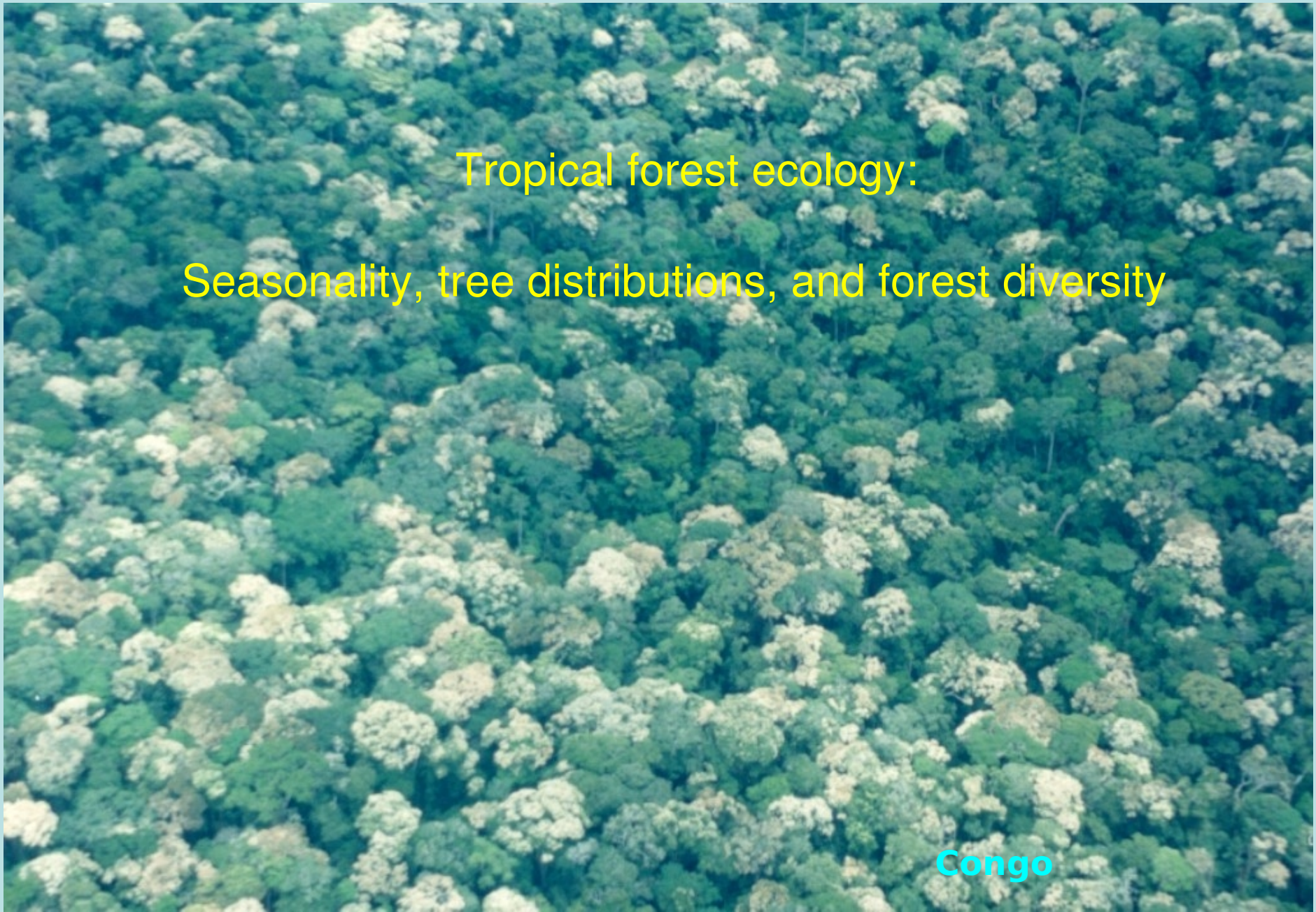
Center for Tropical Forest Science: Global Forest Monitoring Network



Center for Tropical Forest Science: Global Forest Monitoring Network

Tropical forest ecology:

Seasonality, tree distributions, and forest diversity

Richard Condit
Smithsonian Tropical Research Institute

Helmholtz Centre
for Environmental Research
Leipzig, Germany
August 2008

Global Forest Observatory Network (GFON)

~ 8,200 species
~ 3 million trees monitored globally

CTFS Network

PANAMA - STRI

COLOMBIA - Instituto Humboldt

ECUADOR - Universidad Catolica de Ecuador, University of Aarhus (Denmark), Field Museum (USA)

PUERTO RICO - University of Puerto Rico, USDA Forest Service

BRAZIL - INPA, Universidade de Sao Paulo, Louisiana State University

INDIA - Indian Institute of Science

MALAYSIA- Forest Research Institute of Malaysia, Sarawak Forest Department, Osaka City University (Japan), Kyoto University (Japan), National Institute of Environmental Studies (Japan), Harvard University (USA)

PHILIPPINES - Isabela State University, PLAN International, Conservation International-Philippines, Harvard University (USA)

SINGAPORE - Nanyang Technological University, Singapore National Parks Board

SRI LANKA - University of Peradeniya, Sri Lanka Forest Department, University of Sri Jayawardenepura

THAILAND - Royal Forest Department, National Institute of Environmental Studies (Japan), Harvard University (USA)

CAMEROON - University of Buea, Oregon State University

DEM. REP. CONGO - CEFRECOF, Wildlife Conservation Society

TAIWAN - Tunghai University

Forest Dynamics Plots

	species ≥ 1 cm dbh	annual rainfall (mm)	dry season (months)
Panama, BCI	274	2500	4
Ecuador, Yasuni	1104	3000	0
Colombia, La Planada	241	3500	0
Puerto Rico, Luquillo *	120	3500	0
India, Mudumalai	66	1200	6
Thailand, HKK	206	1450	6
Thailand, Kao Chong	660	1600	2
Malaysia, Pasoh	785	1800	0
Malaysia, Lambir	1111	2700	0
Sri Lanka, Sinharaja	205	4400	0
China, Xishuangbanna			
China, Changbaishan	*52*	*1000*	*(winter)*
Cameroon, Korup	482	5000	2
D.R. Congo, Ituri			
--monodominant *	403	1700	2
--mixed *	409	1700	2

* species in exactly 25 hectares unless noted with asterisk (16-20 ha)

Forest Dynamics Plots

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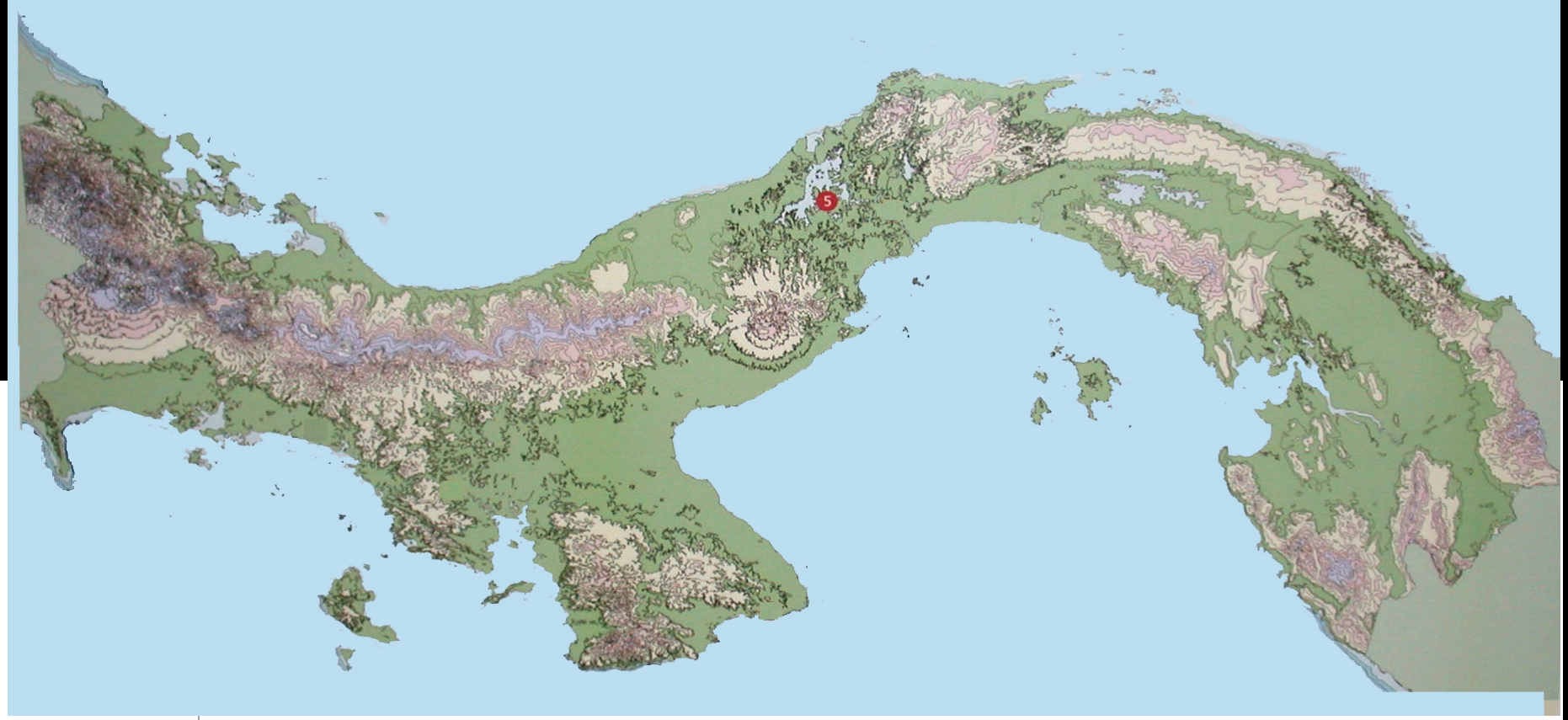
The dry season as driver of forest patterns:

- 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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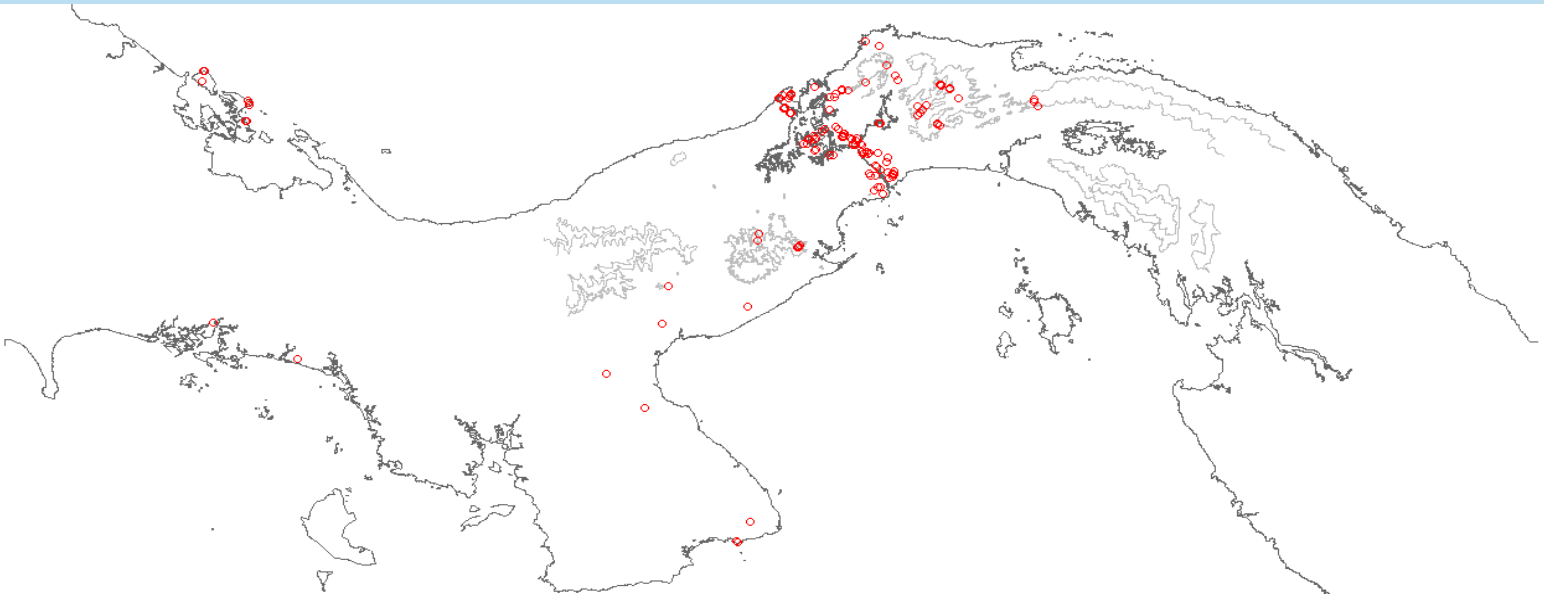
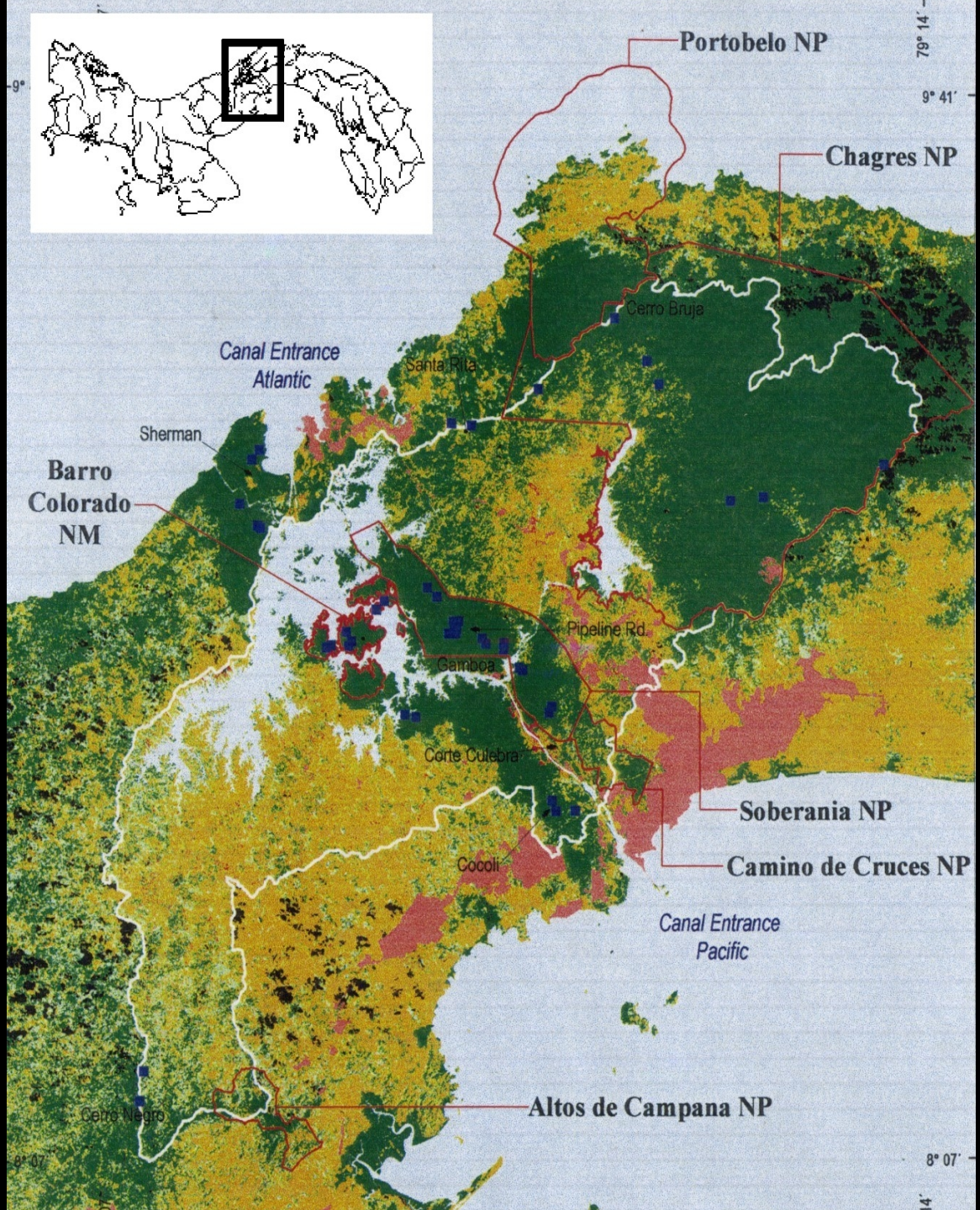
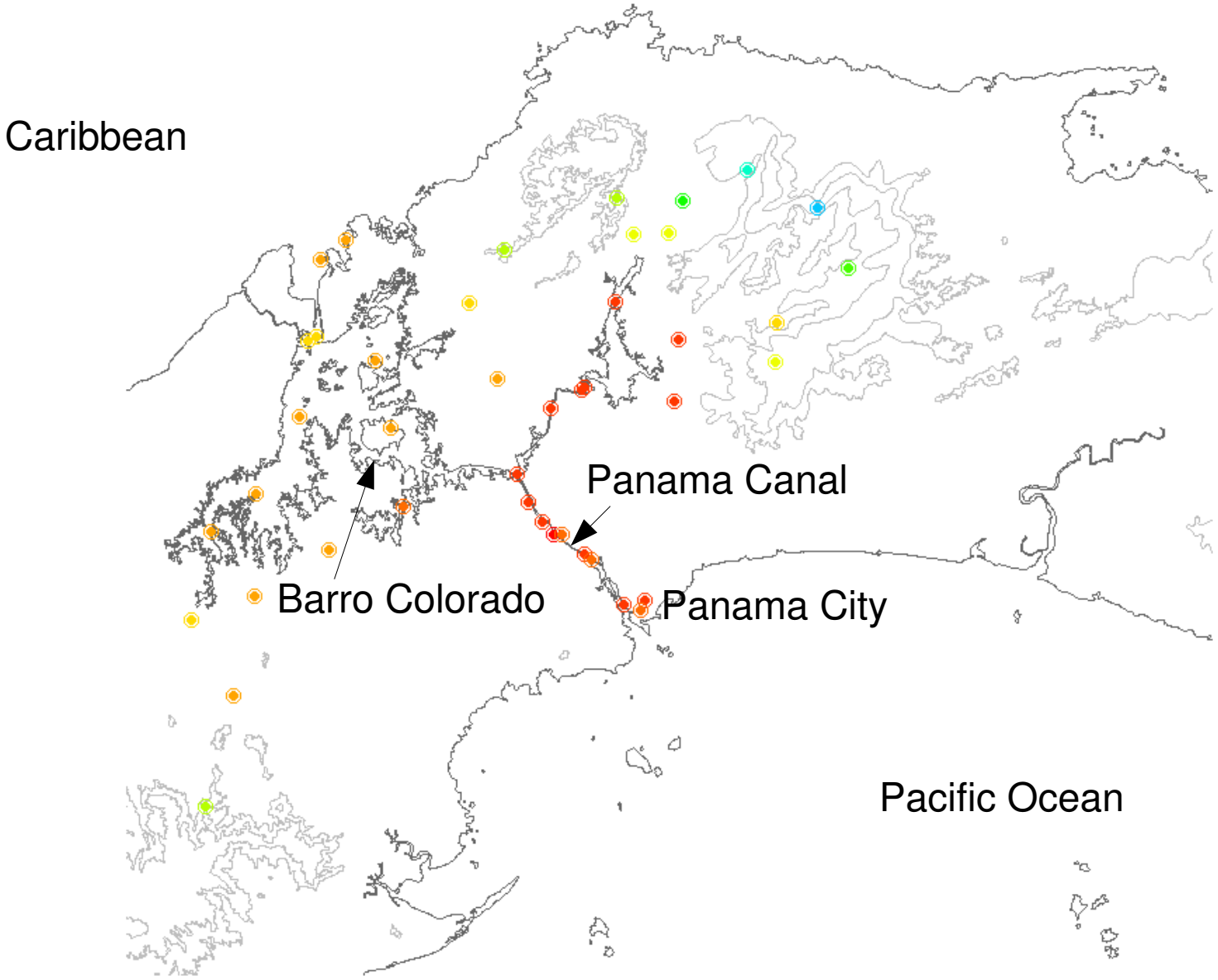


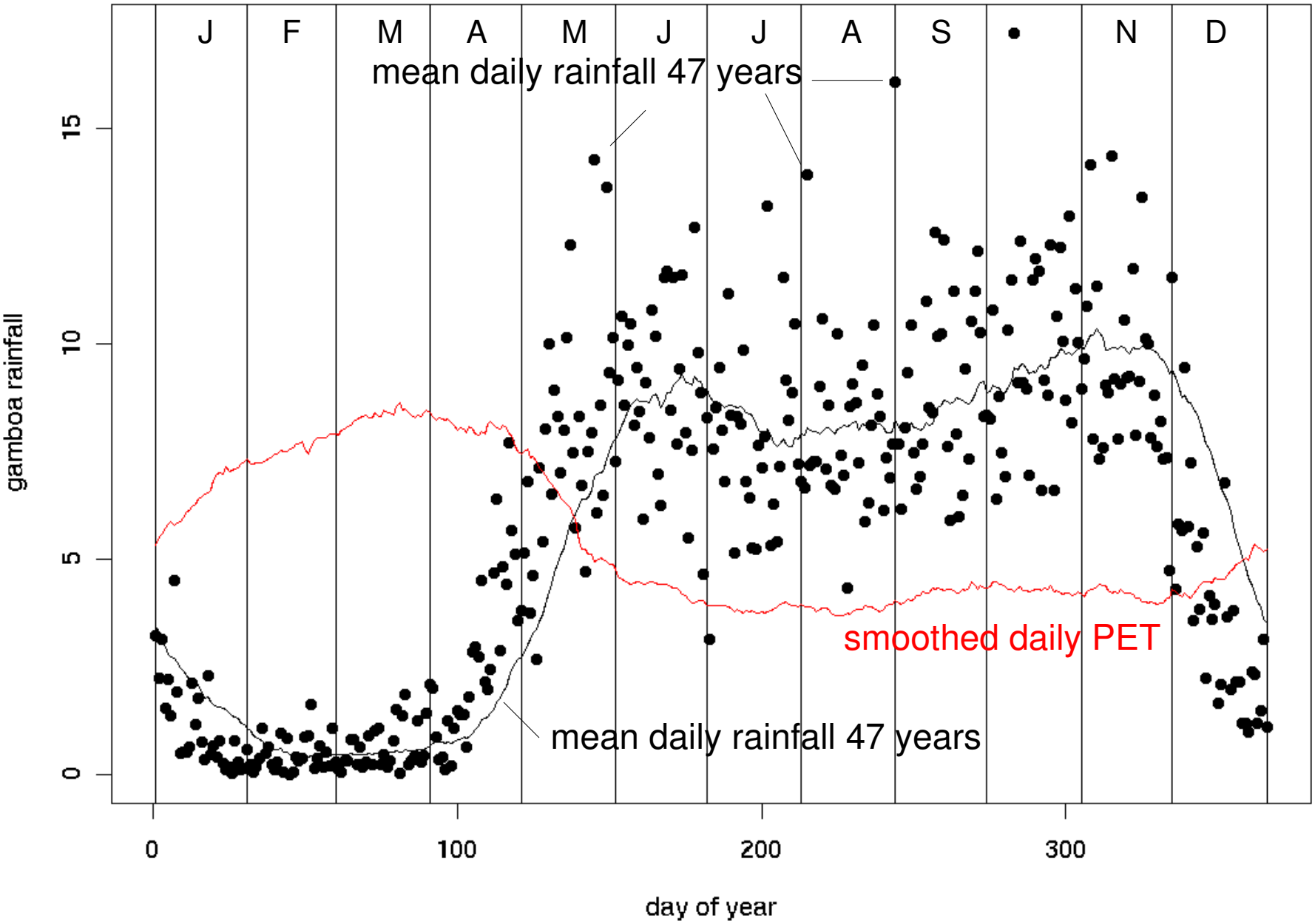

Portobelo NP
Chagres NP
Cerro Bruja
Canal Entrance
Atlantic
Santa Rita
Sherman
Barro
Colorado
NM
Pipeline Rd.
Gamboa
Corte Culebra
Soberania NP
Cocoli
Camino de Cruces NP
Canal Entrance
Pacific
Altos de Campana NP
Cerro Negro
79° 14′
9° 41′
8° 07′

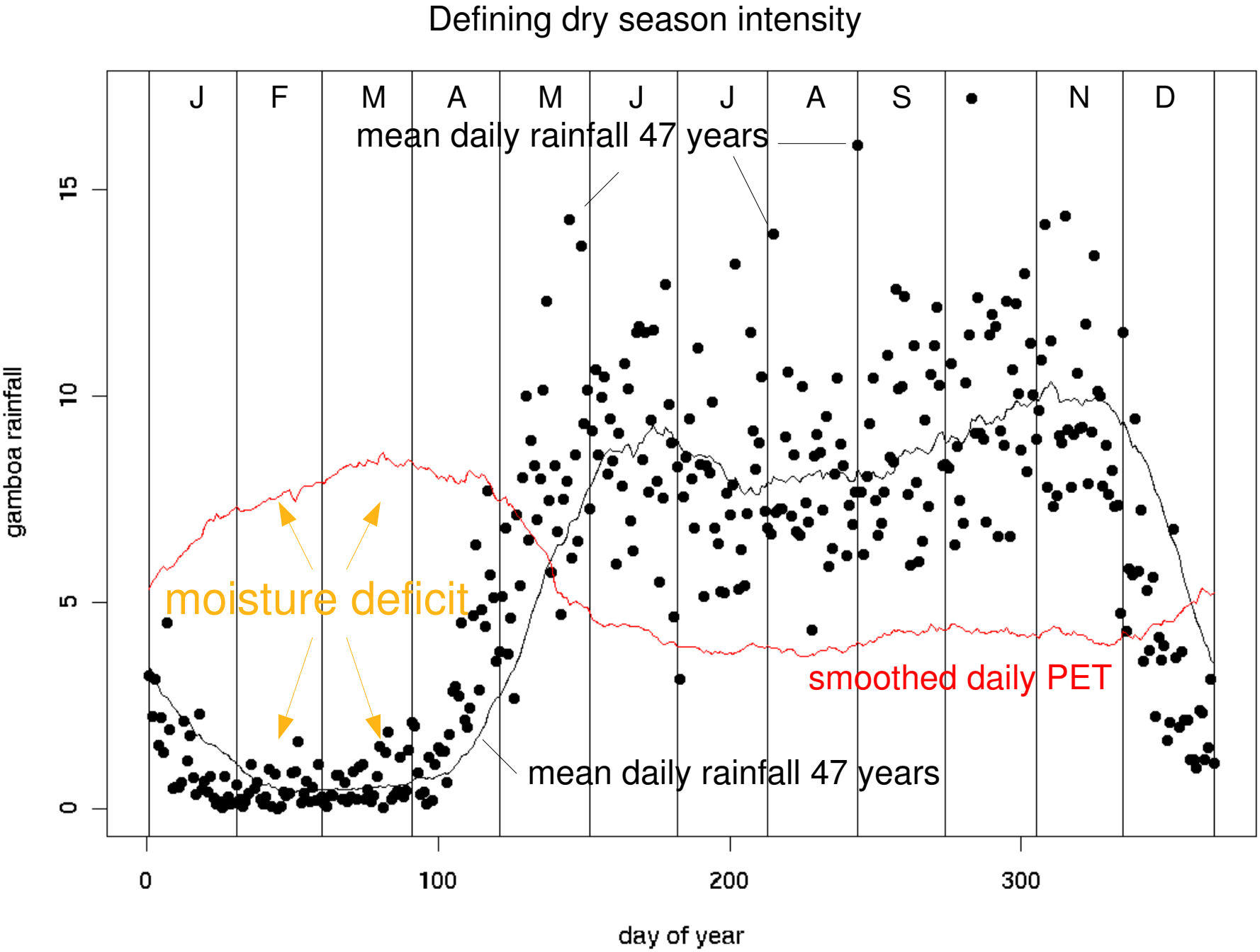
Dry season intensity...

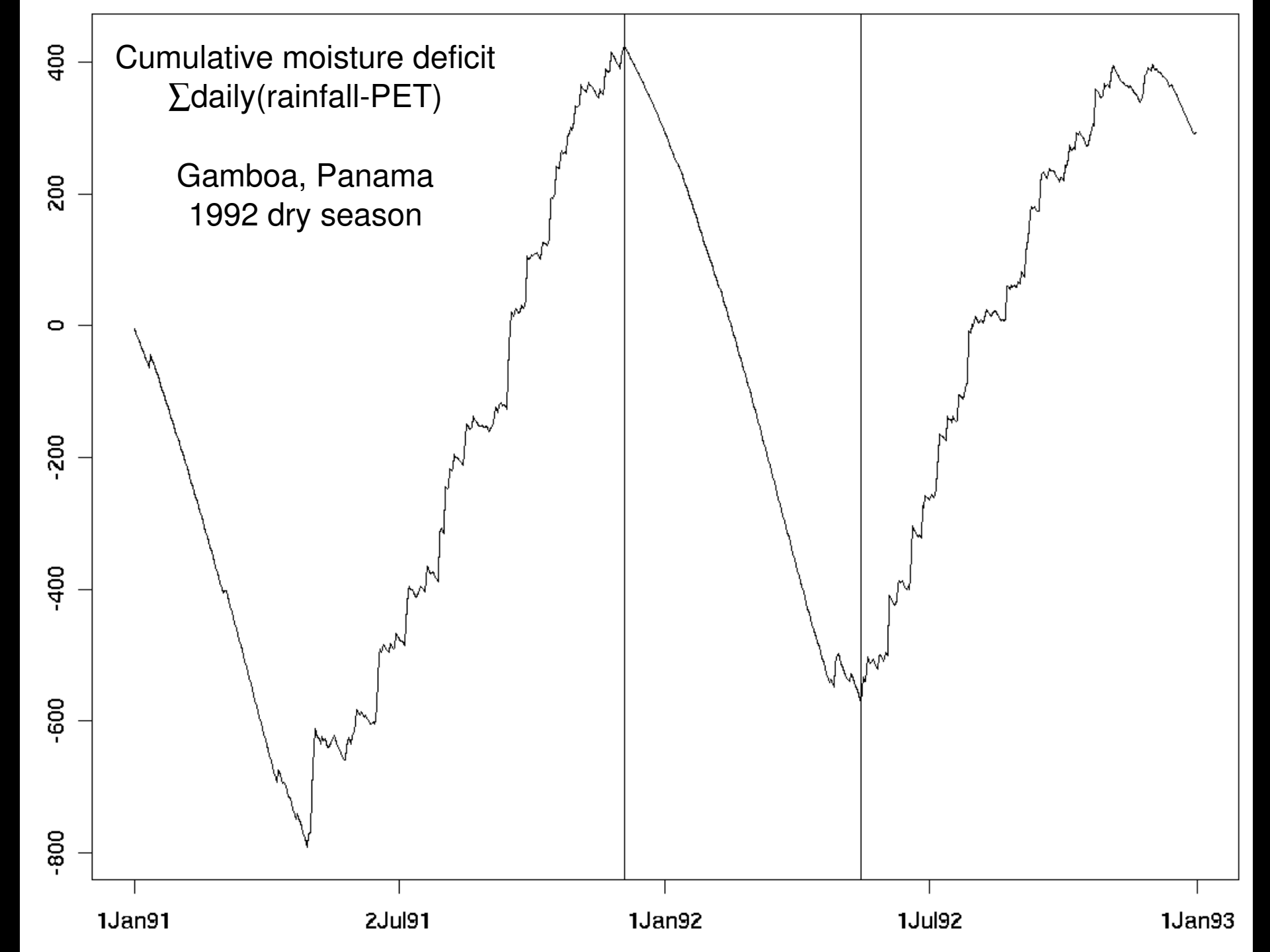
Panama Canal Authority rainfall gauges
3-100 year records

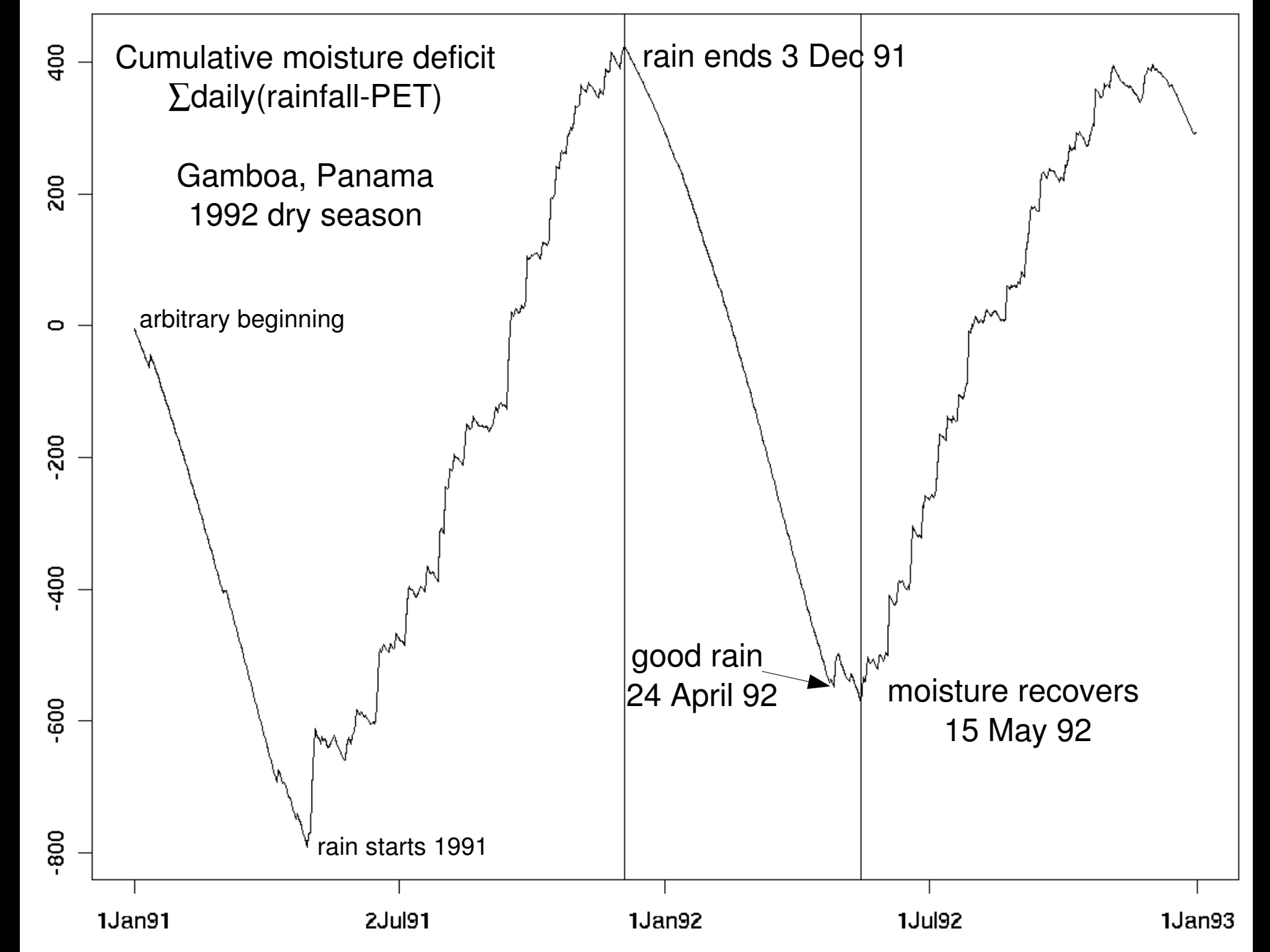


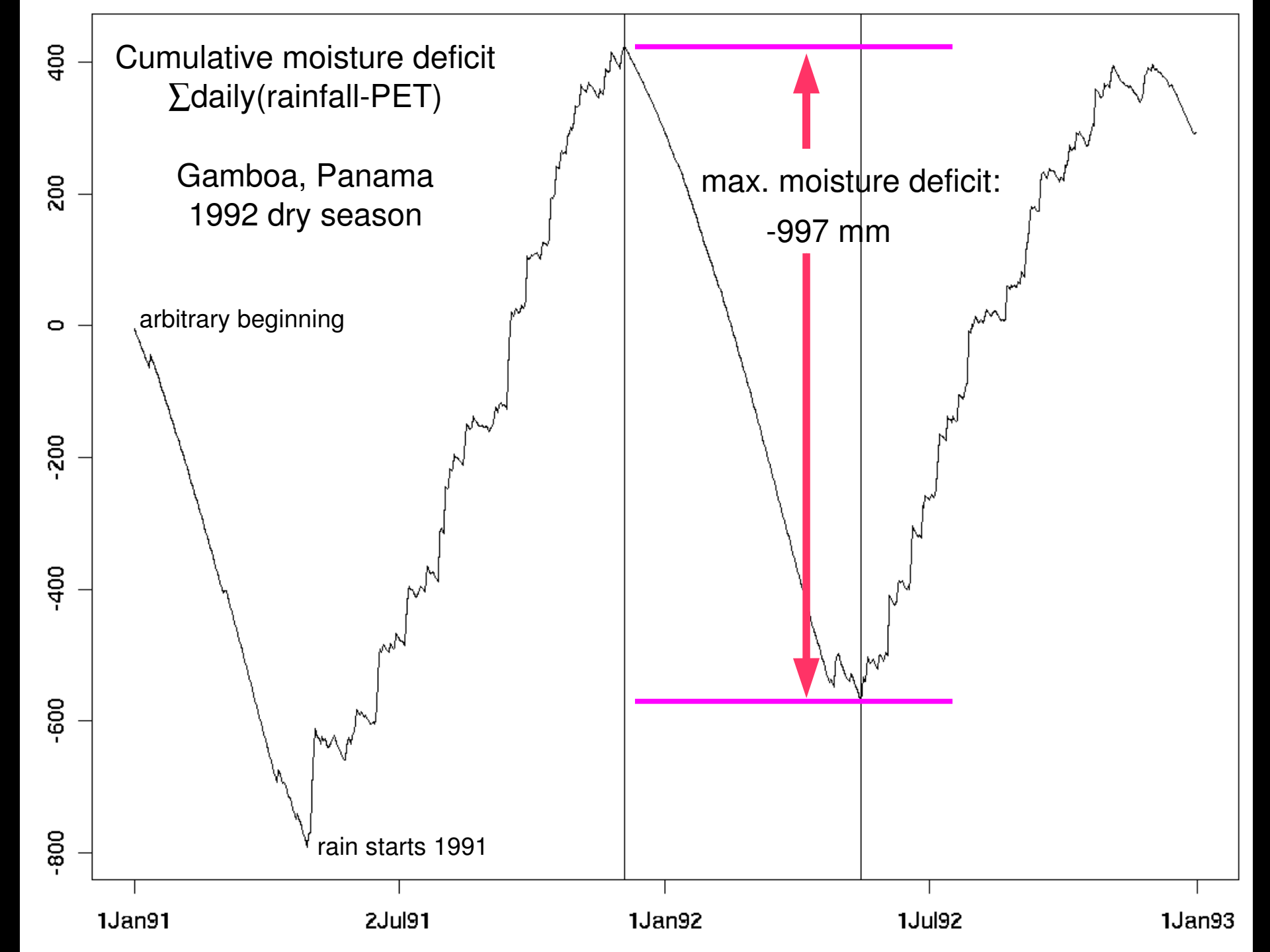
Defining dry season intensity

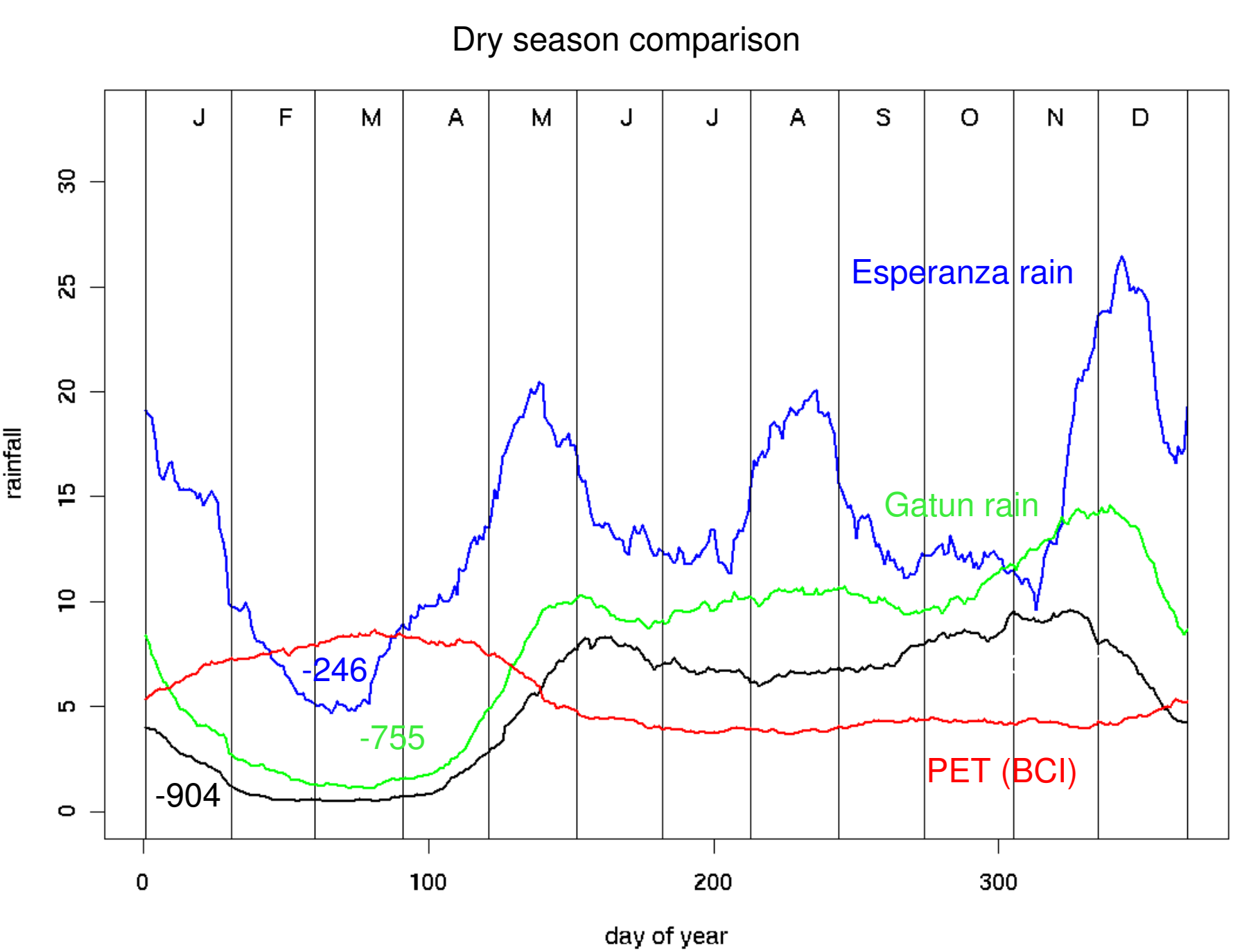



Defining dry season intensity
J
F
M
A
M
J
J
A
S
N
D
mean daily rainfall 47 years
moisture deficit
smoothed daily PET
mean daily rainfall 47 years
gamboa rainfall
0
5
10
15
0
100
200
300
day of year

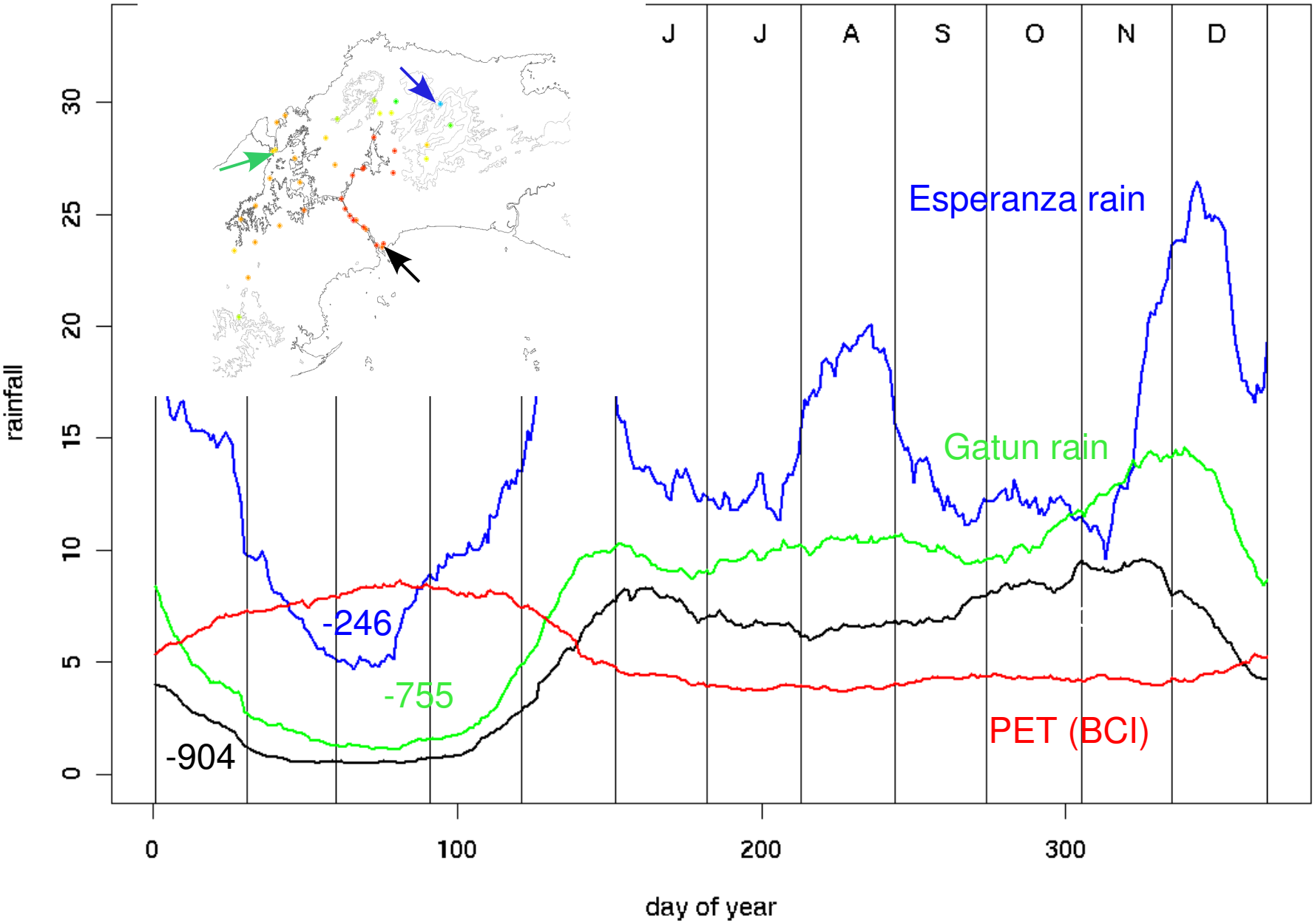

Cumulative moisture deficit
∑daily(rainfall-PET)
Gamboa, Panama
1992 dry season
400
200
0
-200
-400
-600
-800
1Jan91
2Jul91
1Jan92
1Jul92
1Jan93

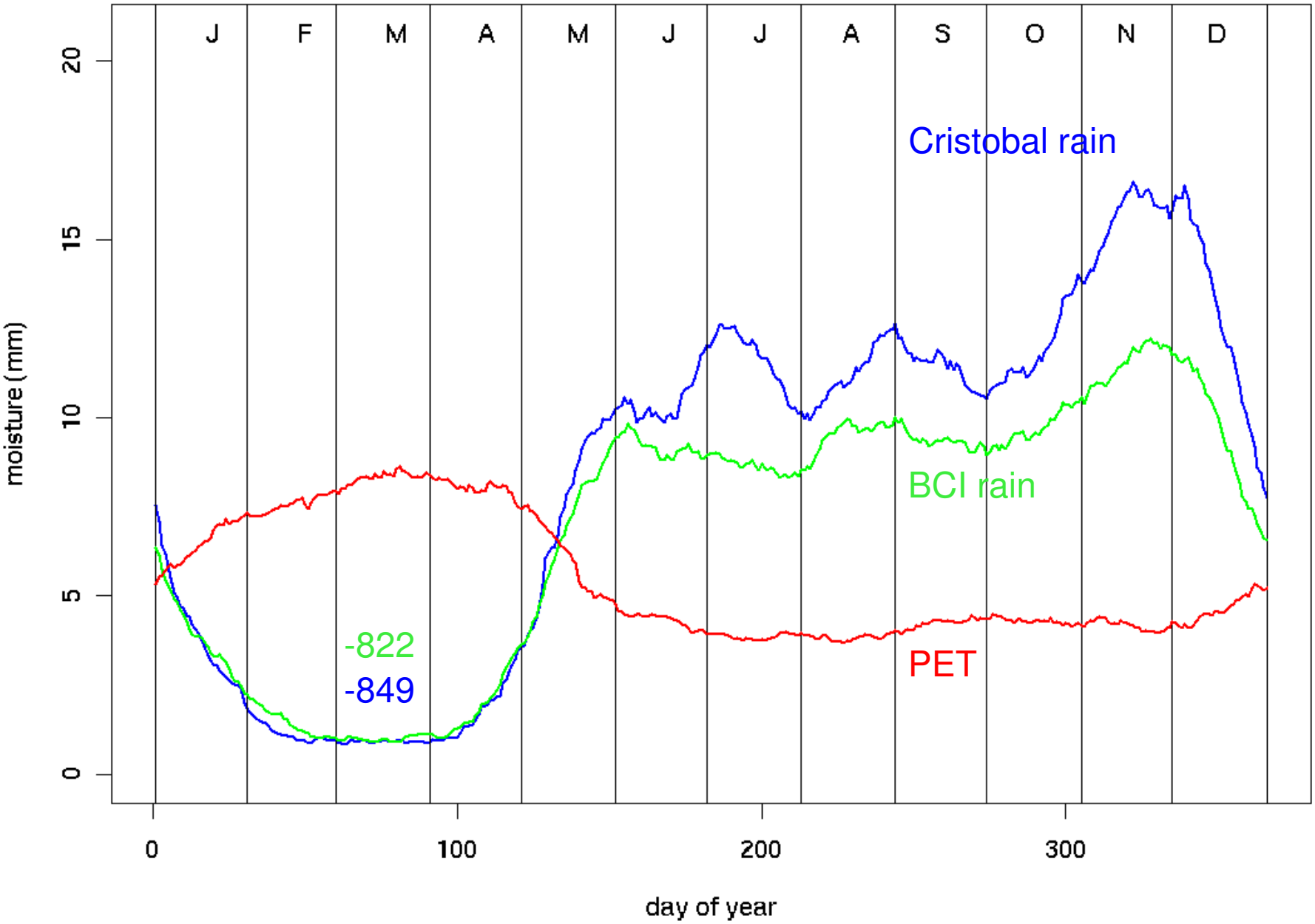

Cumulative moisture deficit
∑daily(rainfall-PET)
Gamboa, Panama
1992 dry season
arbitrary beginning
rain starts 1991
rain ends 3 Dec 91
good rain
24 April 92
moisture recovers
15 May 92
400
200
0
-200
-400
-600
-800
1Jan91
2Jul91
1Jan92
1Jul92
1Jan93


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

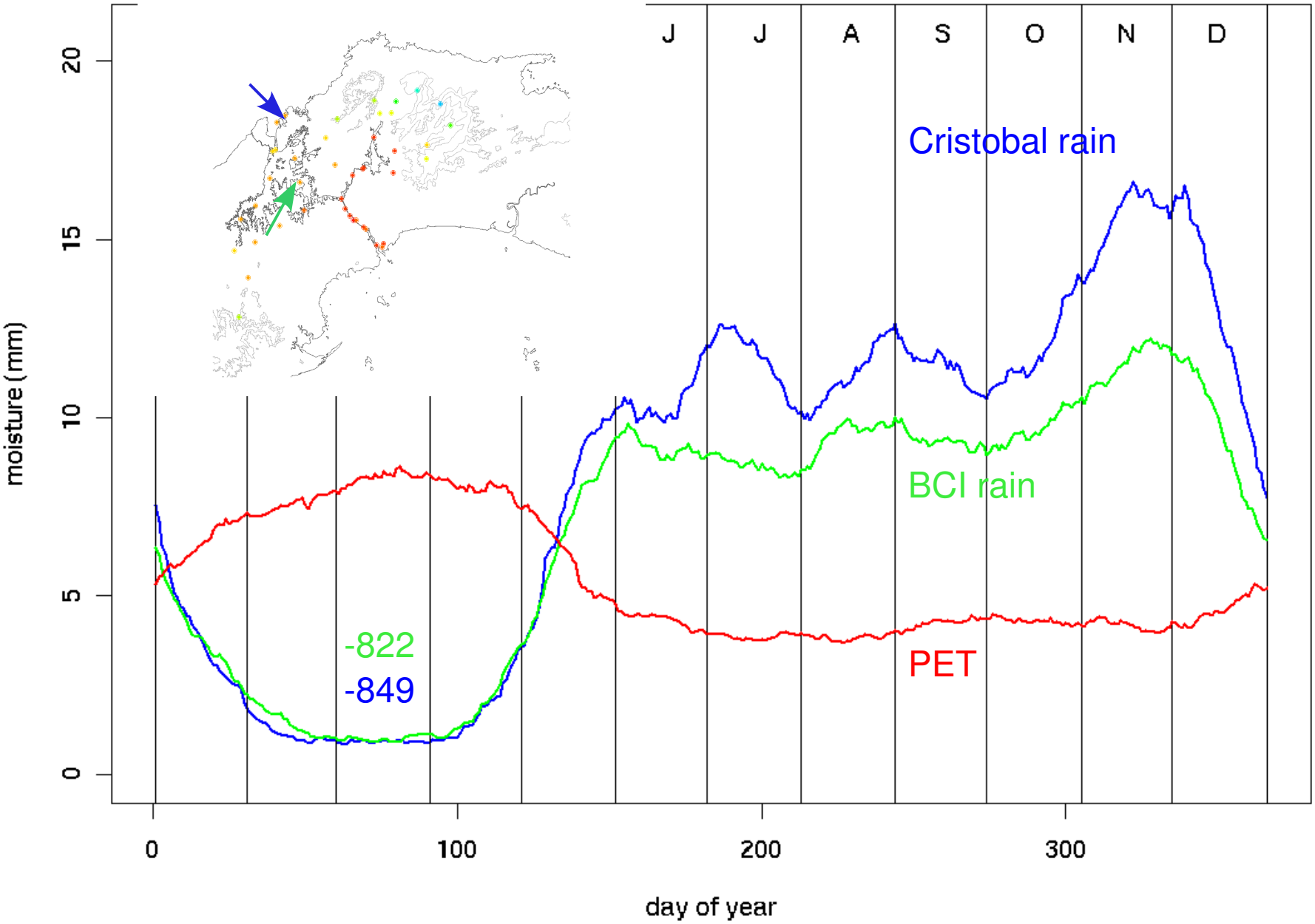

Dry season comparison
J
F
M
A
M
J
J
A
S
O
N
D
rainfall
0
5
10
15
20
25
30
Esperanza rain
Gatun rain
PET (BCI)
-246
-755
-904
0
100
200
300
day of year

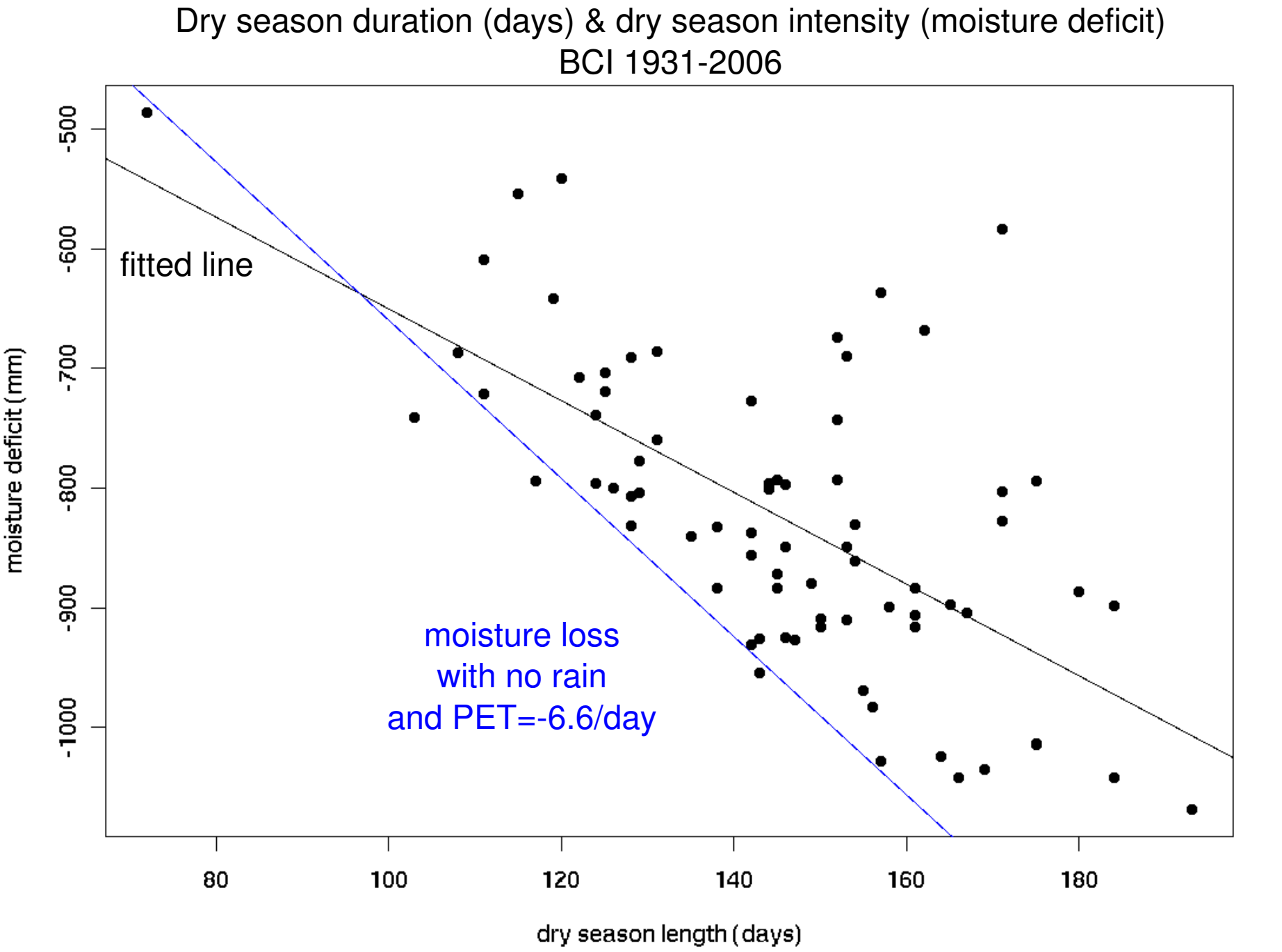
Dry season comparison

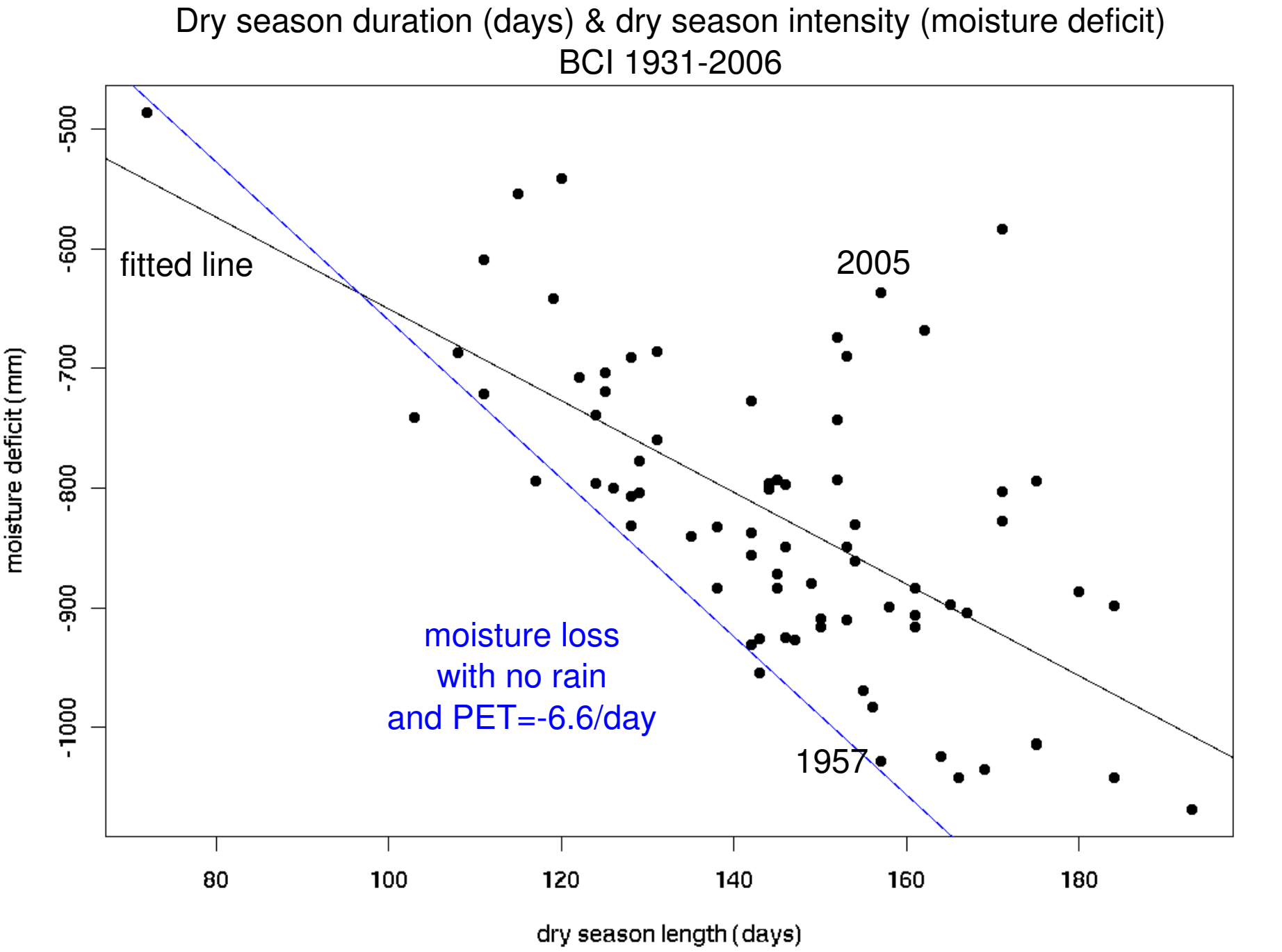


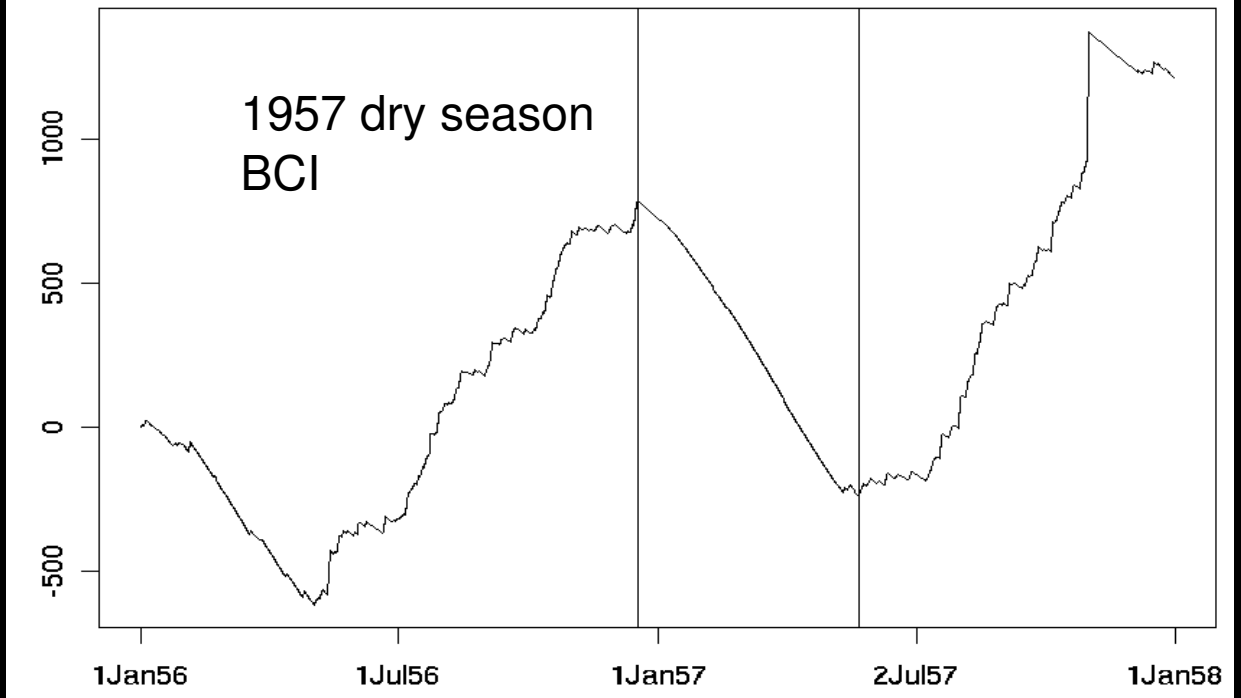

Dry season comparison
J
F
M
A
M
J
J
A
S
O
N
D
Cristobal rain
BCI rain
PET
-822
-849
moisture (mm)
0
5
10
15
20
0
100
200
300
day of year

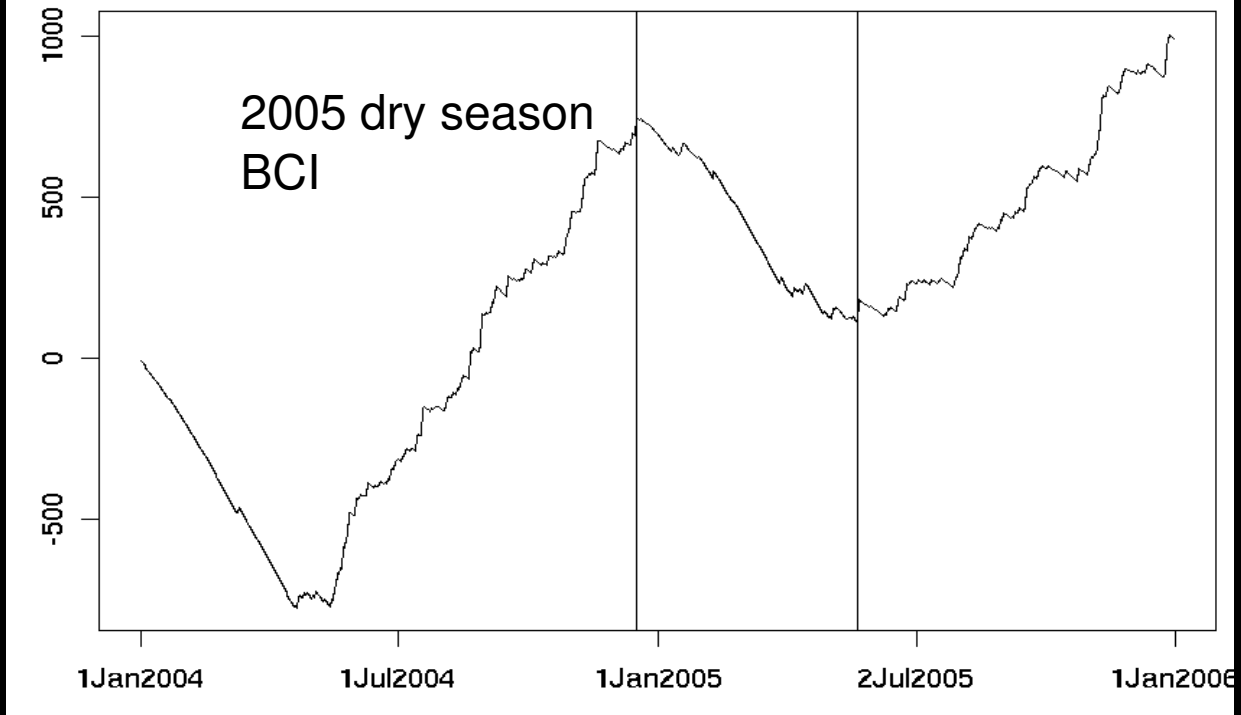
Dry season comparison

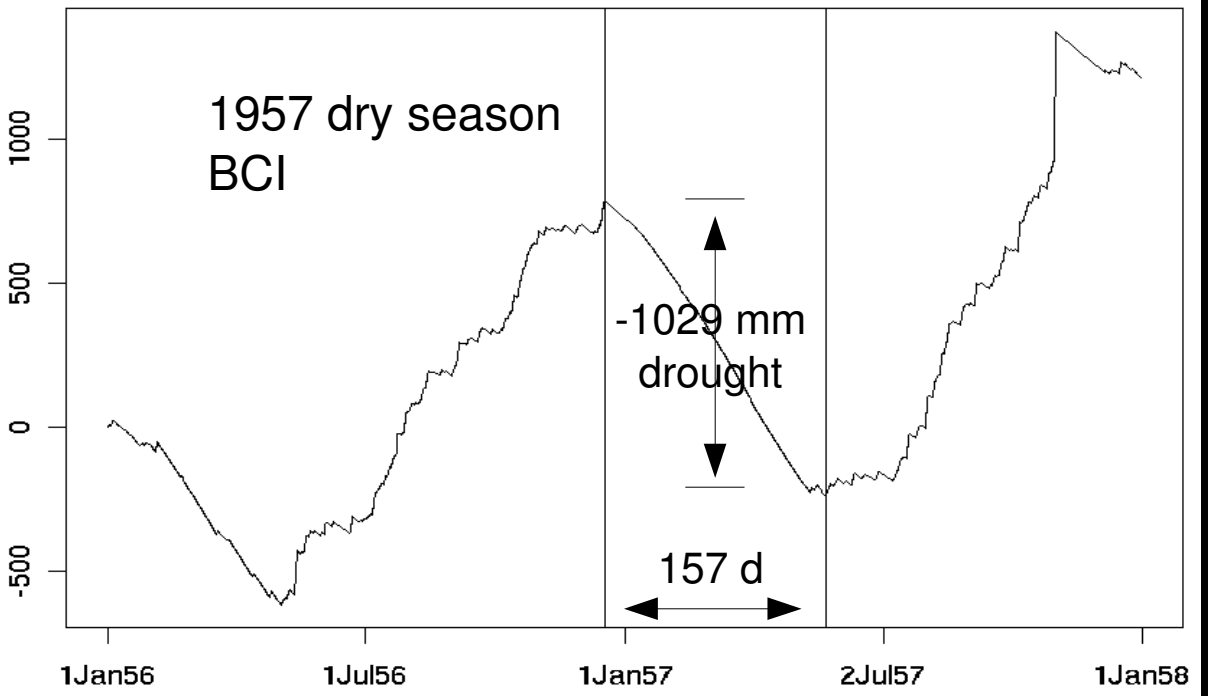


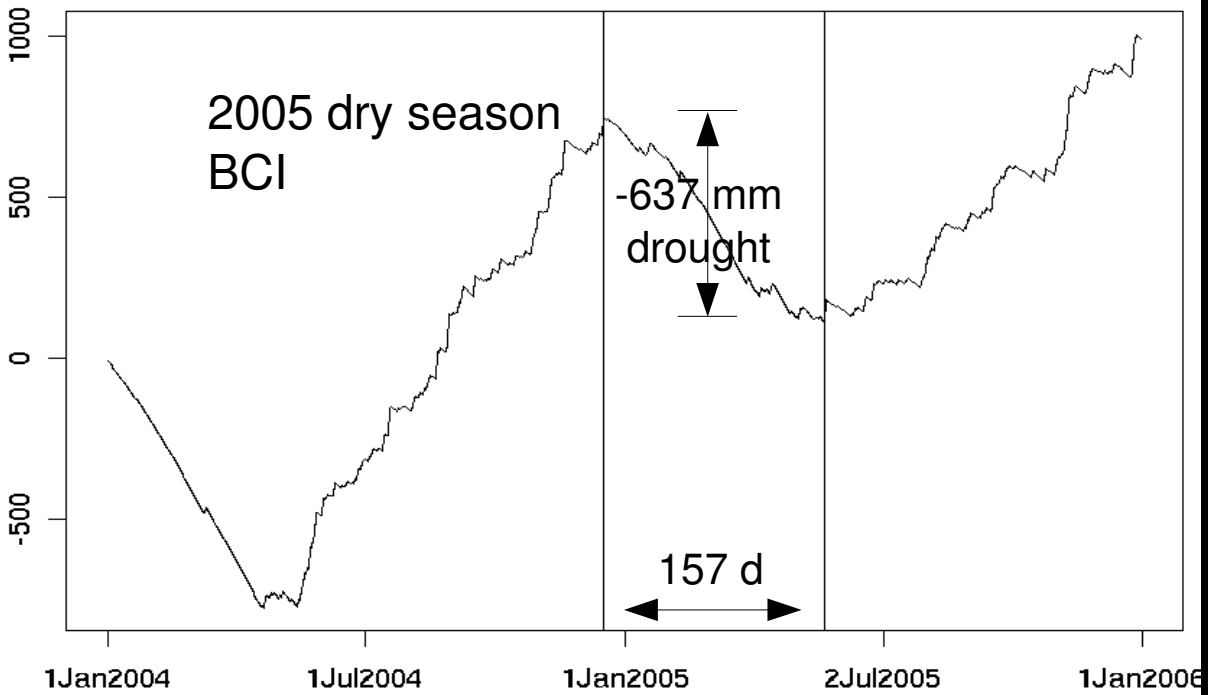

Dry season duration (days) & dry season intensity (moisture deficit)
BCI 1931-2006
fitted line
moisture loss
with no rain
and PET=-6.6/day
moisture deficit (mm)
-500
-600
-700
-800
-900
-1000
80
100
120
140
160
180
dry season length (days)


Dry season duration (days) & dry season intensity (moisture deficit)
BCI 1931-2006
fitted line
2005
moisture loss
with no rain
and PET=-6.6/day
1957
moisture deficit (mm)
-500
-600
-700
-800
-900
-1000
80
100
120
140
160
180
dry season length (days)

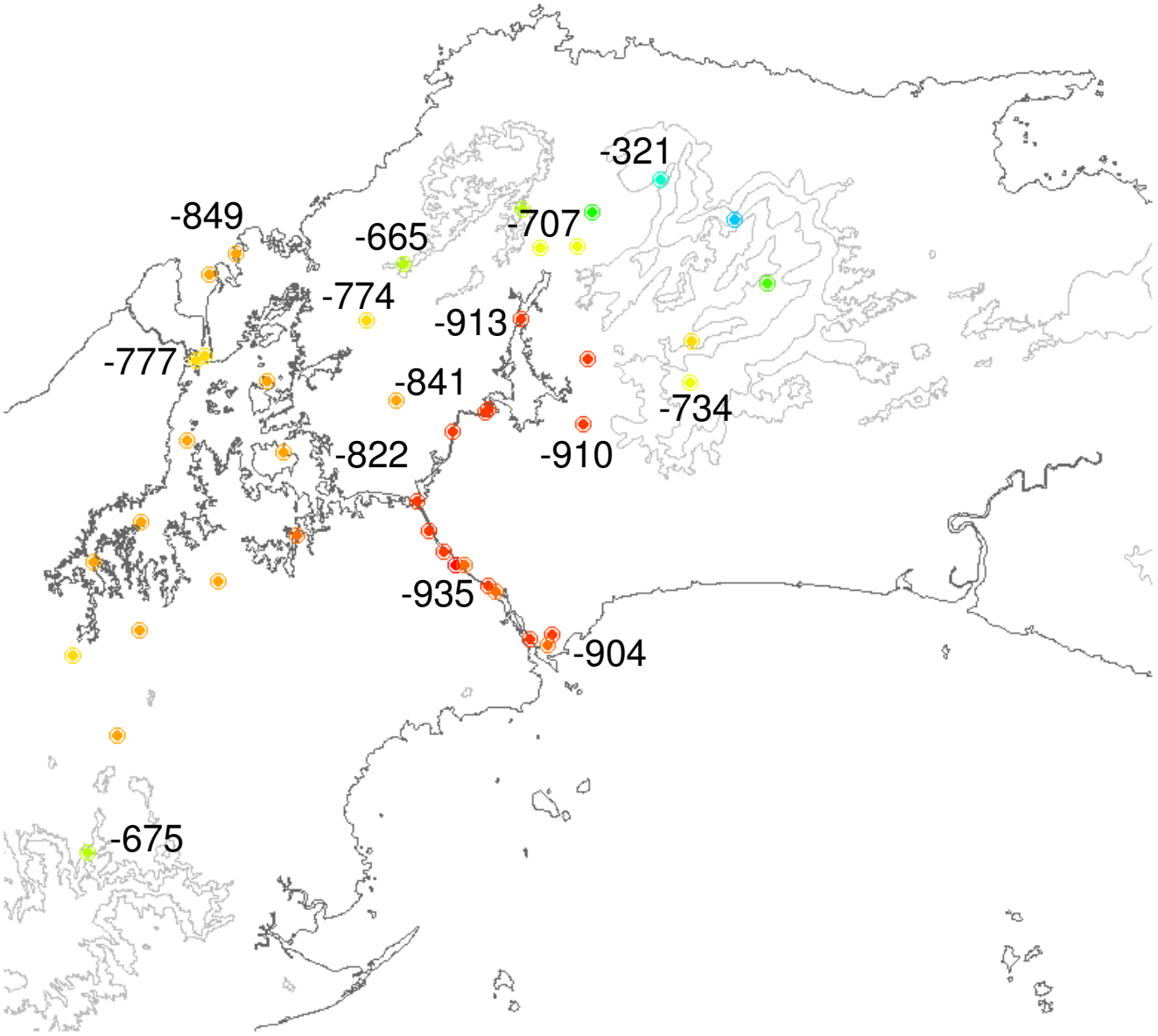

1957 dry season
BCI
1000
500
0
-500
1Jan56
1Jul56
1Jan57
2Jul57
1Jan58


2005 dry season
BCI
1000
500
0
-500
1Jan2004
1Jul2004
1Jan2005
2Jul2005
1Jan2006

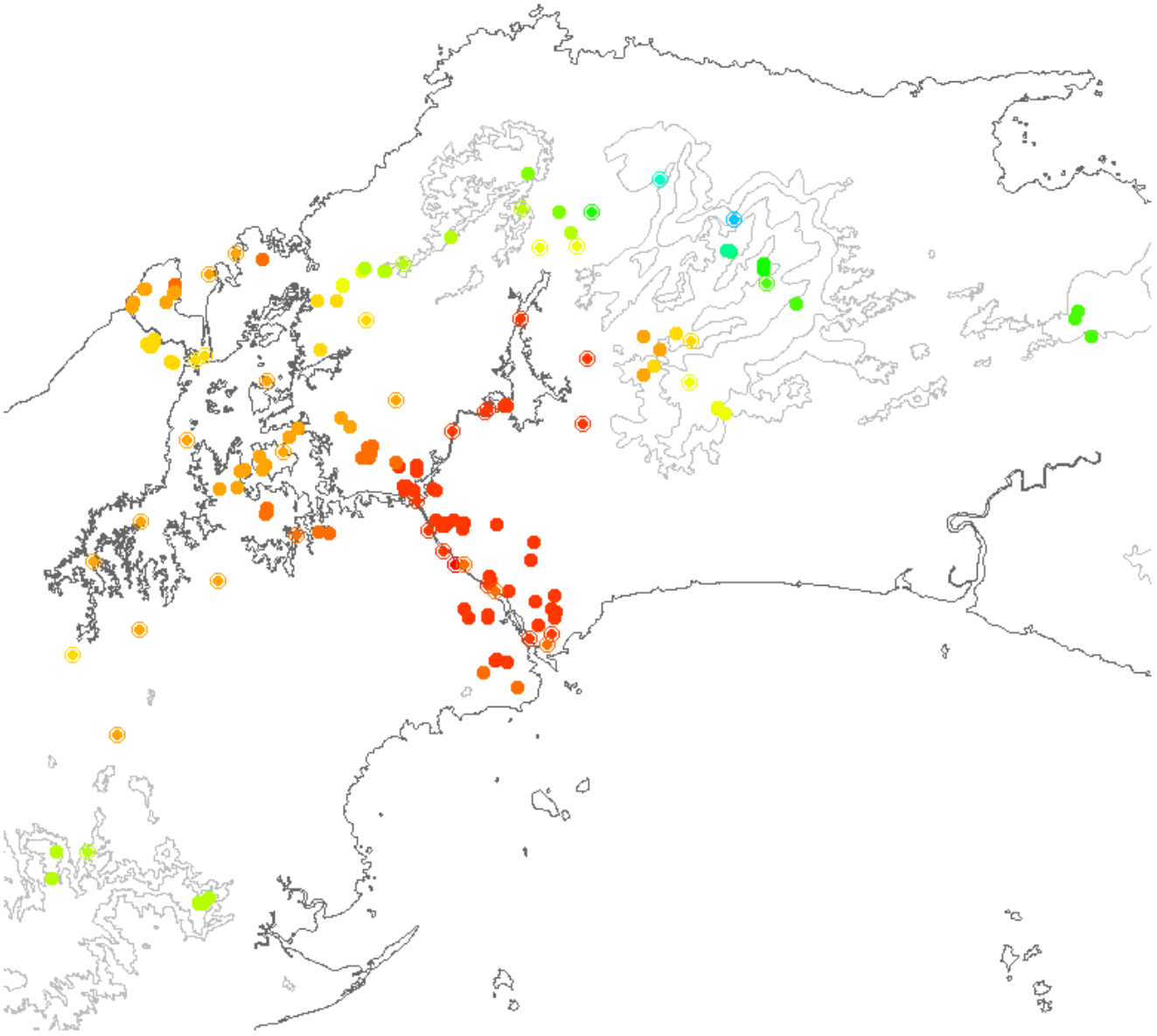

1957 dry season
BCI
-1029 mm
drought
157 d
1000
500
0
-500
1Jan56
1Jul56
1Jan57
2Jul57
1Jan58


2005 dry season
BCI
-637 mm
drought
157 d
1000
500
0
-500
1Jan2004
1Jul2004
1Jan2005
2Jul2005
1Jan2006

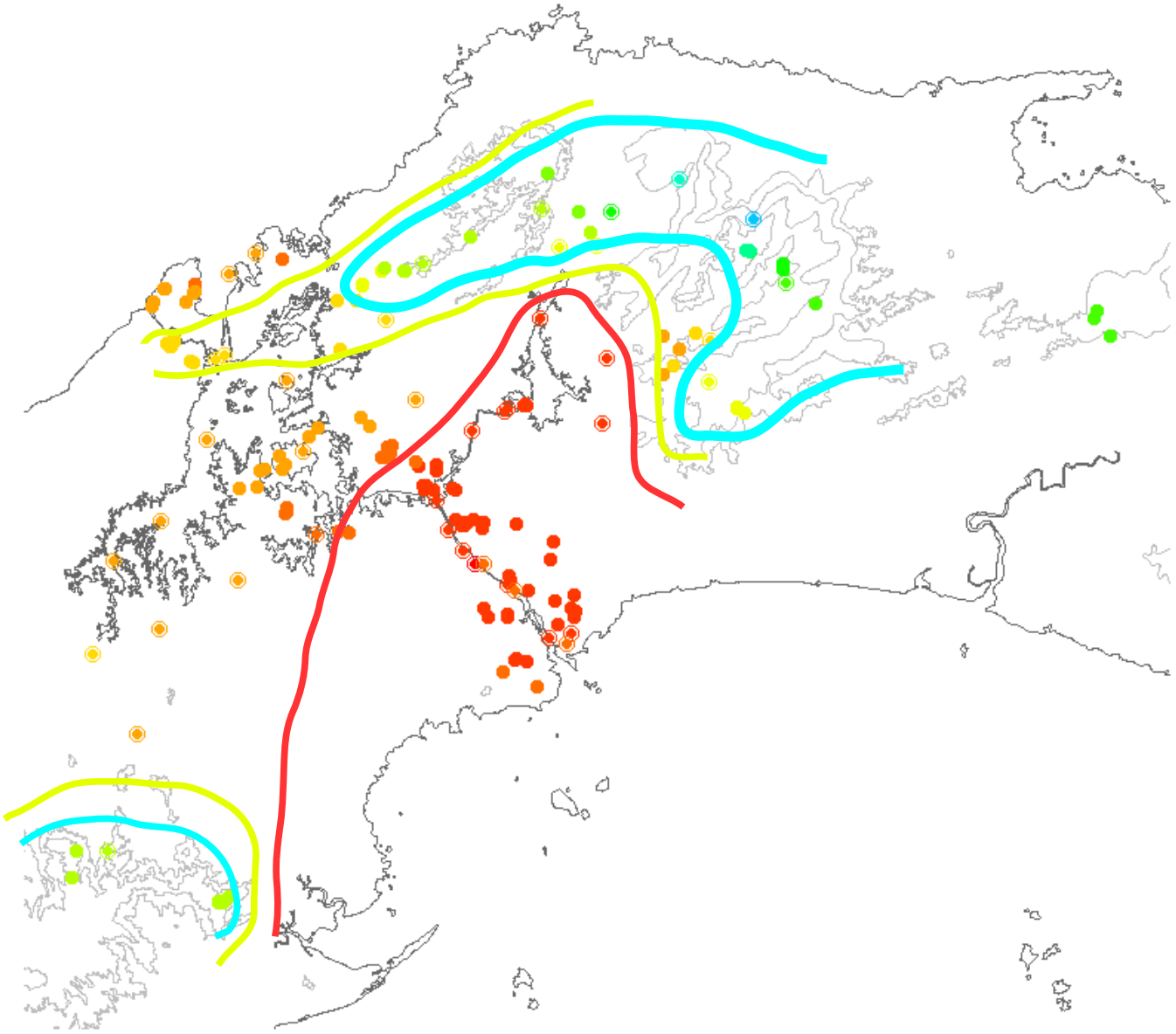
Panama Canal Authority rainfall gauges
Dry season intensity



Tree inventories
Estimated dry season intensity at each



Tree inventories
Estimated dry season intensity at each



Tree distributions across the gradient in drought

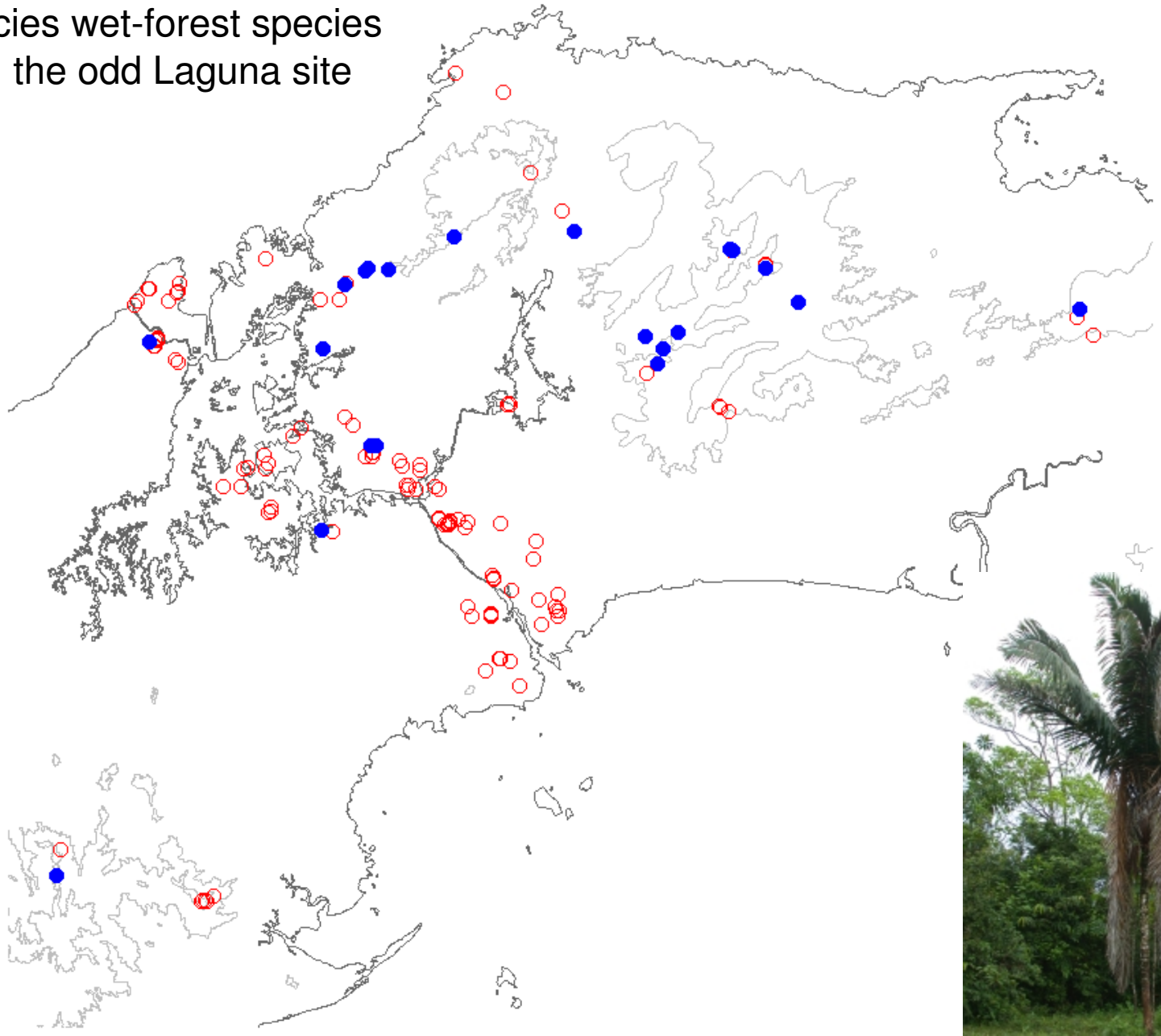
Lecointea amazonica plots and inventories

Manilkara bidentata plots and inventories

Maranthes panamensis plots and inventories

Welfia regia plots and inventories

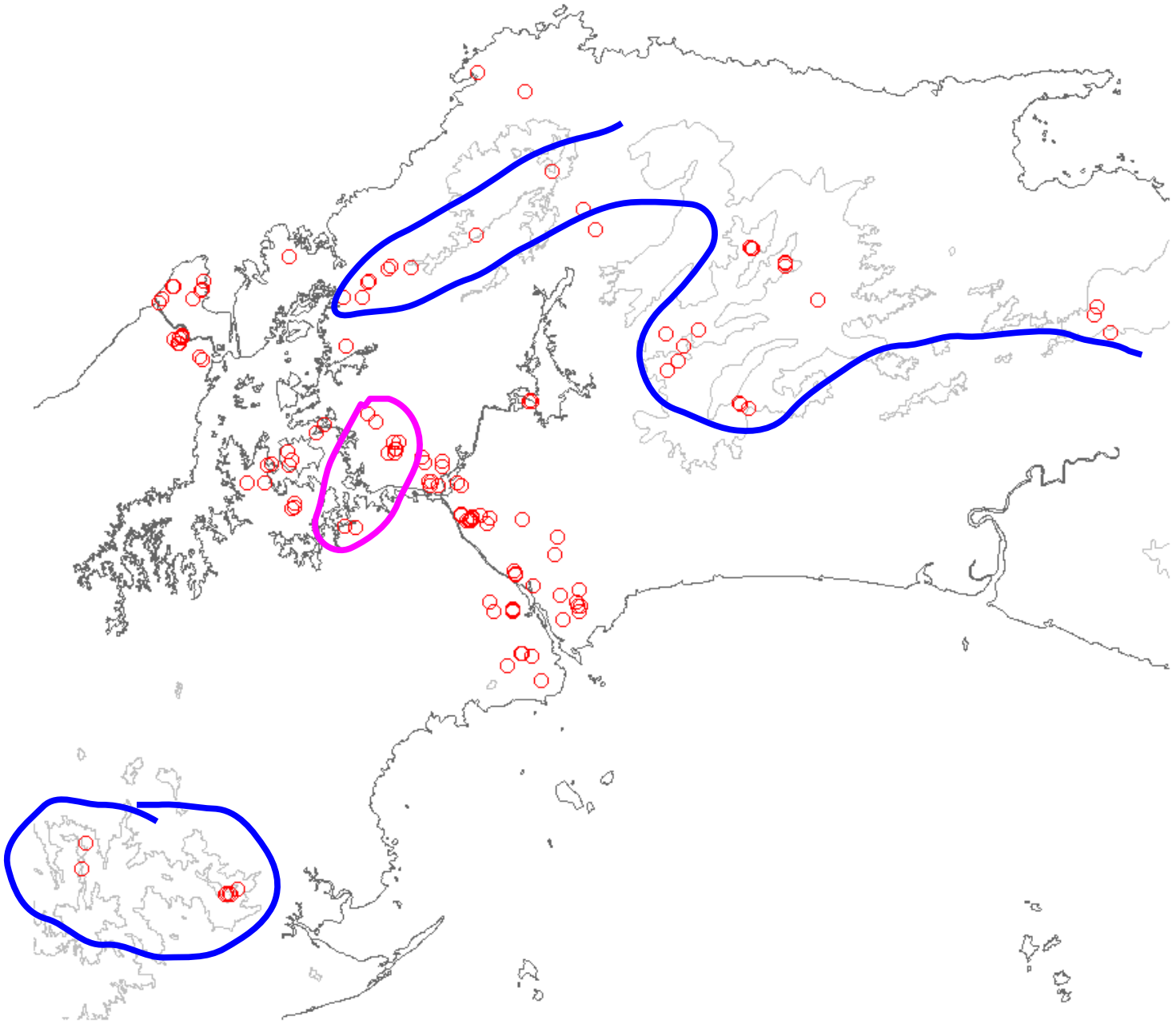
32 species wet-forest species reach the odd Laguna site



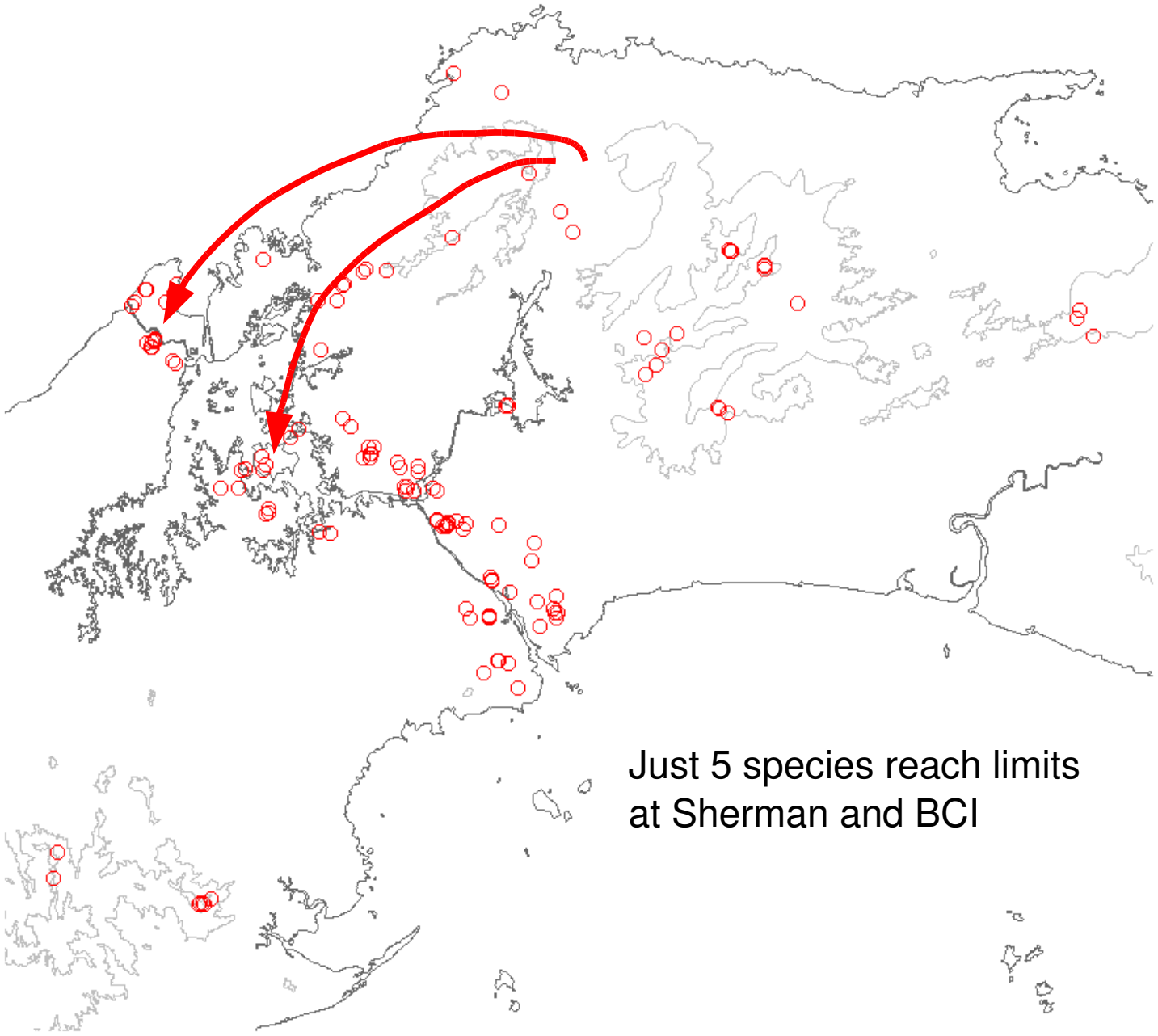
Podocarpus guatemalensis plots and inventories

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

Frequent climatic limits of wet forest species



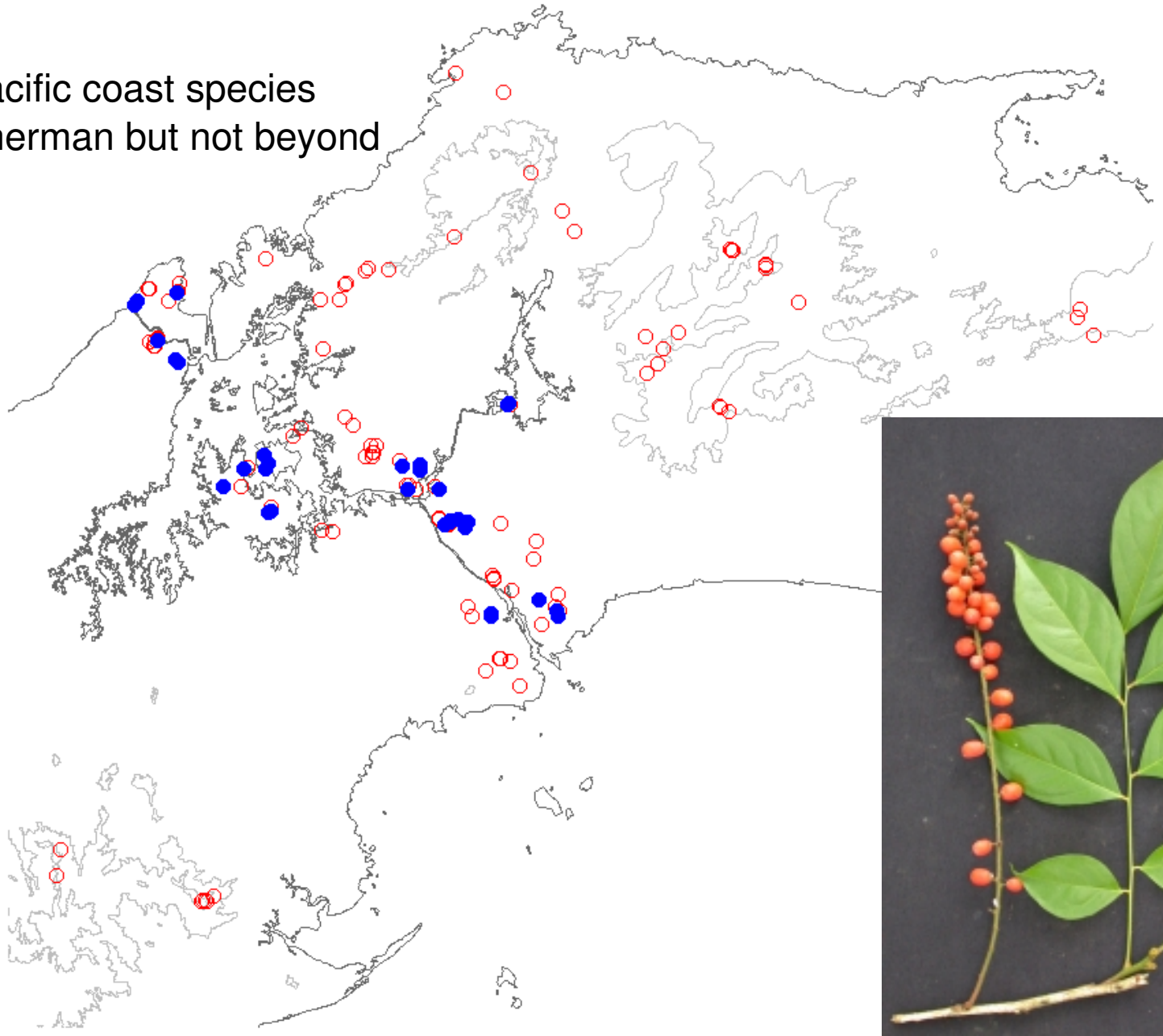
Unusual climatic limits of wet forest species



Just 5 species reach limits
at Sherman and BCI

Picramnia latifolia plots and inventories

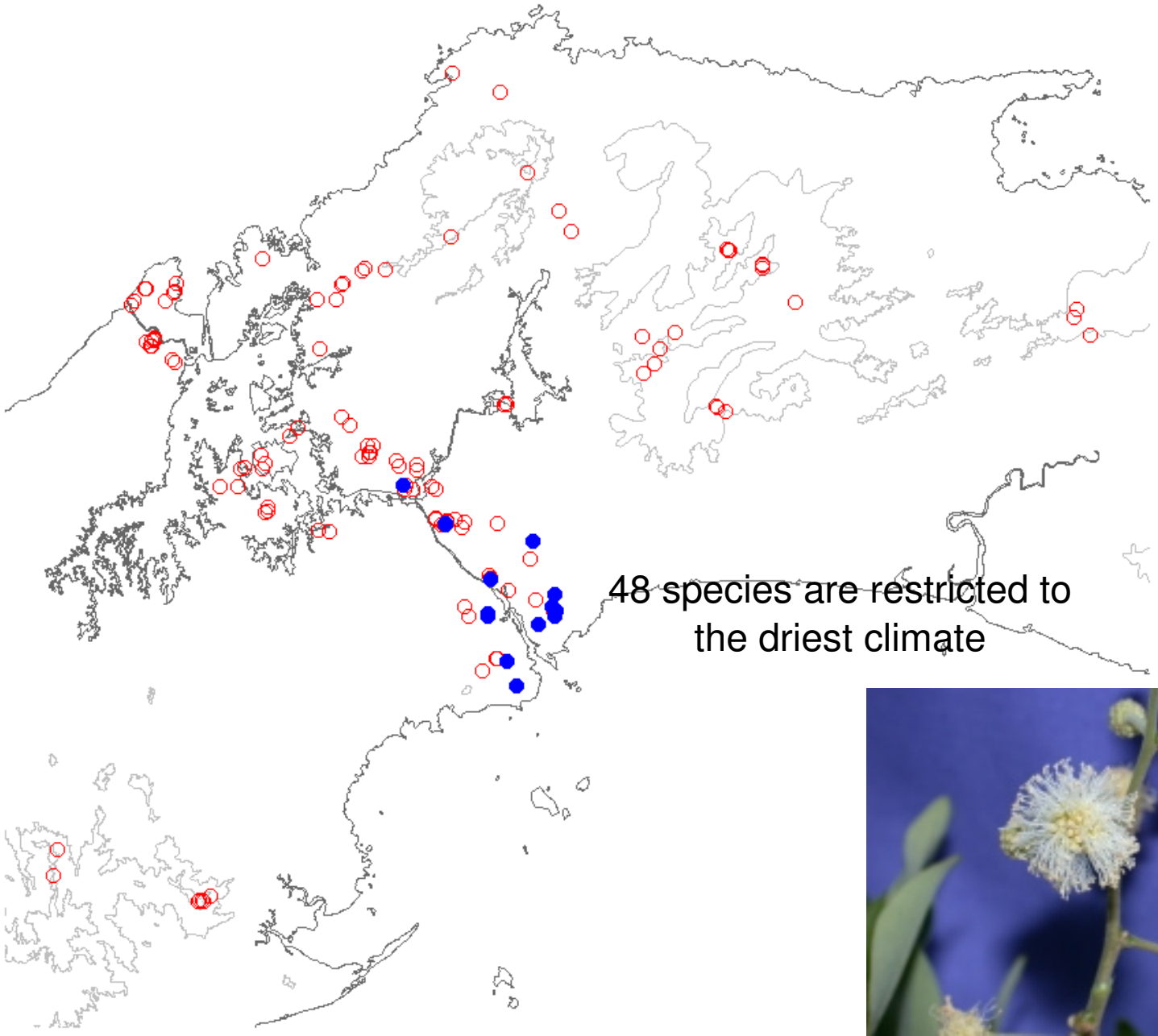
50 Pacific coast species
reach Sherman but not beyond



Faramea occidentalis plots and inventories

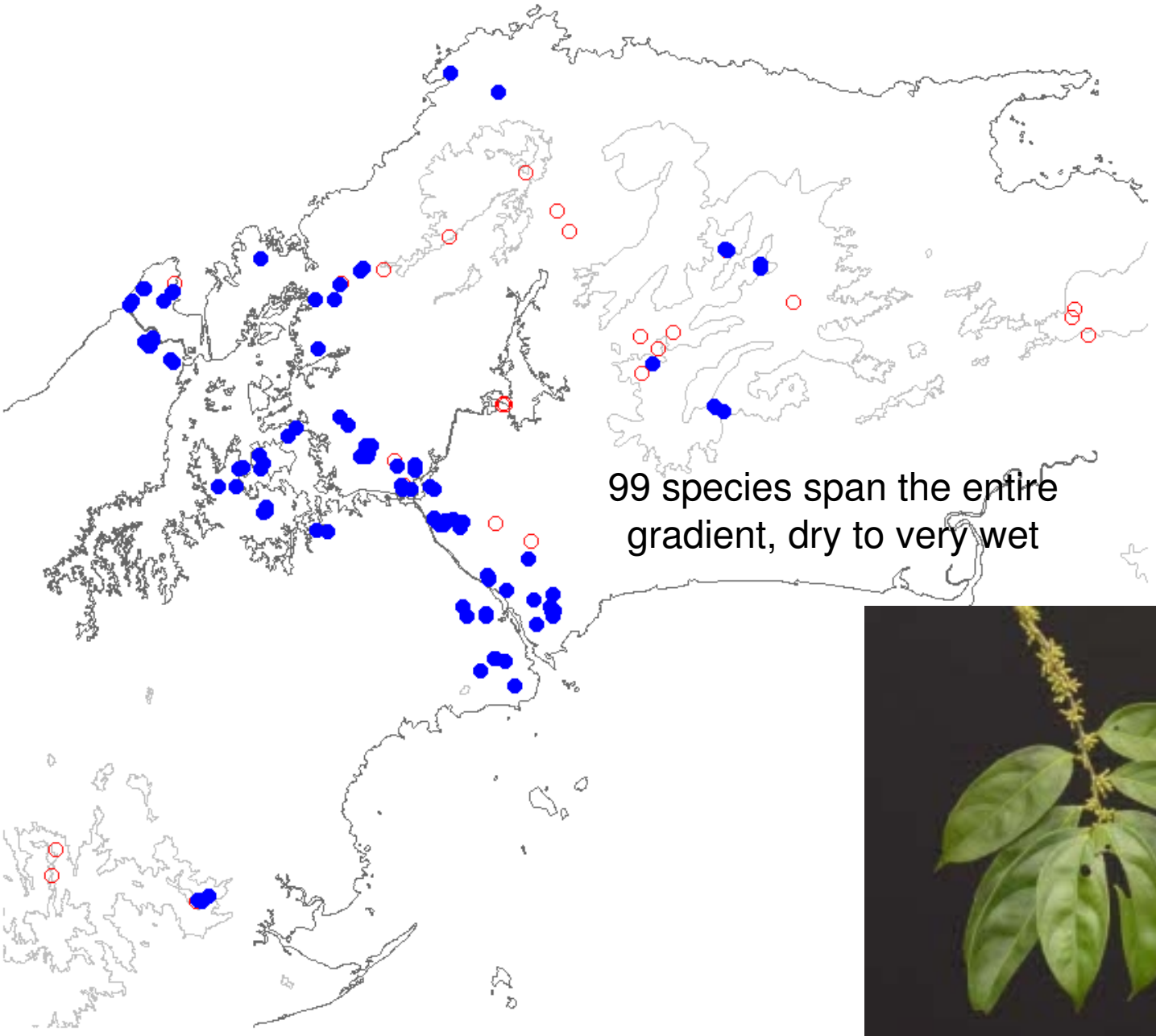
87 Pacific species reach C. Campana
but not the very wet sites

Albizia adinocephala plots and inventories

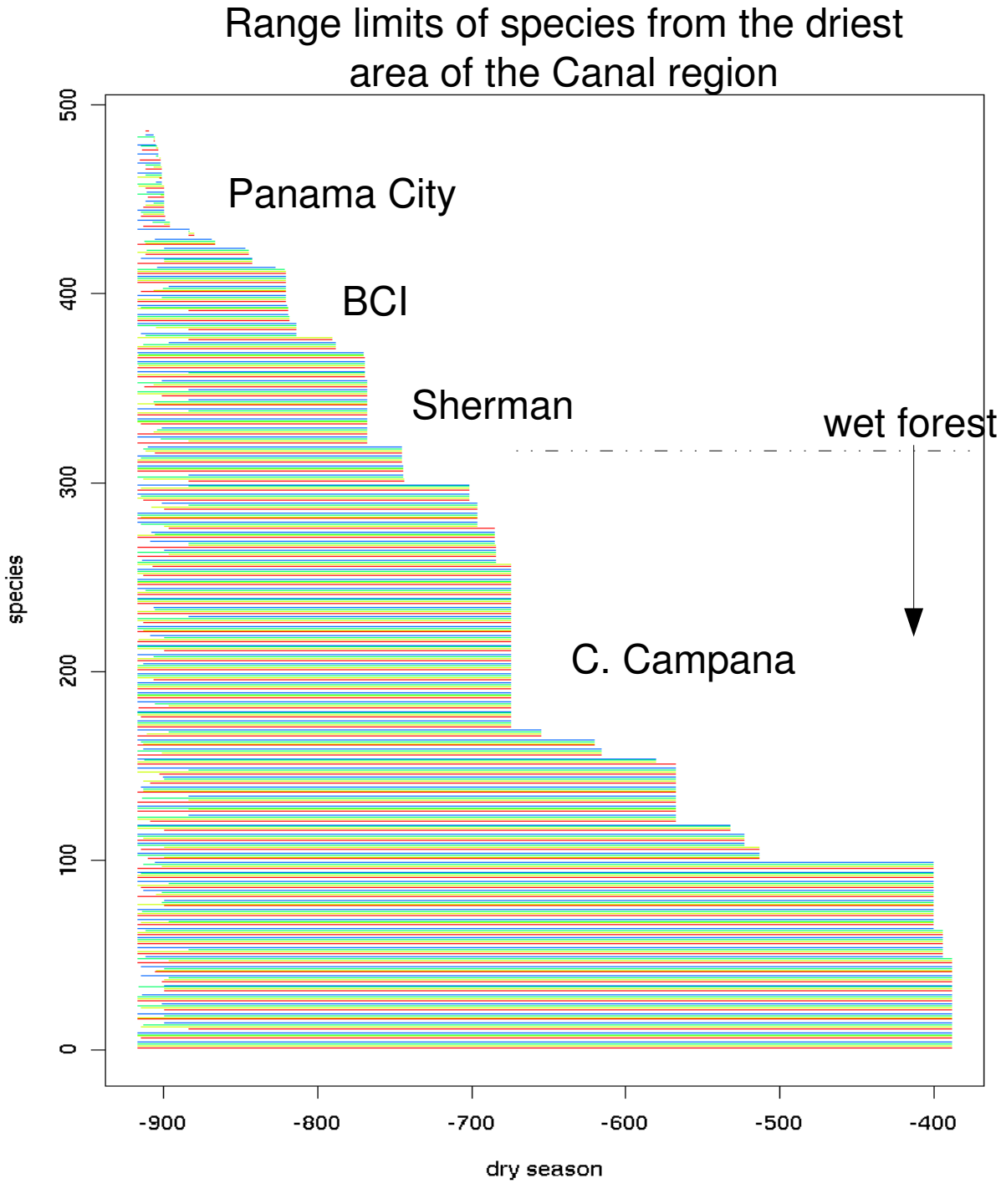


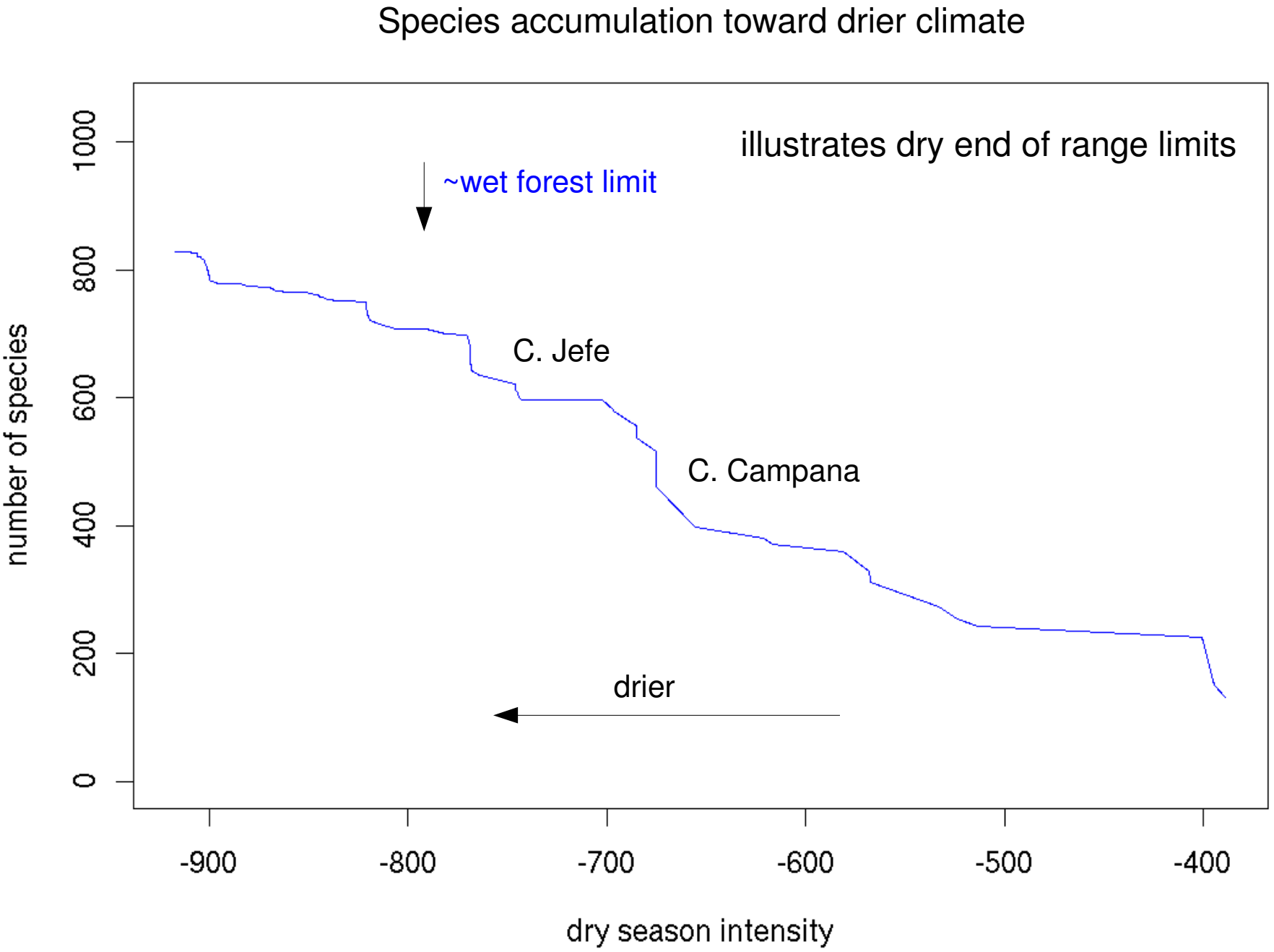
48 species are restricted to the driest climate

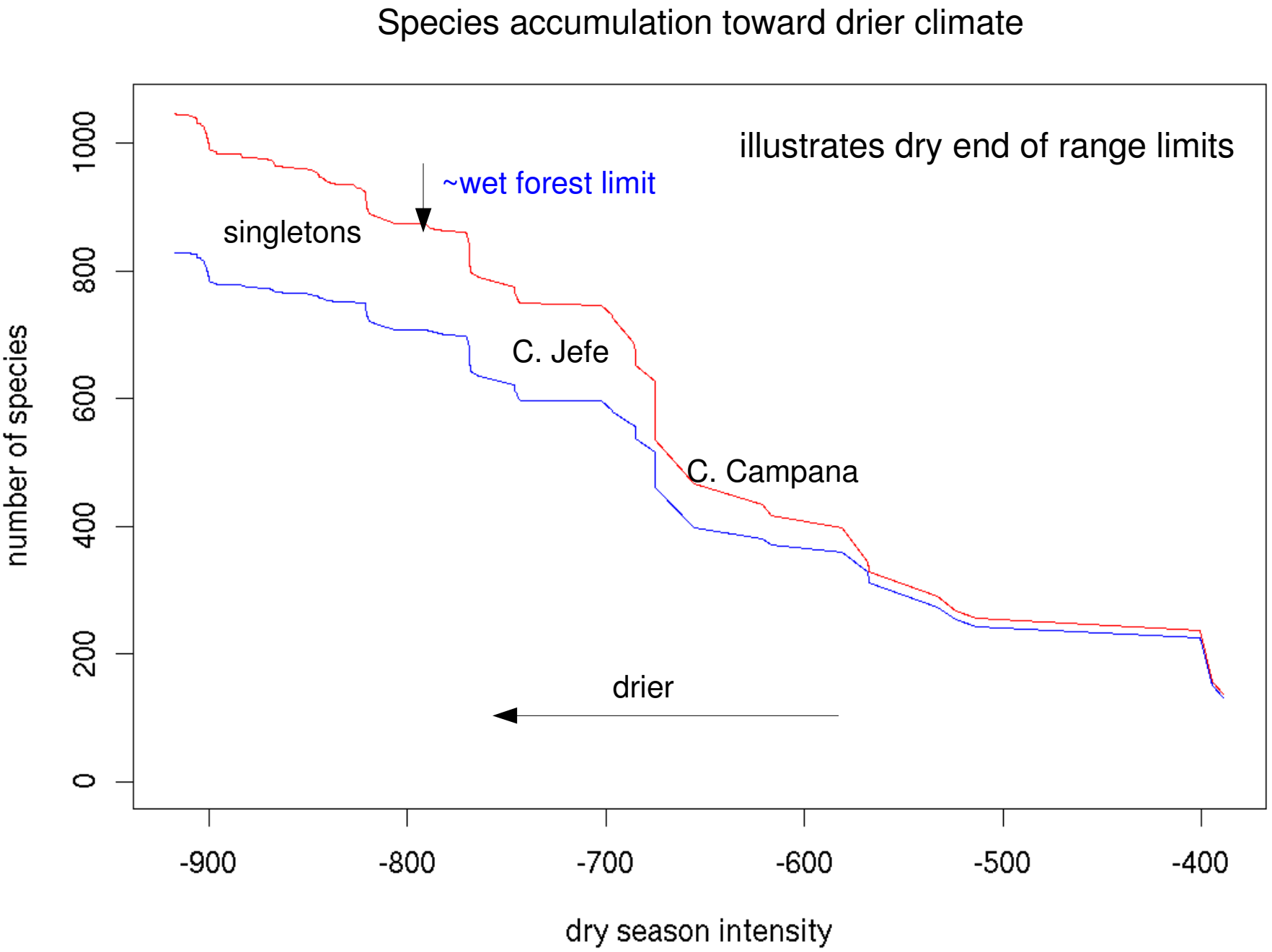
Lacistema aggregatum plots and inventories



99 species span the entire gradient, dry to very wet

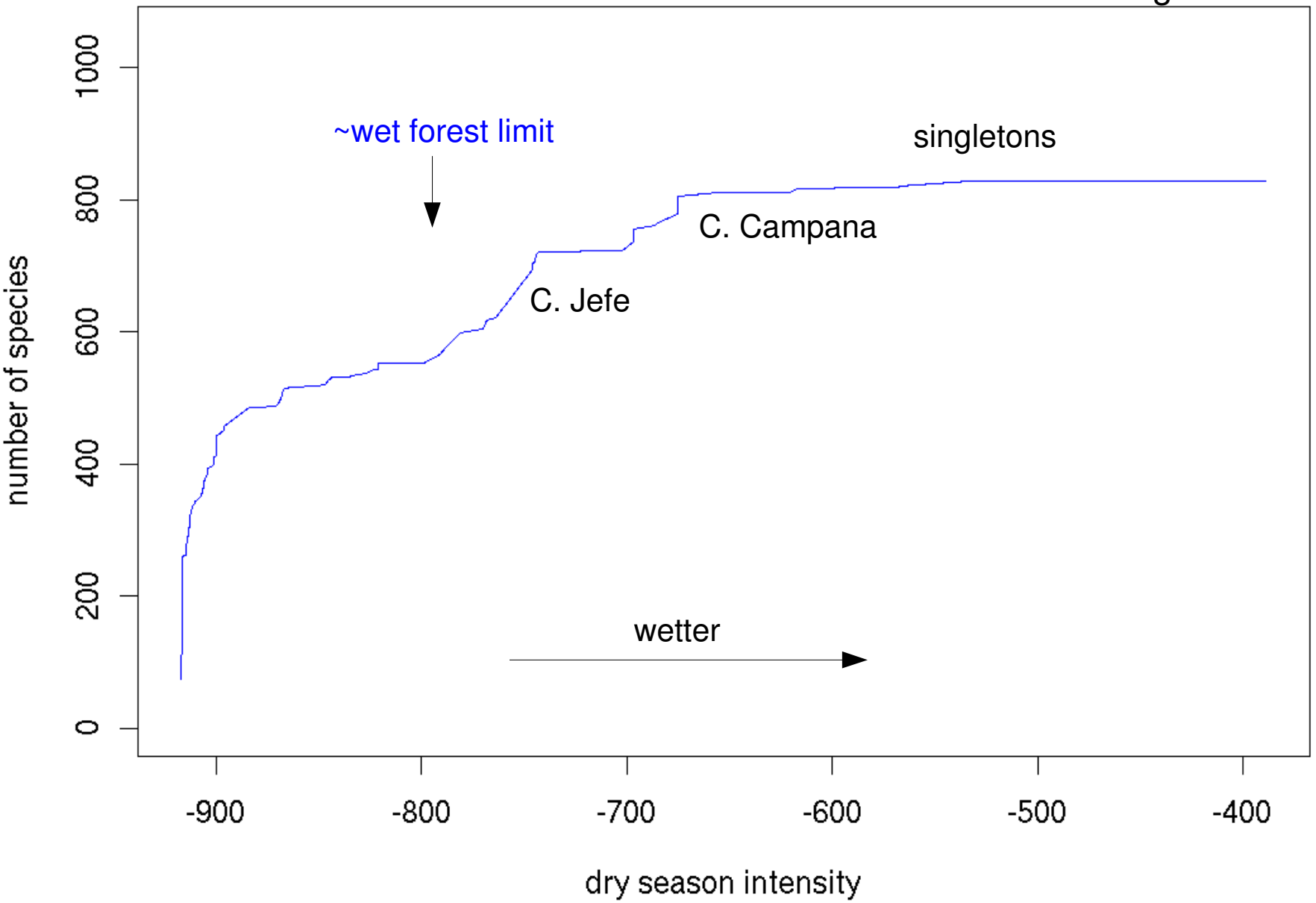

Range limits of species from the driest area of the Canal region
Panama City
BCI
Sherman
wet forest
C. Campana
species
dry season
500
400
300
200
100
0
-900
-800
-700
-600
-500
-400

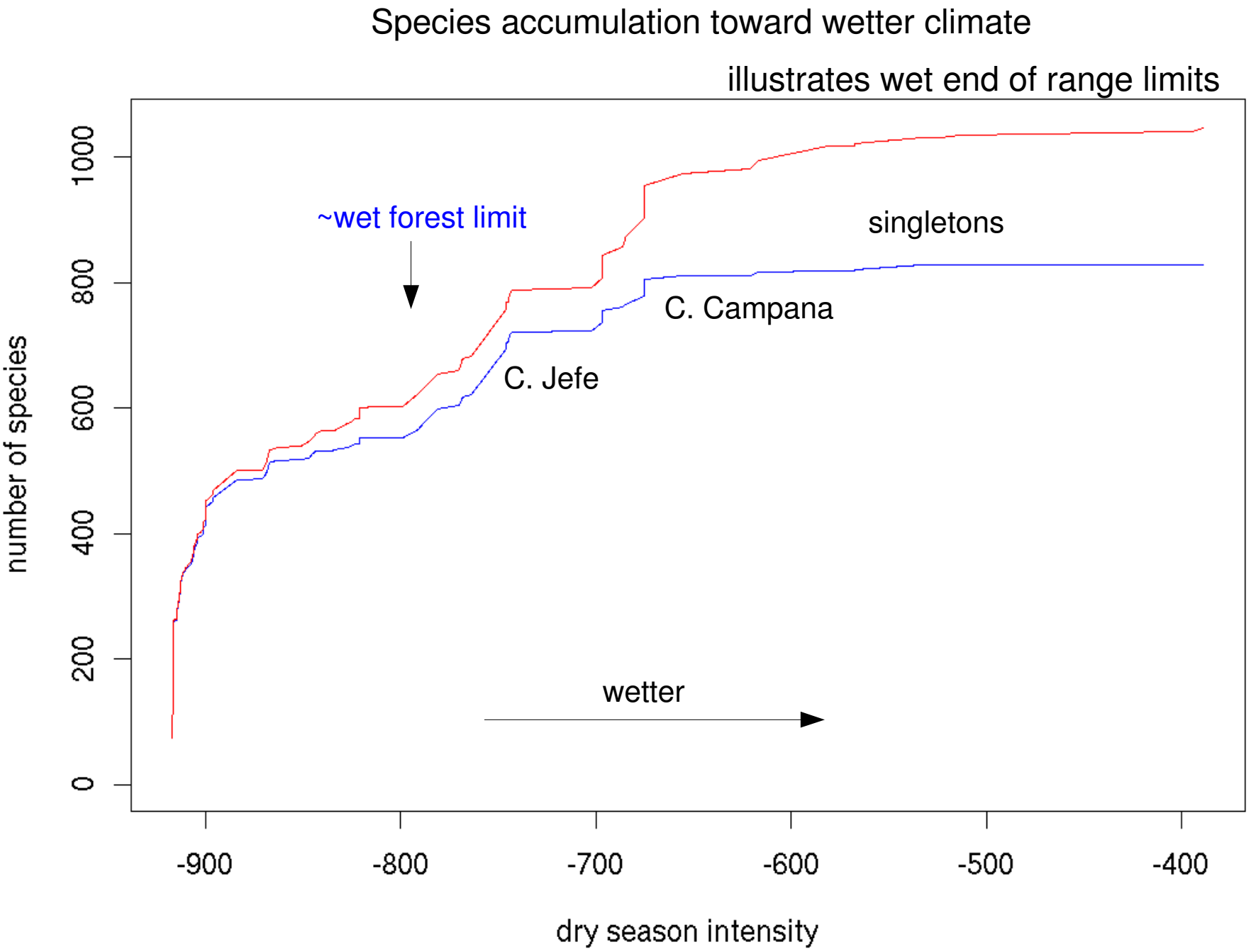

Species accumulation toward drier climate
illustrates dry end of range limits
~wet forest limit
C. Jefe
C. Campana
drier
number of species
0
200
400
600
800
1000
-900
-800
-700
-600
-500
-400
dry season intensity


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

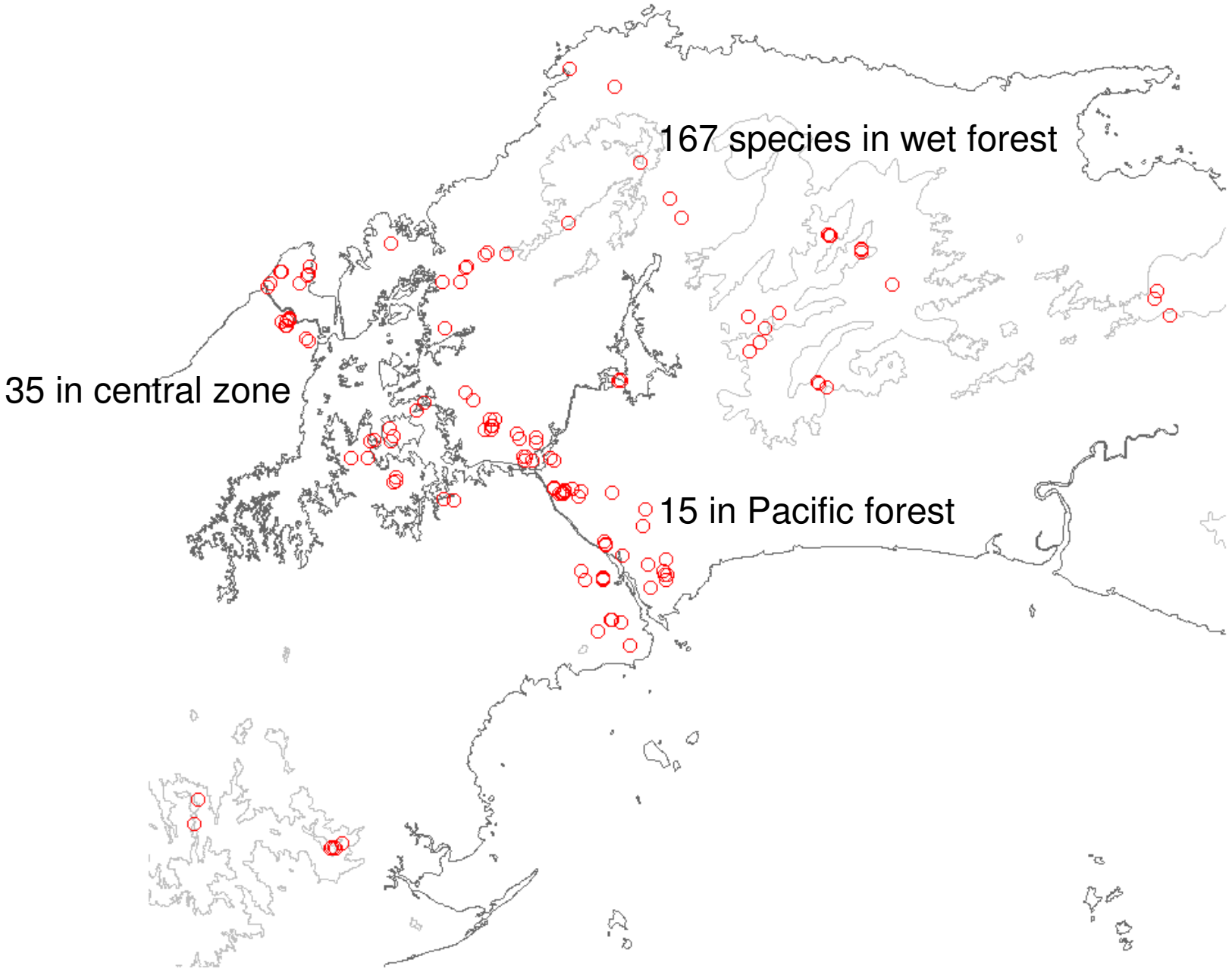
Species accumulation toward wetter climate

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

Singletons


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

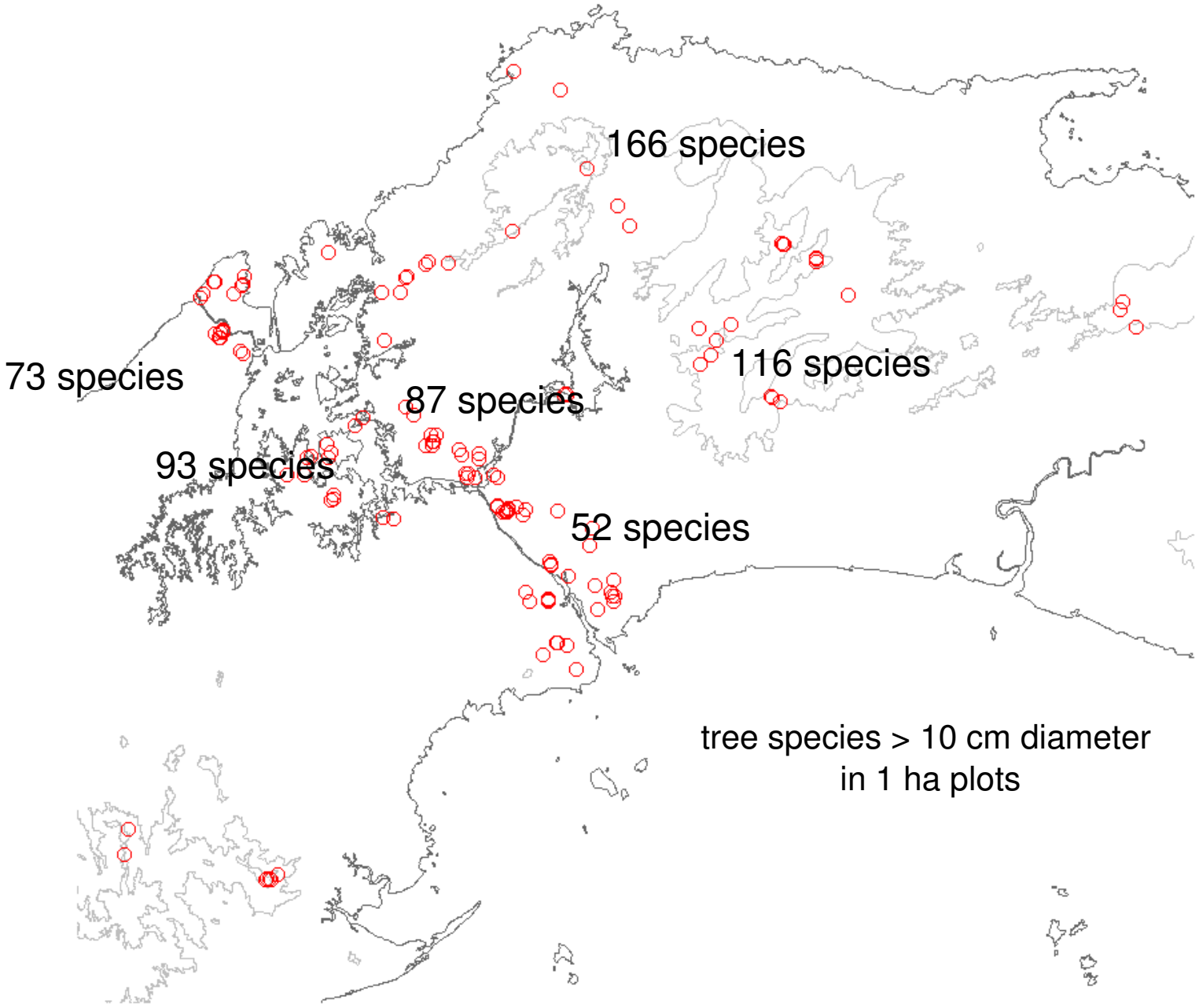
Tree species richness near the Panama Canal

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	

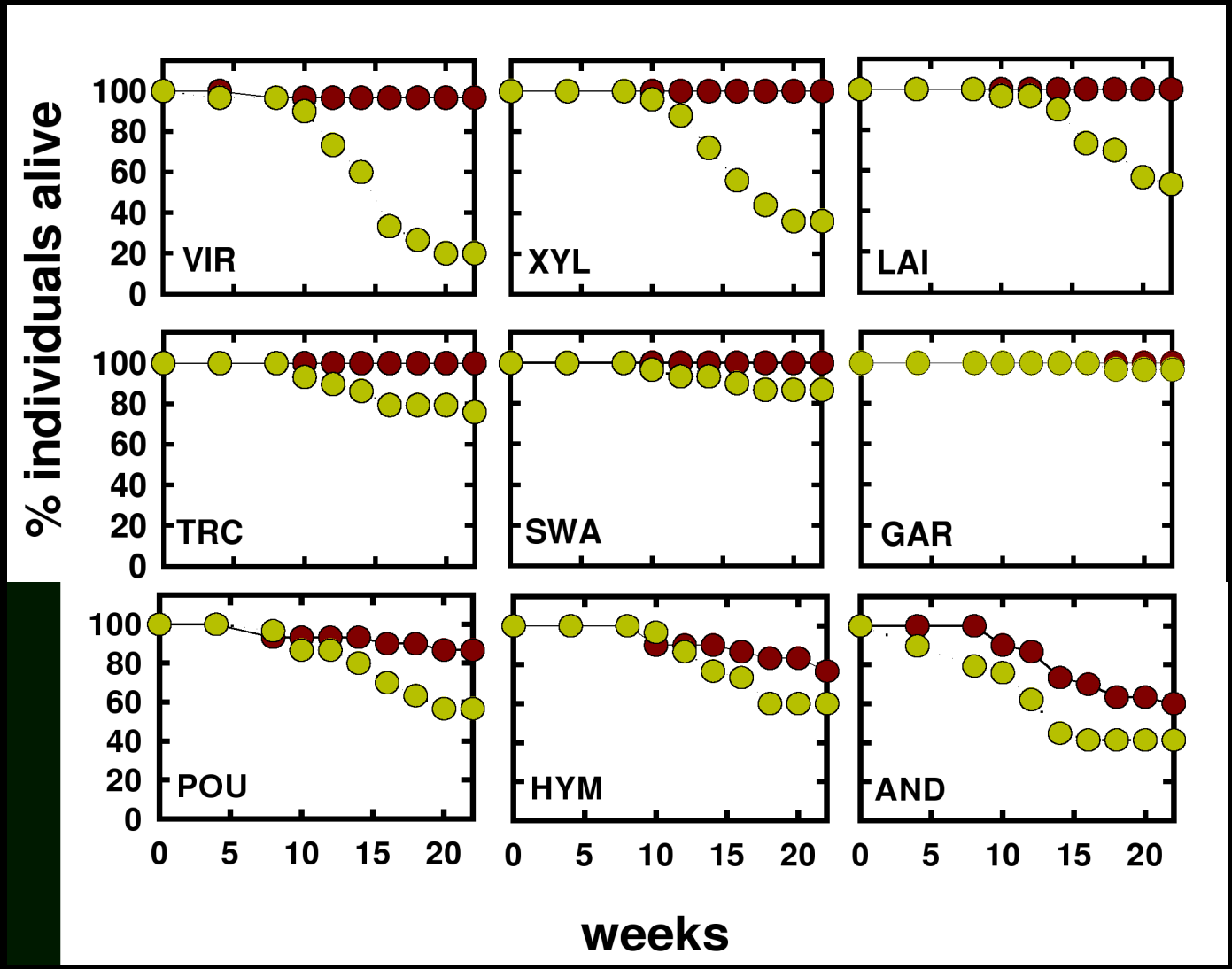
Source pool for tree species (with singletons):

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

Species diversity per hectare

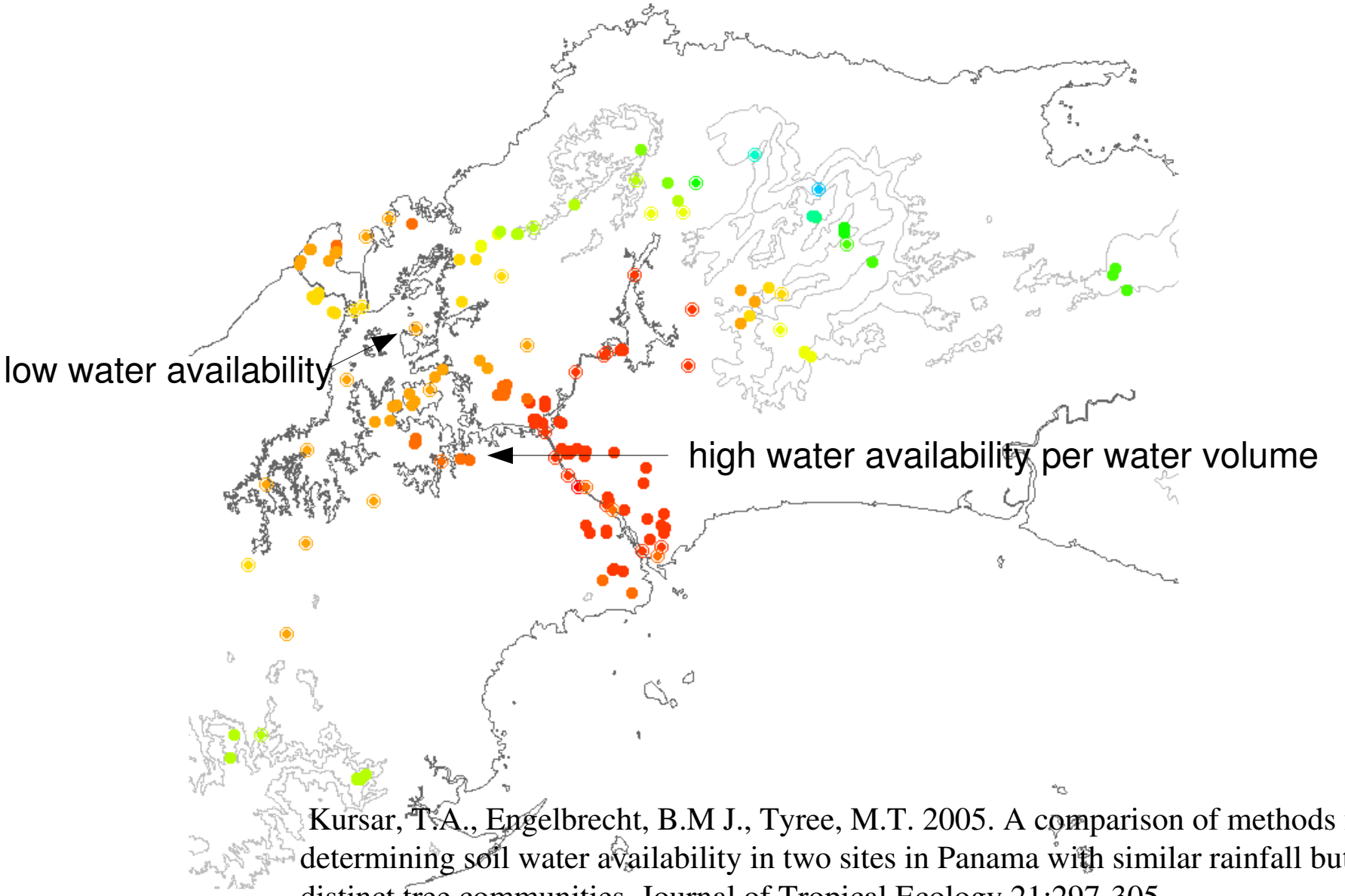


Experimental drought tolerance: survival rate without water



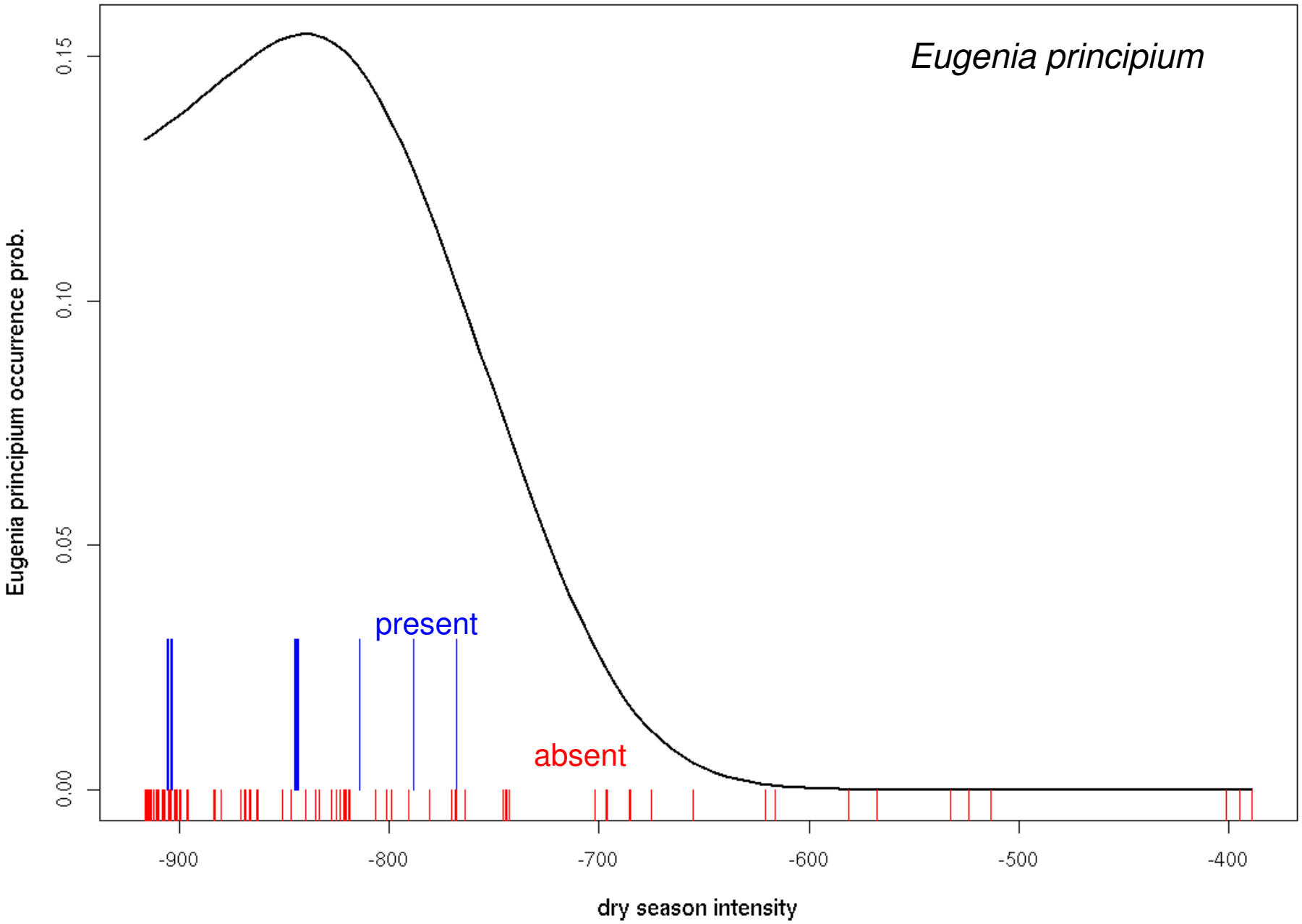
Engelbrecht *et al., Nature, 2007*

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

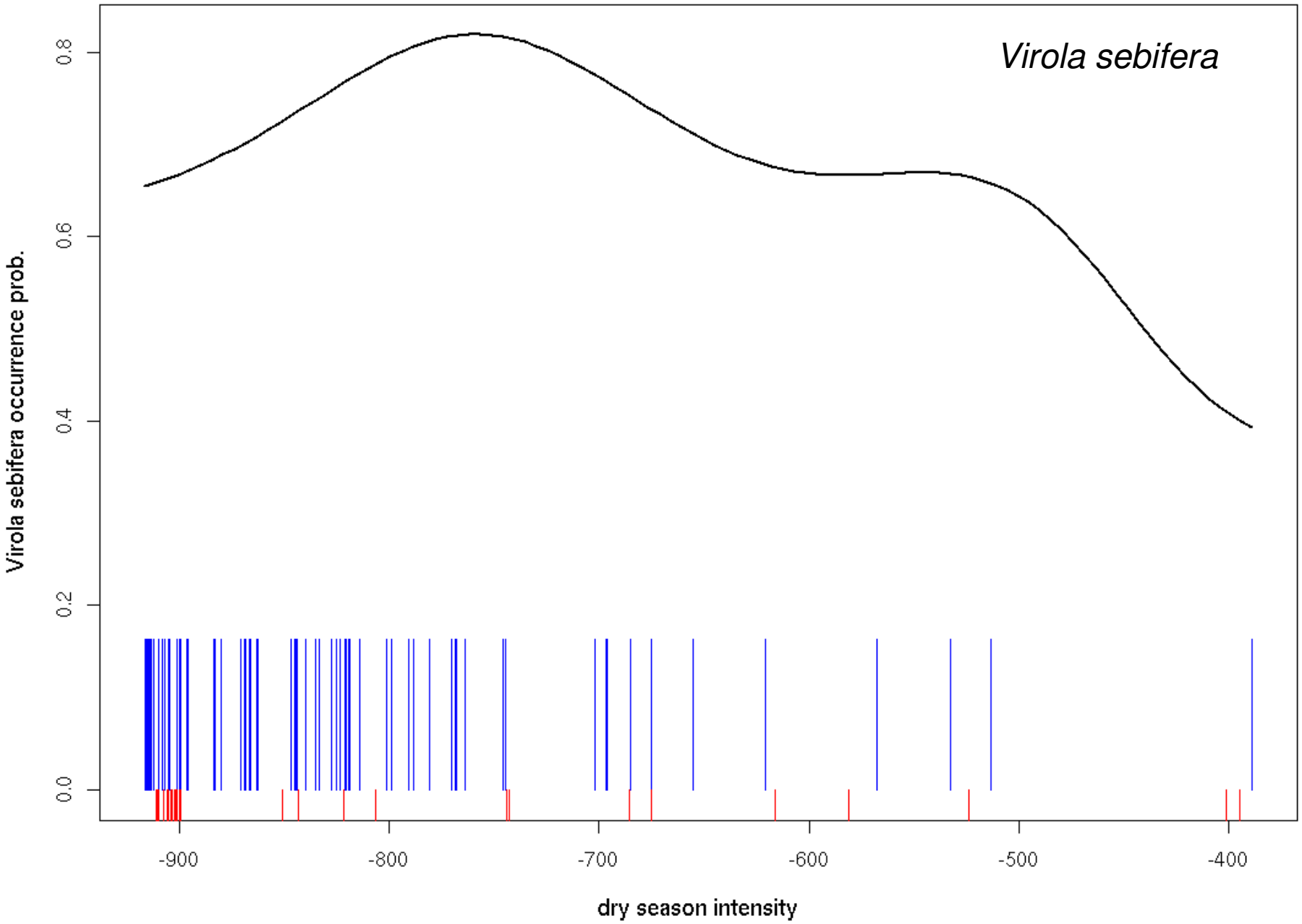


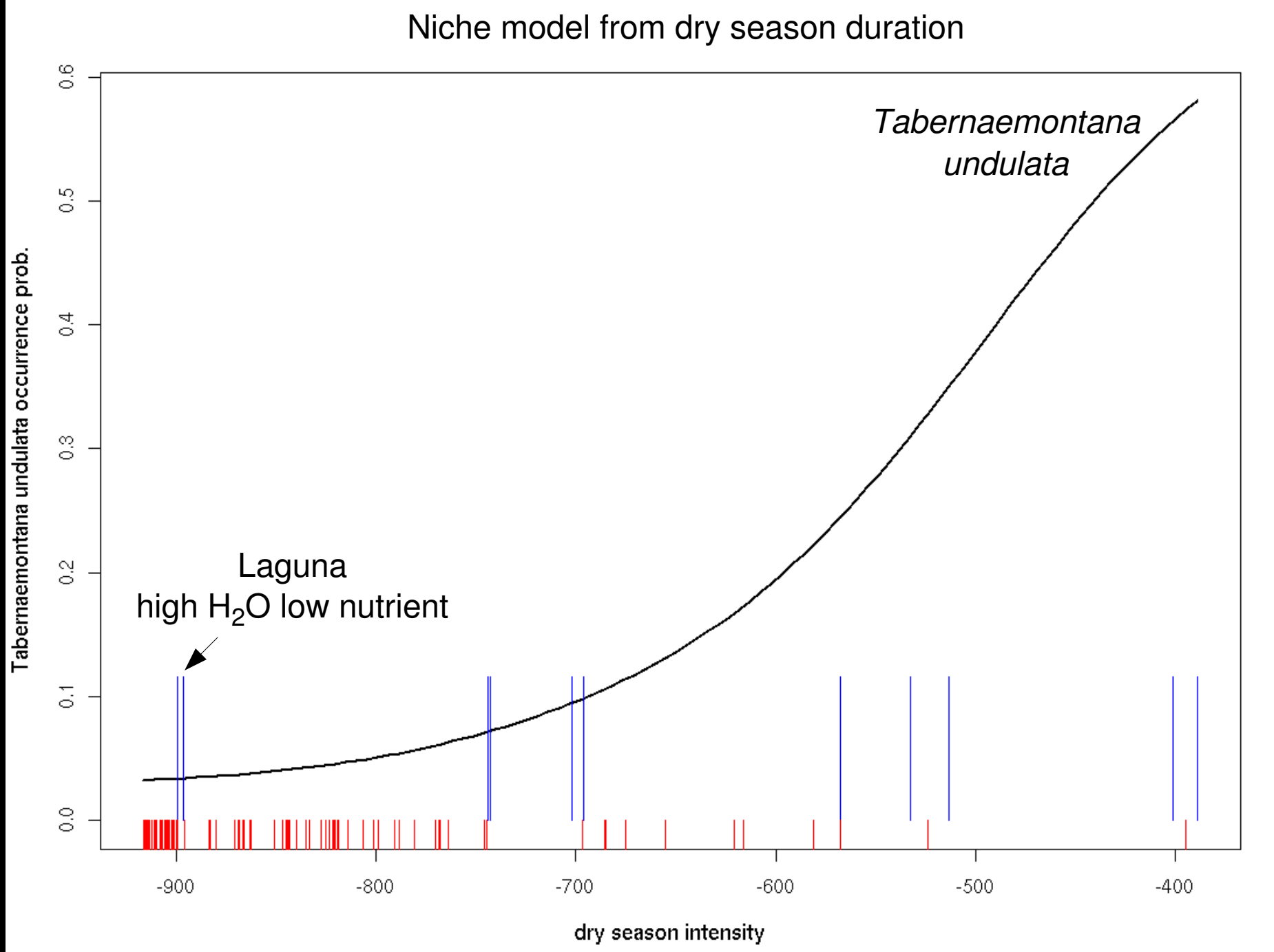
Kursar, T.A., Engelbrecht, B.M J., Tyree, M.T. 2005. A comparison of methods for determining soil water availability in two sites in Panama with similar rainfall but distinct tree communities. Journal of Tropical Ecology 21:297-305.

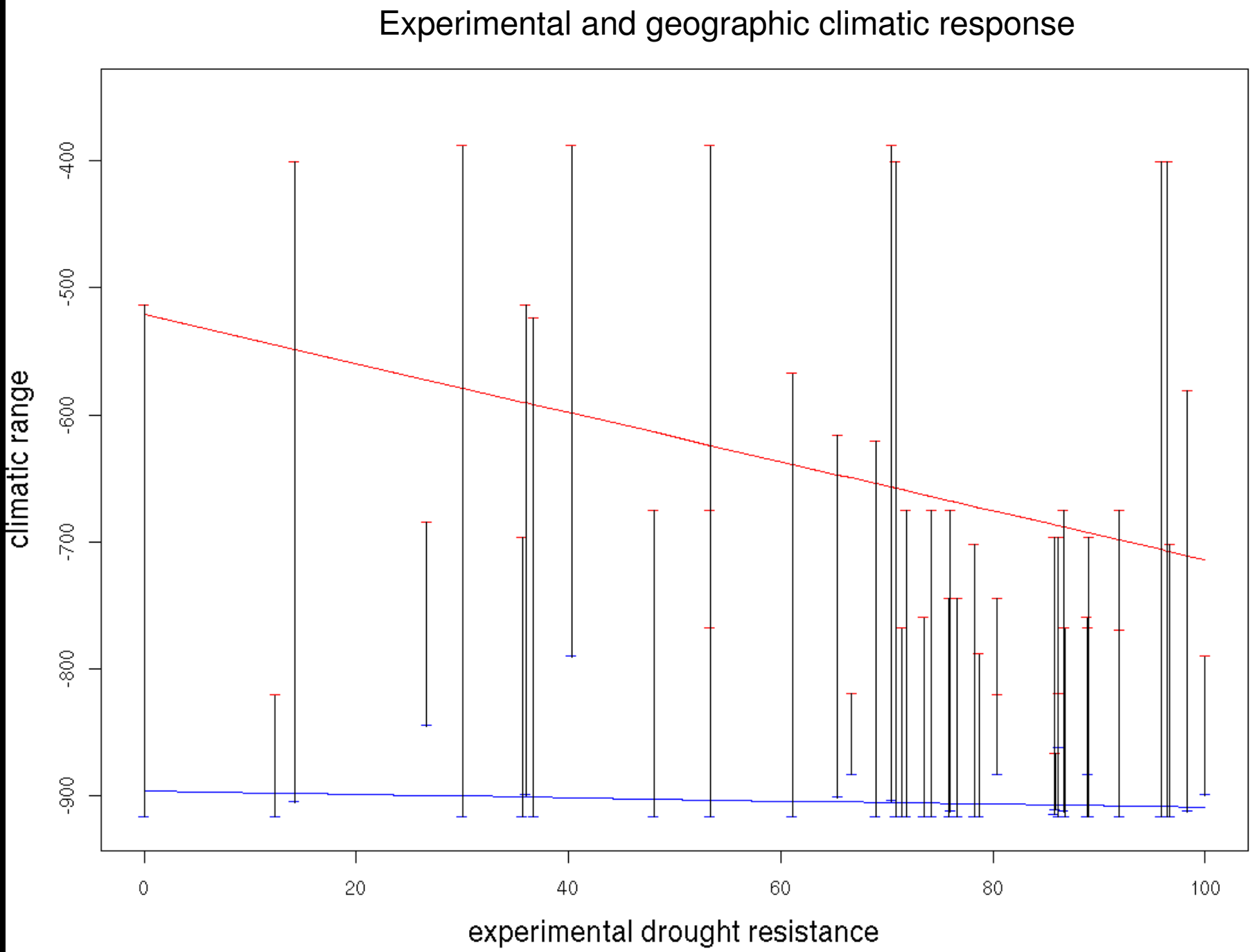
Niche model from dry season duration



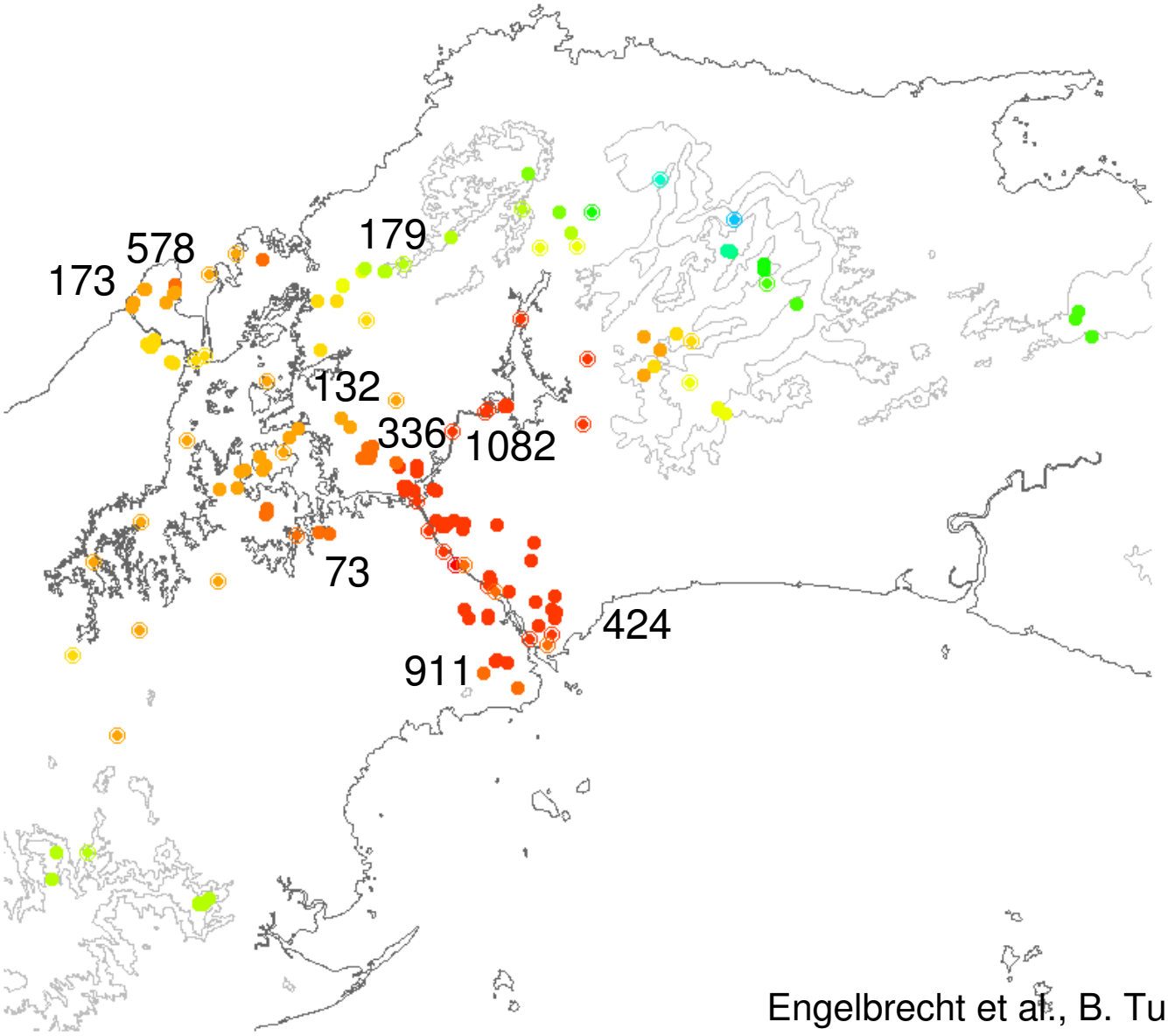
Niche model from dry season duration




Niche model from dry season duration
Tabernaemontana undulata occurrence prob.
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Tabernaemontana undulata
Laguna
high H2O low nutrient
-900
-800
-700
-600
-500
-400
dry season intensity


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

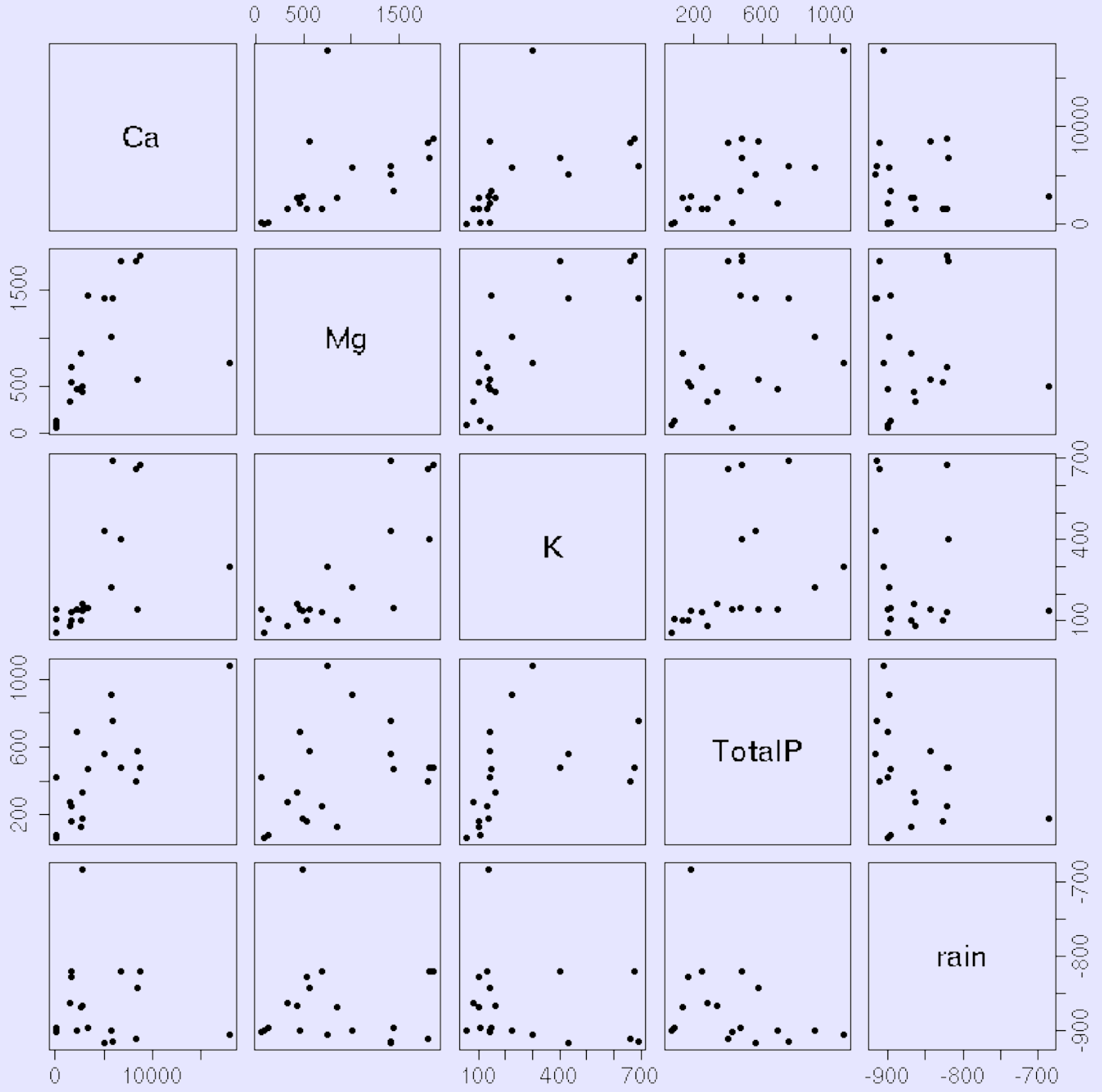
Soil phosphorus in tree plots



Engelbrecht et al., B. Turner unpub.

Soil nutrients
19 sites

Ben Turner (unpub)



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