Geology and tree species distributions

Beta-diversity in tropical forests of Panama

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Ecology and Evolutionary Biology
UCLA
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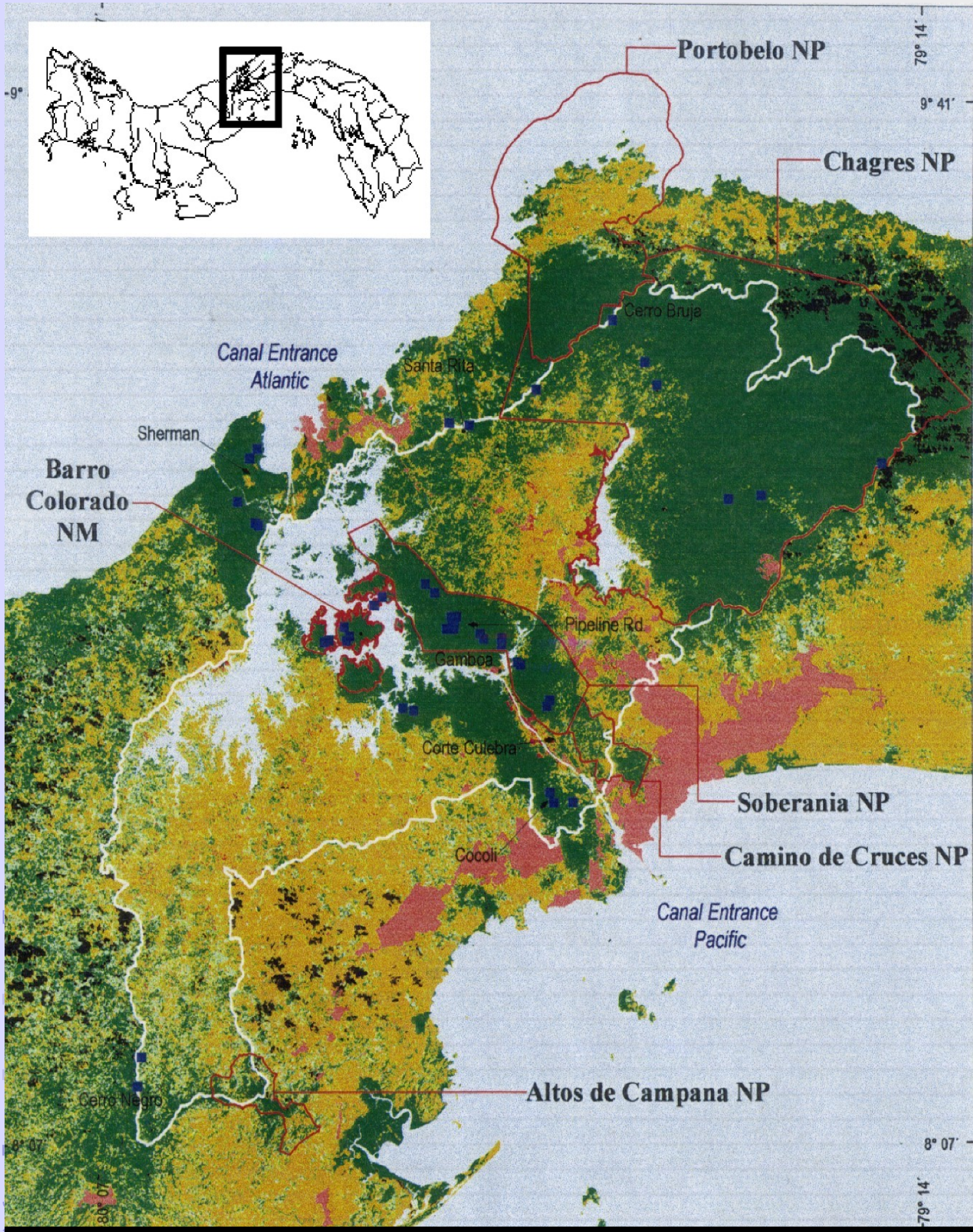
$\theta \propto J_m V$

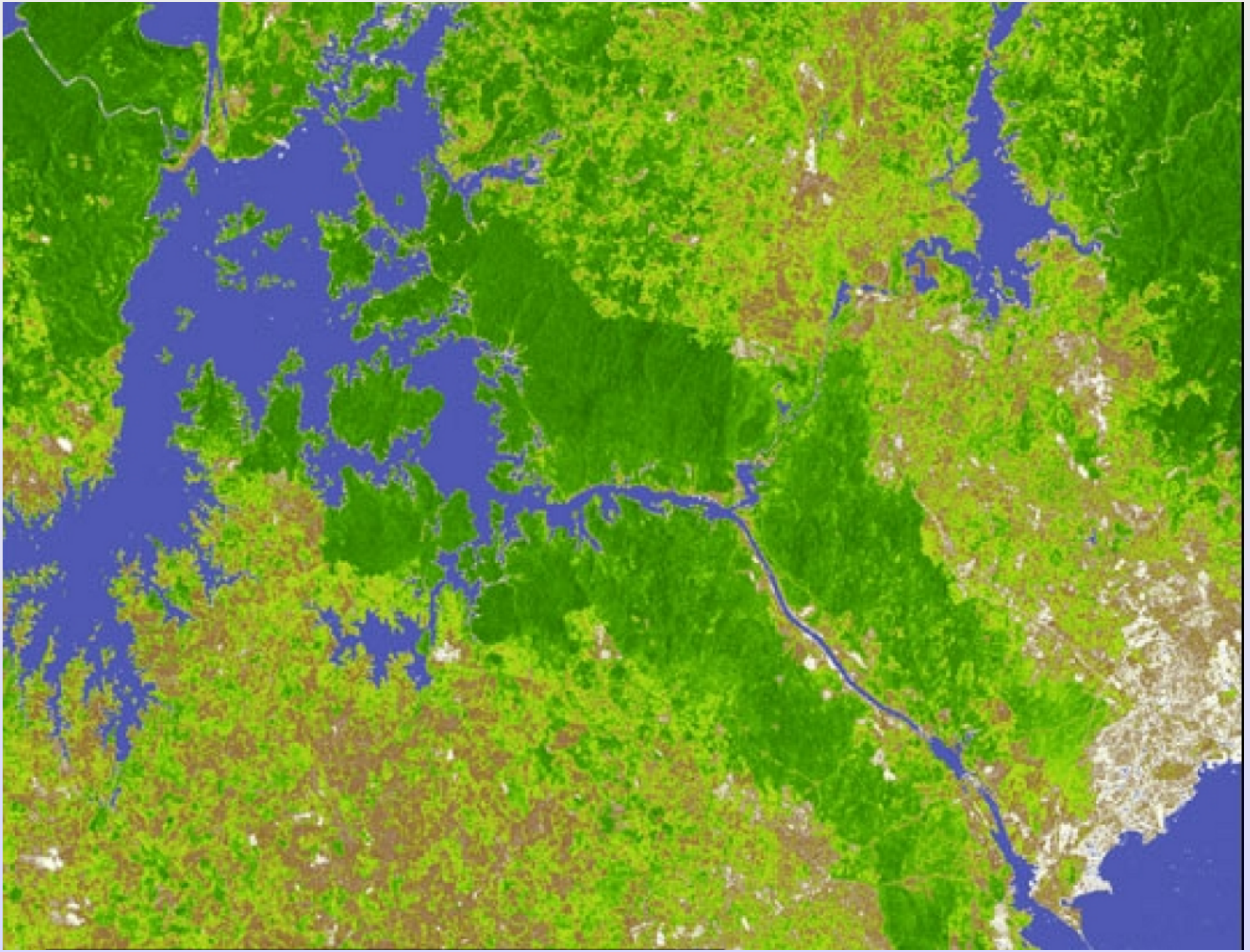
Robin Foster

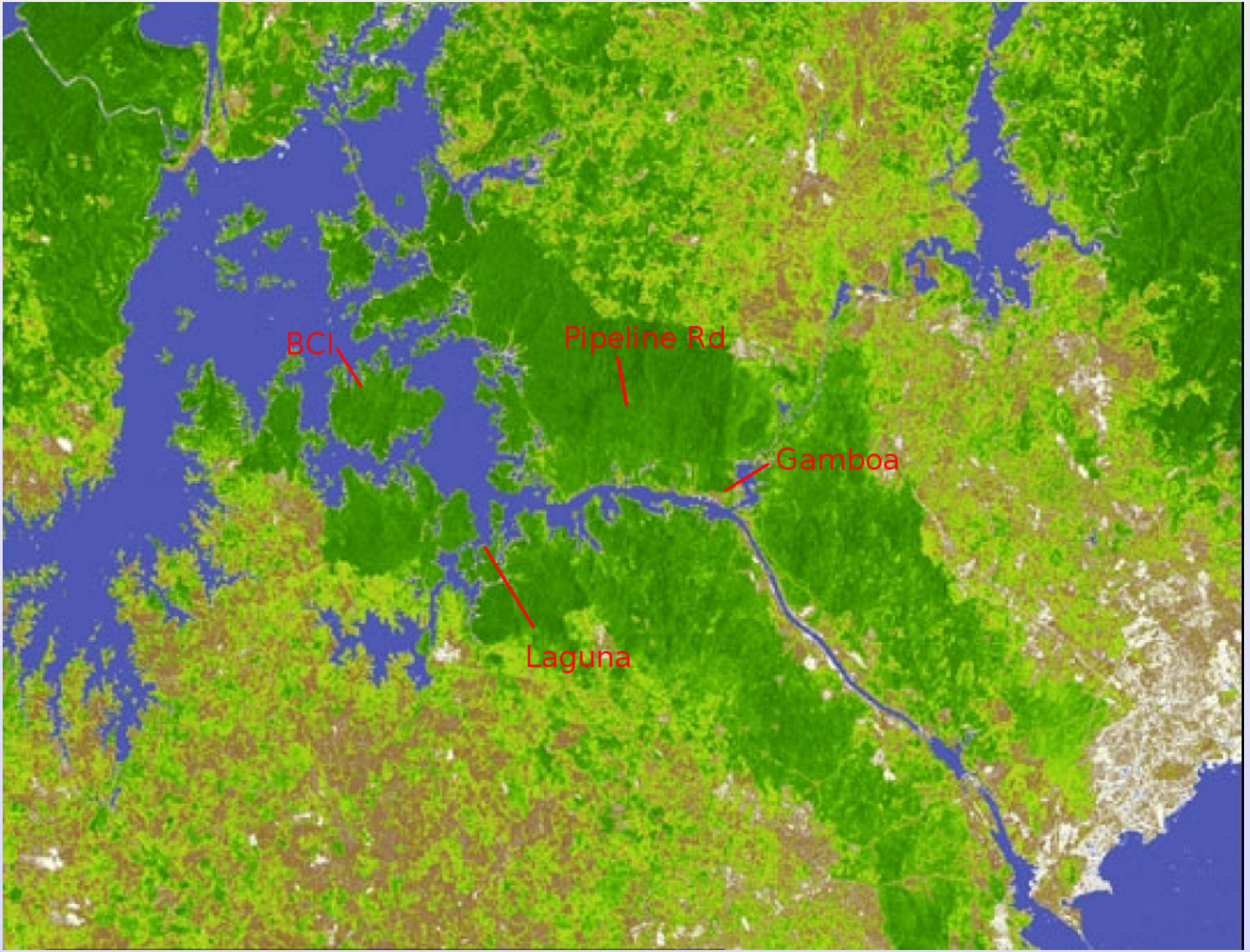

Gulf of Mexico
North Atlantic Ocean
Caribbean Sea
North Pacific Ocean
UNITED STATES
Tampa
St. Petersburg
Miami
Key West
Straits of Florida
THE BAHAMAS
Grand Bahama
Freeport
Great Abaco
BIMINI ISLANDS
New Providence
Nassau
Eleuthera
Cat Island
San Salvador
Rum Cay
Long Island
Andros Island
Great Bahama Canyon
Cay Sal Bank (THE BAHAMAS)
Great Exuma
Samana Cay
Crooked Island
Mayaguana
RAGGED ISLAND RANGE (THE BAHAMAS)
Acklins Island
Turks and Caicos Islands (U.K.)
Grand Turk
Great Inagua
Guinchos Cay (THE BAHAMAS)
Cay Lobos (THE BAHAMAS)
Tropic of Cancer
Havana
Matanzas
Santa Clara
Cienfuegos
Pinar del Río
CUBA
Nuevitas
Camagüey
Holguín
Manzanillo
Santiago de Cuba
Guantánamo
U.S. Naval Base Guantanamo Bay
Windward Passage
Isla de la Juventud
Campeche Bank
Yucatan Channel
Isla Cozumel
Bahía de Campeche
Mérida
Cancún
Campeche
Ciudad del Carmen
MEXICO
Chetumal
Villahermosa
Belize City
Belmopan
Flores
Tuxtla Gutiérrez
BELIZE
ISLAS DE LA BAHIA
SWAN ISLANDS (HONDURAS)
George Town
Cayman Islands (U.K.)
Cayman Trench
Montego Bay
Kingston
JAMAICA
Navassa Island (U.S.)
Cap-Haïtien
Port-au-Prince
Les Cayes
HAITI
Santiago
DOMINICAN REPUBLIC
Santo Domingo
Puerto Rico Trench
Milwaukee Deep (deepest point in the Atlantic Ocean, 8605 m)
Mona Passage
Isla Mona
San Juan
Puerto Rico (U.S.)
Anegada Passage
British Virgin Is. (U.K.)
Virgin Is. (U.S.)
St. Croix
Neth. Antilles (NETH.)
Anguilla (U.K.)
St. Martin (Guad. and Neth. Antilles)
St. Barthelemy (Guad.)
ANTIGUA AND BARBUDA
St. John's
Basseterre
ST. KITTS AND NEVIS
Plymouth
Montserrat (U.K.)
Guadeloupe (FRANCE)
Basse-Terre
Marie-Galante
Isla Aves (VENEZUELA)
DOMINICA
Roseau
Martinique (FRANCE)
Fort-de-France
Castries
ST. LUCIA
Aves Ridge
Kingstown
ST. VINCENT AND THE GRENADINES
BARBADOS
Bridgetown
GRENADA
St. George's
Tobago
TRINIDAD AND TOBAGO
Port-of-Spain
Trinidad
Isla de Margarita
Isla la Tortuga
Golfo de Venezuela
Aruba (NETH.)
Oranjestad
Netherlands Antilles (NETH.)
Curaçao
Bonaire
Willemstad
Puerto Cabello
Caracas
Barquisimeto
Valencia
Maracay
Maracaibo
Lago de Maracaibo
Coro
Cumaná
Barcelona
Maturín
Barranquilla
Santa Marta
Cartagena
Monteria
Medellín
Bucaramanga
Cúcuta
San Cristóbal
Mérida
San Fernando
Ciudad Bolivar
Ciudad Guayana
Georgetown
VENEZUELA
GUYANA
GUIANA HIGHLANDS
Puerto Ayacucho
Arauca
COLOMBIA
CORDILLERA ORIENTAL
Pereira
Ibagué
Bogotá
Cali
Buenaventura
Peru - Chile Trench
BRAZIL
Boa Vista
Isla del Coco (COSTA RICA)
Tapachula
Quetzaltenango
Guatemala
GUATEMALA
Puerto Barrios
San Pedro Sula
La Ceiba
HONDURAS
Puerto Lempira
Tegucigalpa
Santa Ana
San Salvador
San Miguel
Choluteca
EL SALVADOR
Cayos Miskitos
Puerto Cabezas
Mosquito Coast
Isla de la Providencia (COLOMBIA)
Isla de San Andrés (COLOMBIA)
Matagalpa
León
NICARAGUA
Managua
Bluefields
Granada
Lago de Nicaragua
ISLAS DEL MAIZ
Middle America Trench
Puntarenas
San José
Puerto Limón
COSTA RICA
Bocas del Toro
Colón
Panama
Golfito
David
Balboa
PANAMA
Santiago
La Palma
Scale 1:12,500,000
Lambert Conformal Conic Projection, standard parallels 9°N and 17°N
0 100 200 300 Kilometers
0 100 200 300 Miles
Boundary representation is not necessarily authoritative.


Portobelo NP
Chagres NP
Cerro Bruja
Canal Entrance
Atlantic
Santa Rita
Sherman
Barro
Colorado
NM
Pipeline Rd.
Gamboa
Corte Culebra
Soberania NP
Camino de Cruces NP
Cocoli
Canal Entrance
Pacific
Altos de Campana NP
Cerro Negro
9° 41'
79° 14'
8° 07'
80° 07'

Forest Composition in Tropics of Panama

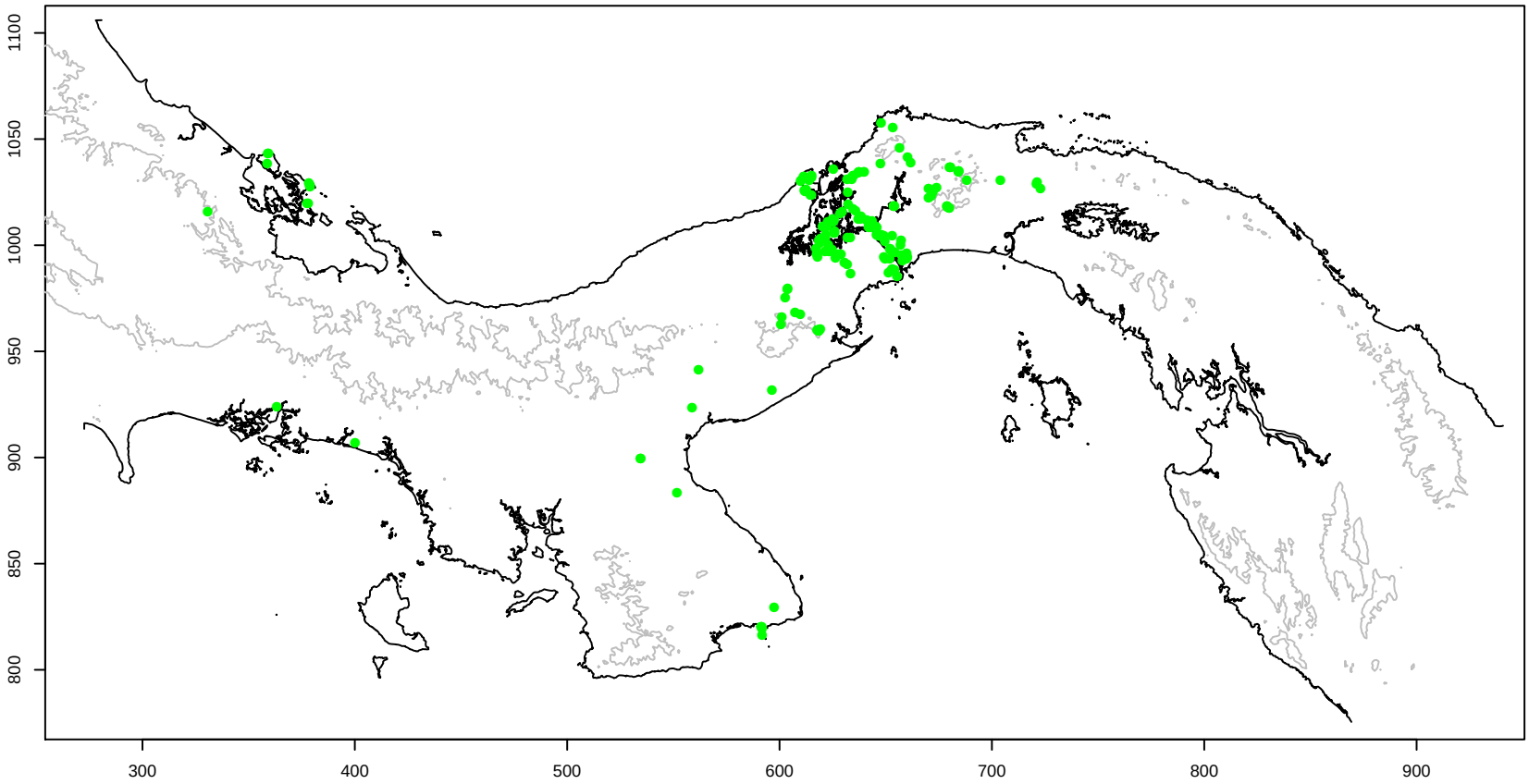
1. Climate (dry season)
2. Geology
3. Soil Chemistry
4. Tree Response to Phosphorus and Moisture



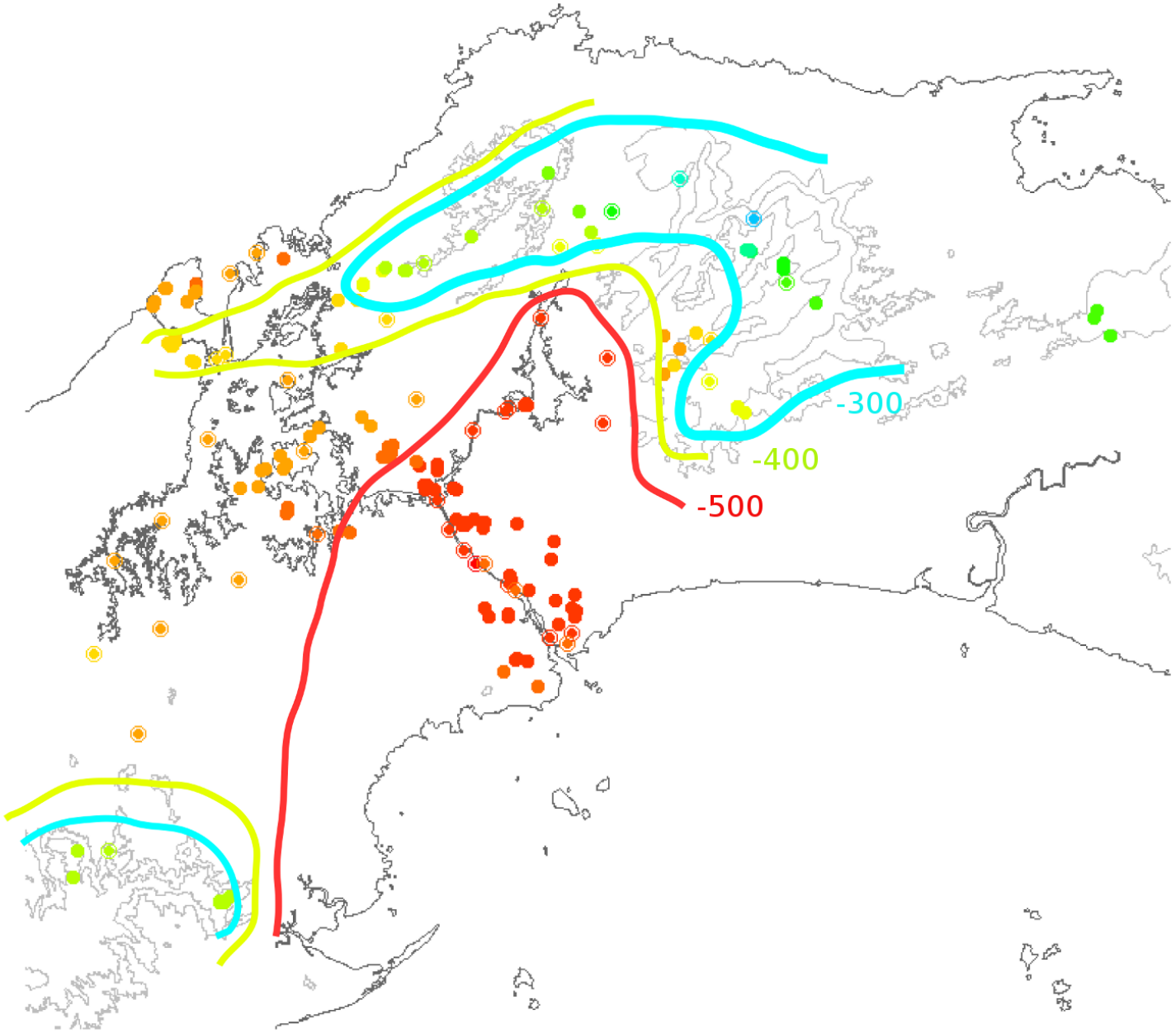

BCI
Pipeline Rd
Gamboa
Laguna

Surveys of Tree Species

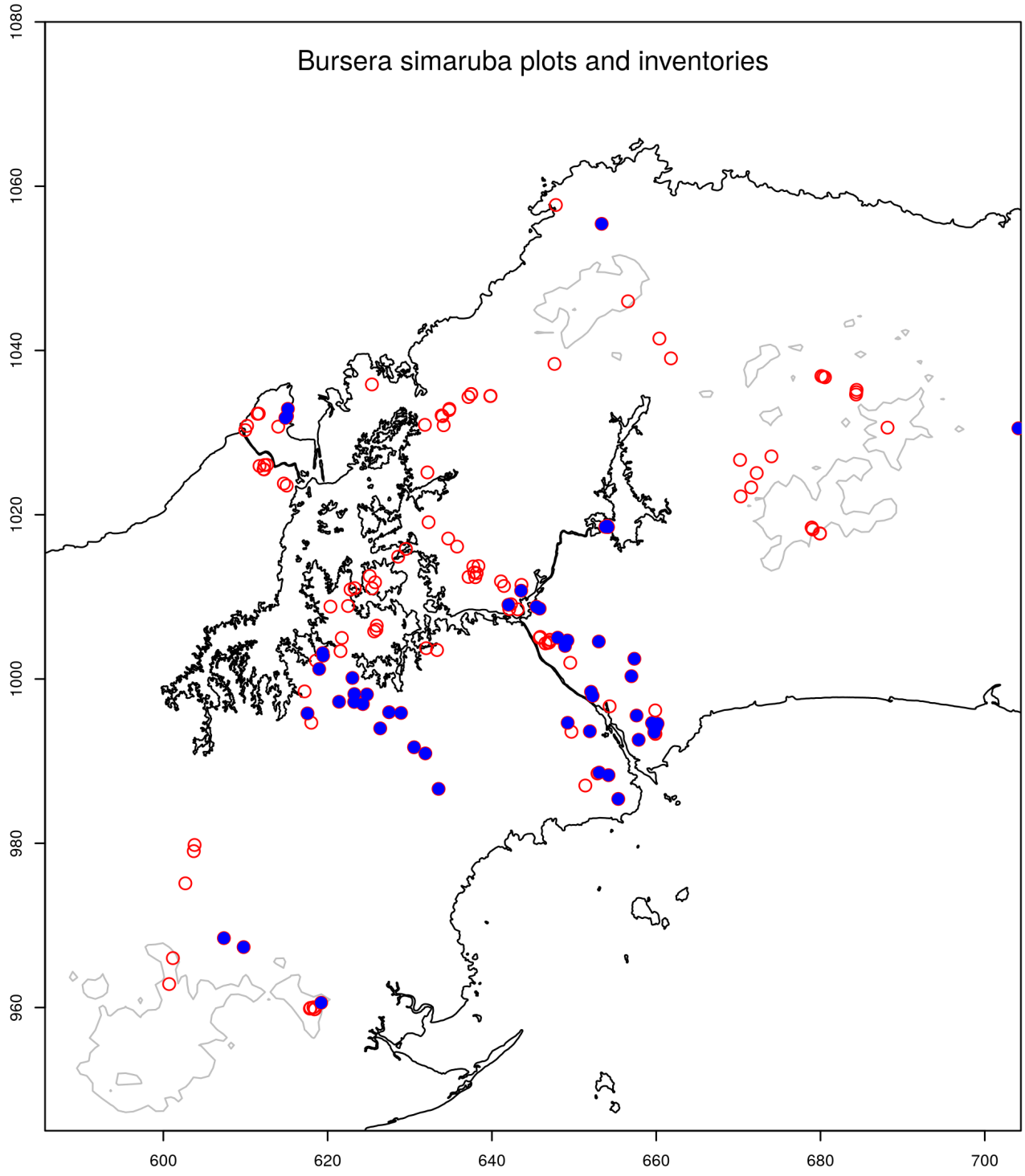
183 sites in Panama:
61 plots (full tree census) & 122 inventories (presence-absence)

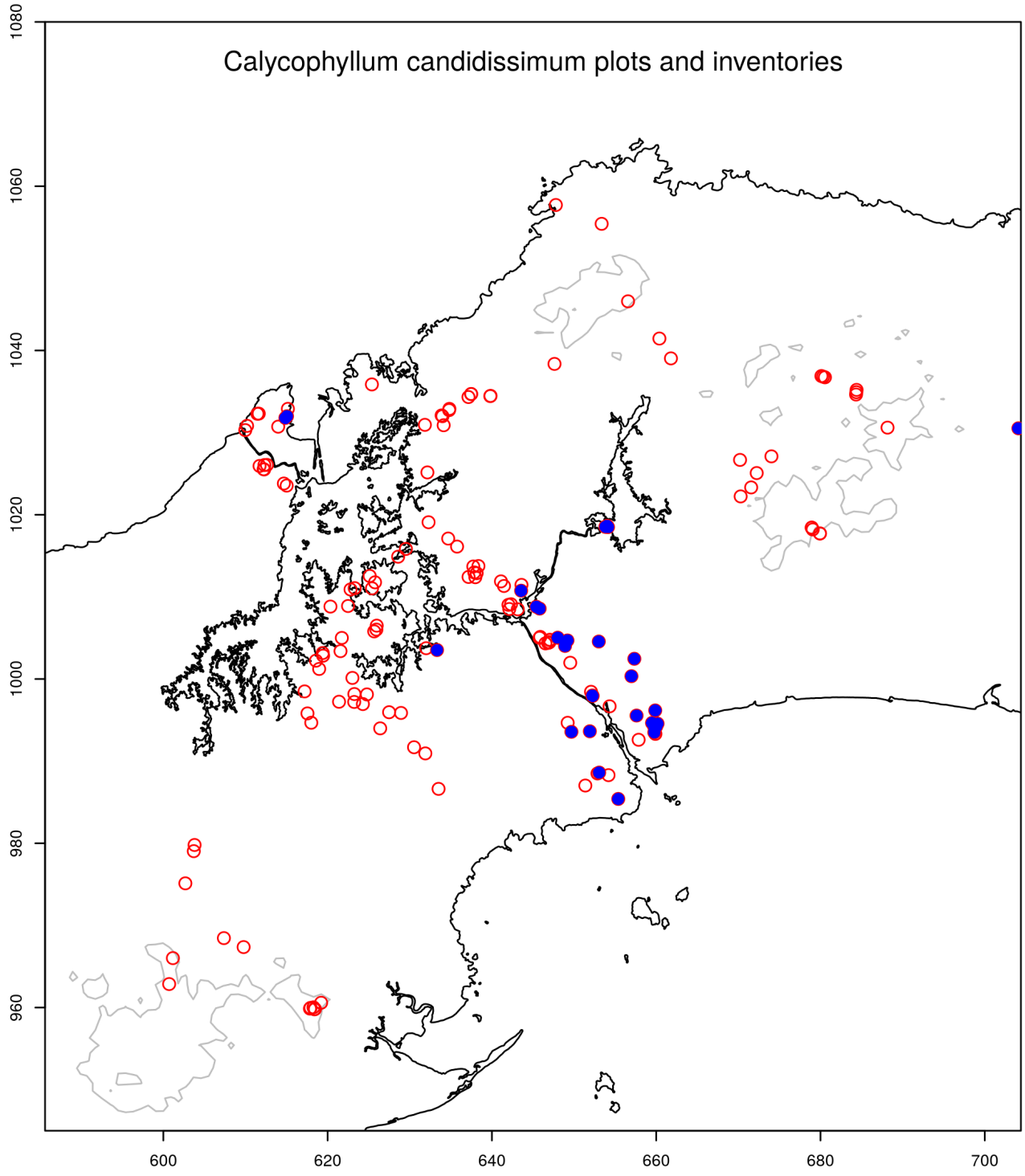


Tree inventories
Estimated dry season intensity at each



Deciduous species and limestone


Bursera simaruba plots and inventories
1080
1060
1040
1020
1000
980
960
600
620
640
660
680
700


Calycophyllum candidissimum plots and inventories
1080
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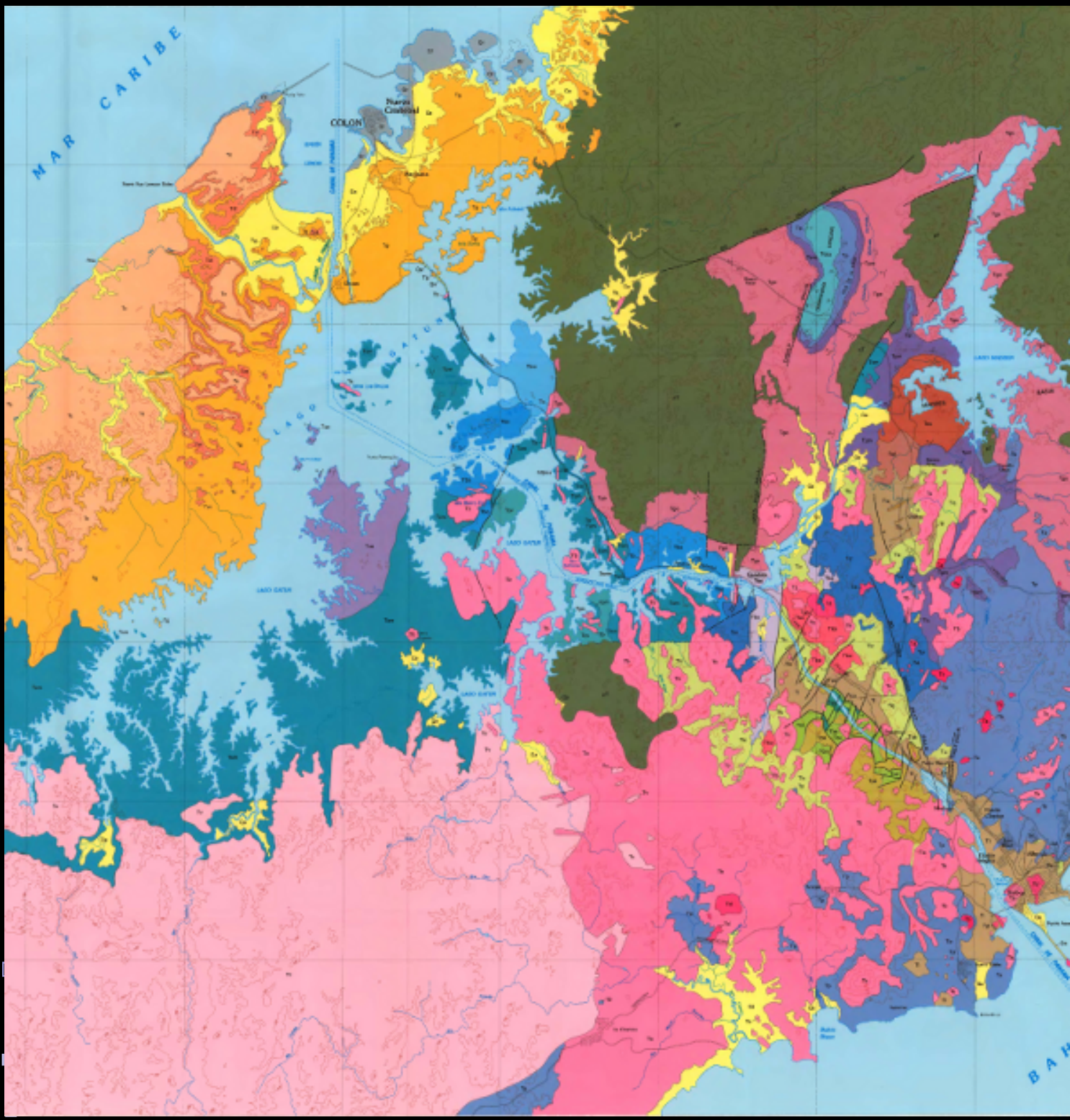
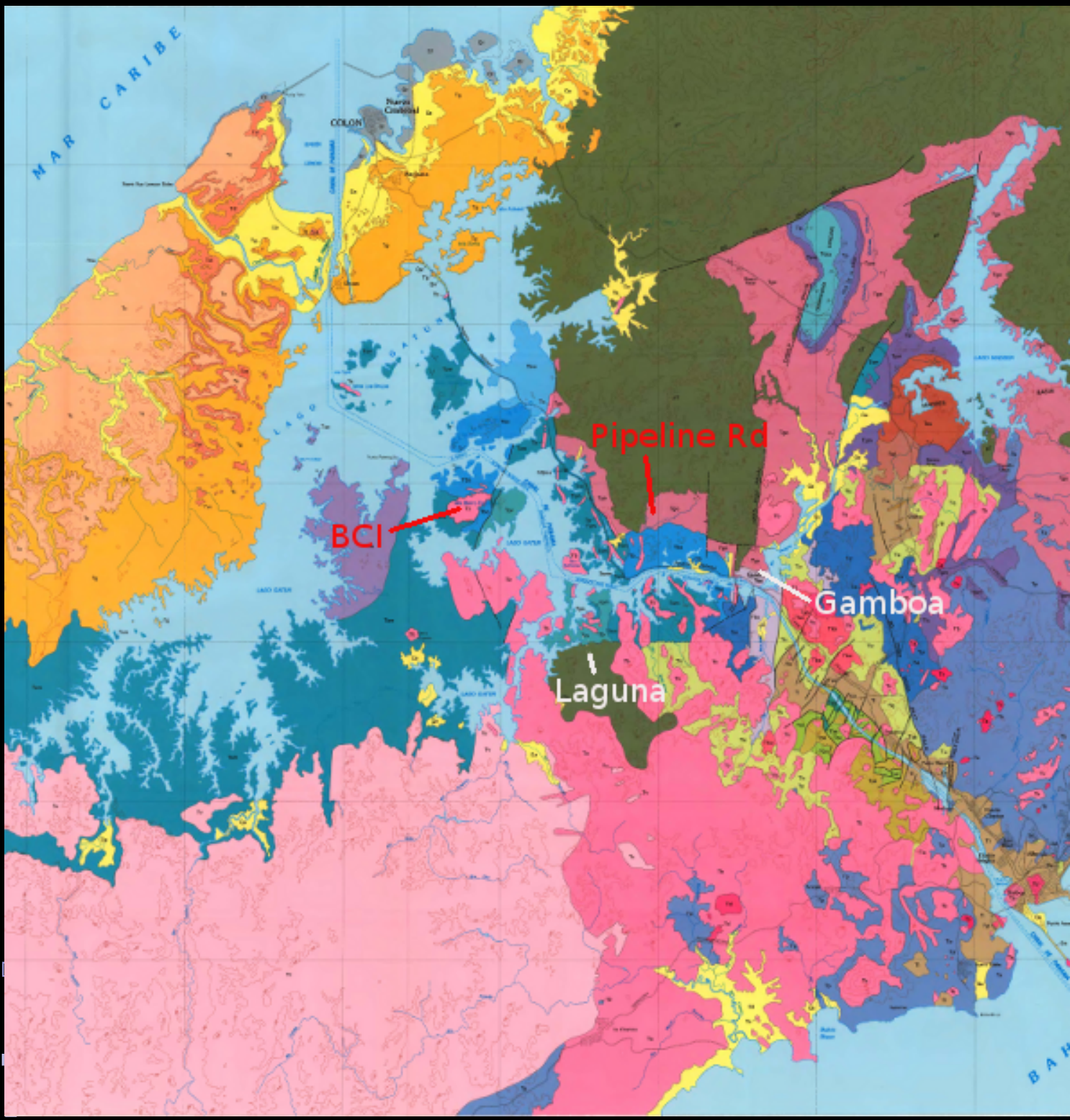
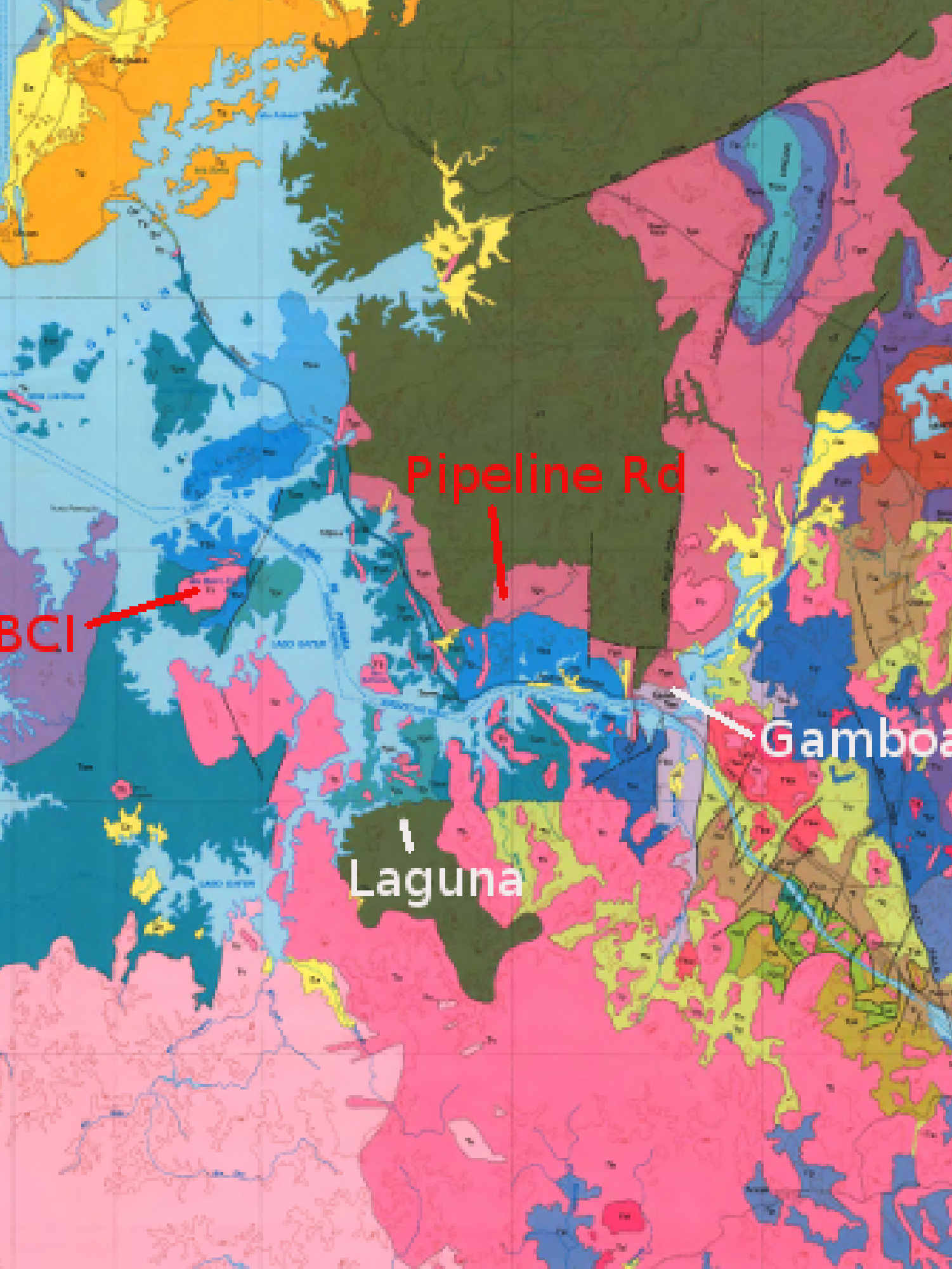
700

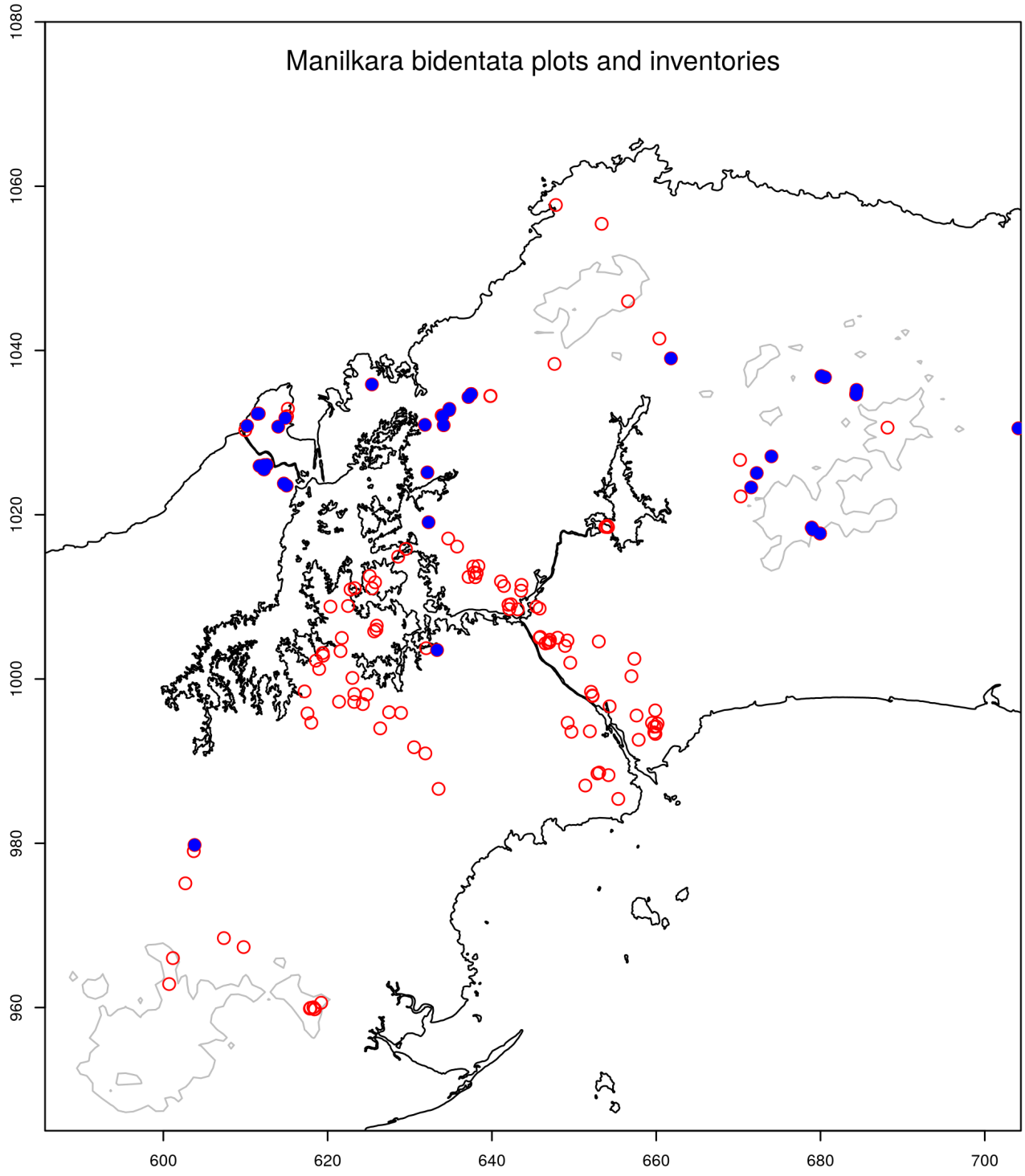


Woodring geology map (1982)



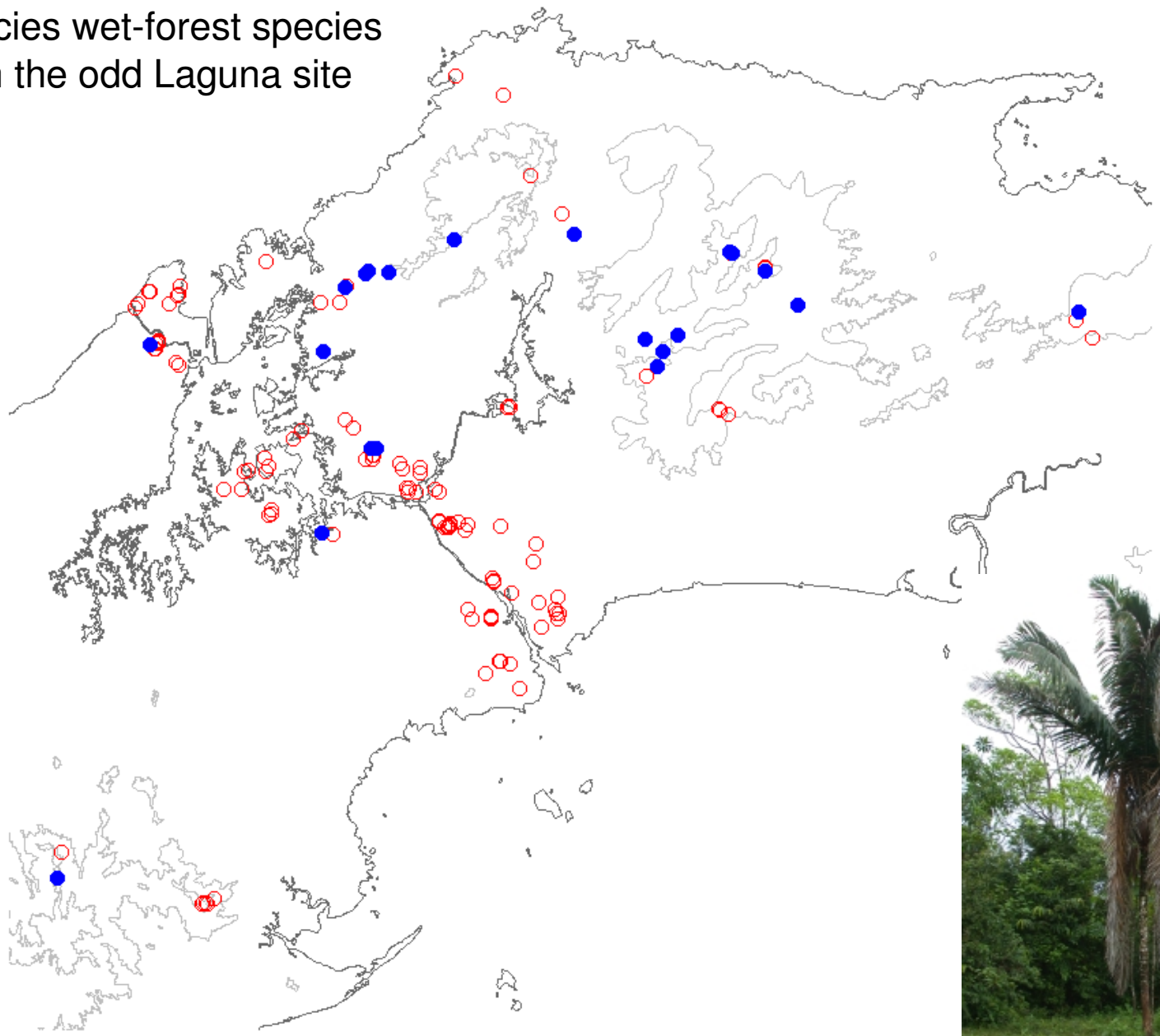
Woodring geology map (1982)

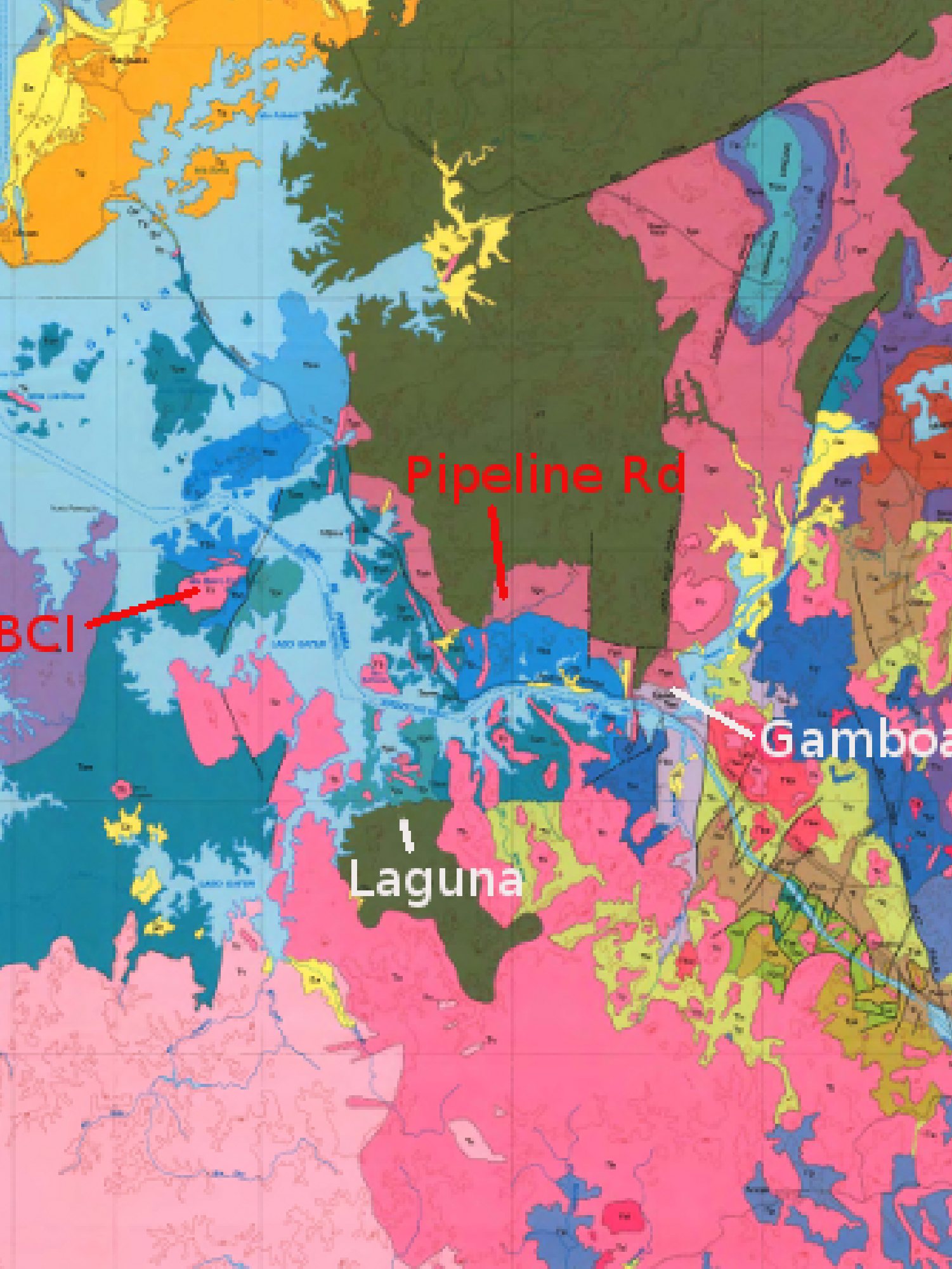

Pipeline Rd
BCI
Gamboa
Laguna


Manilkara bidentata plots and inventories
1080
1060
1040
1020
1000
980
960
600
620
640
660
680
700

Welfia regia plots and inventories

32 species wet-forest species reach the odd Laguna site




Pipeline Rd
BCI
Gamboa
Laguna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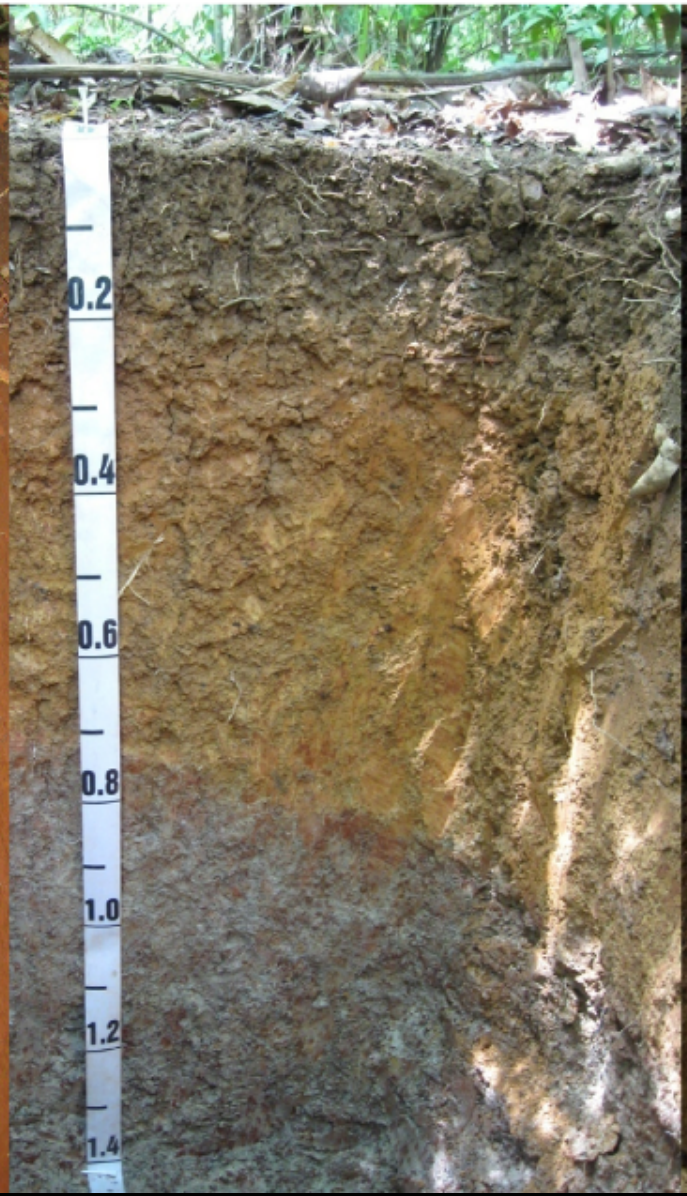
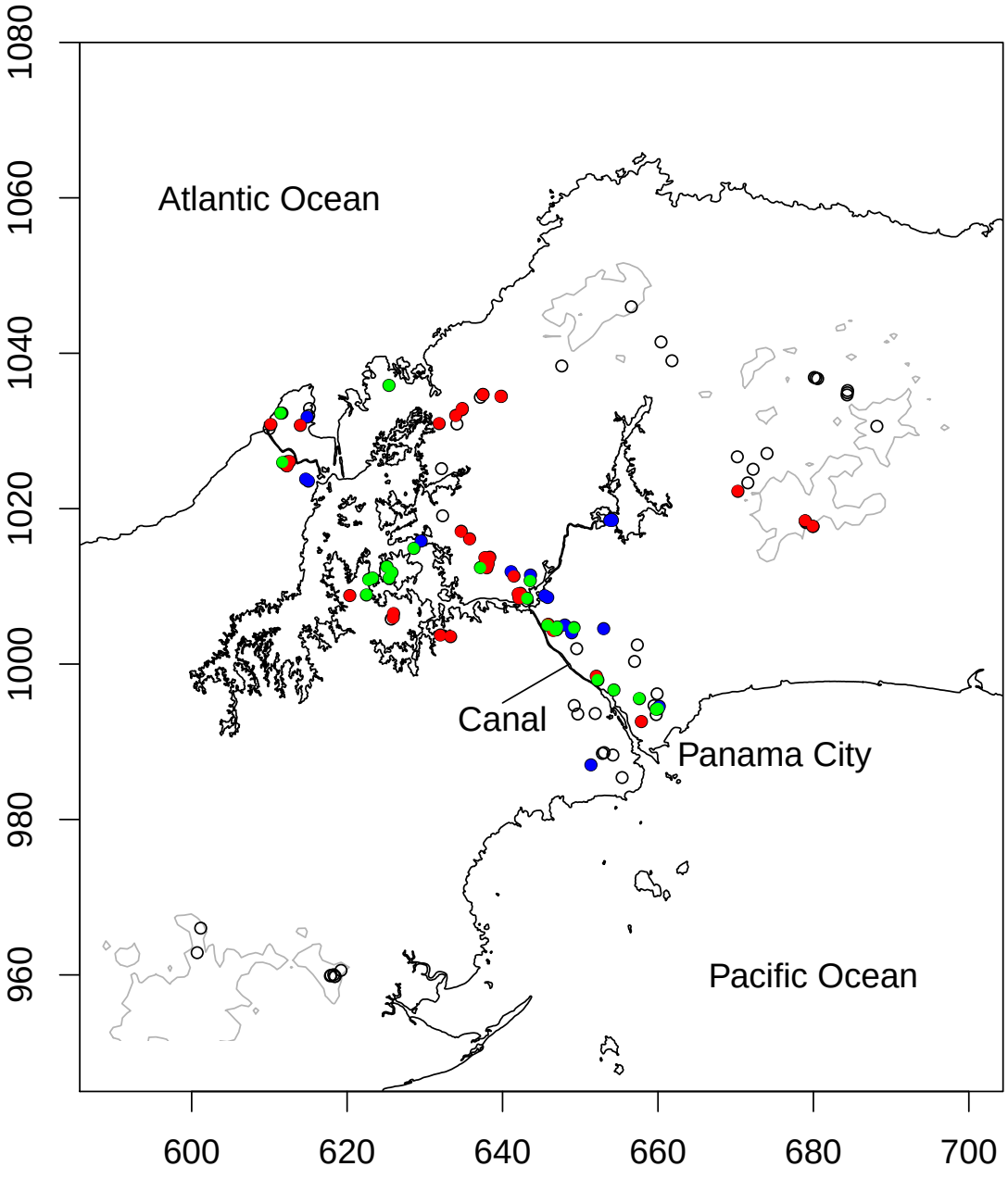
Oxisols
(Typic Eutrudox)

Alfisols and Ultisols
(Oxyaquic Vertic Hapludalf)

Mollisols (?)



Phosphorus Map



Low phosphorus

Medium phosphorus

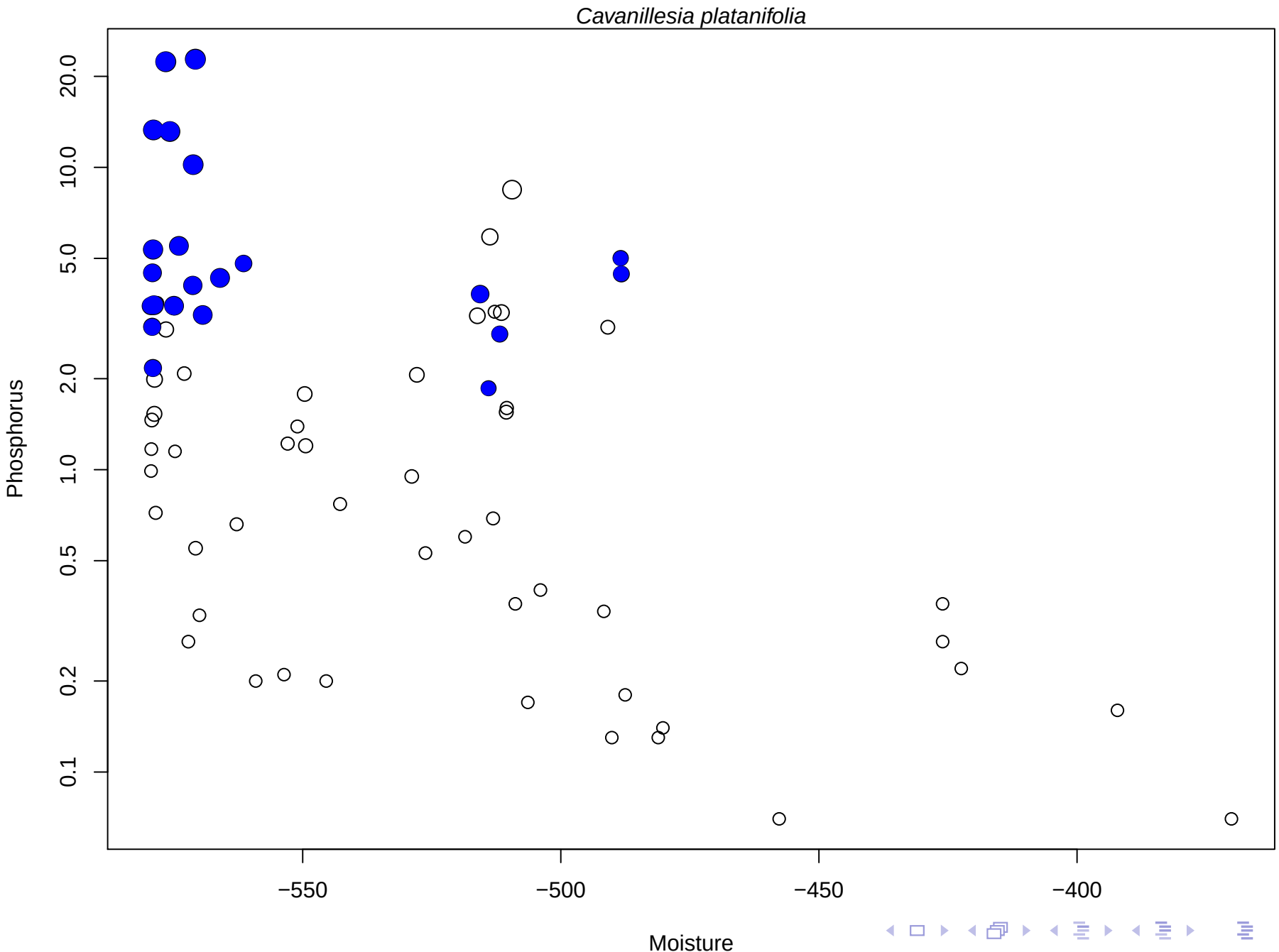
High phosphorus

Soil nutrient comparison

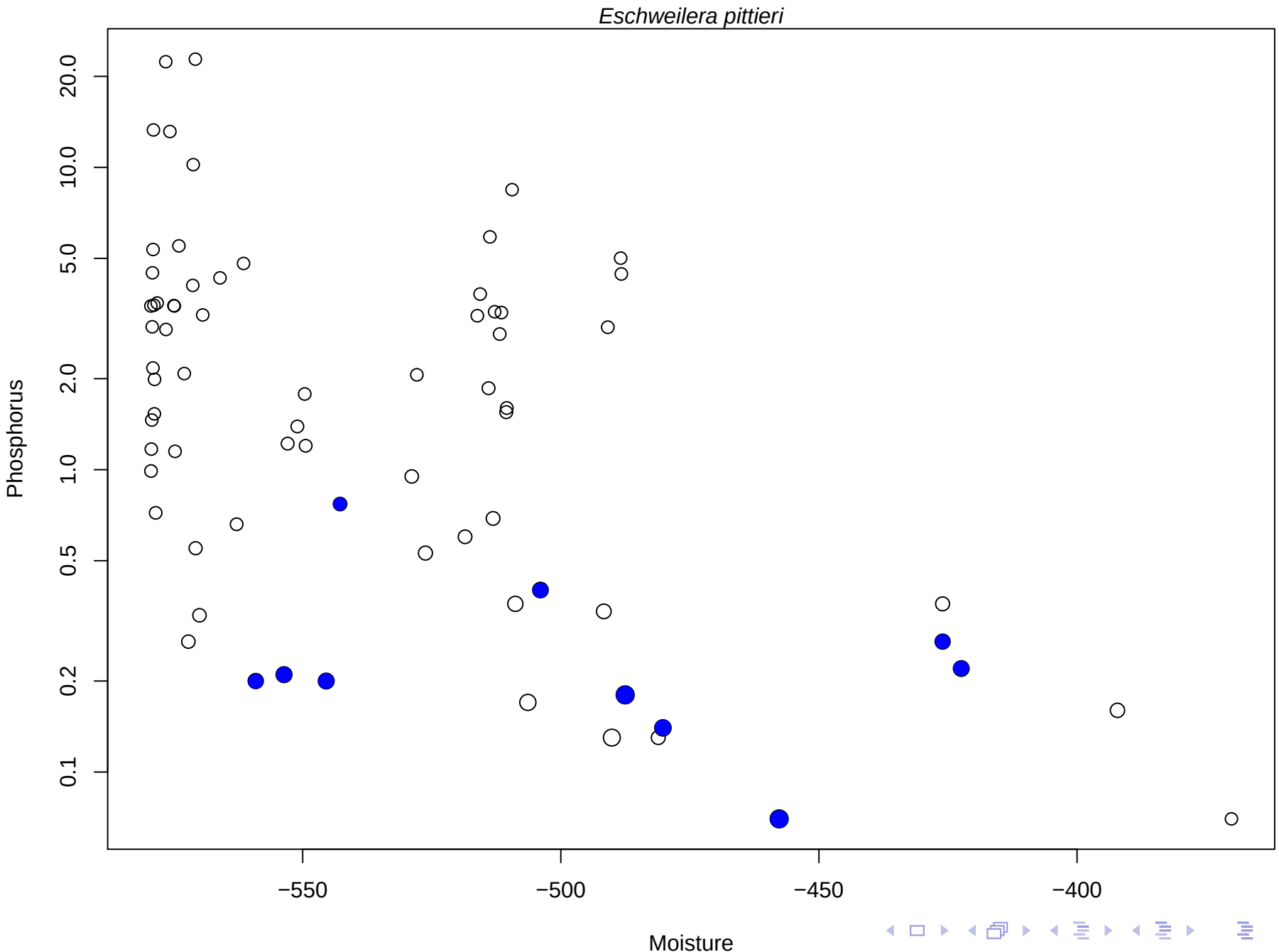
	Panama		Amazon*	
	Min	Max	Min	Max
Ca	25.00	9738.60	2.90	3402.00
K	12.30	351.90	3.80	197.00
P(resin)	0.07	22.80	1.00	21.80
TotalP	72.20	1552.80	25.00	968.00

* Phillips *et al.* 2003, Quesada *et al.* 2011

Phosphorus-Moisture Relation



Phosphorus-Moisture Relation



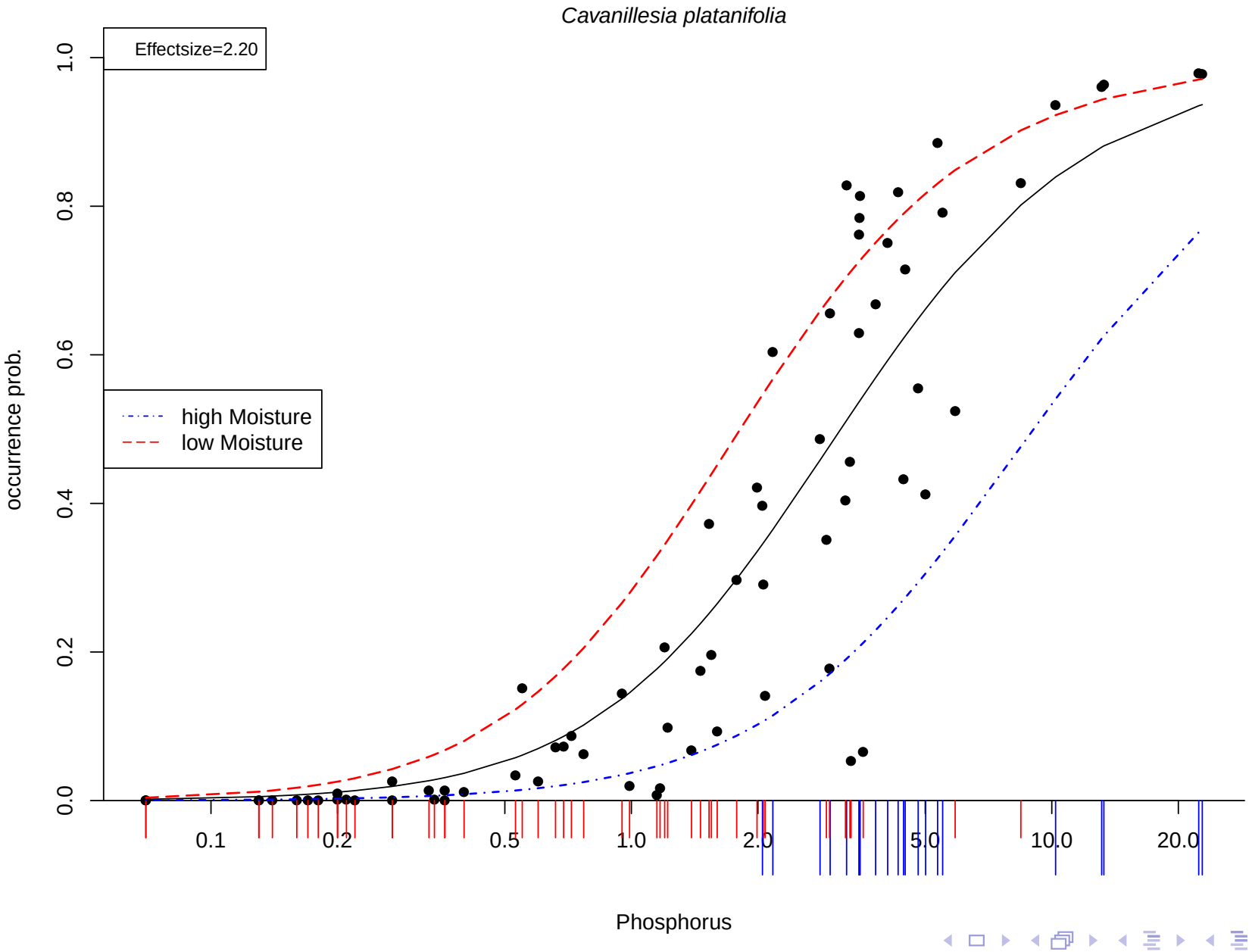
Habitat response model

Multiple logisitic regression
Hierarchical component for species

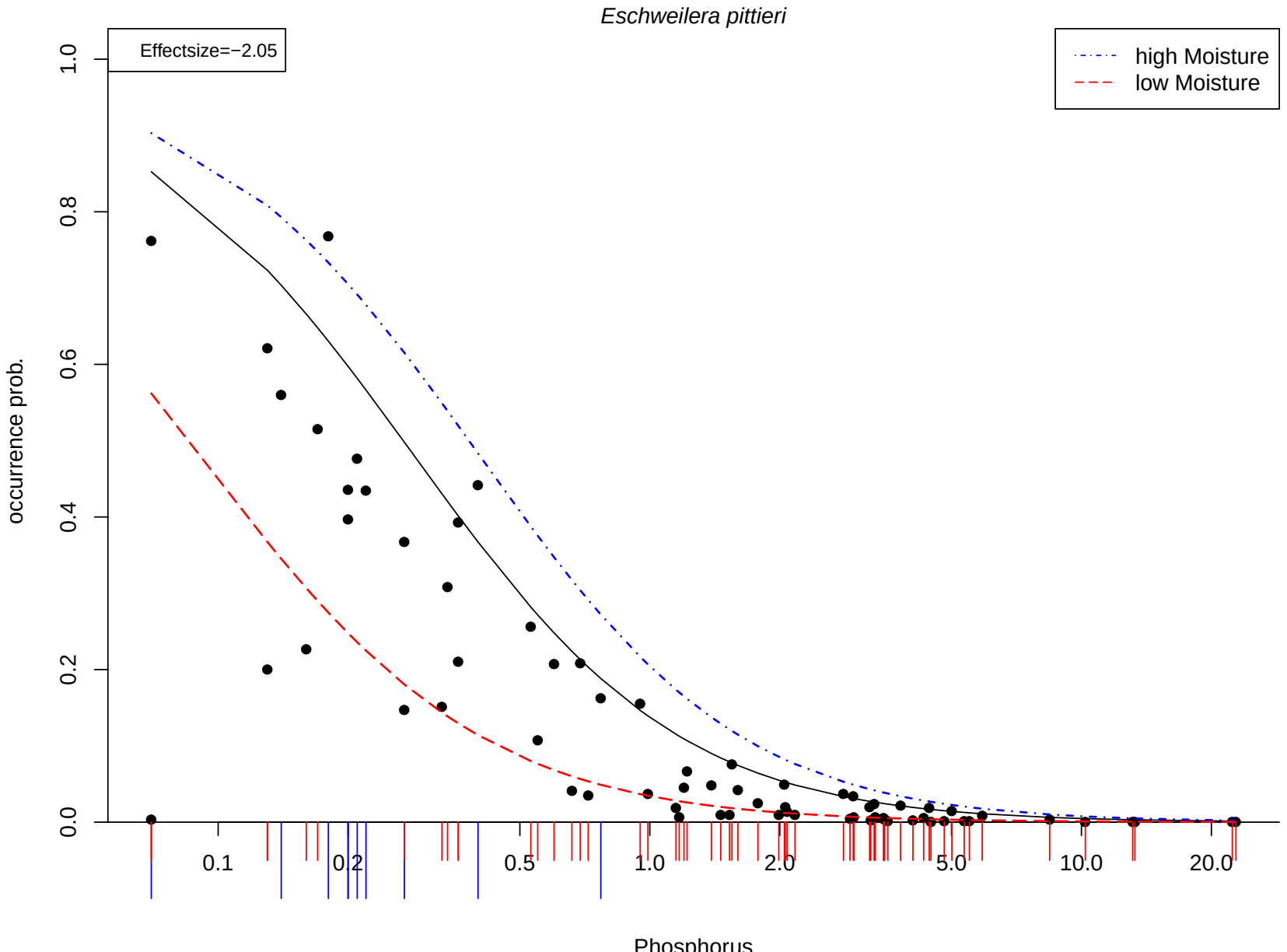
- Multiple logistic regression
  – standard for occurrence modeling against many resources
- $\text{OccurrenceProb} \sim \text{InverseLogit}(\text{Climate} + \text{Soil} + \text{Climate}^2 + \text{Soil}^2)$
- Eight predictors in model:

  Dry season moisture
  Al
  Ca
  Fe
  K
  P (plant available)
  Zn
  N (inorganic)

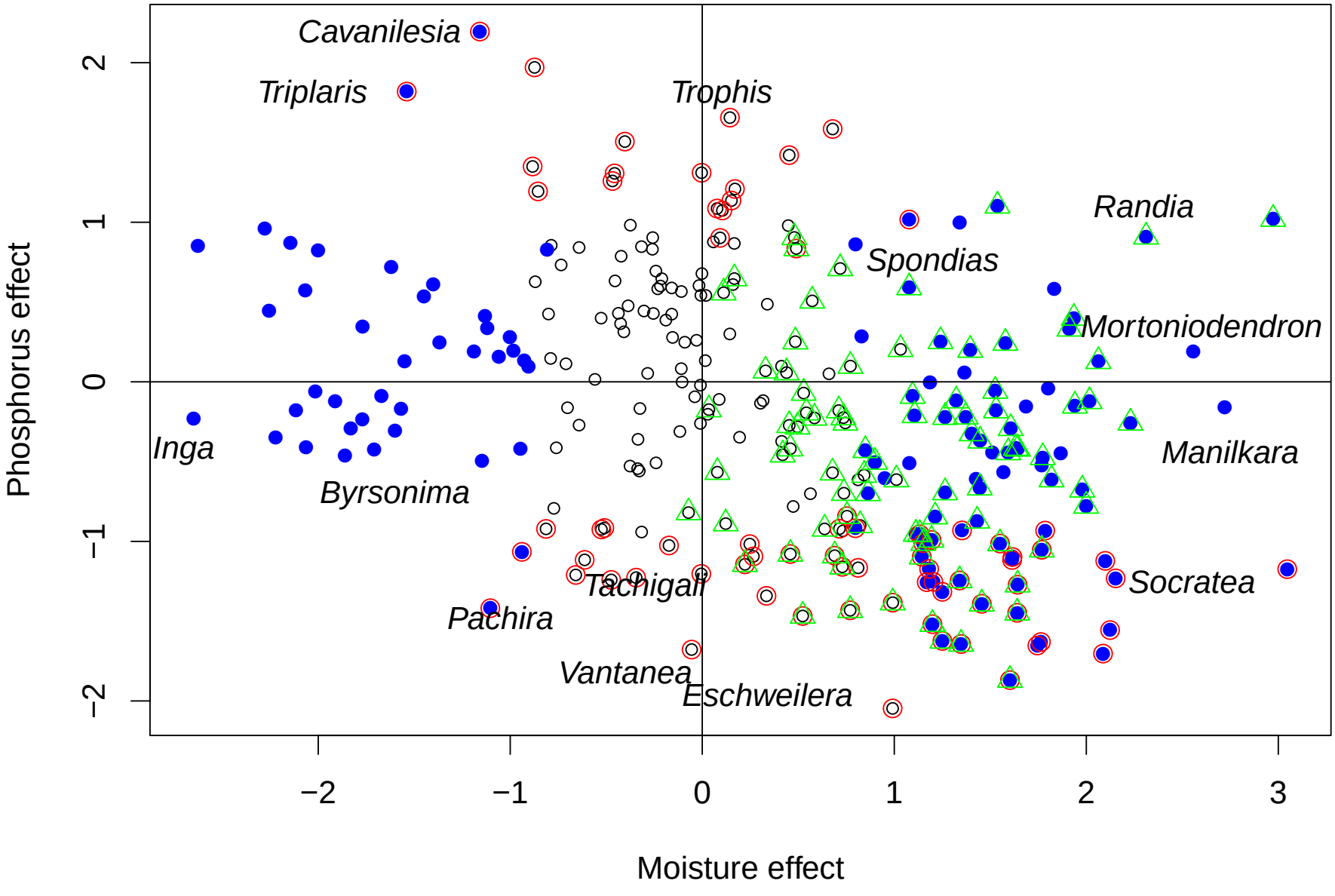
Habitat response model



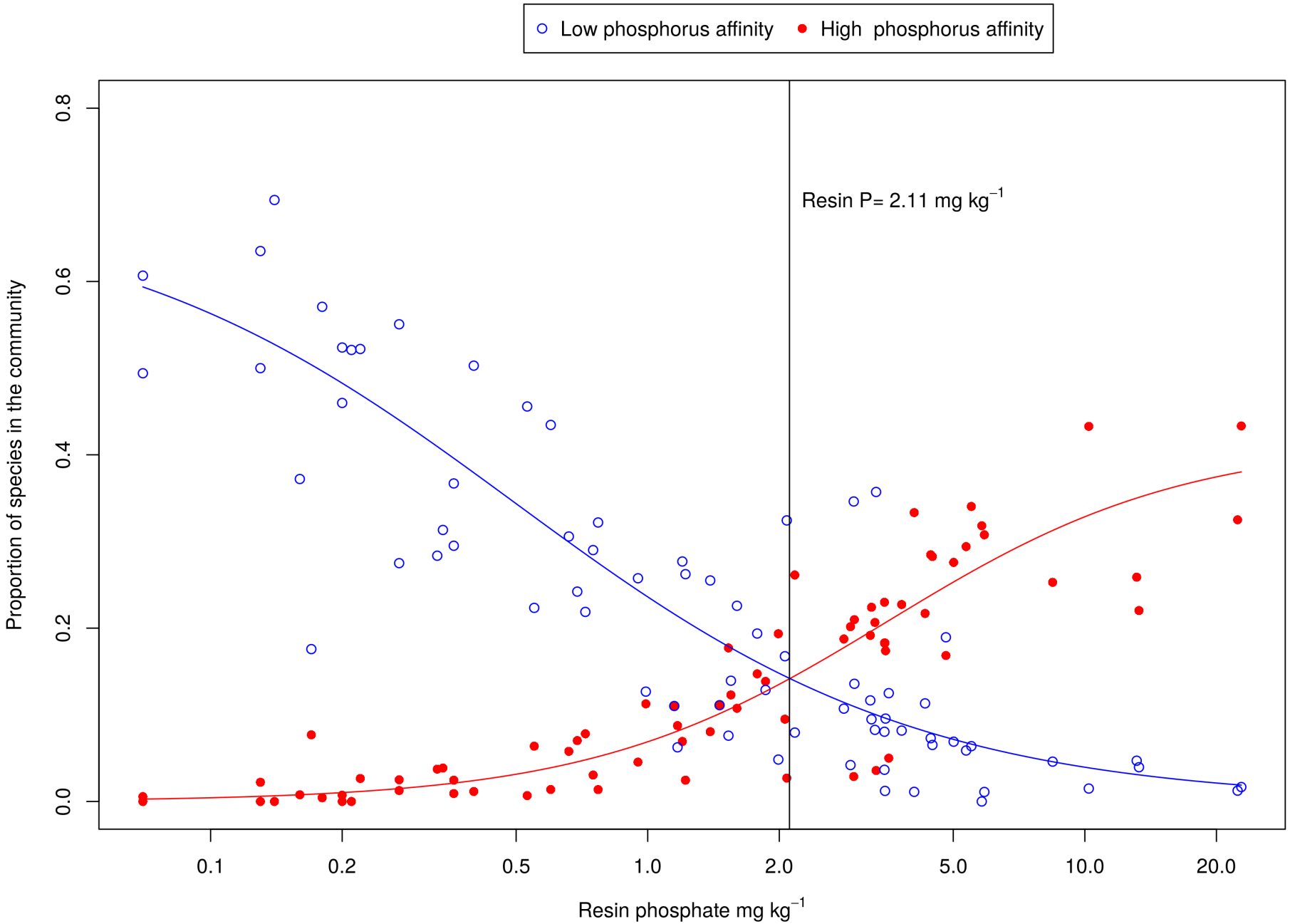
Habitat response model



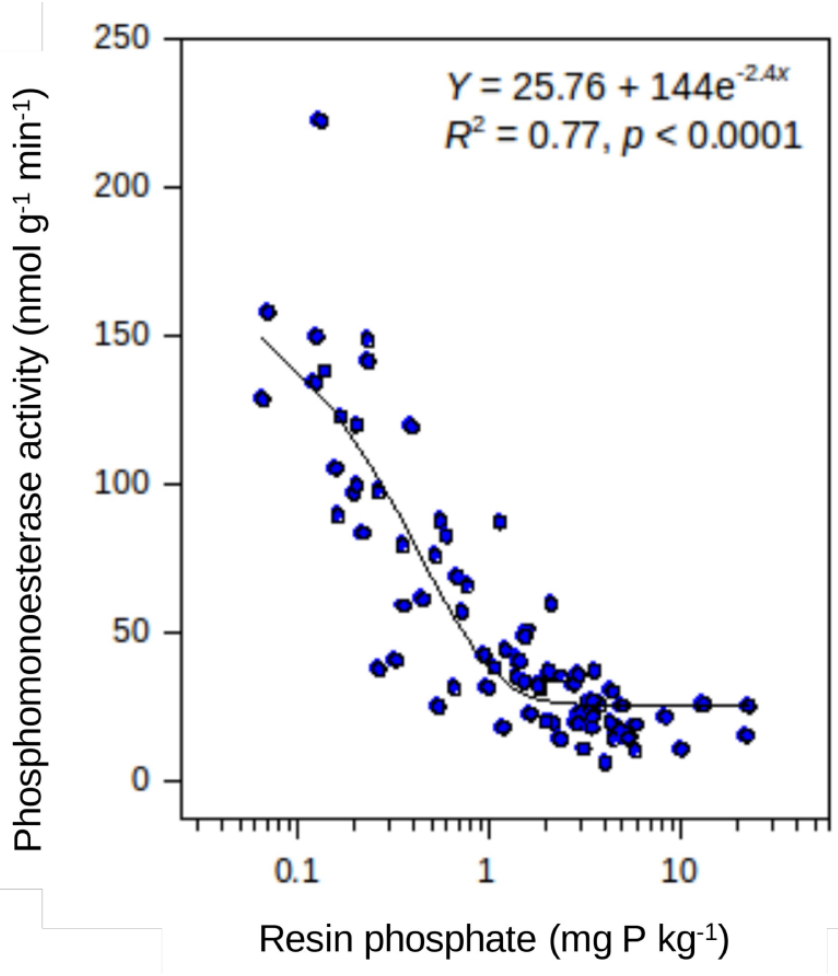
Bivariate Responses, Moisture and P

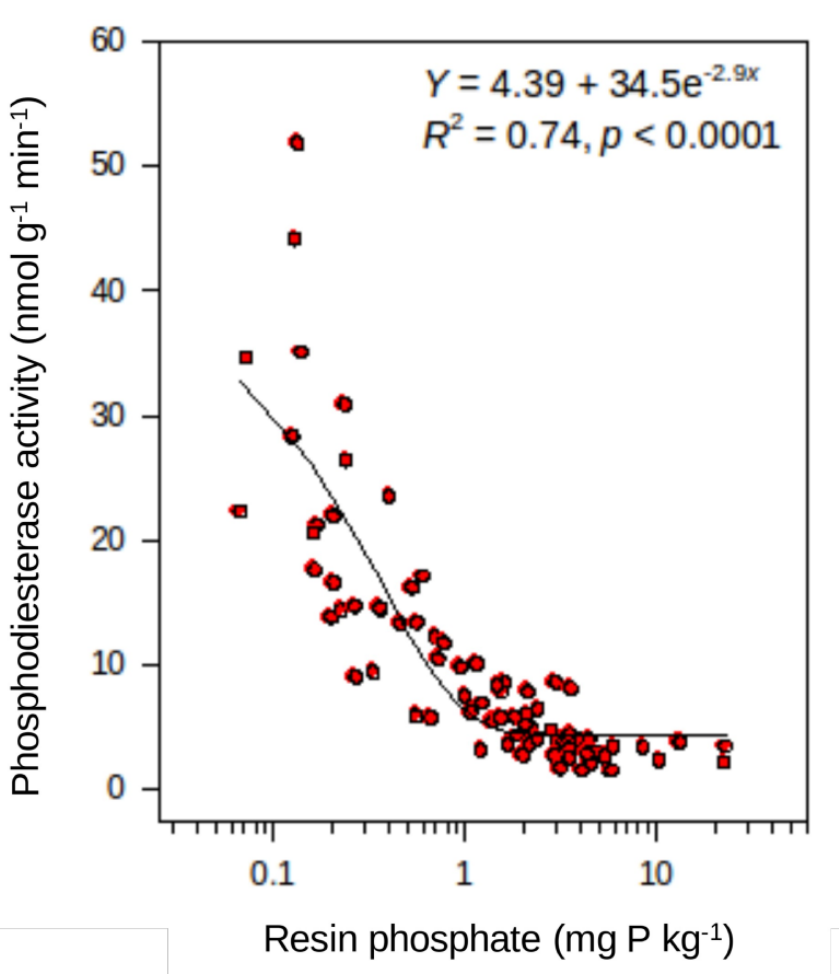


Turnover of Specialists



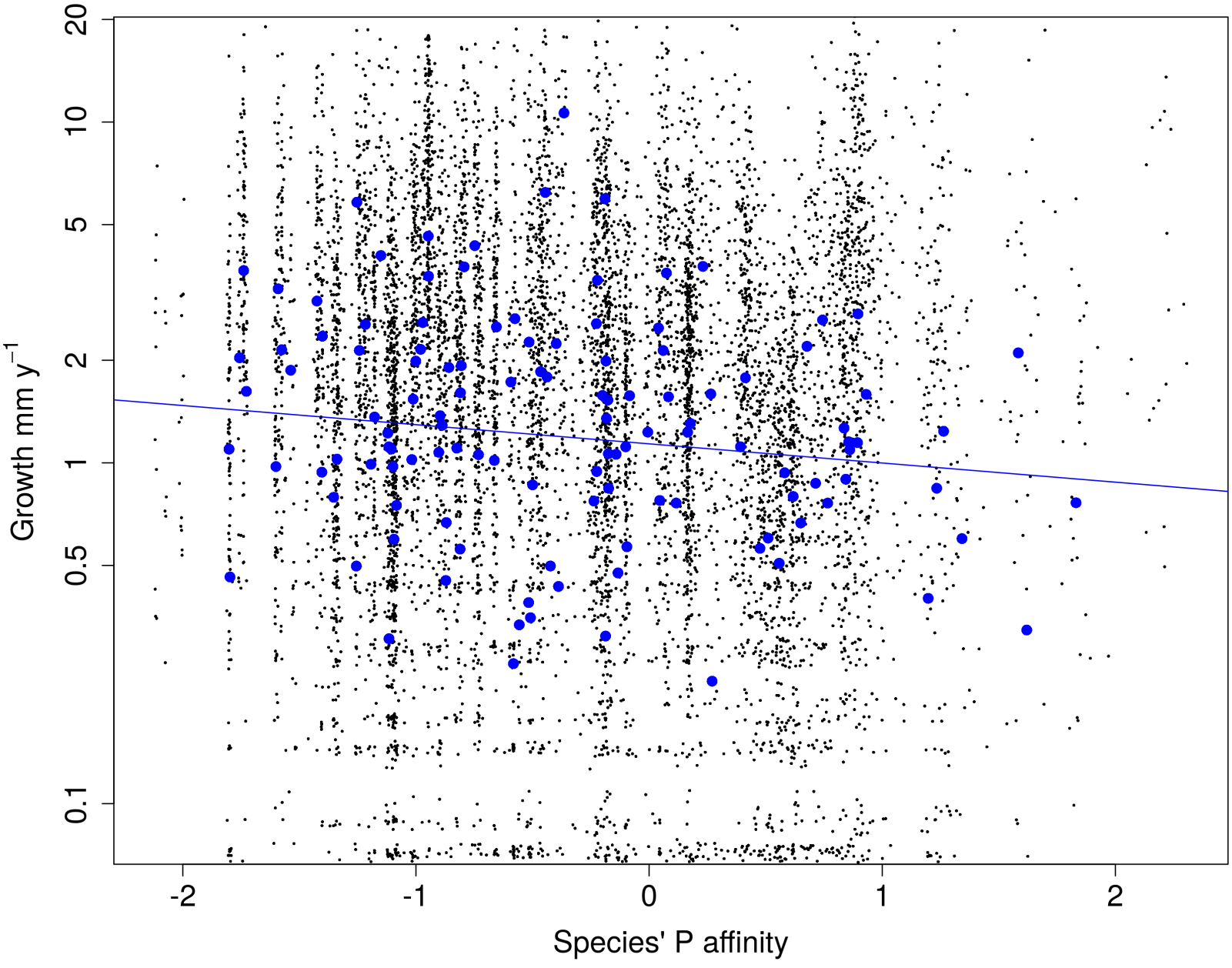
Microbial Response to Phosphorus



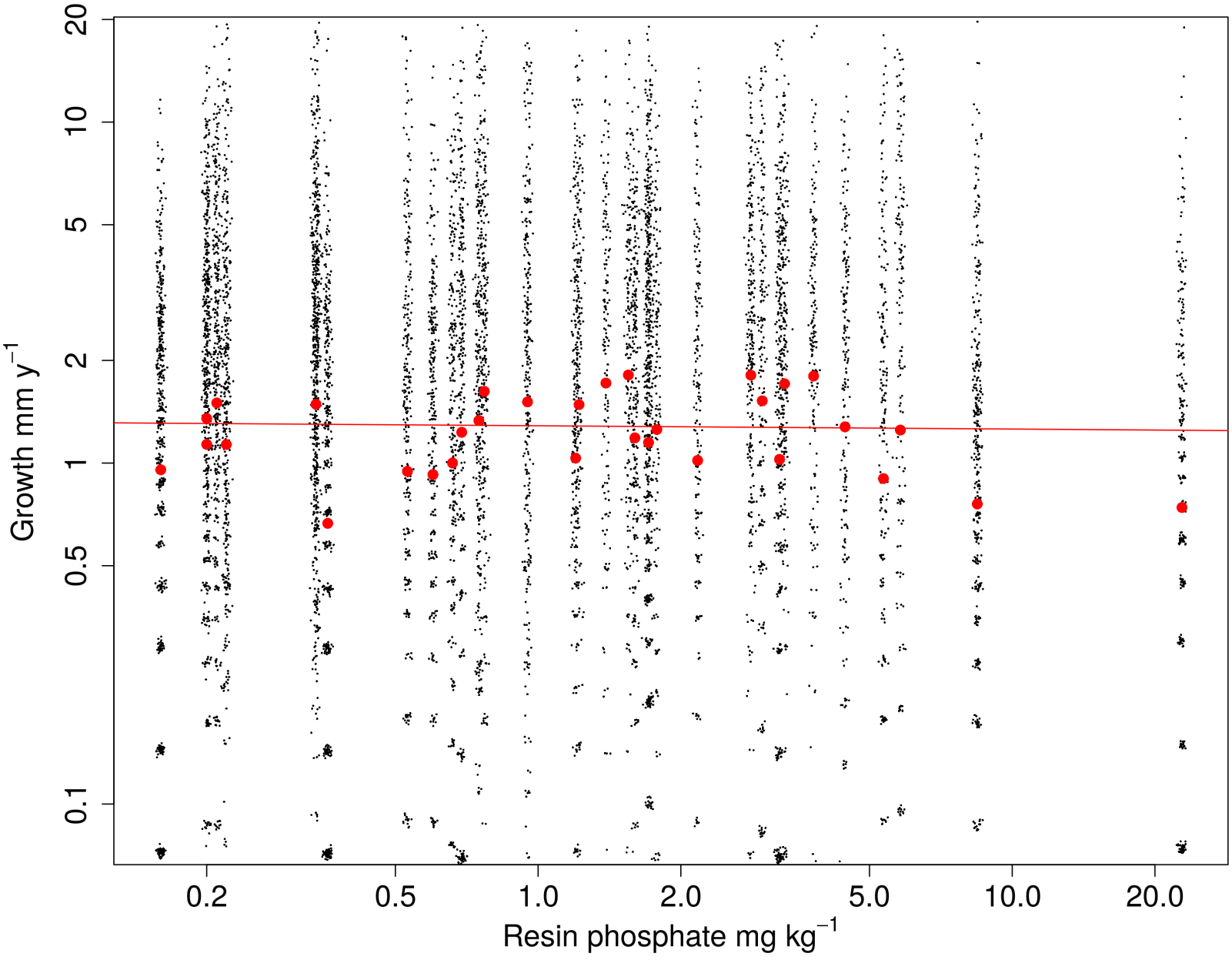


Species' Growth Response to Phosphorus

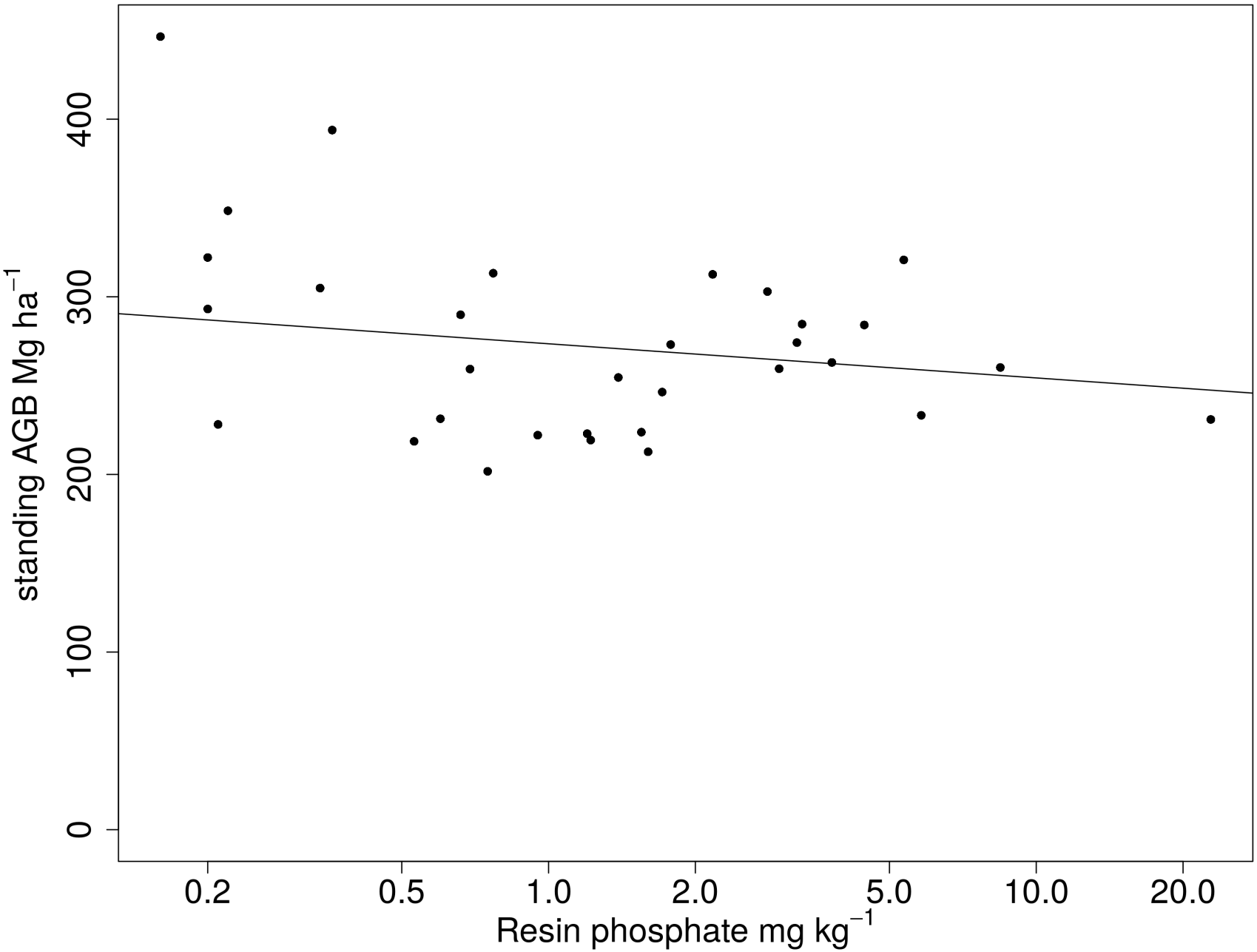
Mean Species Growth and Phosphorus Affinity



Mean Forest Growth and Phosphorus



Forest Biomass and Phosphorus



My understanding of Panama's forests:
Environmental variation and species composition

Climate and forest

- Species composition varies greatly with dry season variation
- But there is far more variation than wet vs. moist of Holdridge
- And there are no distinct forest types

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Geology and forest

- Parent rocks can alter forest beyond the climate
- Many species limited by phosphorus: avoiders and demanders
- Forest community is not limited by phosphorus

Ecological theory of
Environmental variation and species composition

- Why are there specialists to certain kinds of variation but not others?
- What environmental variation is sufficient for specialization?
- Species evolve specialization given any variation with enough time and population

Lecointea amazonica