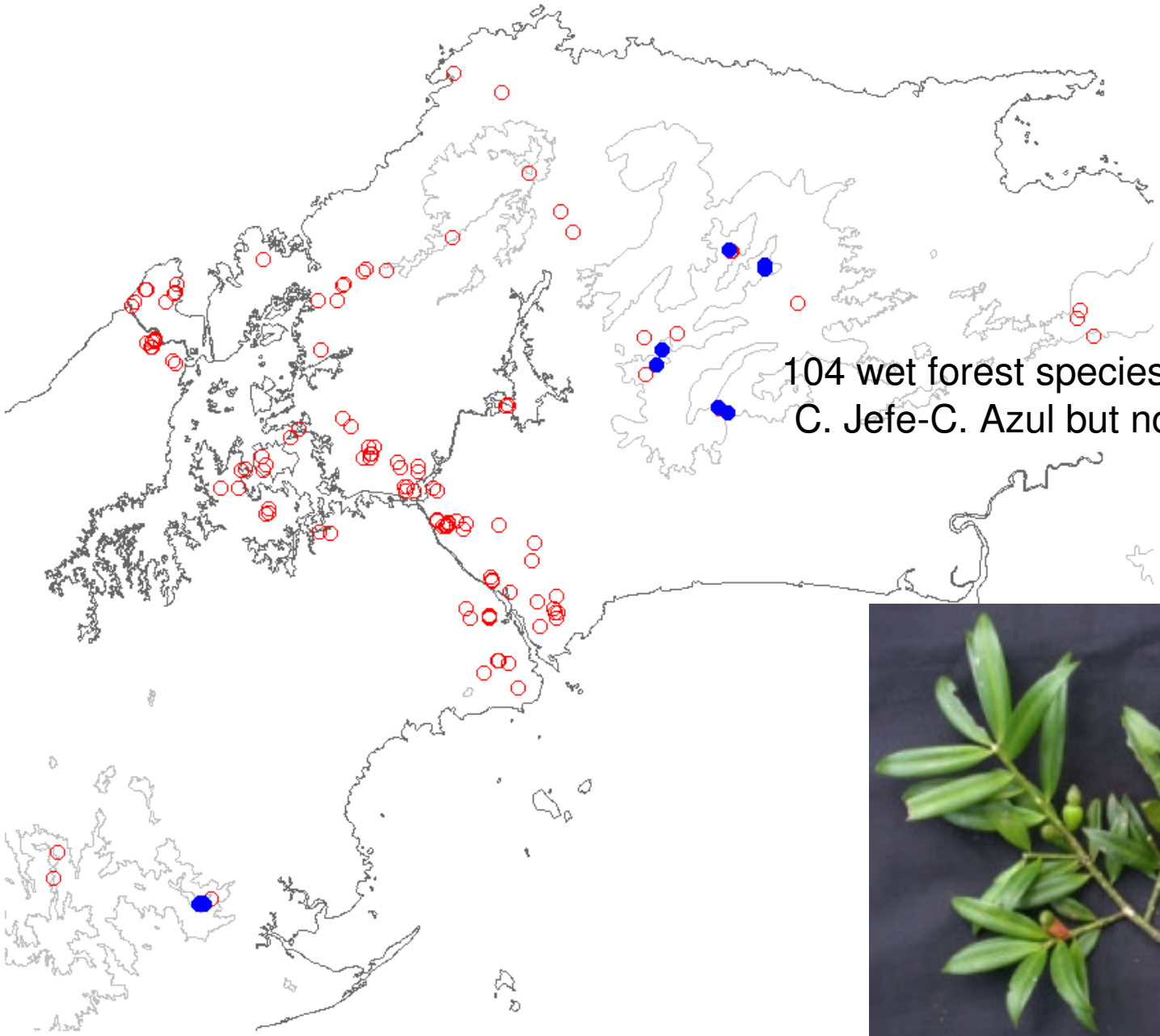


Welfia regia plots and inventories

32 species wet-forest species reach the odd Laguna site

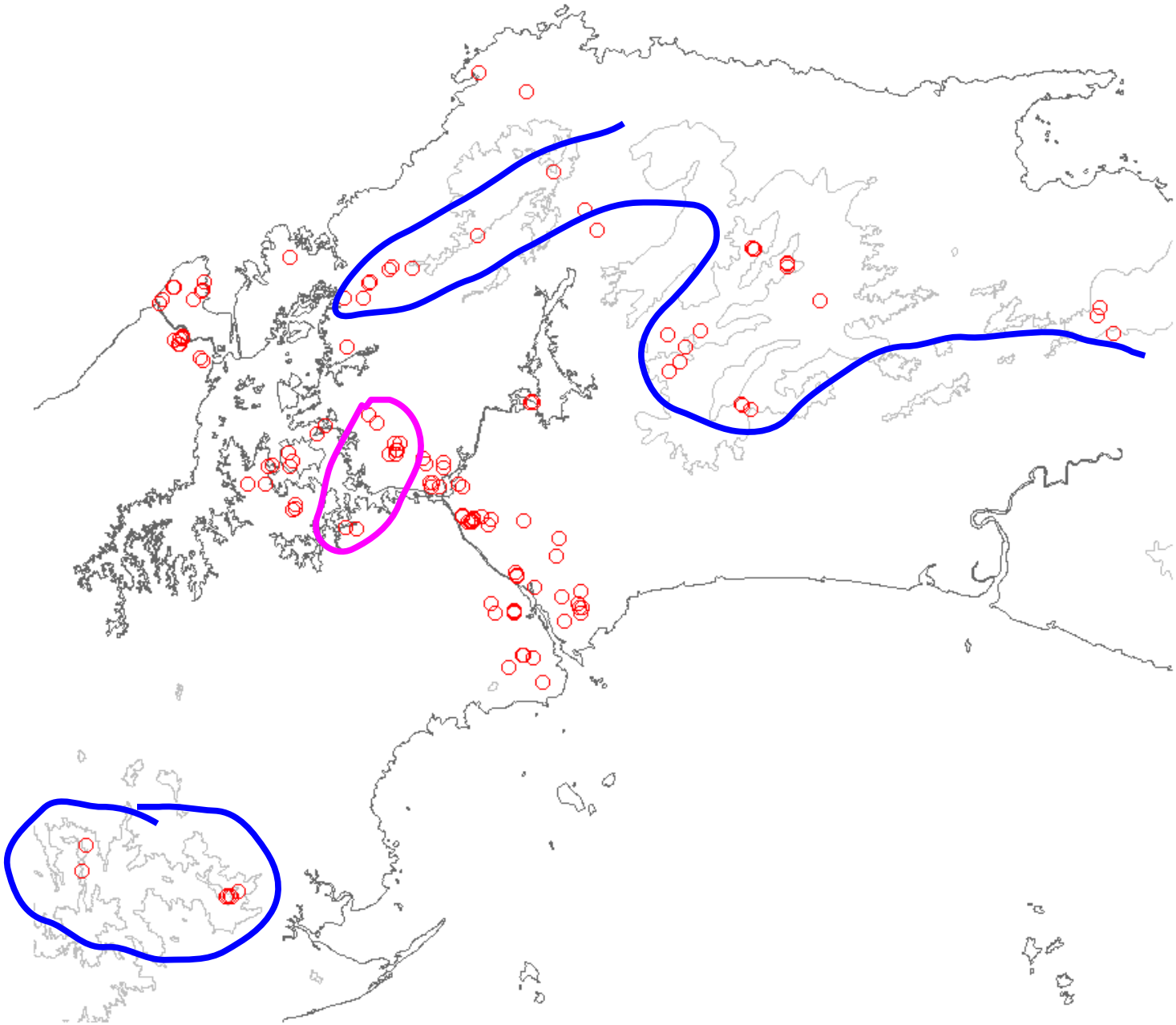


Podocarpus guatemalensis plots and inventories

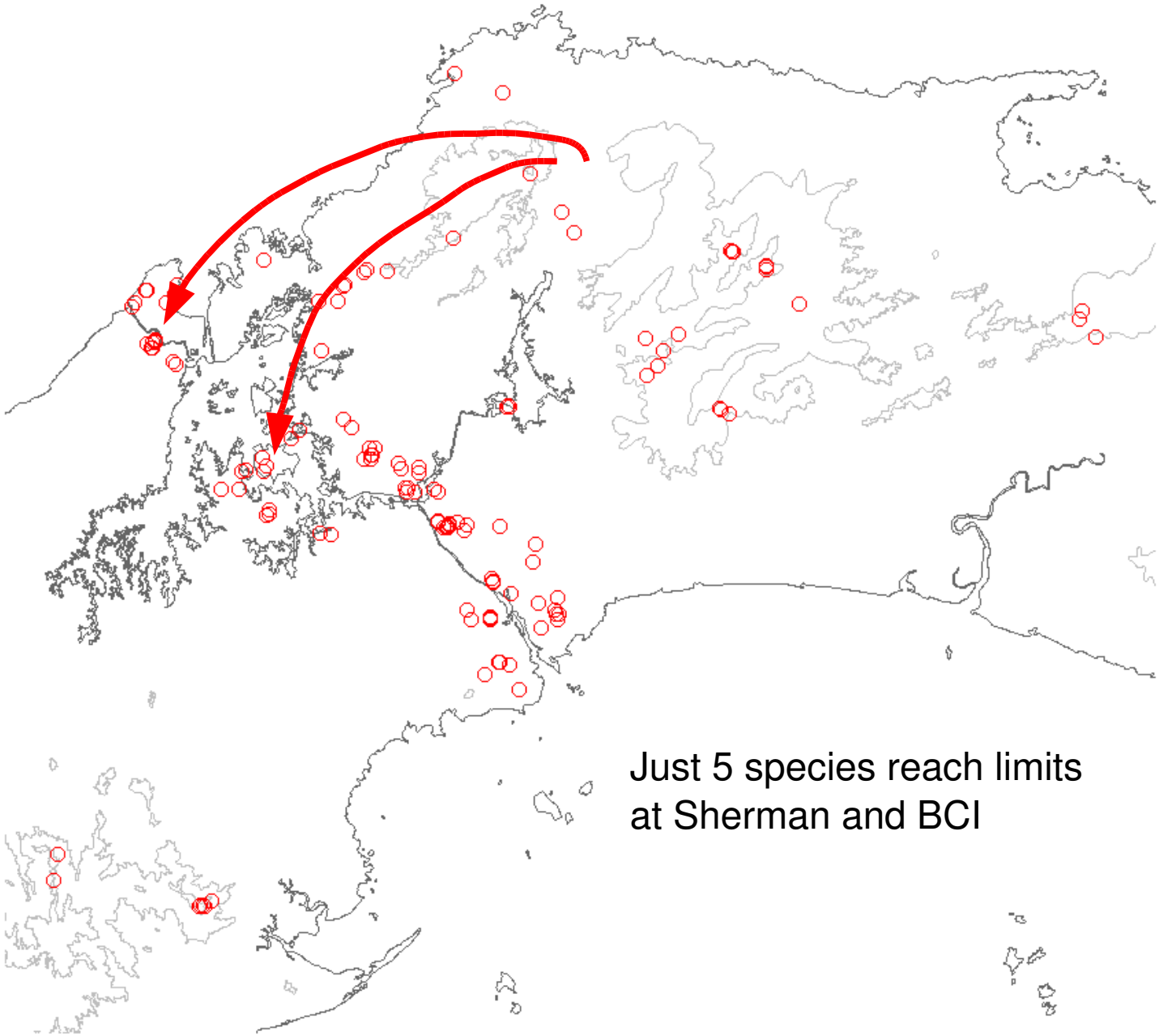


104 wet forest species reach C. Jefe-C. Azul but no drier

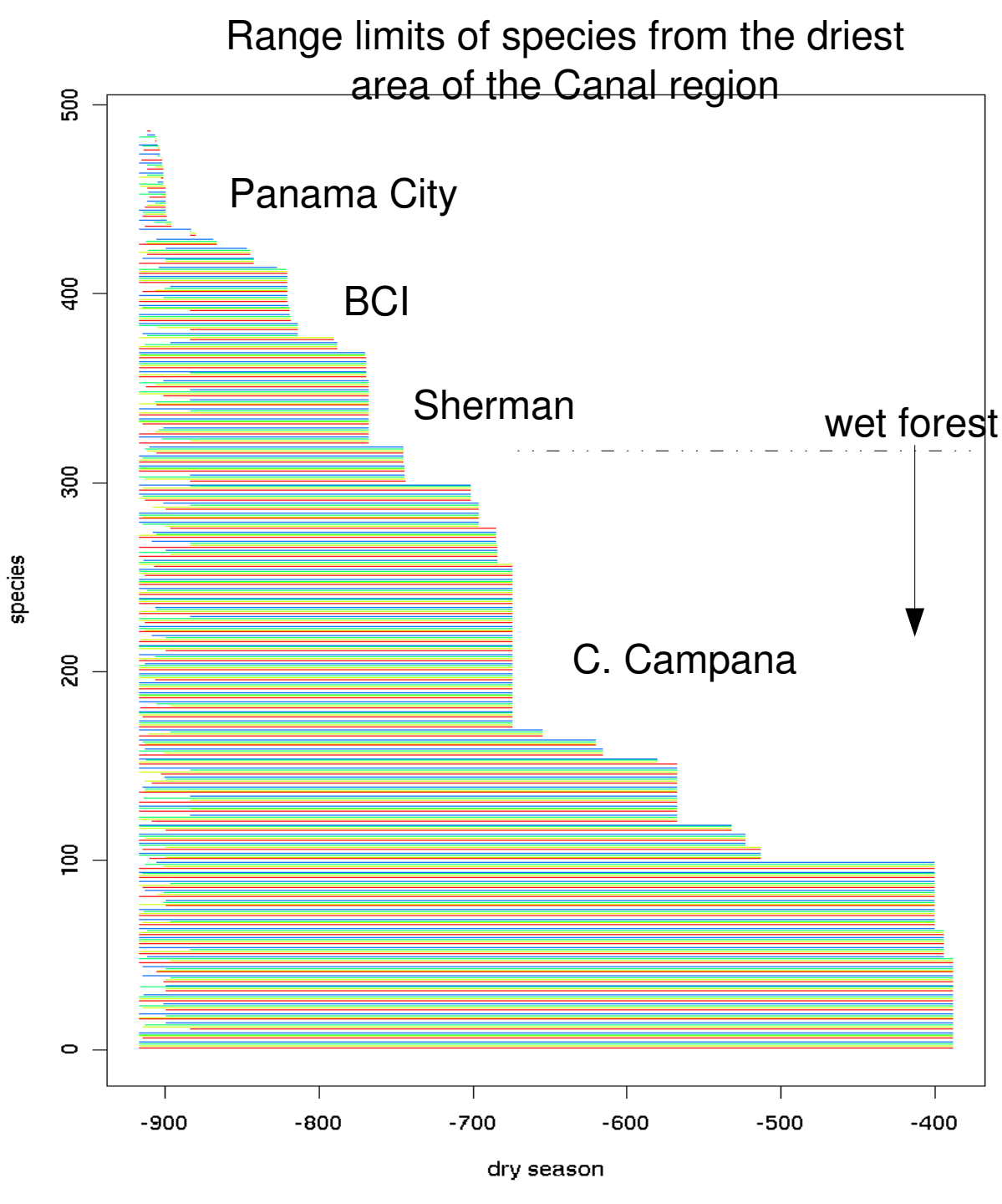
Frequent climatic limits of wet forest species

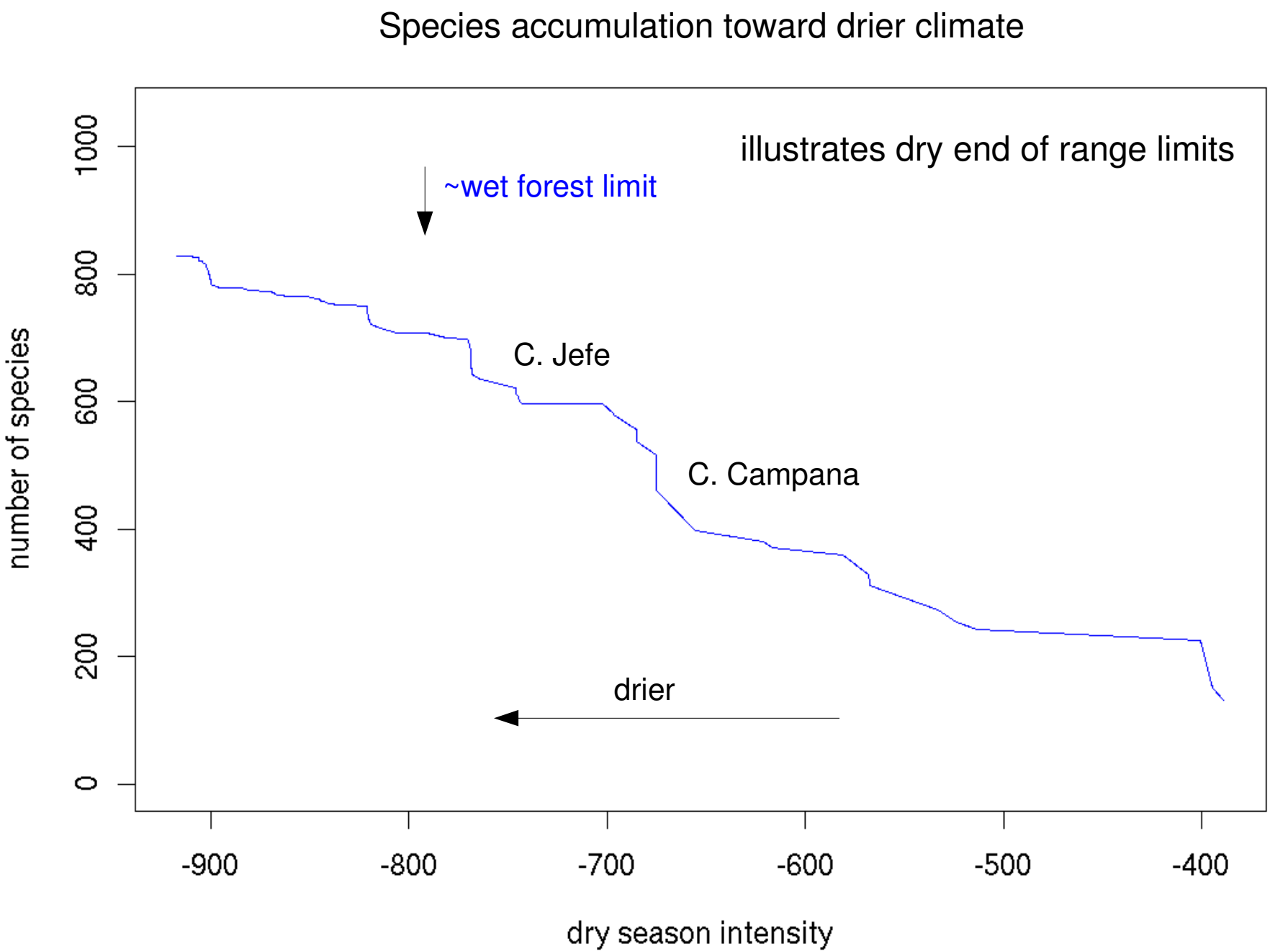


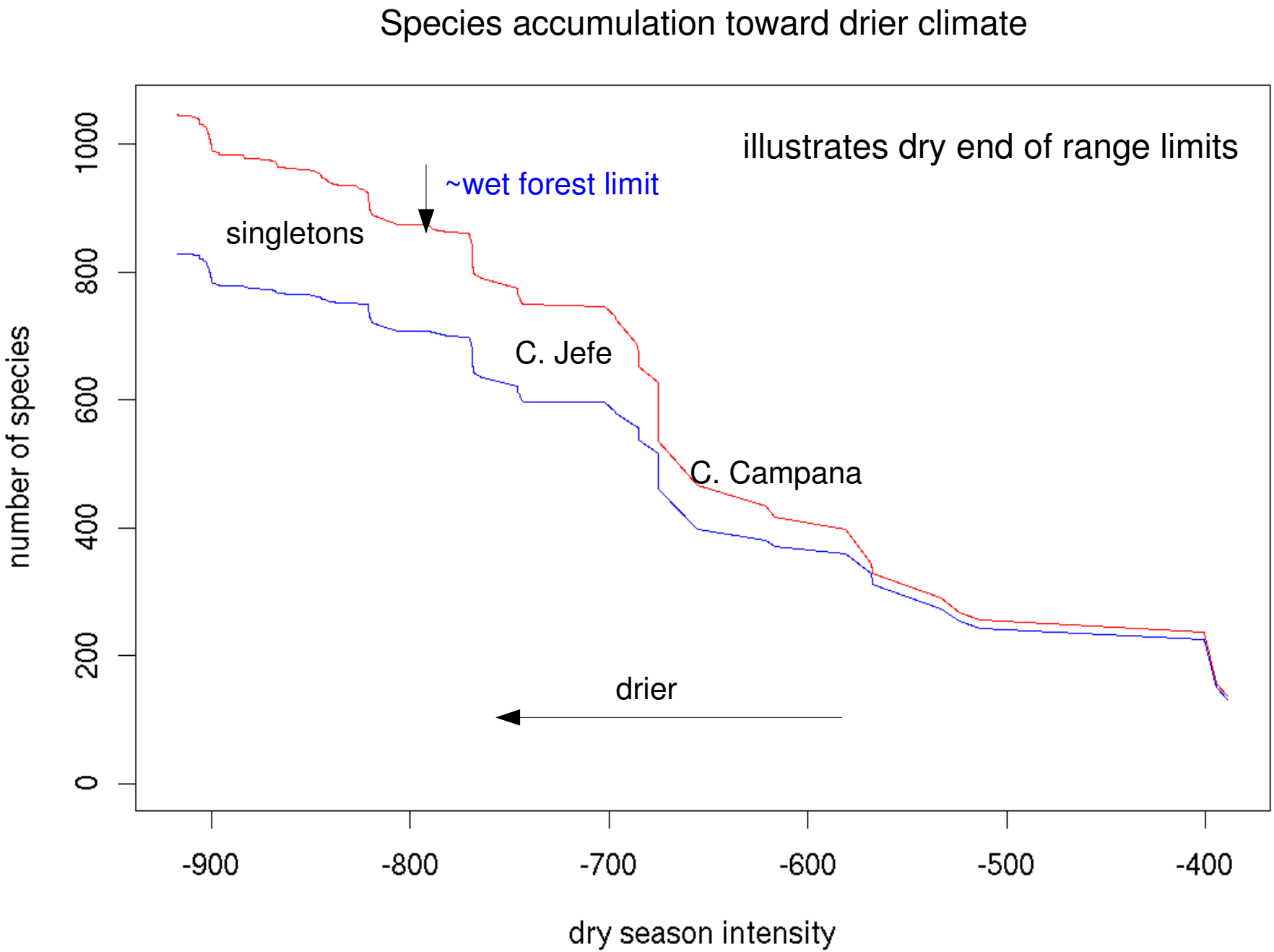
Unusual climatic limits of wet forest species



Just 5 species reach limits
at Sherman and BCI

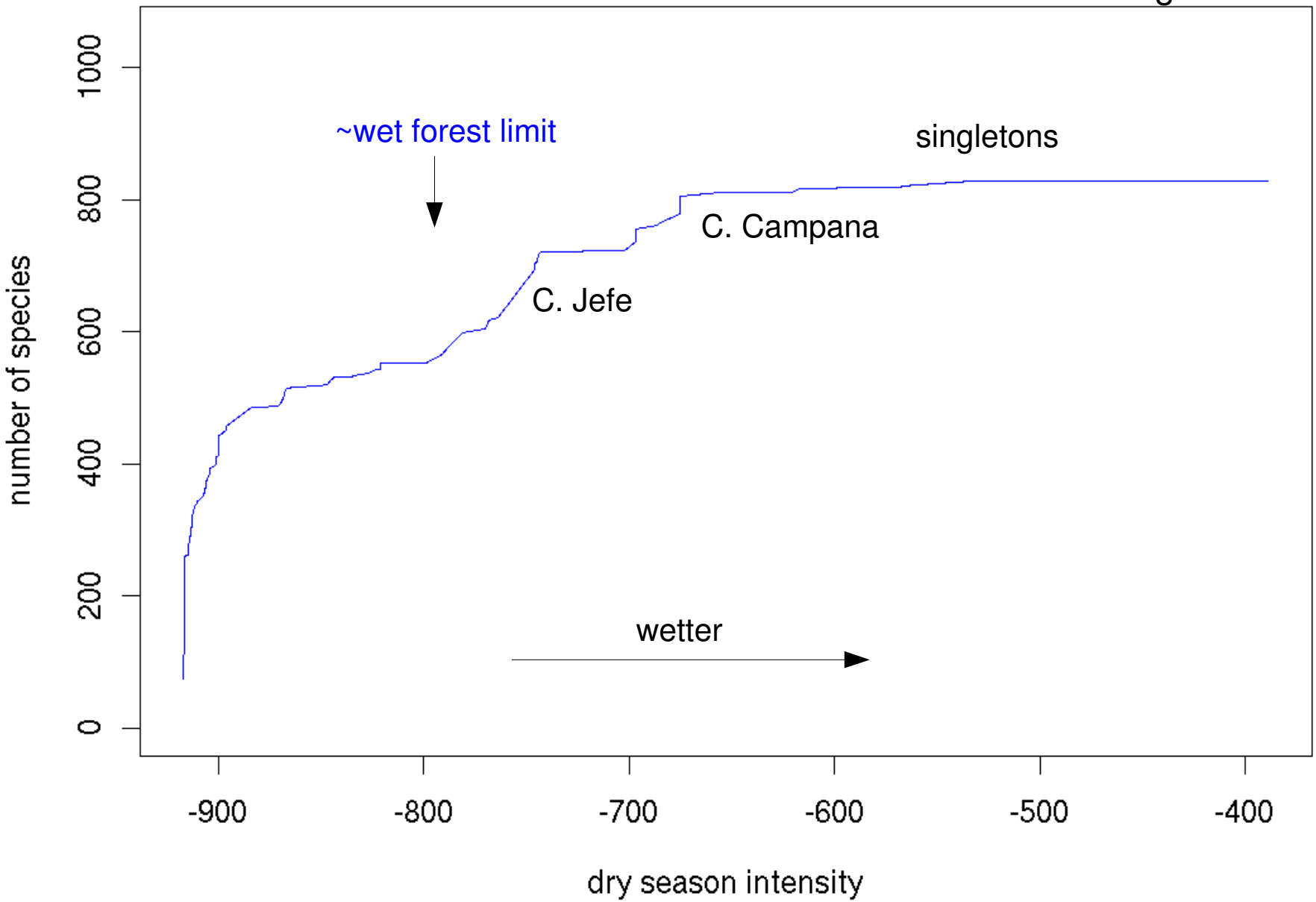

Range limits of species from the driest area of the Canal region
Panama City
BCI
Sherman
wet forest
C. Campana
species
0
100
200
300
400
500
-900
-800
-700
-600
-500
-400
dry season

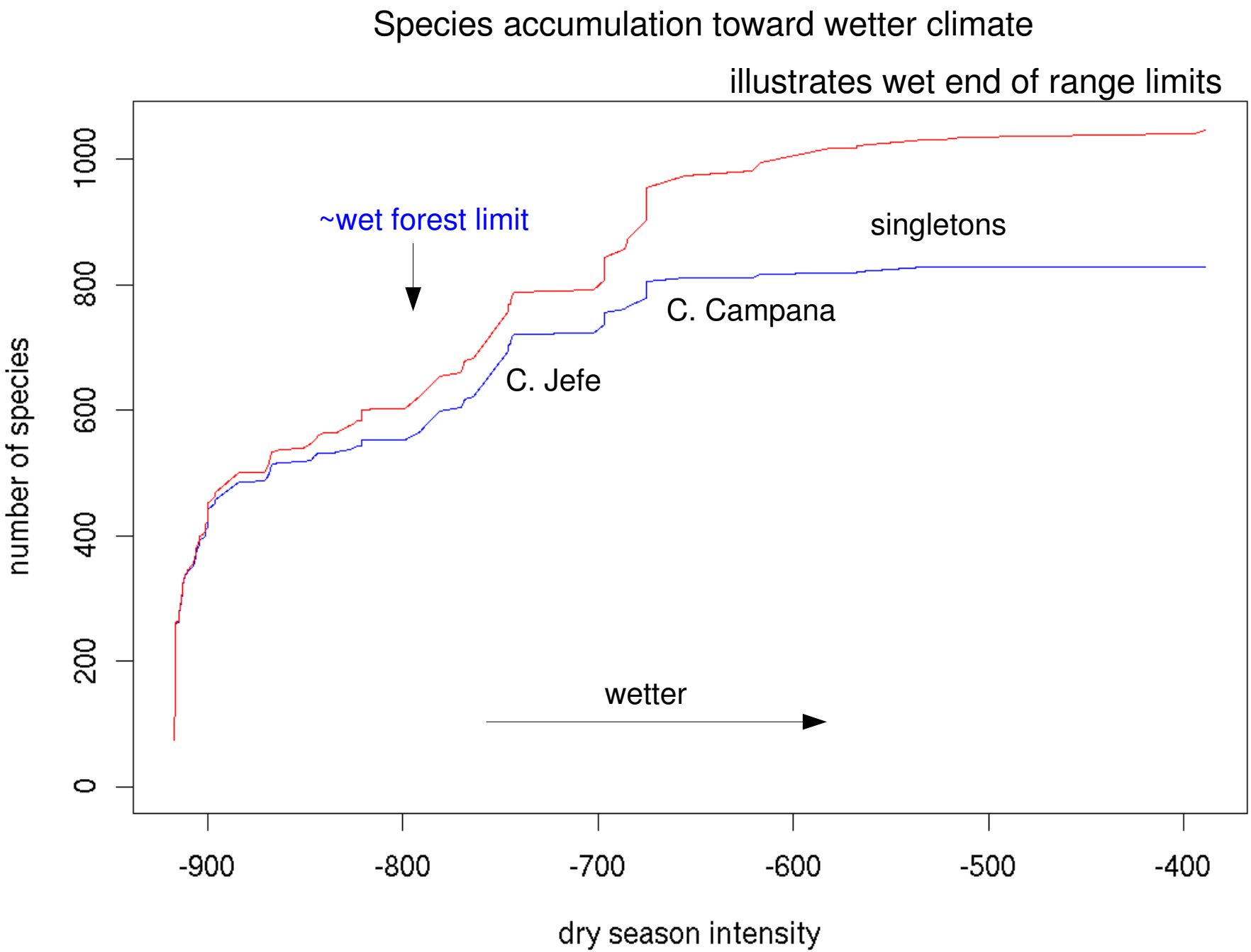

Species accumulation toward drier climate
illustrates dry end of range limits
~wet forest limit
C. Jefe
C. Campana
drier
number of species
0
200
400
600
800
1000
-900
-800
-700
-600
-500
-400
dry season intensity


Species accumulation toward drier climate
illustrates dry end of range limits
~wet forest limit
singletons
C. Jefe
C. Campana
drier
number of species
0
200
400
600
800
1000
-900
-800
-700
-600
-500
-400
dry season intensity

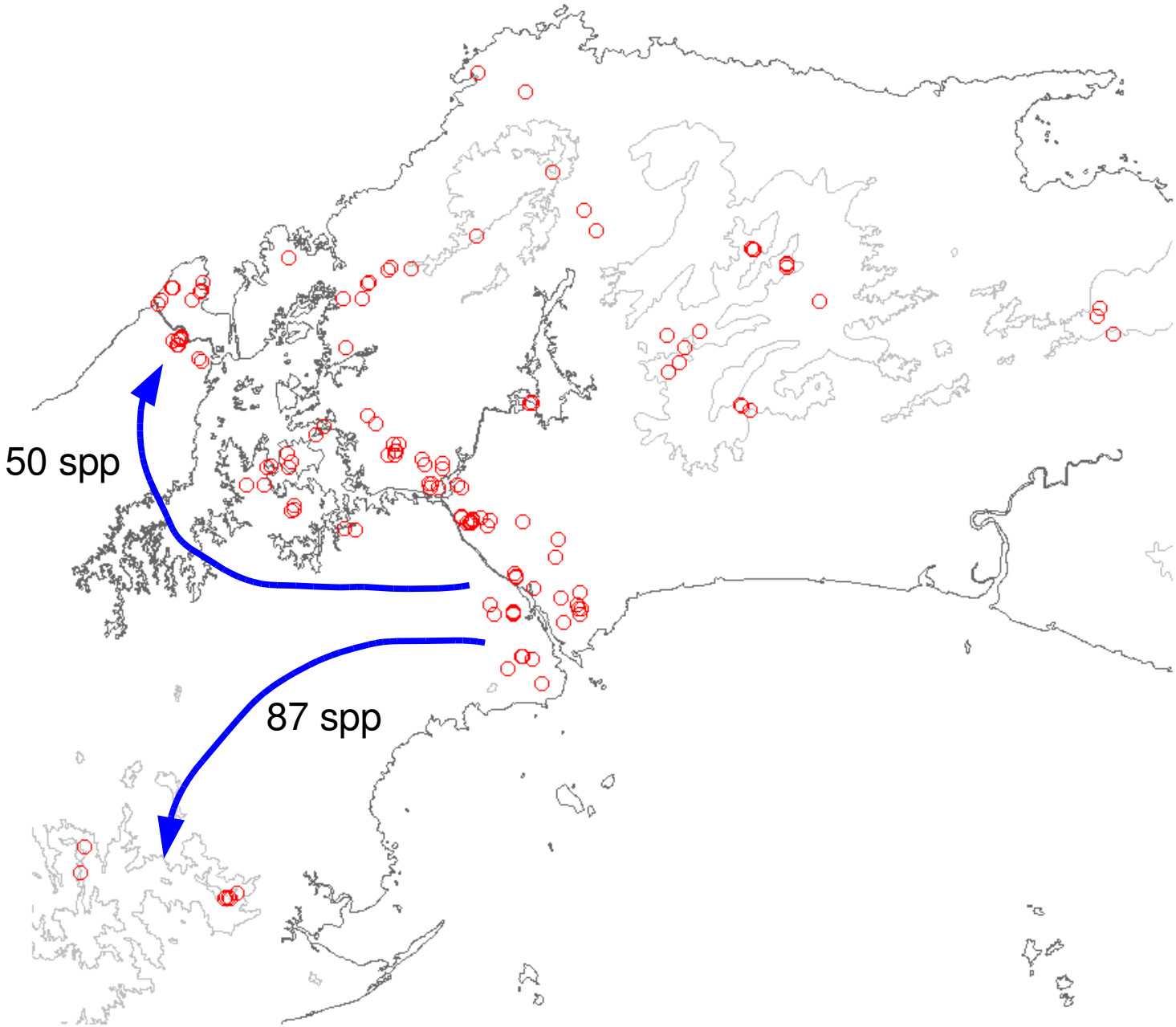
Species accumulation toward wetter climate

illustrates wet end of range limits



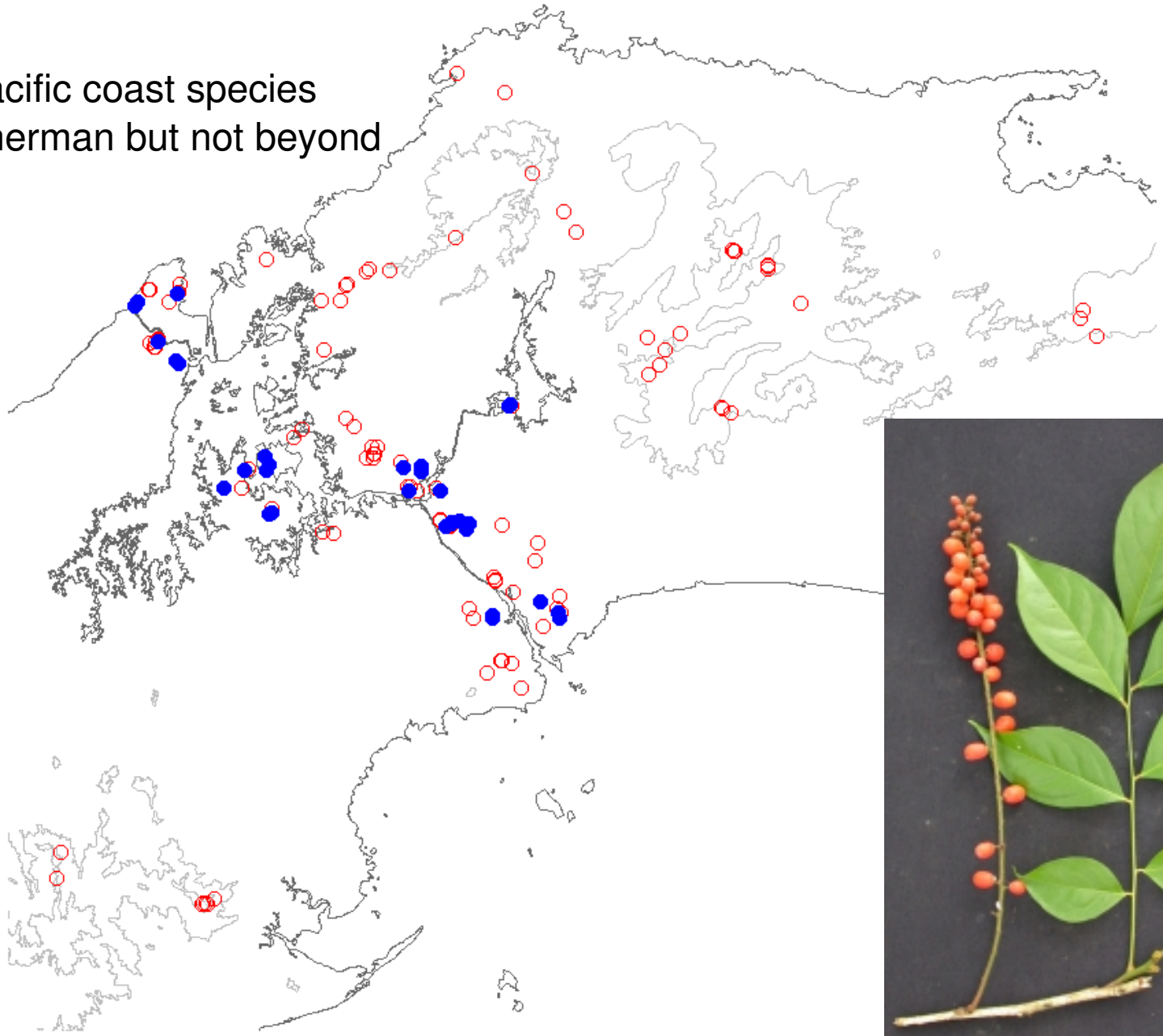

Species accumulation toward wetter climate
illustrates wet end of range limits
~wet forest limit
singletons
C. Campana
C. Jefe
wetter
number of species
0
200
400
600
800
1000
-900
-800
-700
-600
-500
-400
dry season intensity

Frequent climatic limits of Pacific slope species



Picramnia latifolia plots and inventories

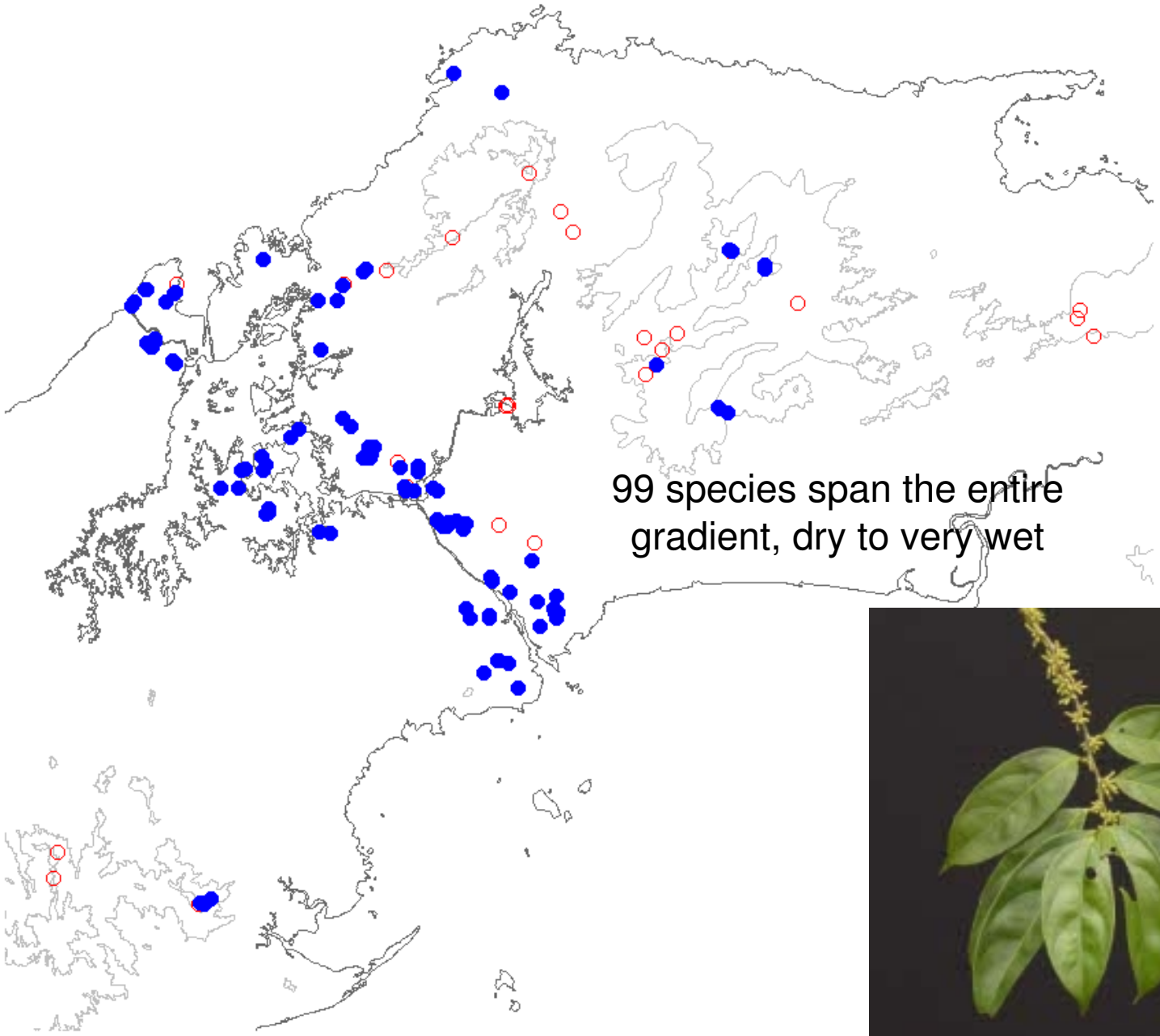
50 Pacific coast species
reach Sherman but not beyond



Albizia adinocephala plots and inventories

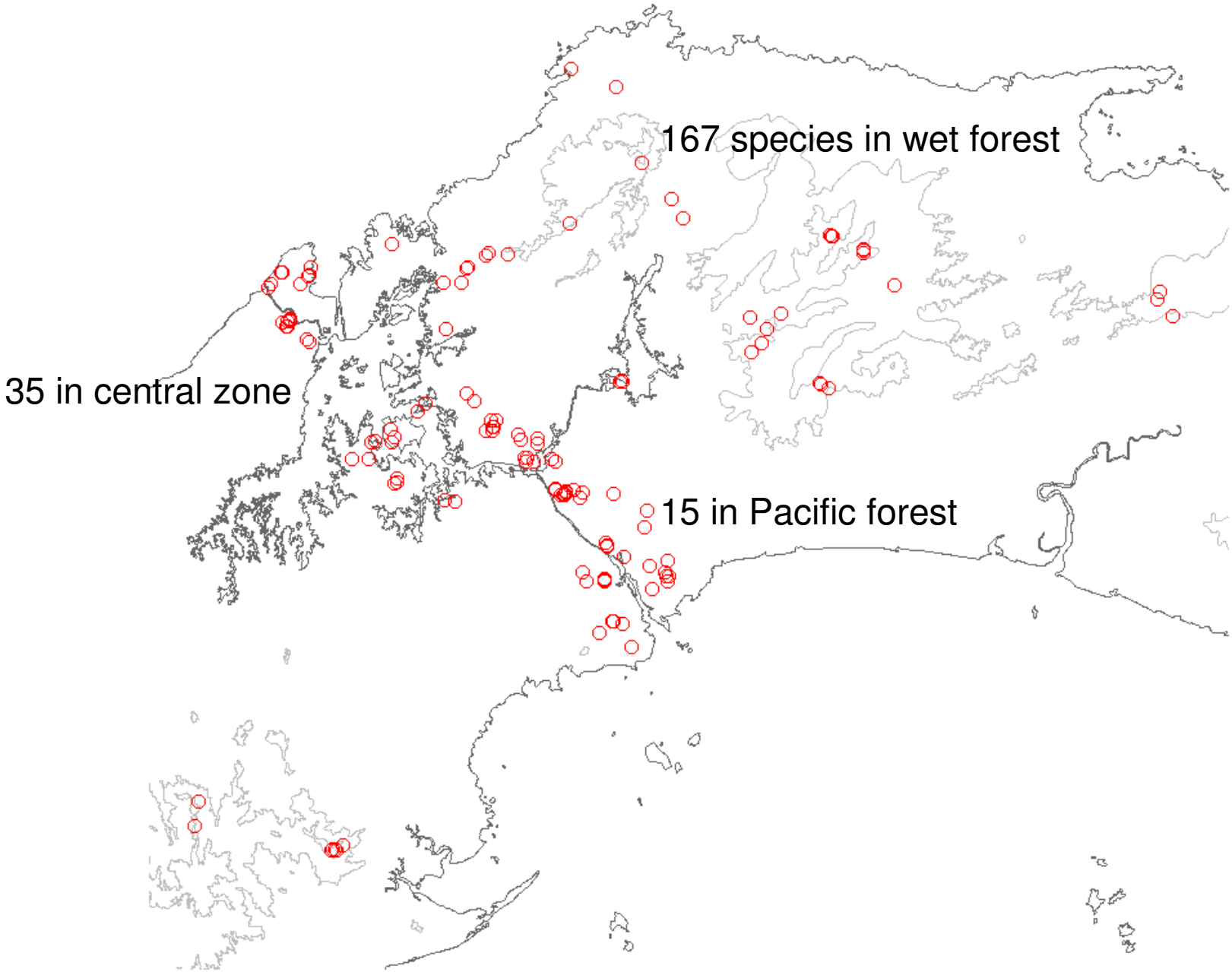
48 species are restricted to the driest climate

Lacistema aggregatum plots and inventories



99 species span the entire gradient, dry to very wet

Singletons


167 species in wet forest
35 in central zone
15 in Pacific forest

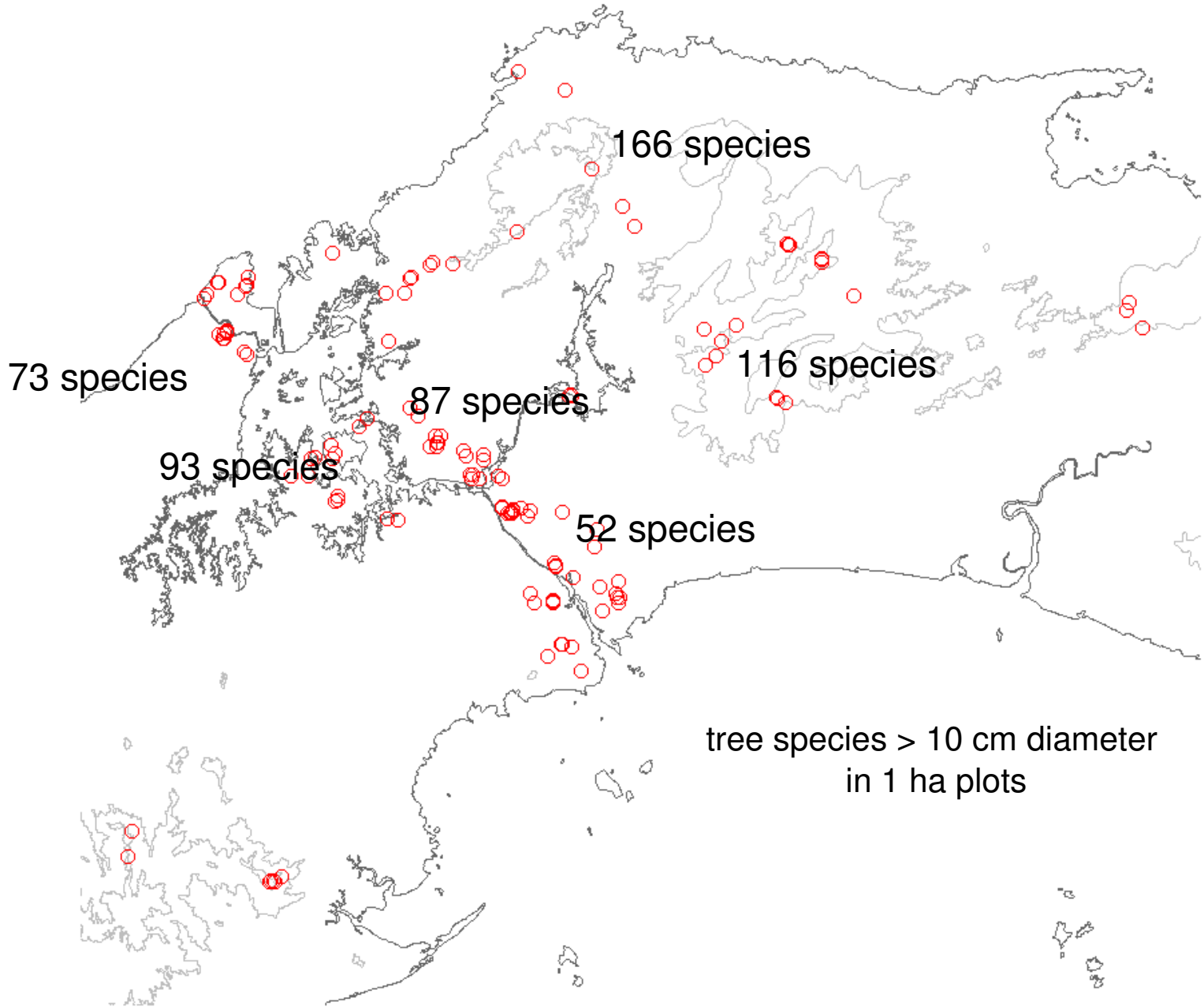
Tree species richness near the Panama Canal

Confined to wet forest	276	26%
Not restricted	432	41%
Confined to mid to dry	121	12%
singleton (wet forest)	166	16%
singleton (mid to dry)	51	5%
Total	1046	
(other not included)	50	

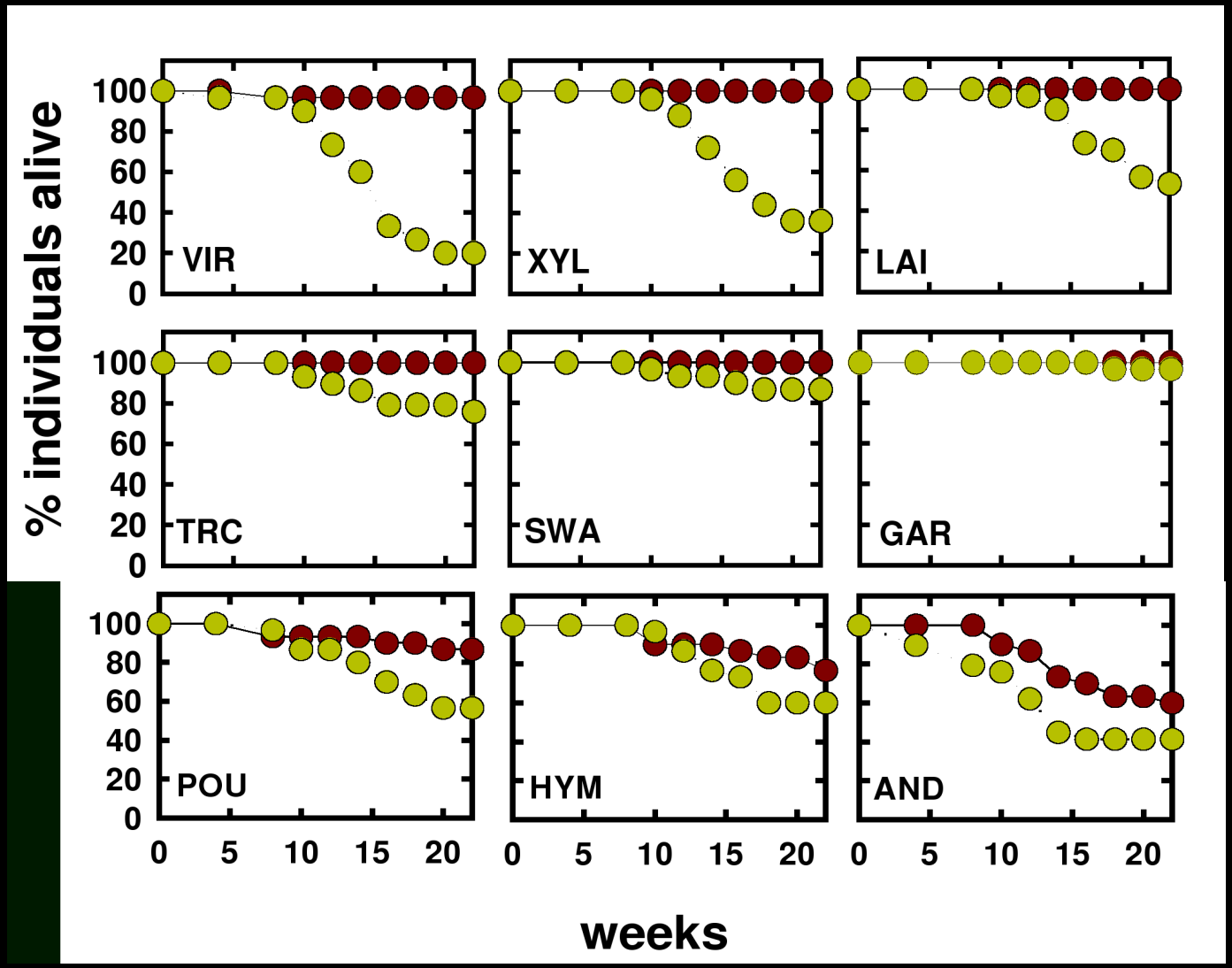
Source pool for tree species (with singletons):

Wet forest: 874 (and more to be found)
Moist forest: 604 (few to be found?)

Species diversity per hectare

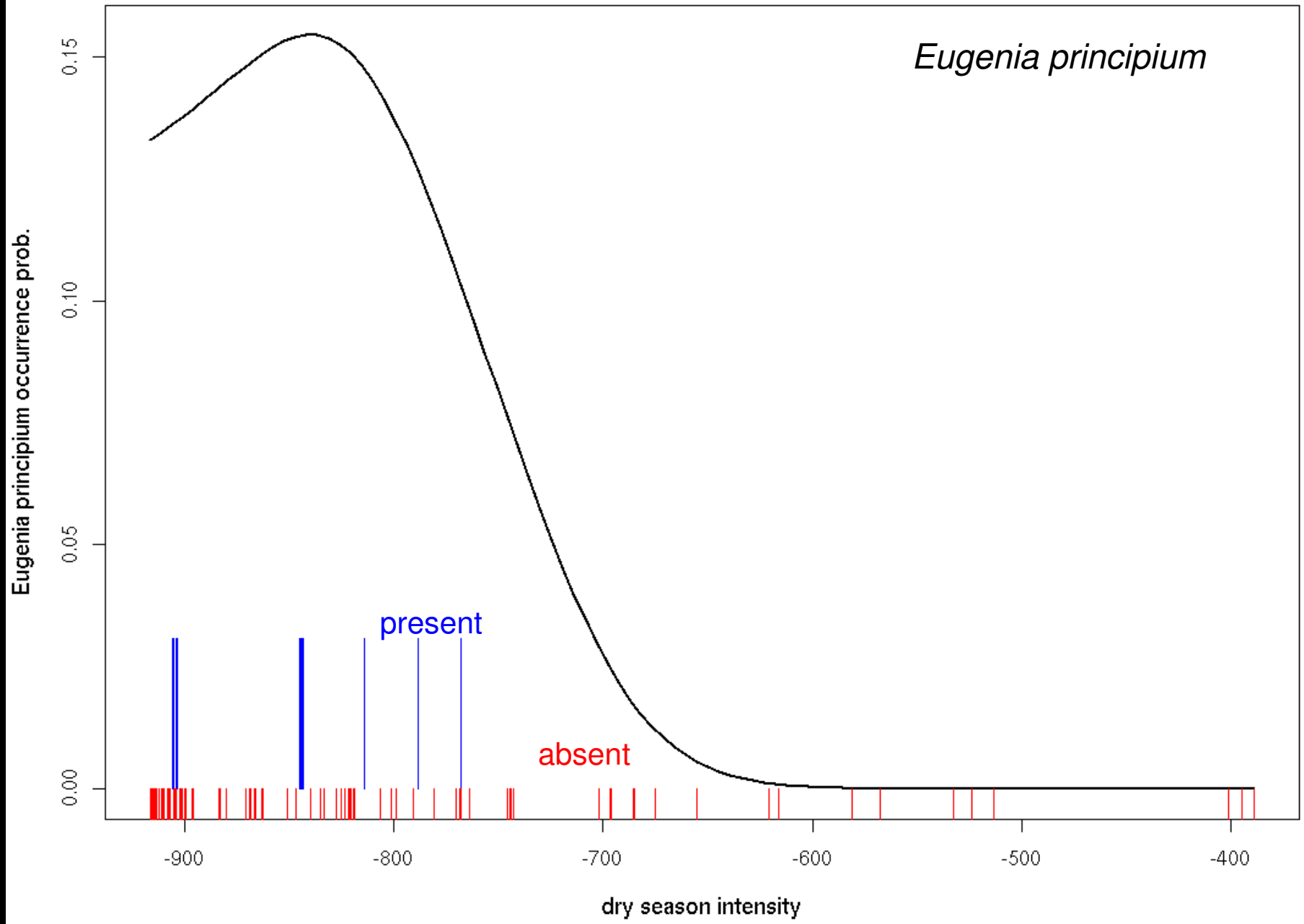


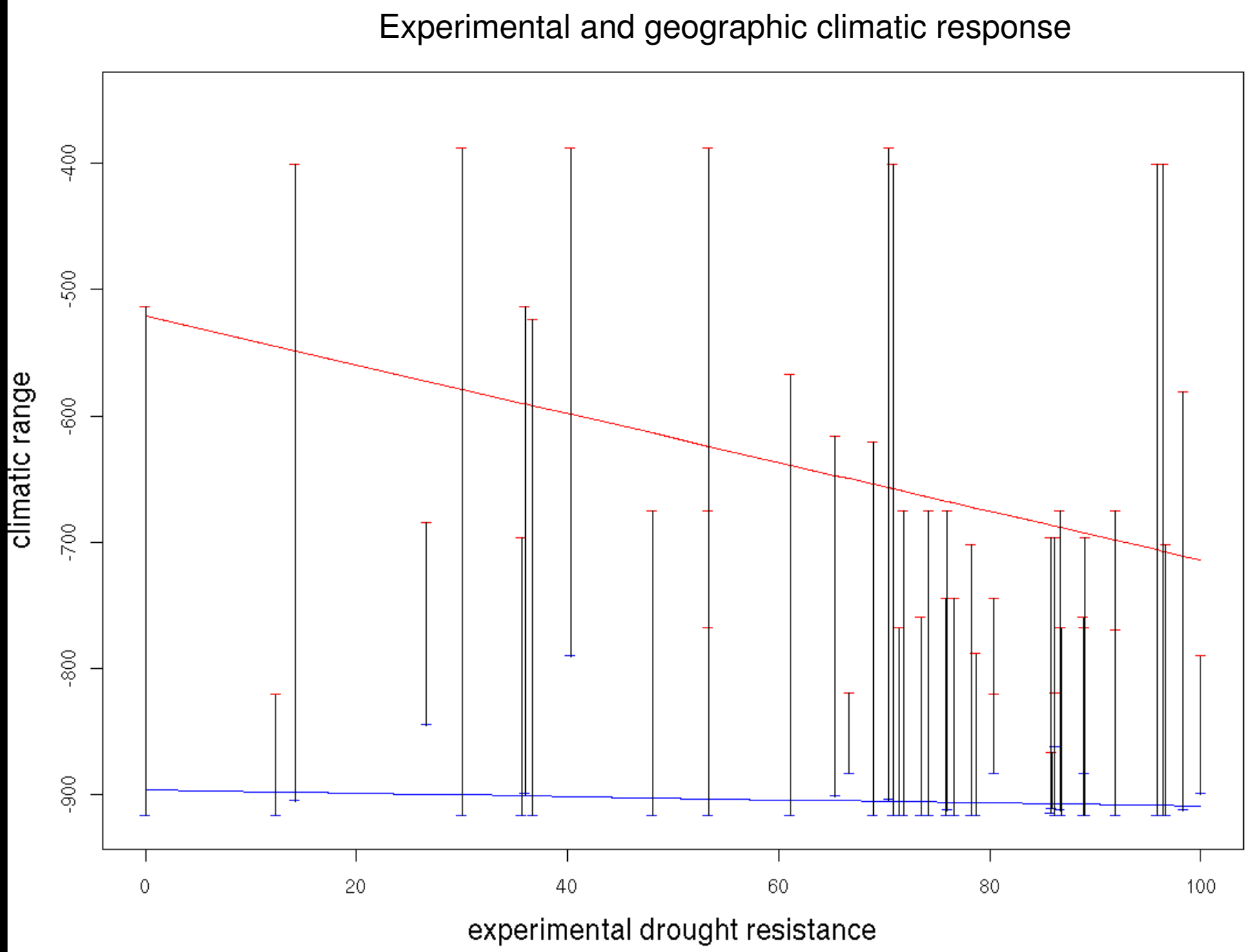
Experimental drought tolerance: survival rate without water



Engelbrecht *et al., Nature, 2007*

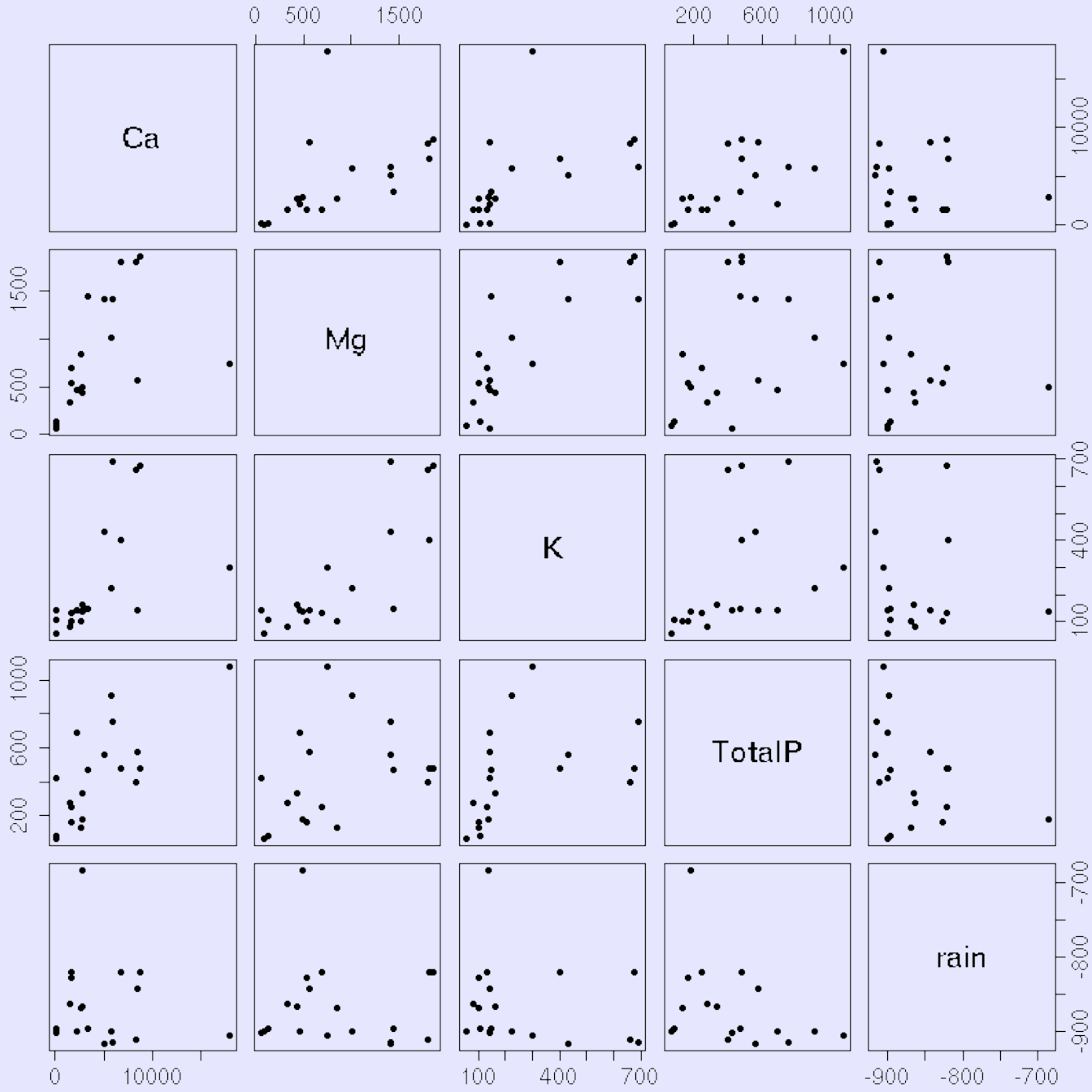
Niche model from dry season duration



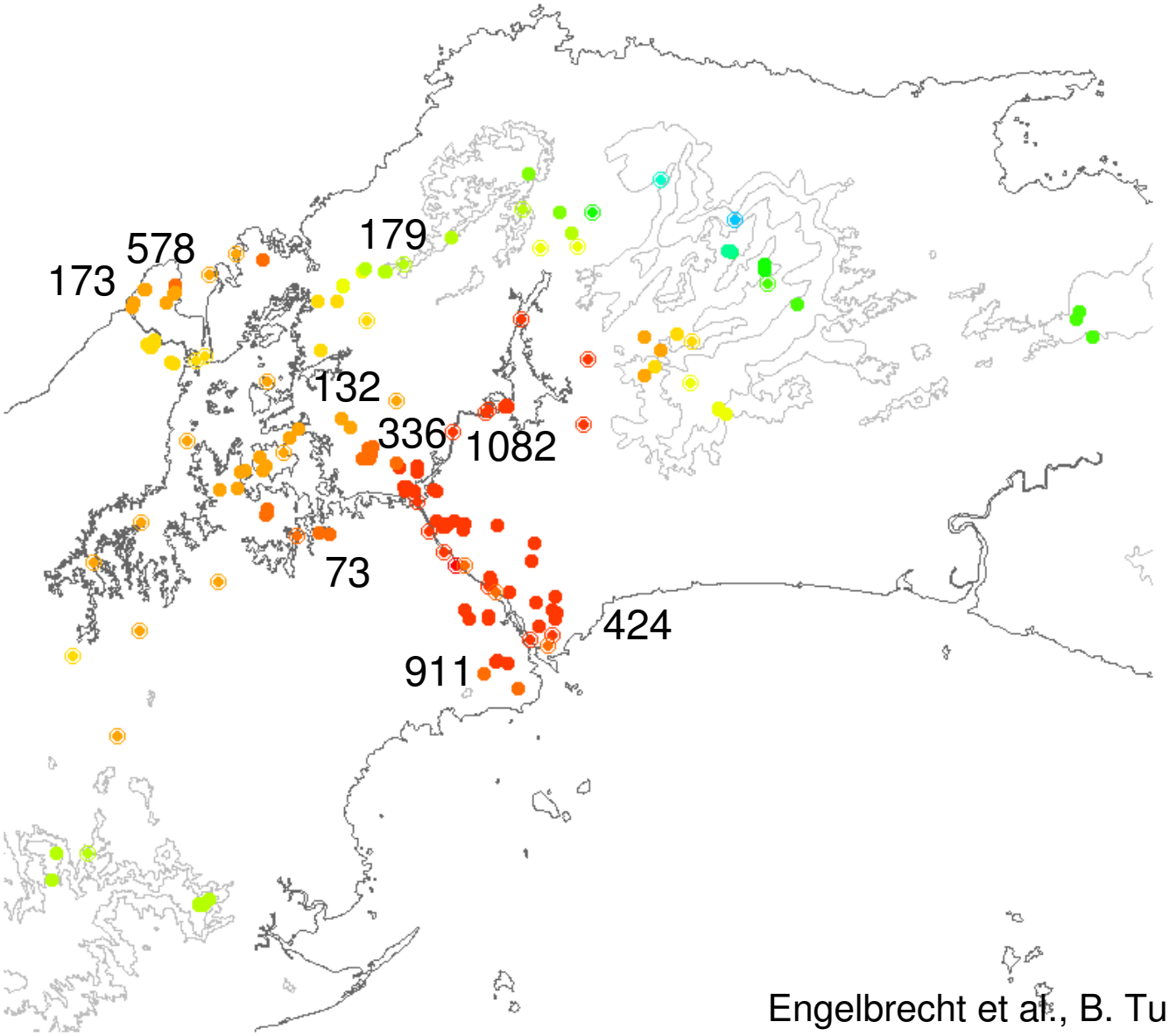

Experimental and geographic climatic response
climatic range
-400
-500
-600
-700
-800
-900
0
20
40
60
80
100
experimental drought resistance

Soil nutrients
19 sites

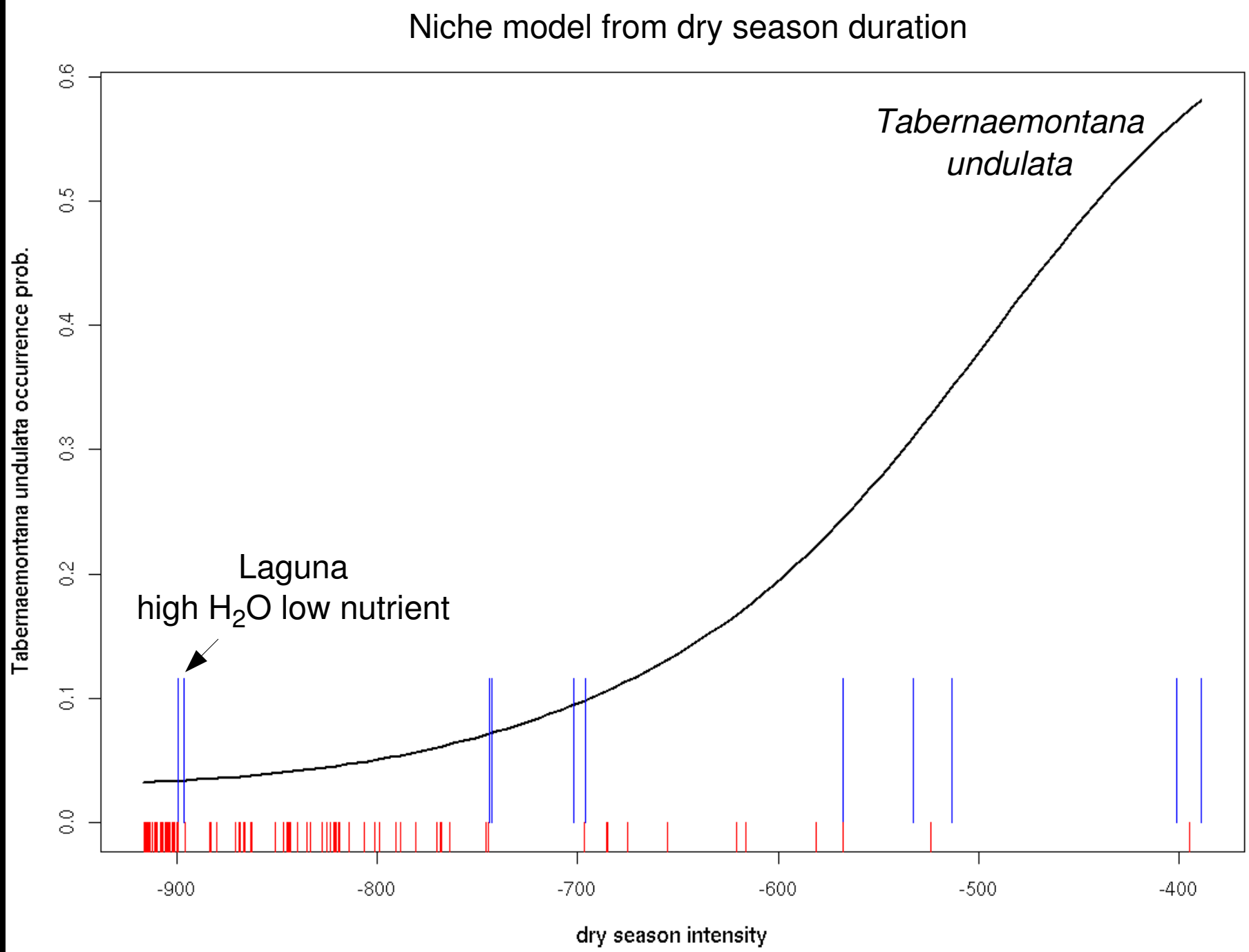
Ben Turner (unpub)



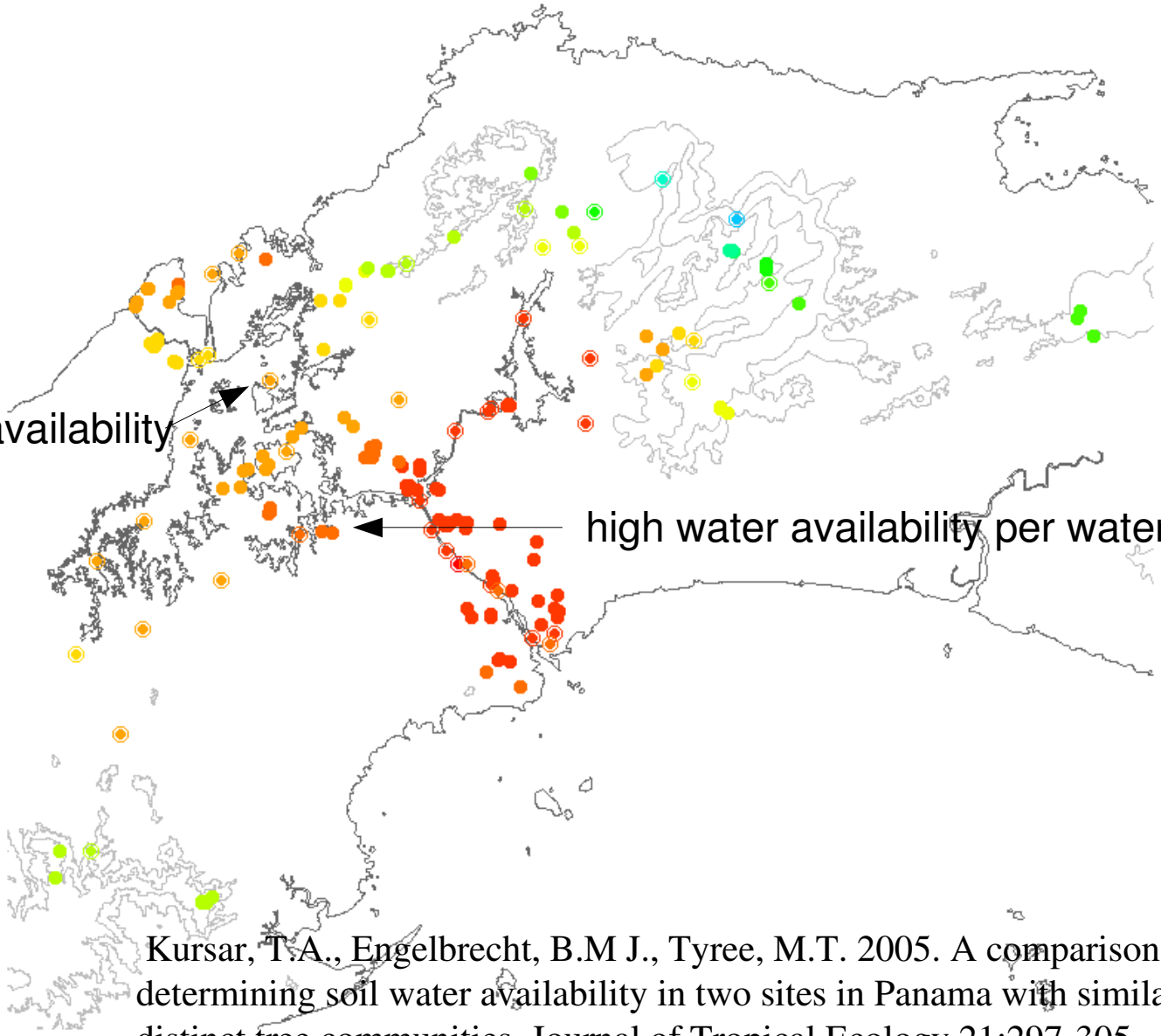
Soil phosphorus in tree plots



Engelbrecht et al., B. Turner unpub.


Niche model from dry season duration
Tabernaemontana undulata
Laguna
high H_2O low nutrient
Tabernaemontana undulata occurrence prob.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
-900
-800
-700
-600
-500
-400
dry season intensity

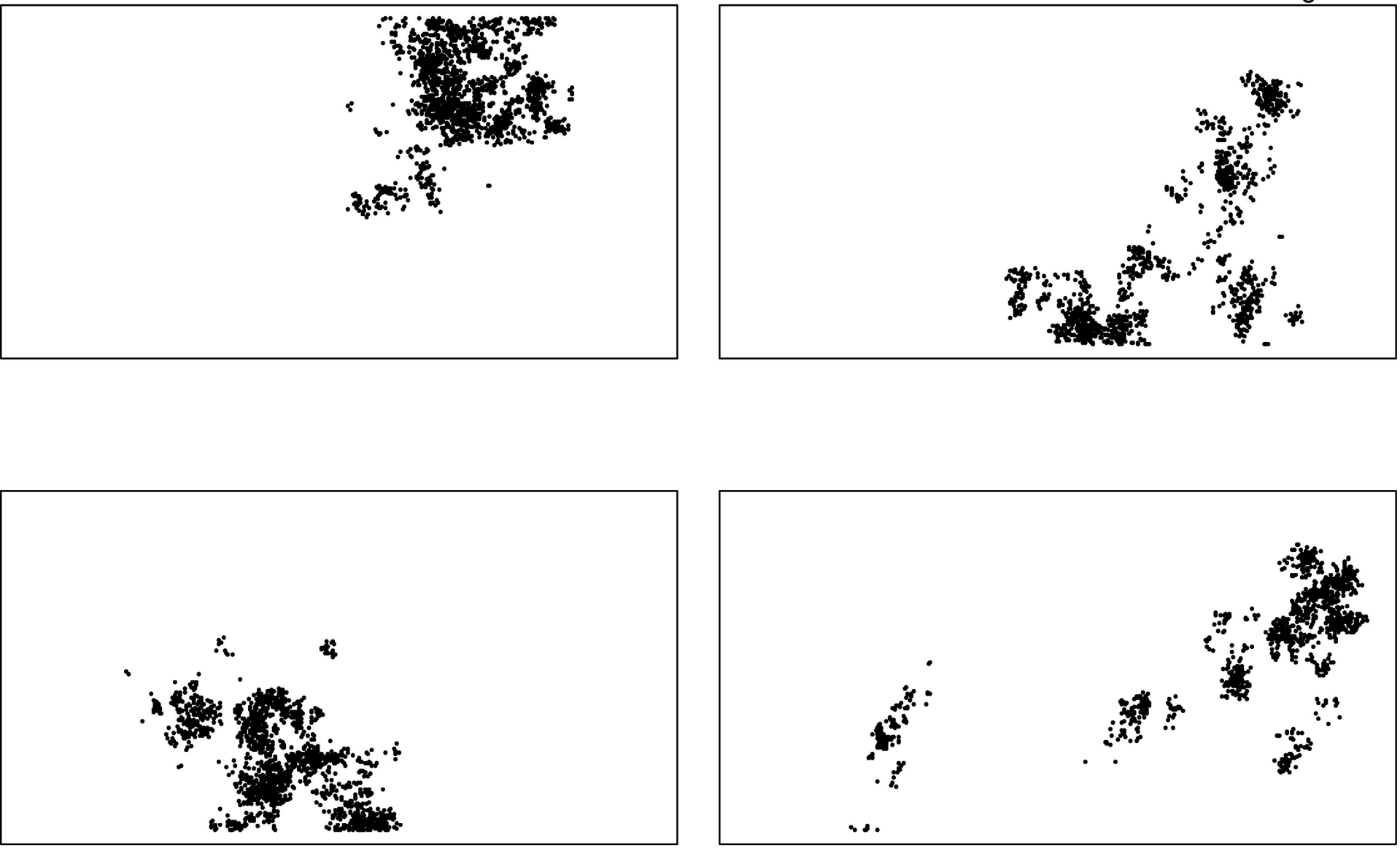
Tree inventories
tree water availability from Kursar et al. (2 sites)



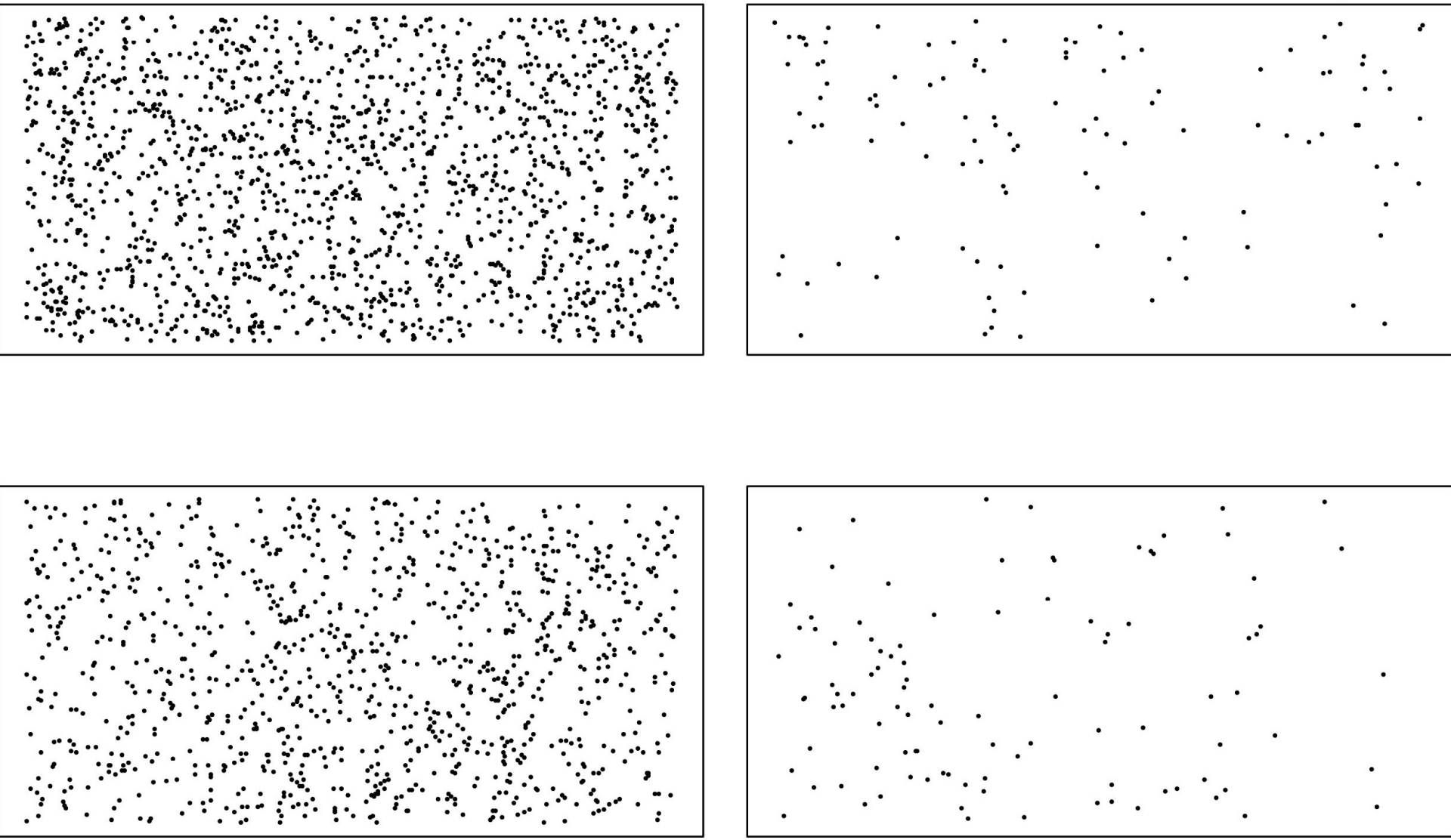
Kursar, T.A., Engelbrecht, B.M J., Tyree, M.T. 2005. A comparison of methods for determining soil water availability in two sites in Panama with similar rainfall but distinct tree communities. Journal of Tropical Ecology 21:297-305.

Dispersal and range size

Simulated species distributions, poor dispersal (relative to plot size)

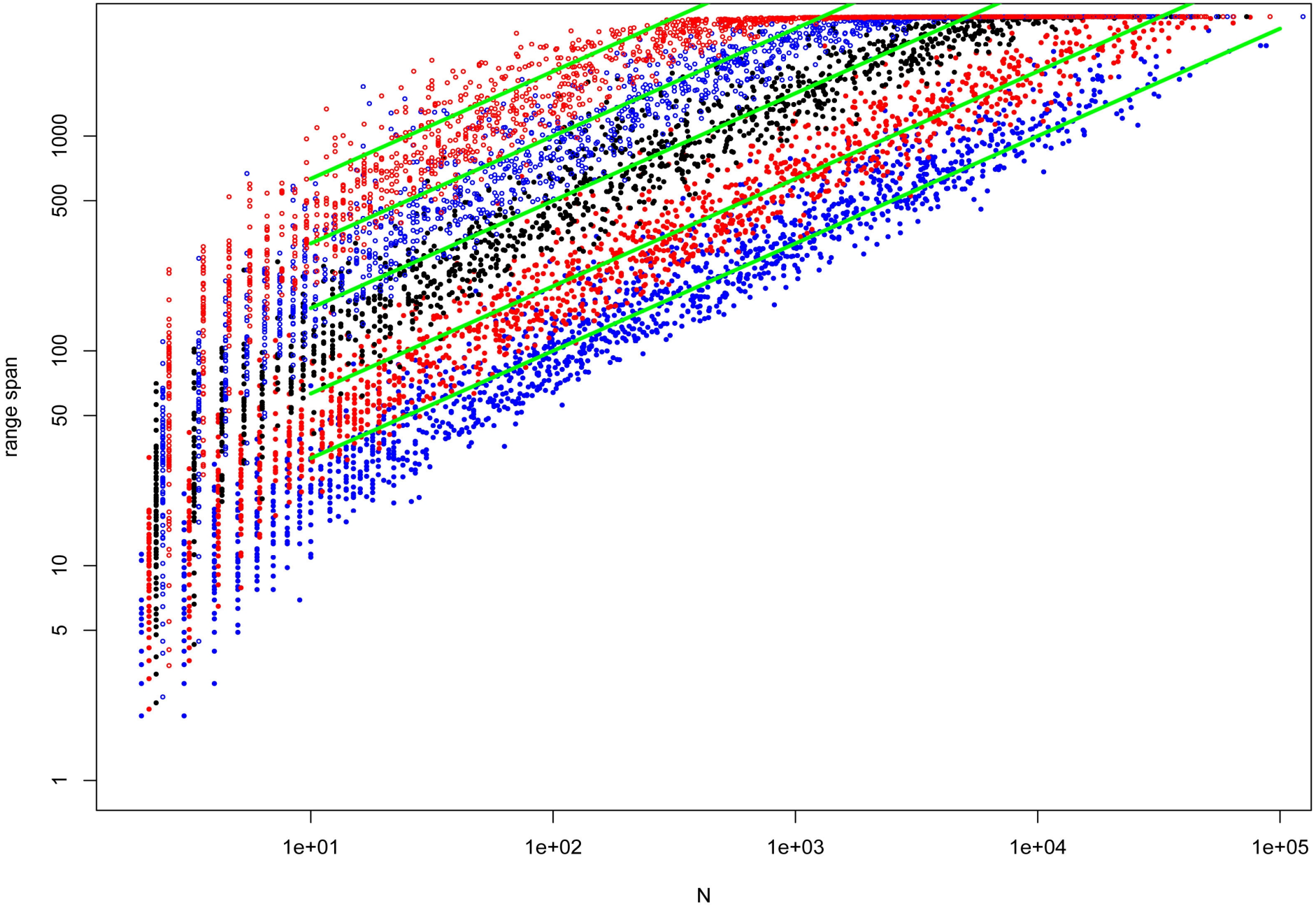


Simulated species distributions, good dispersal (relative to plot size)



Dispersal limiting range size

Fig. 6.9



A theory of dispersal limiting range size

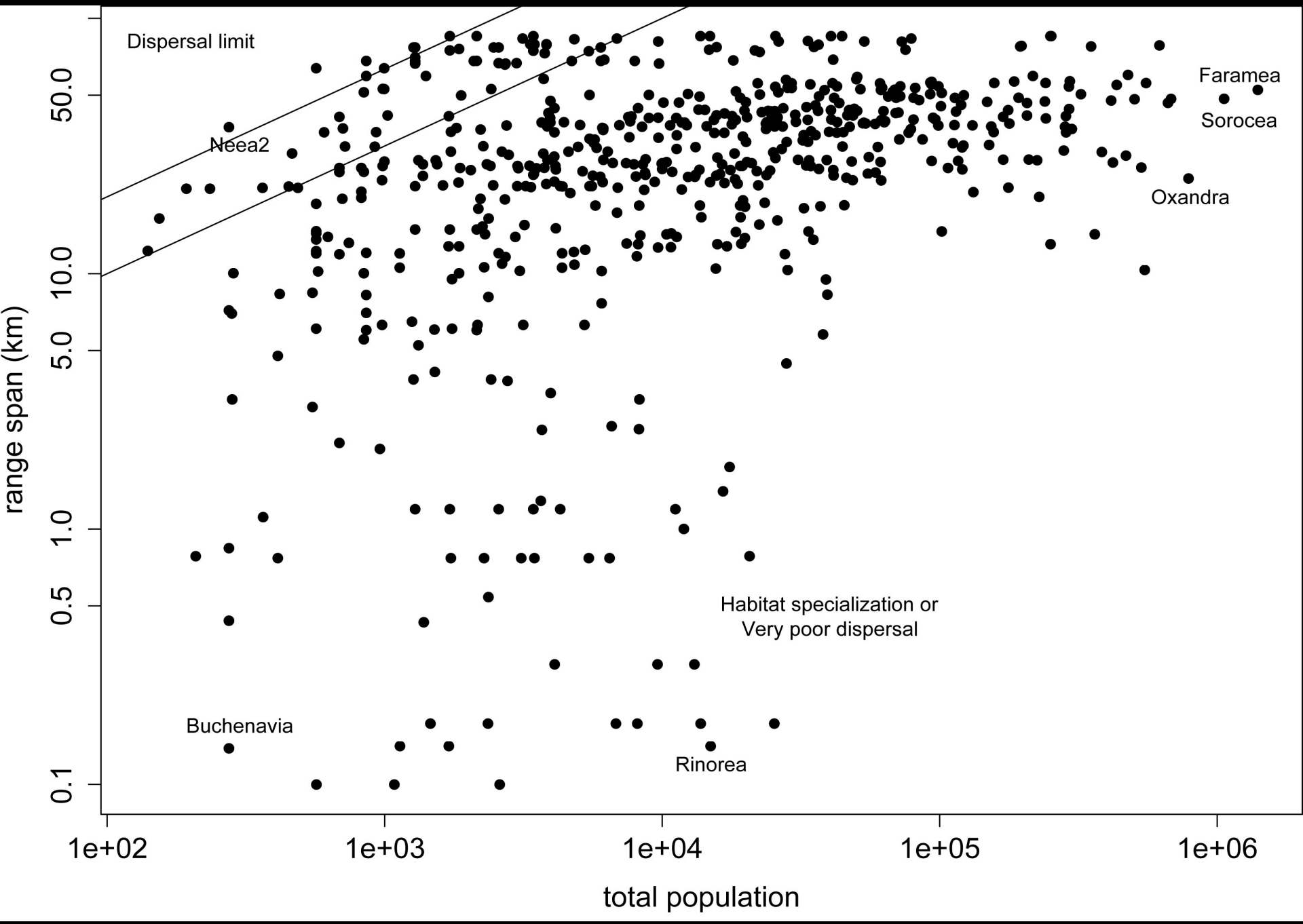
$$R \approx 2D\sqrt{(N)}$$

N = population size

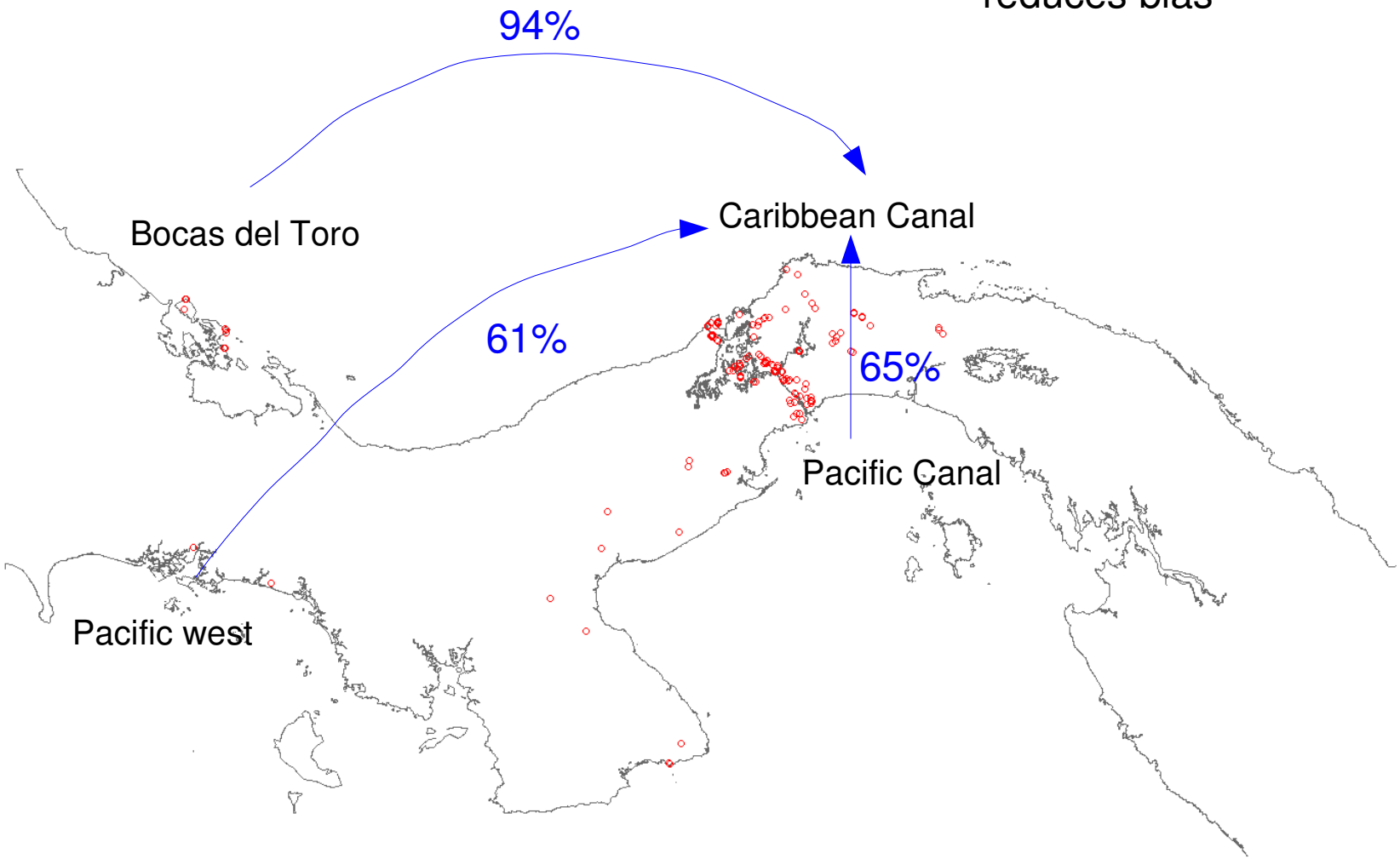
R = linear span of range

D = maximum dispersal distance

Range size in 50 ha plots...


Dispersal limit
Neea2
Faramea
Sorocea
Oxandra
Habitat specialization or
Very poor dispersal
Buchenavia
Rinorea
range span (km)
0.1
0.5
1.0
5.0
10.0
50.0
1e+02
1e+03
1e+04
1e+05
1e+06
total population

Comparisons against a fixed target reduces bias



Conclusions

- Inability to survive drought limits ranges
- More species adapted to wet forest conditions
- Experiments on species responses suggest more than drought is involved
- Only a minority of species have ranges limited by poor dispersal

Field Work

MUDUMALAI, INDIA

KHAO CHONG, THAILAND

CTFS Field Training Courses

CTFS Analytical Courses

Plots: An infrastructure for field research

ca. 70% of the global biodiversity

ca. 30% of stored terrestrial Carbon

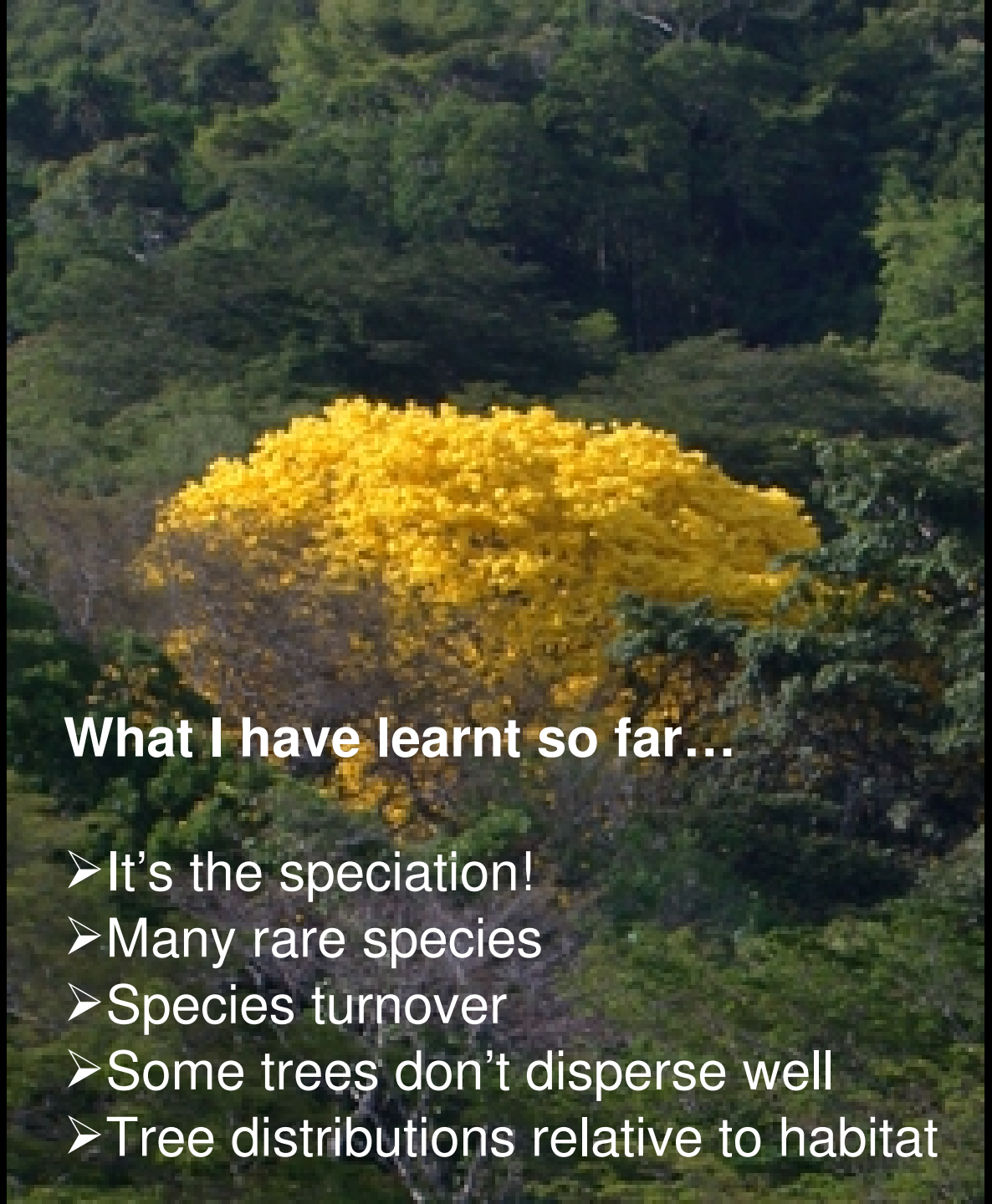
Amazon Basin

The theory (model)…

Neutral theory for diversity

Neutrality is *anti*-diversifying

Speciation maintains diversity



What I have learnt so far…

- It’s the speciation!
- Many rare species
- Species turnover
- Some trees don’t disperse well
- Tree distributions relative to habitat

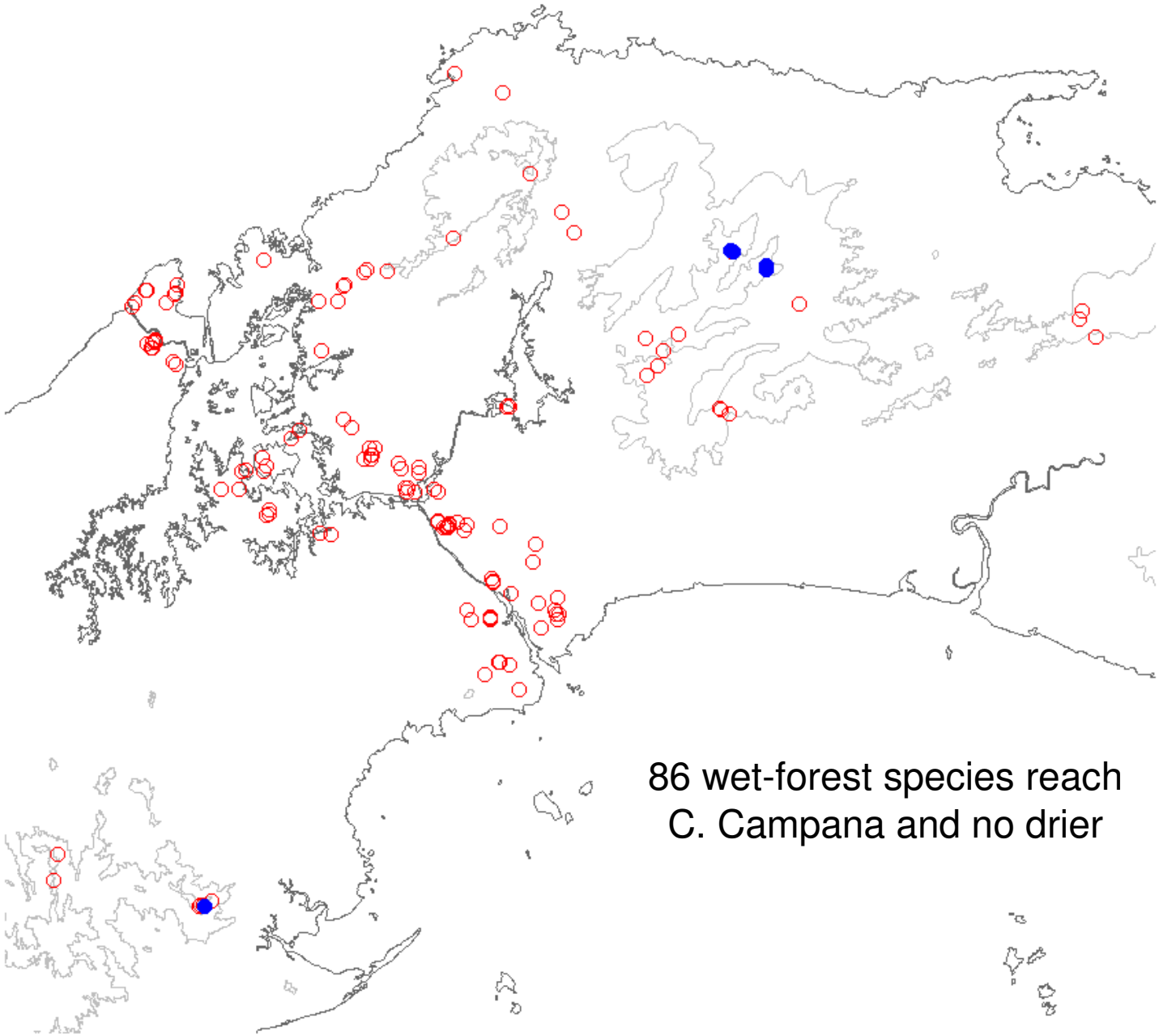
XXX

- xxx
- xxx

XXX

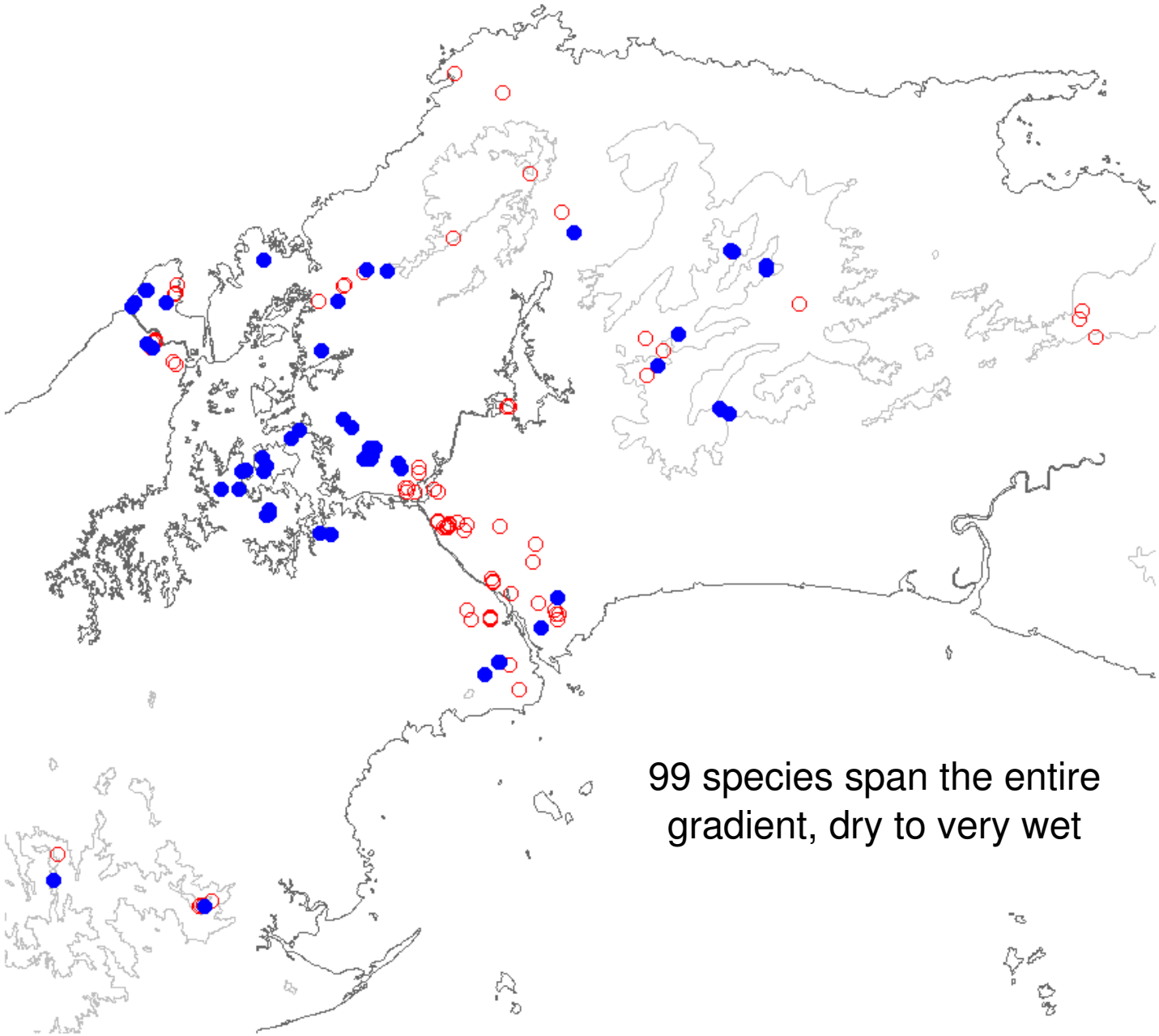
- xxx
- xxx

Faramea eurycarpa plots and inventories



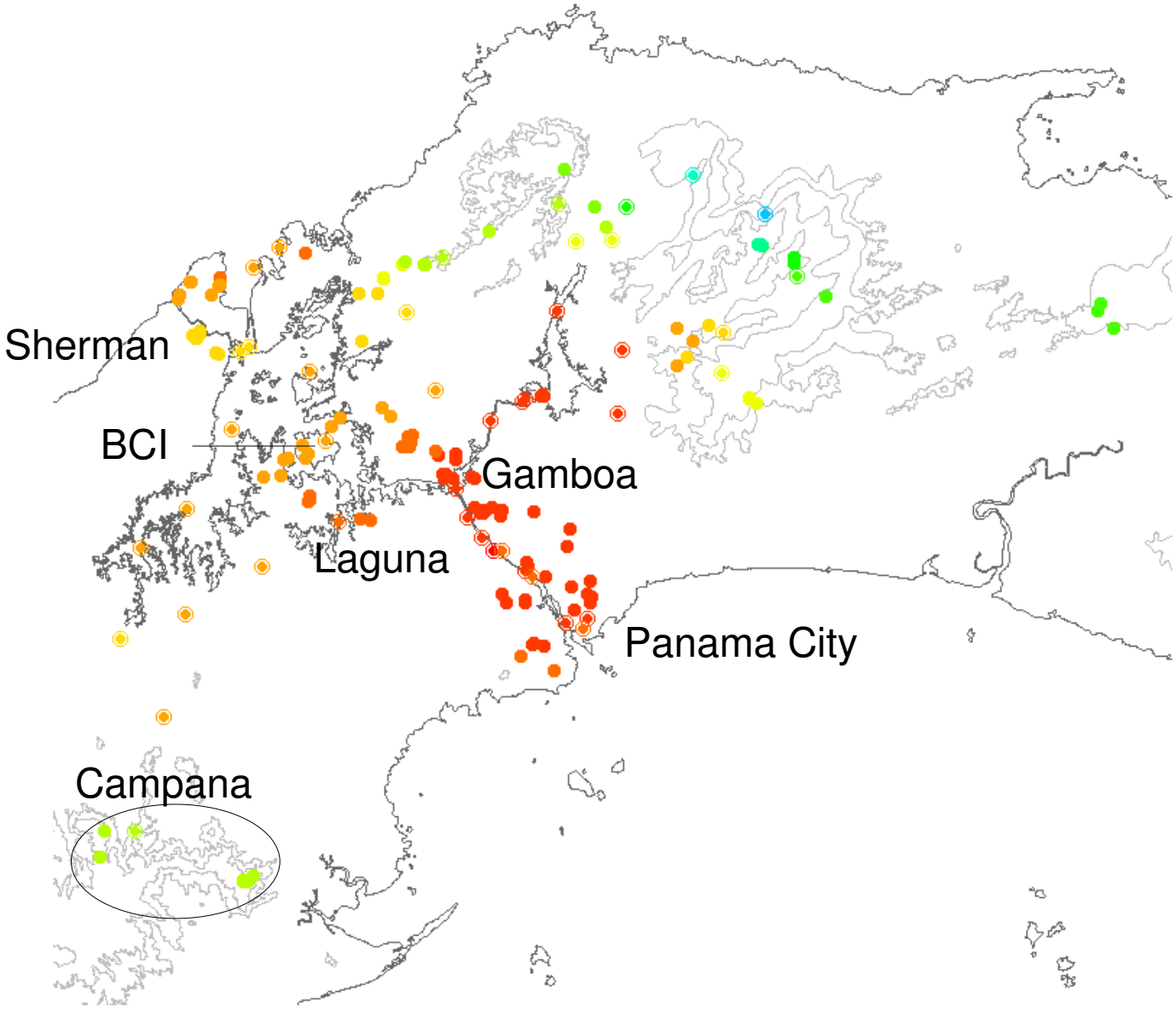
86 wet-forest species reach
C. Campana and no drier

Tetragastris panamensis plots and inventories

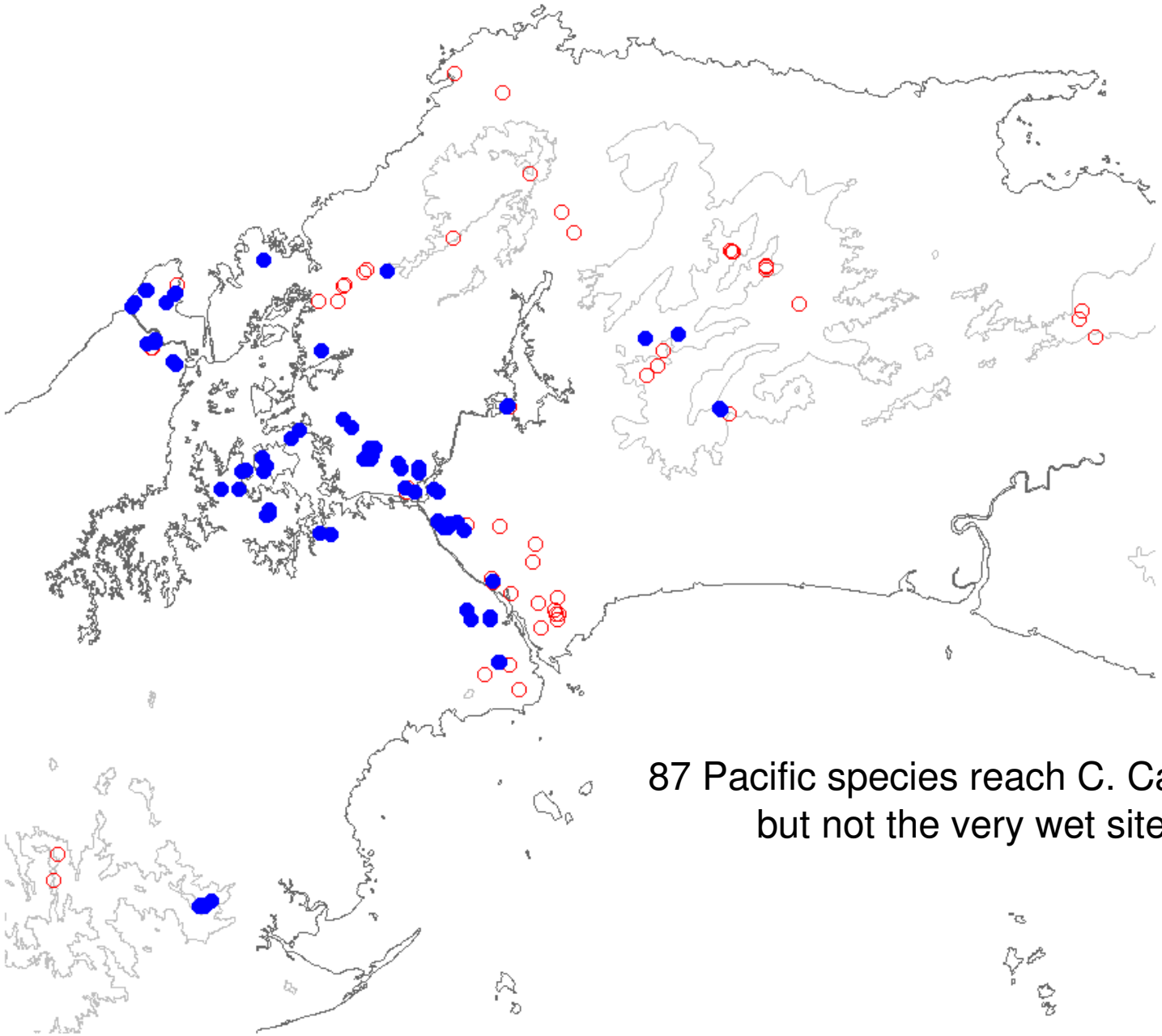


99 species span the entire gradient, dry to very wet

Tree inventories
Estimated dry season intensity at each

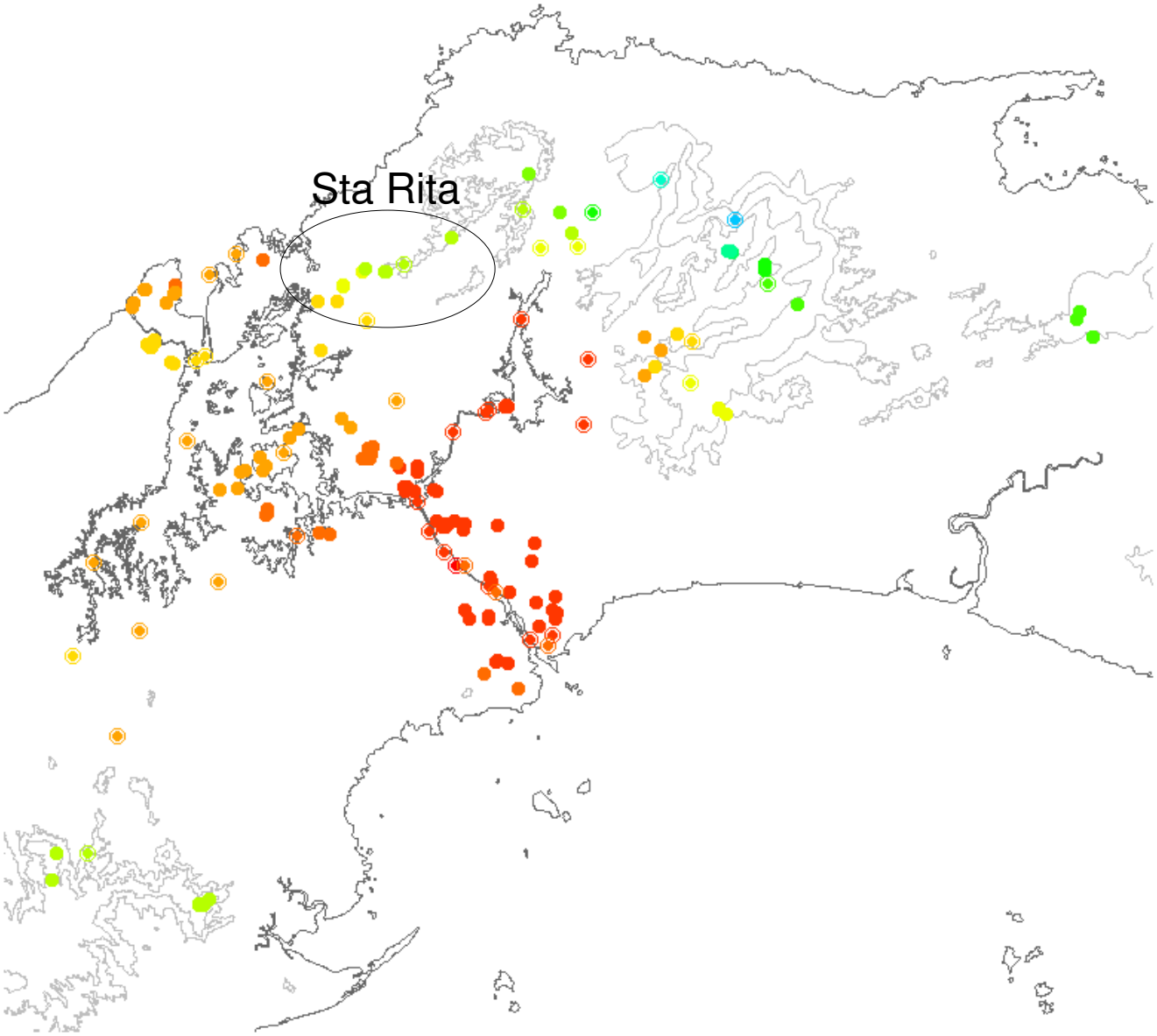


Sorocea affinis plots and inventories

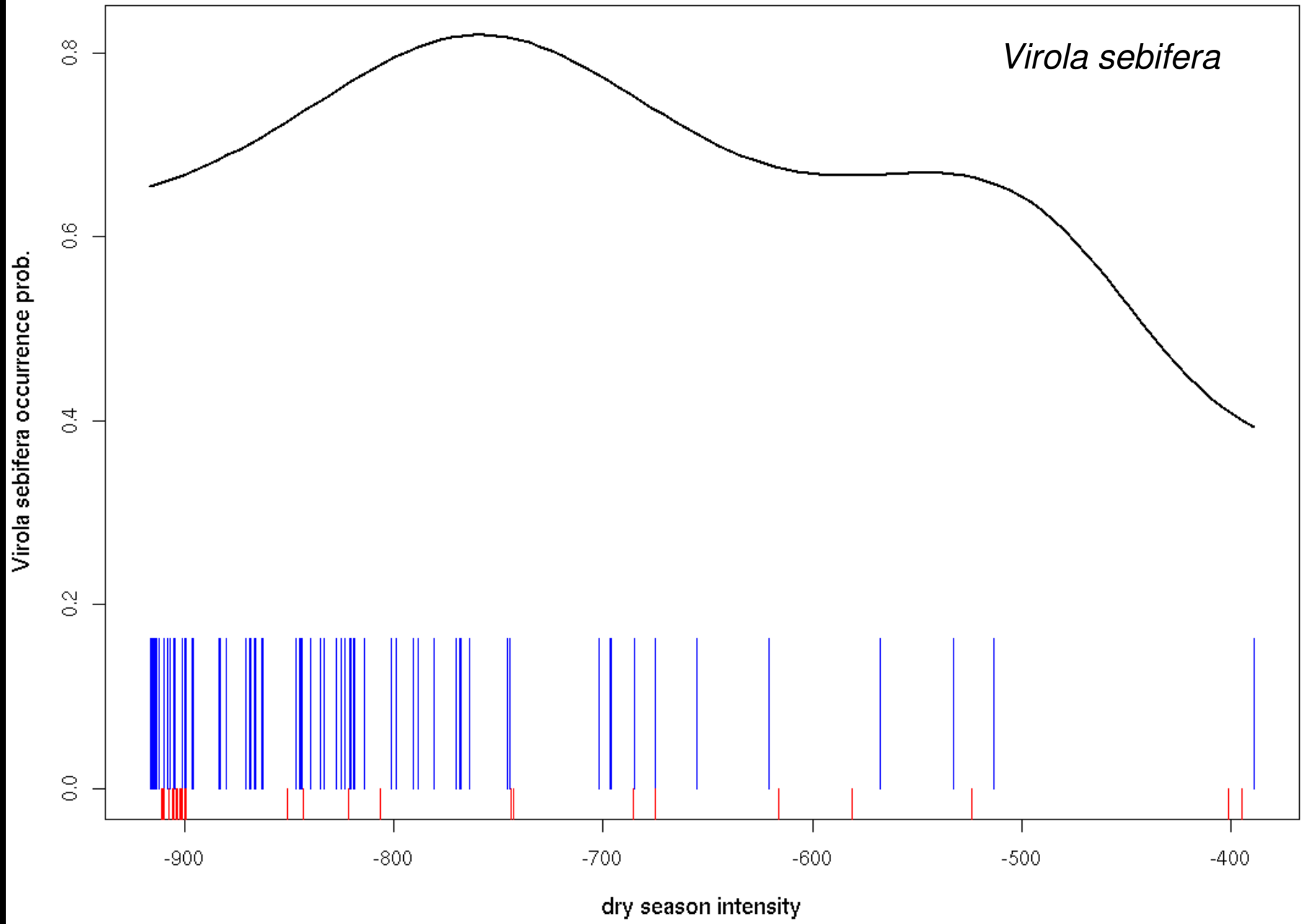


87 Pacific species reach C. Campana
but not the very wet sites

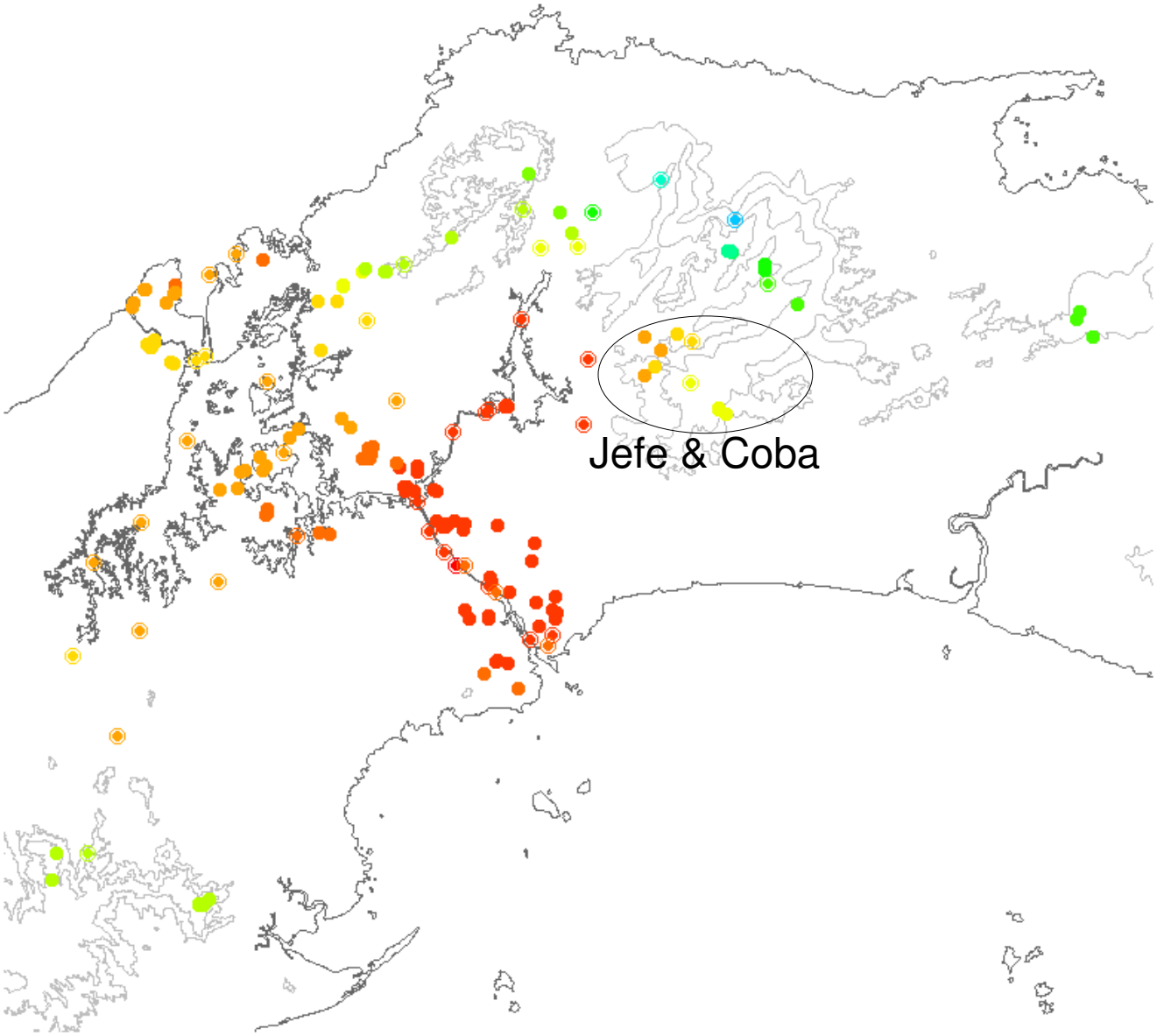
Tree inventories
Estimated dry season intensity at each



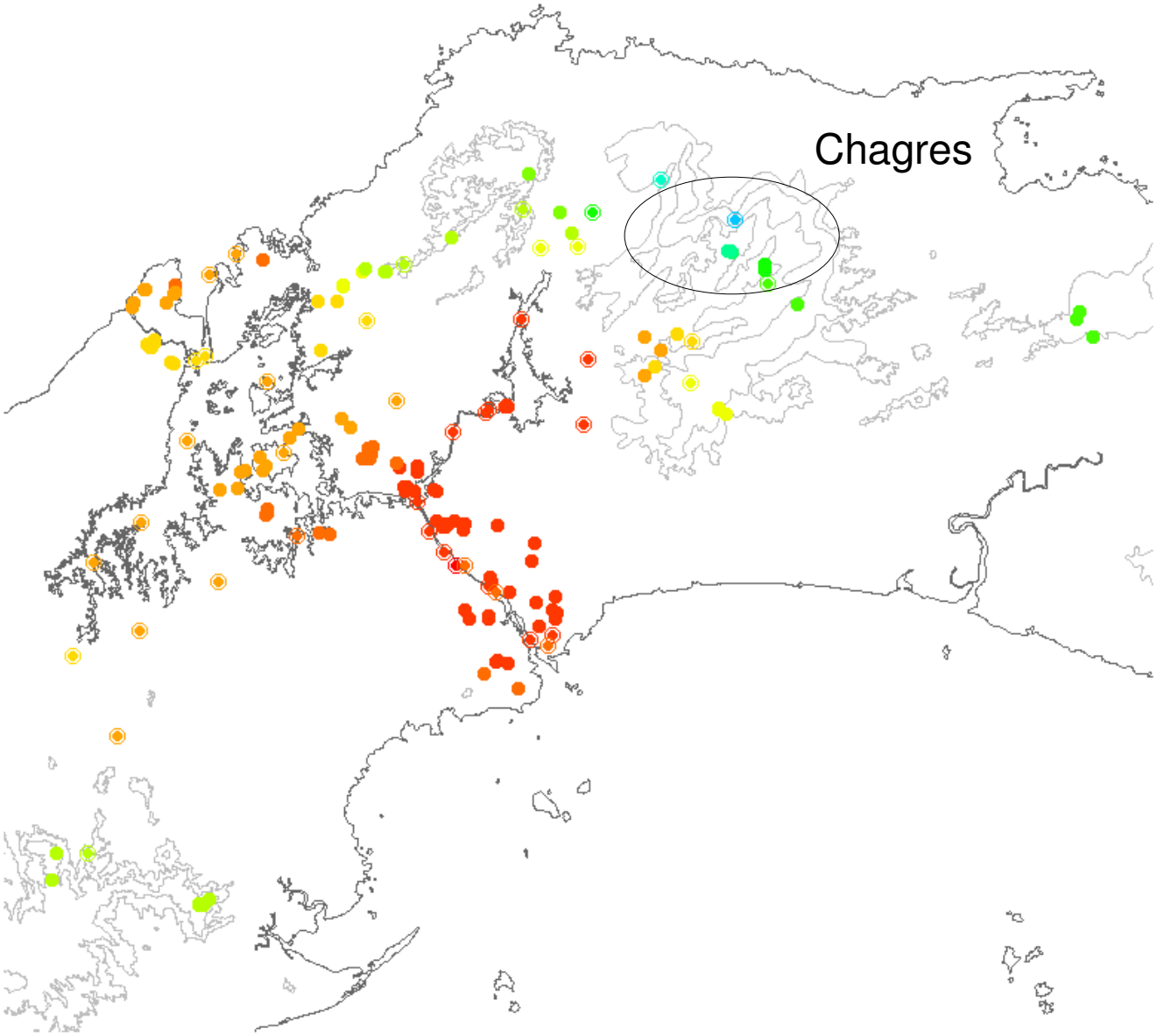
Niche model from dry season duration



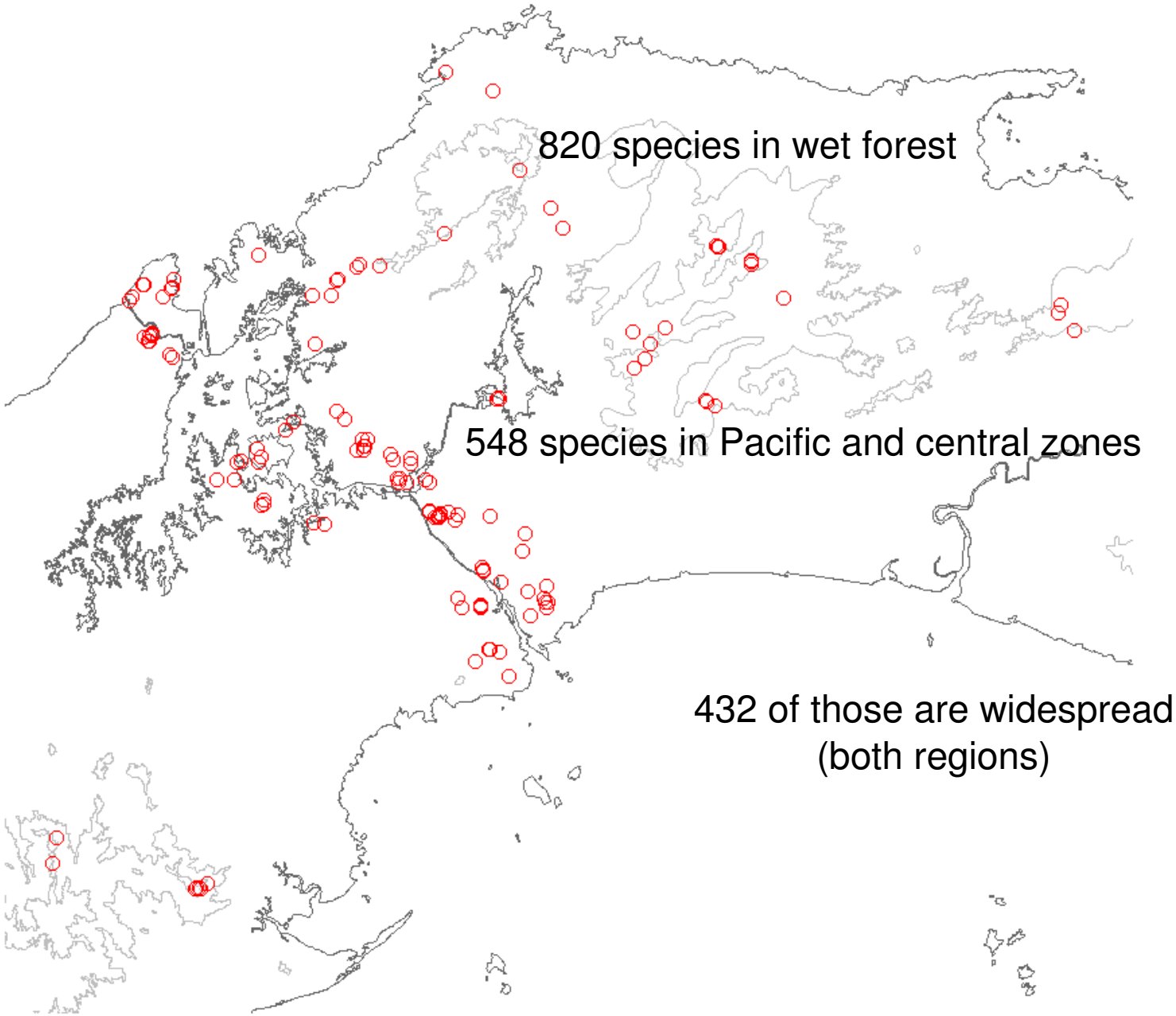
Tree inventories
Estimated dry season intensity at each



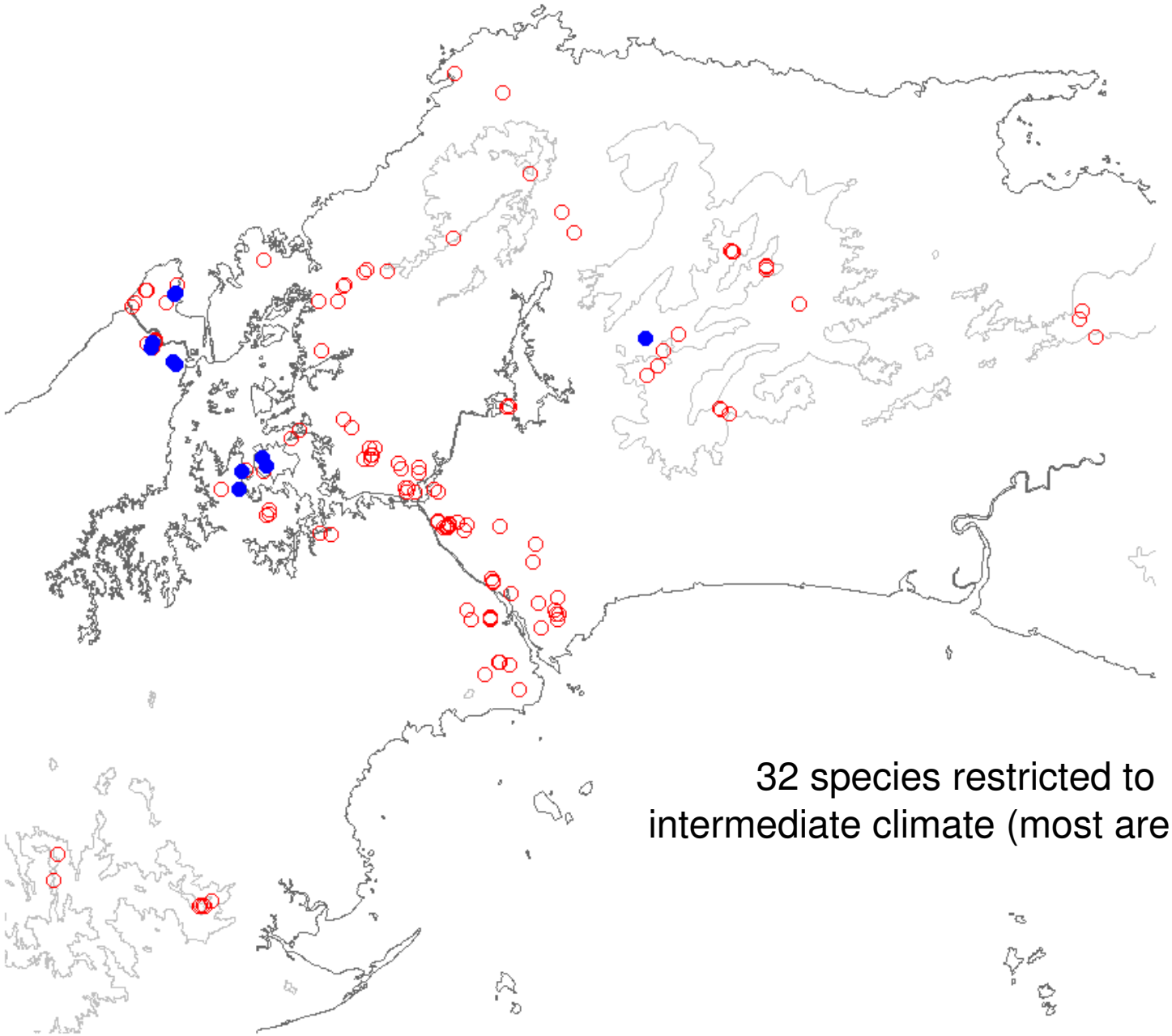
Tree inventories
Estimated dry season intensity at each



Regional species pools

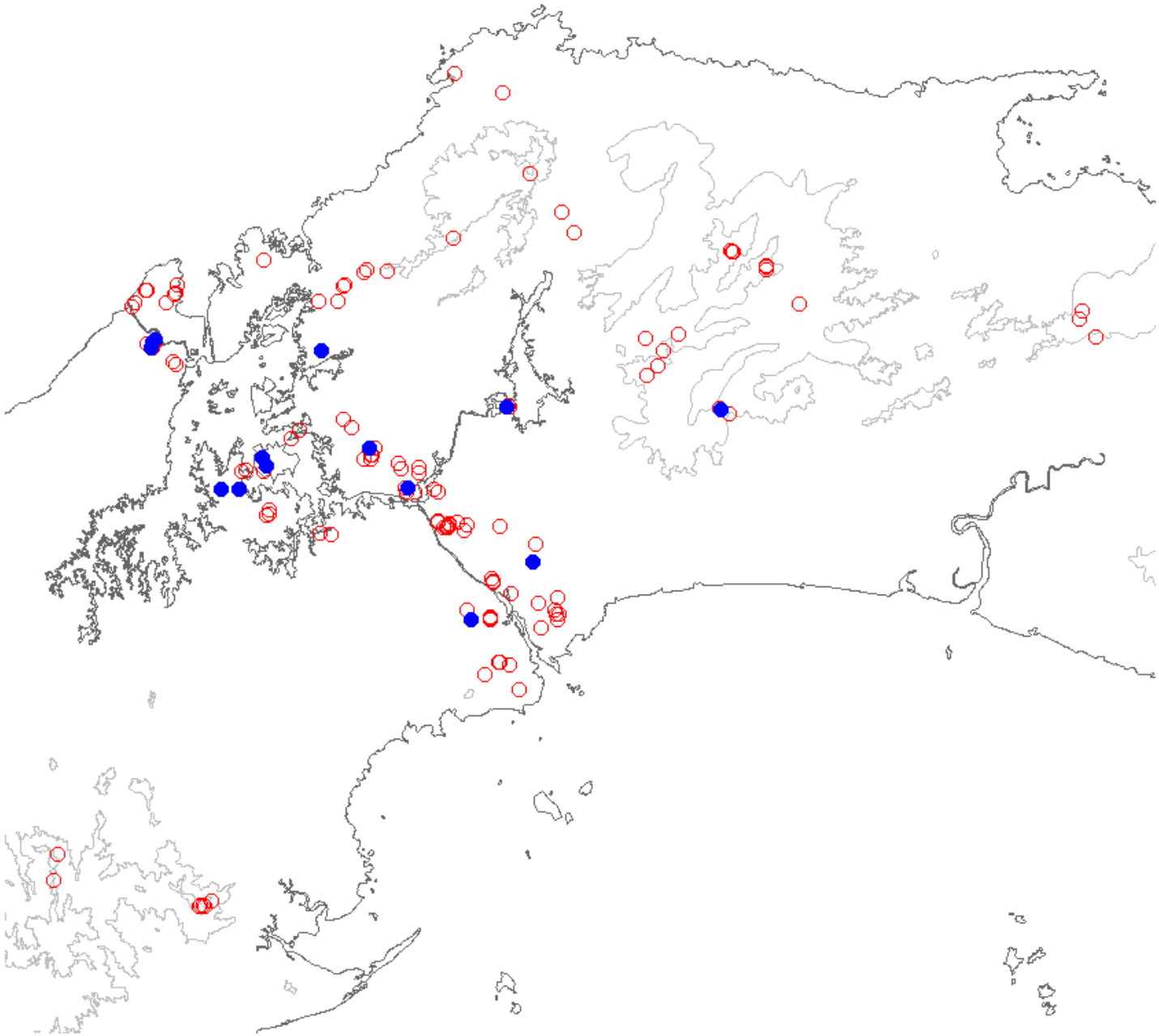


Inga marginata plots and inventories

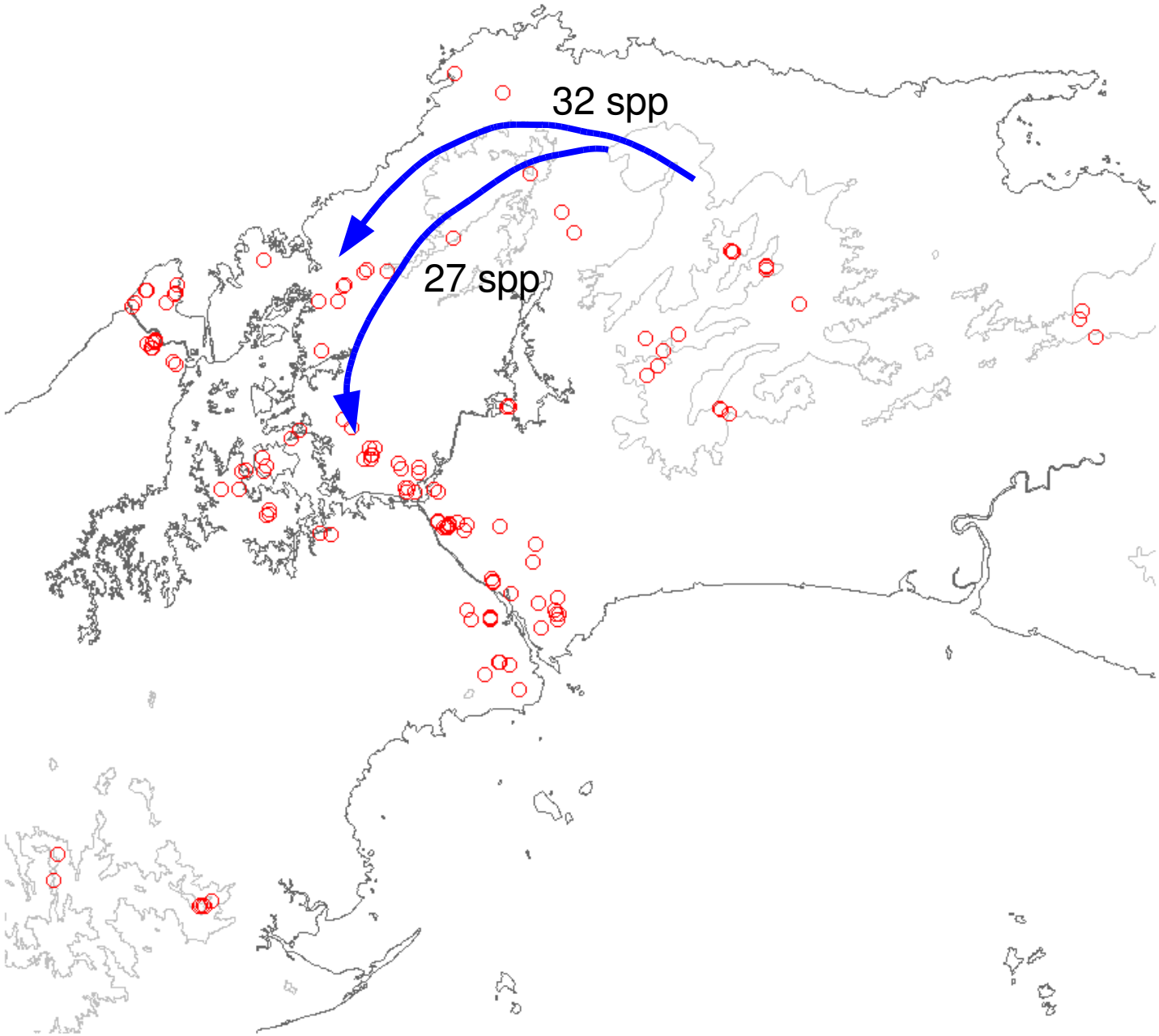


32 species restricted to intermediate climate (most are rare)

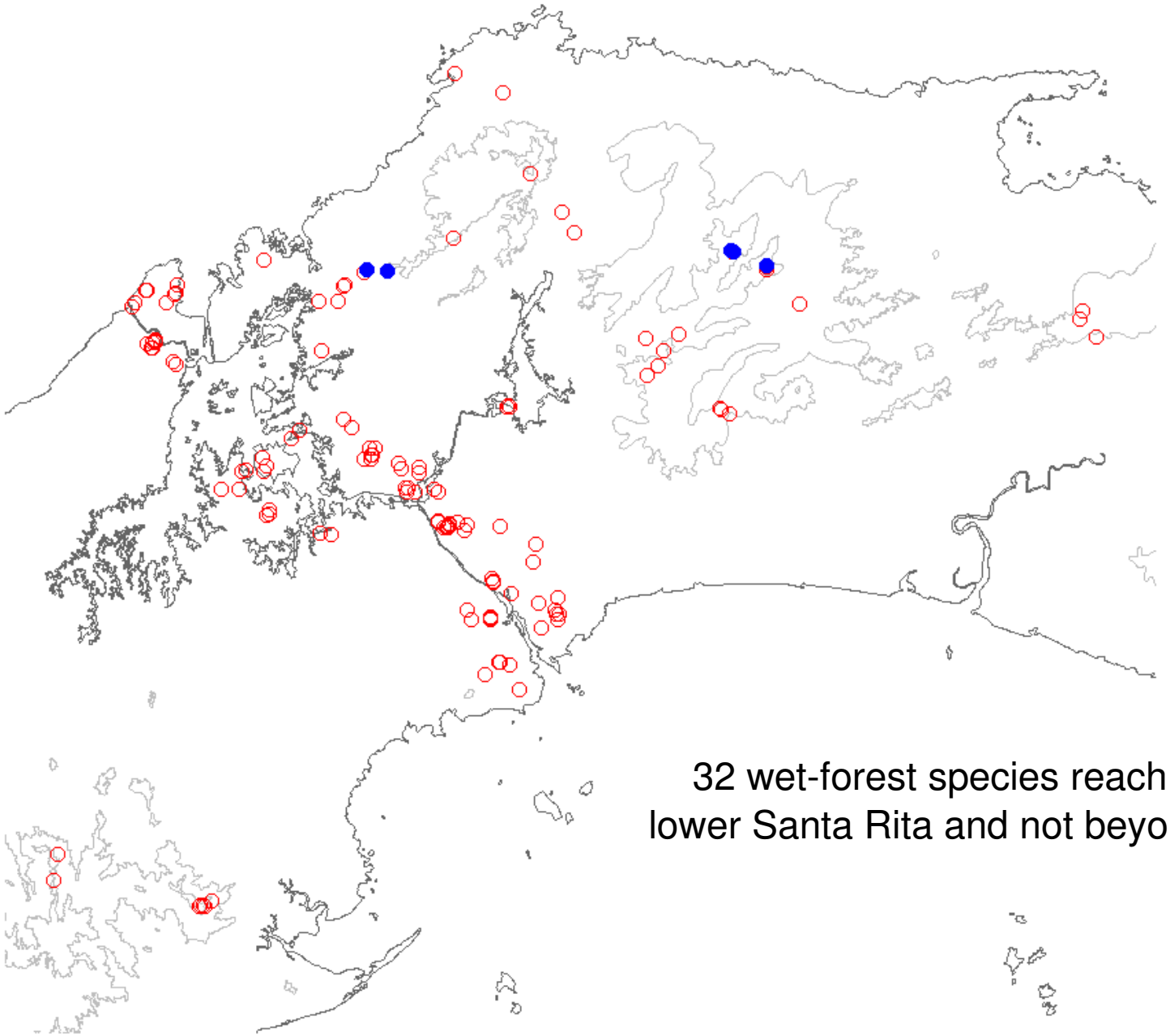
Schizolobium parahyba plots and inventories



Frequent climatic limits of wet forest species



Sloanea laurifolia plots and inventories



32 wet-forest species reach lower Santa Rita and not beyond