



XVI OPTIMA Meeting

**From greenhouse to the
wildlife: global invasion
patterns of *Kalanchoe*
xhoughtonii (Crassulaceae)**

Athens (Αθήνα), 5th October, 2019

- Sonia Herrando-Moraira
- Daniel Vitales
- Neus Nualart
- Carlos Gómez-Bellver
- Neus Ibáñez
- Sergi Massó
- Pilar Cachón-Ferrero
- Pedro A. González-Gutiérrez
- Ileana Herrera
- Daniel Shaw
- Adriano Stinca
- Zhiqiang Wang
- Jordi López-Pujol (coord.)



Study species: *Kalanchoe* × *houghtonii*

- Artificial hybrid created in the 1930s by the eminent horticulturist A.D. Houghton in California, who named *Bryophyllum tubimontanum* although this name was not validly published
- Perennial herb (1 m without inflorescence, 1.5 m with inflorescence), generally monocarpic, with dark-red flowers.
- Sexual reproduction absent or rare.
- Parental species:
 - *Kalanchoe daigremontiana* ($2n = 34$; endemic to SW Madagascar, naturalized worldwide, invasive in several regions)
 - *Kalanchoe tubiflora* ($2n = 68$; endemic to S Madagascar, naturalized worldwide, invasive in several regions)
- The hybrid does not form naturally.

Study species: *Kalanchoe* × *houghtonii*

- Artificial hybrid created in the 1930s by the eminent horticulturist A.D. Houghton in California, who named *Bryophyllum tubimontanum* although this name was not validly published
- Perennial herb (1 m without inflorescence, 1.5 m with inflorescence), generally monocarpic, with dark-red flowers.



K. daigremontiana



K. tubiflora



Kalanchoe × *houghtonii* has become a very **problematic** species because...

- High capacity to spread and invade because:
 - It is drought-tolerant (as occurs in many species the genus)
 - Easy propagation by very vigorous clonal growth
 - ⇒ bulbils arise from the the leaf margins

“MOTHER OF THOUSANDS”
“MOTHER OF MILLIONS”



- Very extended ornamental use.
- The hybrid seems to be more invasive than the parental spp.
- It can grows in a large variety of habitats



- It can grow in a large variety of habitats
The hybrid can form dense monospecific carpets of 1000-2000 individuals/m²

URBAN AND PERIURBAN HABITATS



Camagüey, Cuba



Caserta, Italia

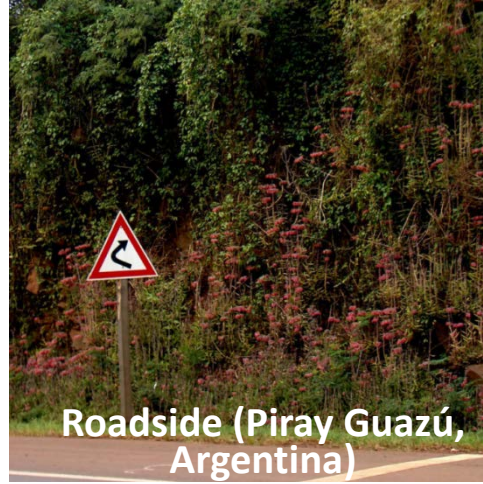


Urban garden (Singapore)



Tunis, Tunisia

SEMI-NATURAL HABITATS



Roadside (Piray Guazú, Argentina)



Disturbed pinewood (Barcelona)



Semi-disturbed coastal area (Cabo Cruz, Cuba)

HÁBITATS NATURALES



Xerophytic thorny shrubland (Saroche, Venezuela)



Highlands Scrub Natural Area (Deerfield Beach, FL, USA)



Oualie Beach, St. Kitts and Nevis

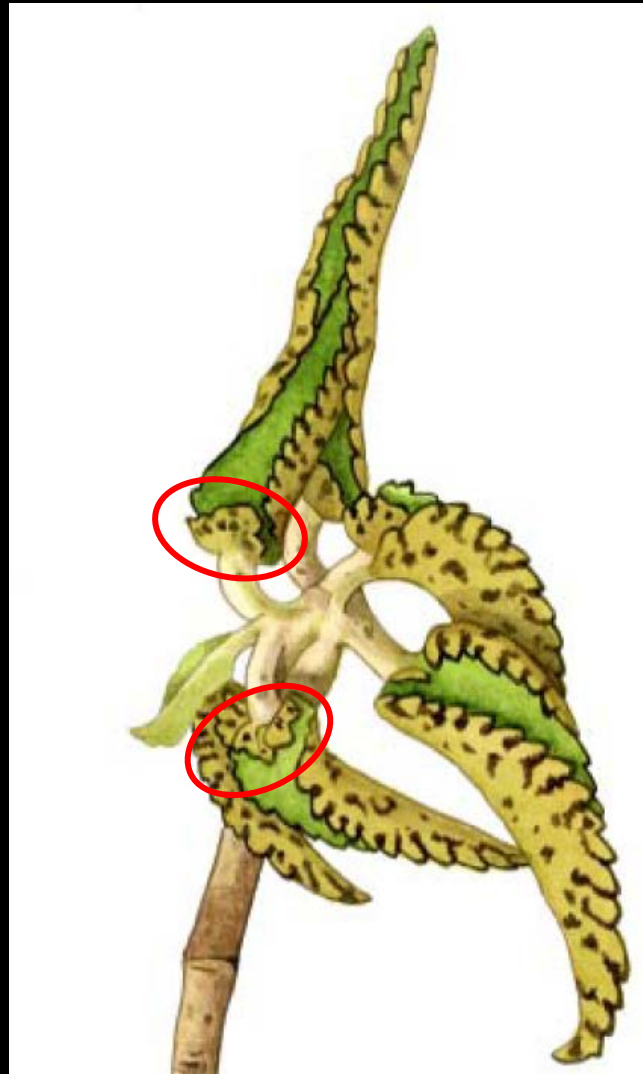


Cliff (Flat Rock Creek, Australia)

However, the distribution of *K. × houghtonii* is **poorly known** because...

- The species was not formally published until 2006 by D.B. Ward
- Its strong morphological resemblance with one of its parents (*K. daigremontiana*)
 - Citations prior to 2006 are under the name *K. daigremontiana*
 - Many citations after 2006 are still under *K. daigremontiana* ... or even under other related species
- Its considerable morphological variability has contributed to taxonomic confusion

K. DAIGREMONTIANA

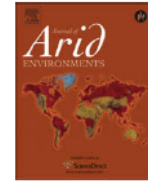


- ▶ Base of the leaf truncate or cordate, conspicuously folded upwards
- ▶ Leaf blade dark green

K. HOUGHTONII



- ▶ Base slightly cordate to decurrent, not folded (or very small).
- ▶ Leaf blade grayish-green



Reproductive and recruitment traits as indicators of the invasive potential of *Kalanchoe daigremontiana* (Crassulaceae) and *Stapelia gigantea* (Apocynaceae) in a Neotropical arid zone

I. Herrera, J.M. Nassar*

Centro de Ecología, Instituto Venezolano de Investigaciones Científicas IVIC, Carretera Panamericana Km. 11, Altos de Pipe, A.P. 21827, Caracas 1020-A, Miranda, Venezuela

ARTICLE INFO

ABSTRACT

Article history:

Received 15 February 2009; received in revised form 15 May 2009; accepted 15 May 2009

I. Herrera, J.M. Nassar / Journal of Arid Environments 73 (2009) 978–986

979

plants in these environments (Brooks, 1999; Loope et al., 1988), the ones that become invasive can generate significant negative effects, including modification of the soil's biophysical and biochemical characteristics and competition with native species for soil nutrients (Belnap and Phillips, 2001).

'Cerro Saroche' National Park (Venezuela) is one of the few protected areas that include arid ecosystems in the Caribbean region. Populations of two ornamental exotic species, *Kalanchoe daigremontiana* Hamet et Perrier de la Bathie (Crassulaceae) and *Stapelia gigantea* L. (Apocynaceae), have been recently detected inside the park (Herrera, 2007). Their distribution and abundance in that location suggest that they already established there and have the potential for becoming invasive. Although both genera have species that are considered invasive in other localities, such as Hawaii (Staples et al., 2000), continental U.S., Puerto Rico (Randall, 2002), and Australia (Hannan-Jones and Playford, 2002), we are not aware of published information about the invasive potential of *K. daigremontiana* and *S. gigantea* in continental Neotropical arid zones. In this study, we tested the invasive potential of these species by characterizing their reproductive biology and recruitment patterns and comparing them against Baker's Law and additional reproductive profiles associated with invasive species. For each species we propose a combination of traits that might confer them the potential to successfully invade xeric ecosystems in the Caribbean region.

Kalanchoe daigremontiana





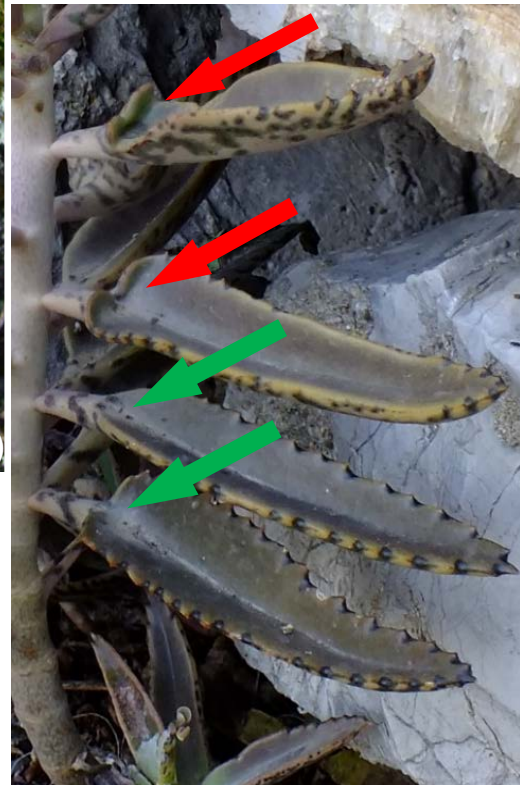
Barcelona (Spain)



Tarragona (Spain)



Rangitoto (New Zealand)



Guadeloupe (Caribbean)



Saroche (Venezuela)

Aims of the study

1. Explore the geographic distribution pattern of the mother of millions (*Kalanchoe* × *houghtonii*) globally
2. Track its temporal and geographical origin and its colonization history around the continents
3. Predict the potential distribution through **ecological niche modelling** (ENM) with the software Maxent v. 3.3.3
4. Predict how the distribution of this hybrid taxon is going to progress according to different scenarios of climate change

1. Geographic pattern

1. An extensive **literature survey** has been carried out :

- Biodiversity web portals (*GBIF*, *Tropicos*, etc.)
- Herbaria & virtual herbaria
- Personal observations & personal communications
- Scientific publications (articles, books)
- Citizen Science web portals (*iNaturalist*, *Noah*, *iSpot*, *Biodiversidad Virtual*, *Tela Botanica*, *Plant PhotoBank of China*, etc.)
- Non-scientific sources:
 - Photography web portals (e.g.. *Flickr*)
 - Personal blogs
 - Internet forums (e.g. *Acta Plantarum*)
 - Newspapers
 - Social media (p.ej. *Instagram*)



flickr



1. Geographic pattern

2. All gathered localities were **validated**:

- Making sure that they were correctly identified
 ⇒ They should have supporting photographs
- They have to be georeferenced, or at least provide enough details for its precise georeferencing [minimum precision: 2.5 arc-min (ca. 5 km)]
- Making sure that they occur in the wild (not cultivated)

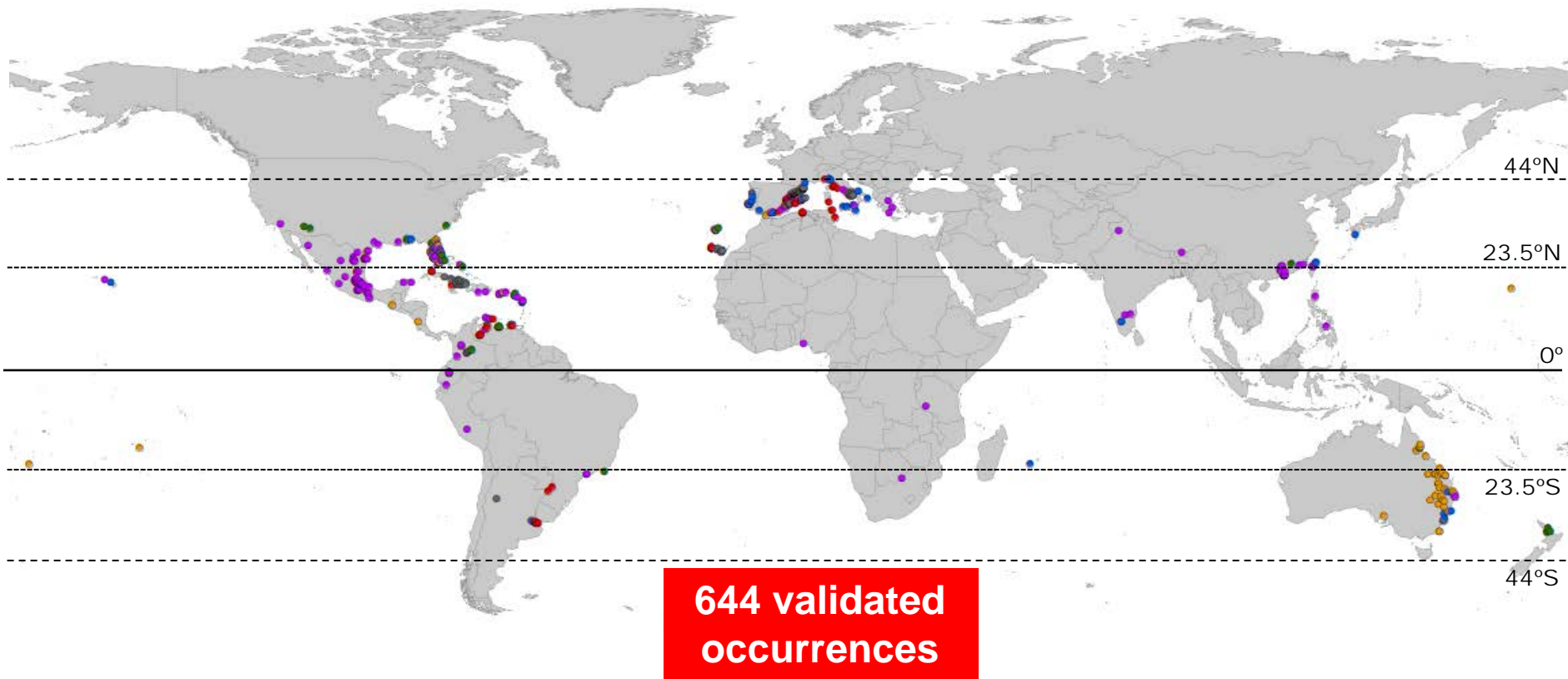
3. Due to taxonomic confusion, we also checked all occurrences to their parental species as well as other “close” taxa

⇒ Up to **47.5%** of the gathered occurrences were originally determined under other names or without proper indication of the species

1. Geographic pattern

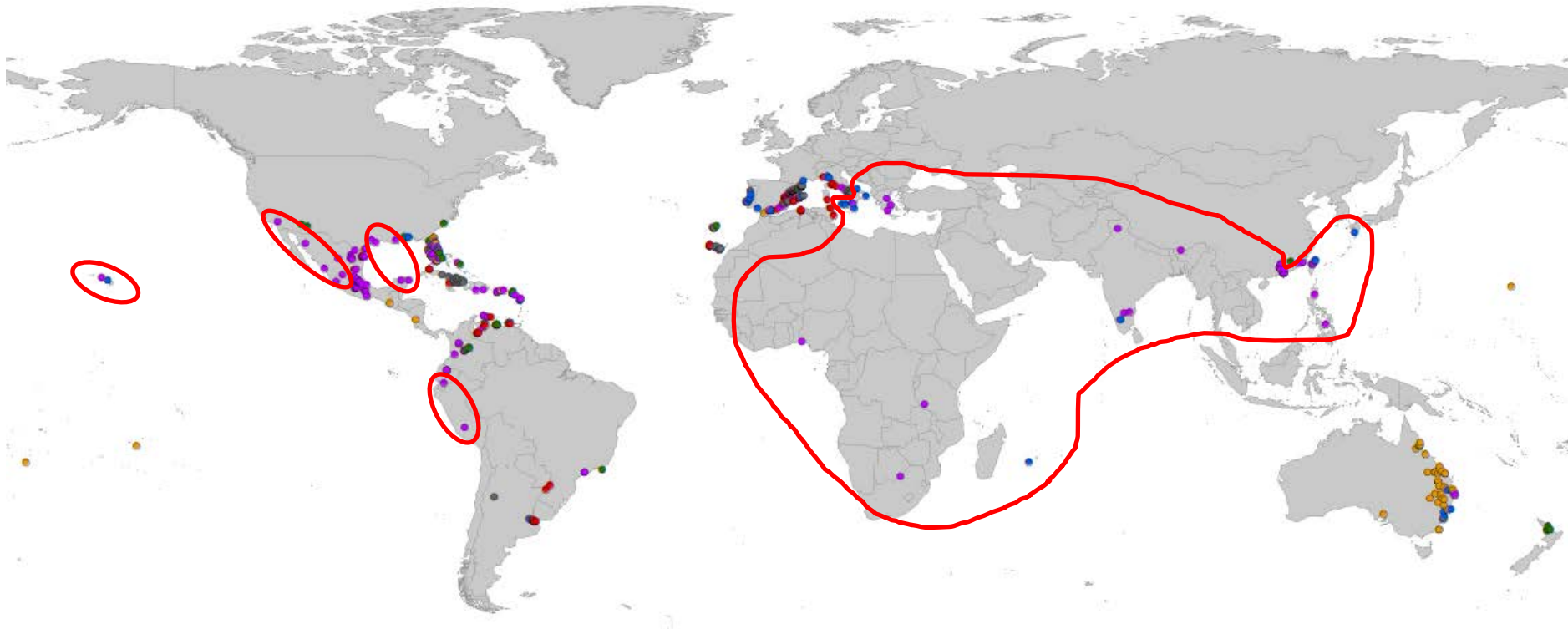
Name in the original source	Occurrences (%)
<i>K. × houghtonii</i> , <i>B. × houghtonii</i> , <i>K. × hybrida</i> or parentals indication	338 (52.5)
<i>K. daigremontiana</i> or <i>B. daigremontianum</i>	155 (24.1)
<i>K. delagoense</i> or <i>B. delagoense</i>	61 (9.5)
<i>K. tubiflora</i> or <i>B. tubiflorum</i>	16 (2.5)
<i>K. serrata</i> or <i>B. serratum</i>	8 (1.2)
<i>B. pinnatum</i>	1 (0.2)
<i>K. rosei</i>	1 (0.2)
<i>Kalanchoe</i> sp. or <i>Bryophyllum</i> sp.	54 (8.4)
Mother of millions	2 (0.3)
Chandelier plant	1 (0.2)
ND	6 (0.9)

1. Geographic pattern



- *K. x houghtonii* is present in all the continents except Antarctica
- Range focused on Mediterranean and subtropical regions
- Main invasion foci: N America, Mediterranean Basin & E Australia

1. Geographic pattern



Primary source

- Biodiversity web portals (11.8%)
- Citizen Science web portals (29.5%)
- Herbaria & Virtual Herbaria (7.8%)
- Non scientific sources (8.7%)
- Personal observations and communications (26.7%)
- Scientific publications (15.5%)

“Non-standard” sources (38.2%)

2. Temporal colonization

AD Houghton



San Fernando (CA)
1930s

Harlingen (TX)
(1960s?)

Bahamas
(1975)

Caracas
(1979)

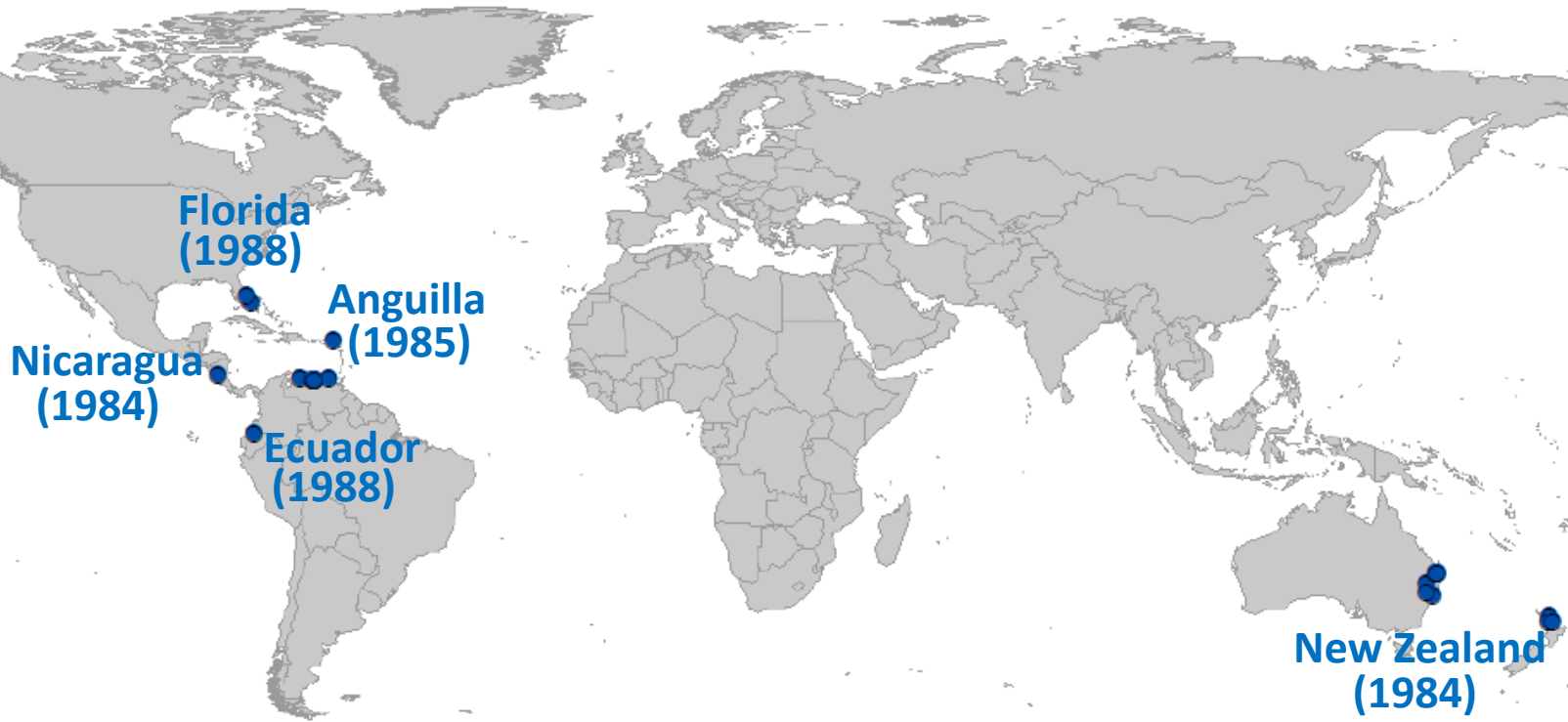
Queensland
(1965-1969?)

New South Wales
(1970)

Occurrences until 1979 (0.6%)

- Probably escaping first from cultivation in the United States, the first record is from 1965 from Australia but from a herbarium specimen without leaves. The first record that we can confidently state as occurring in the wild is from Australia, collected in 1970.

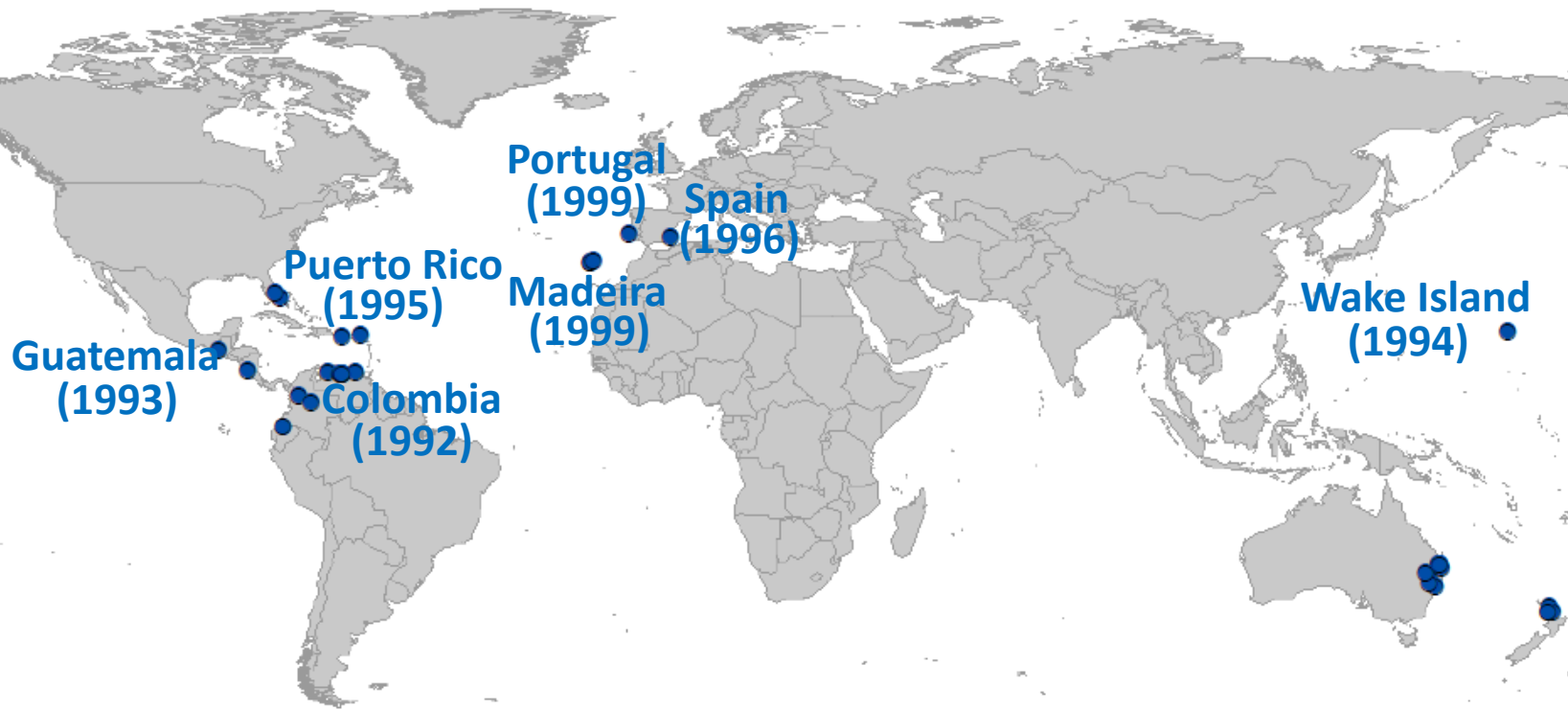
2. Temporal colonization



Occurrences until 1989 (3.3%)

- Present in New Zealand at least since the mid-1980s.
- The first confident observation in the United States is from 1988 in Florida.
- Present in Central America and the Caribbean since mid-1980s.

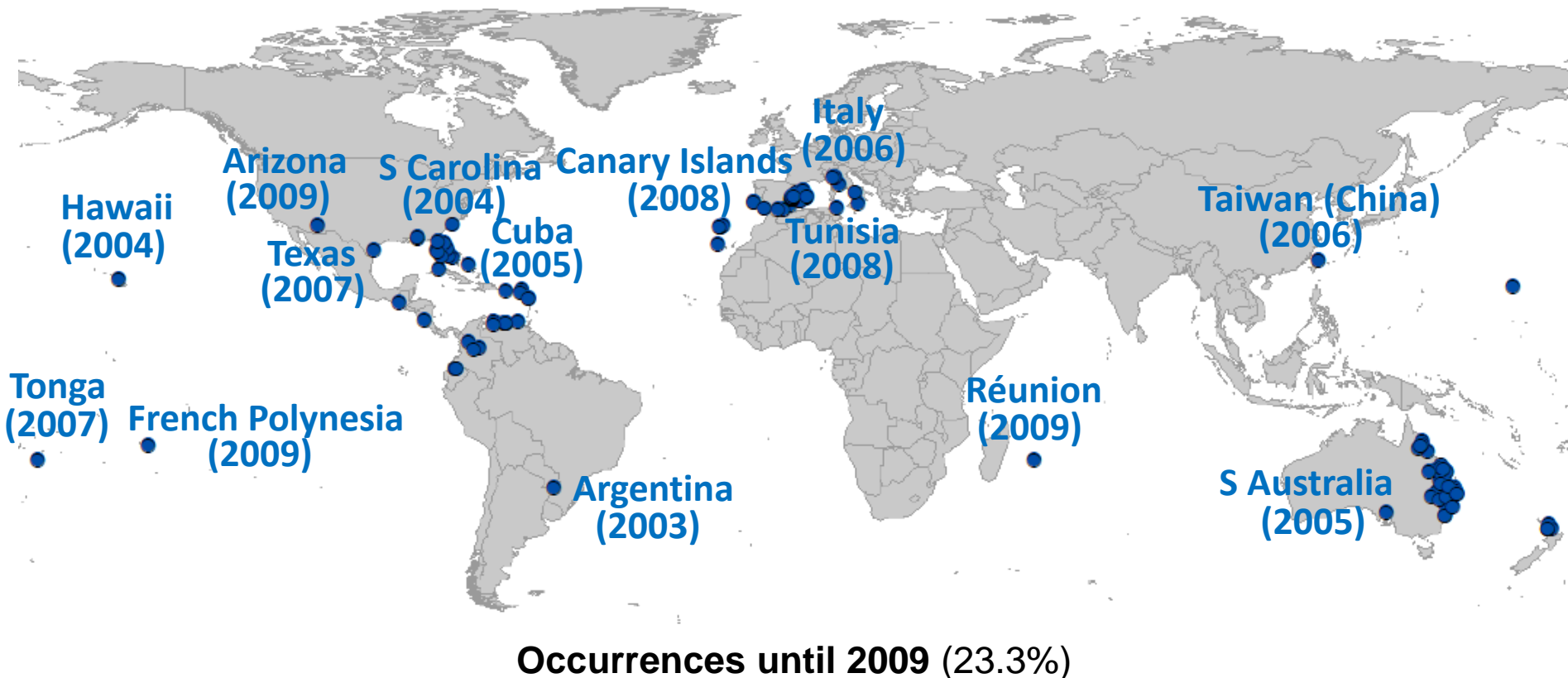
2. Temporal colonization



Occurrences until 1999 (5.4%)

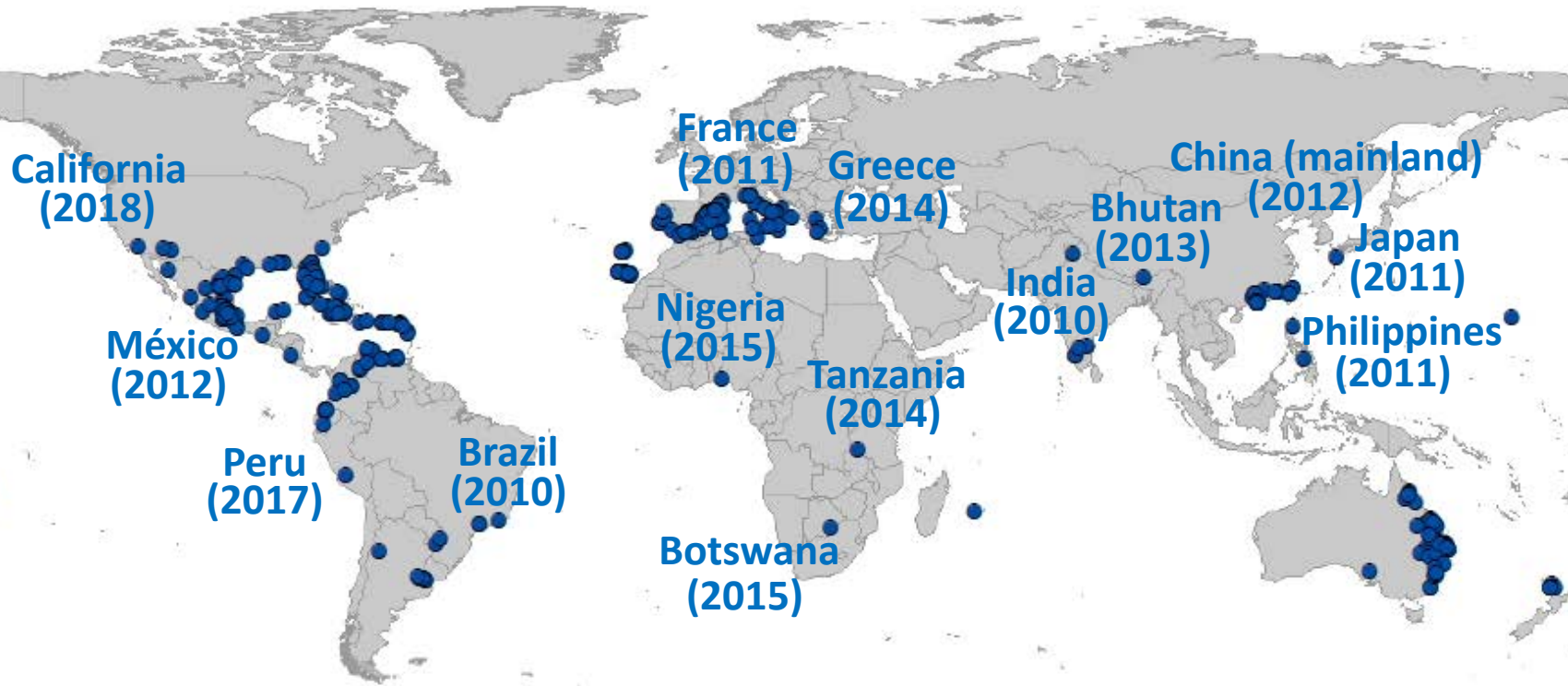
- Present in Europe since 1996 (Valencian Country); soon appeared near Lisbon (1999).
- The first record in Africa is from Madeira (1999).

2. Temporal colonization



- Present in East Asia since 2006 (Taiwan) and in continental Africa since 2008 (Tunisia).
- The first record in temperate South America is from Misiones (Argentina, 2003).

2. Temporal colonization

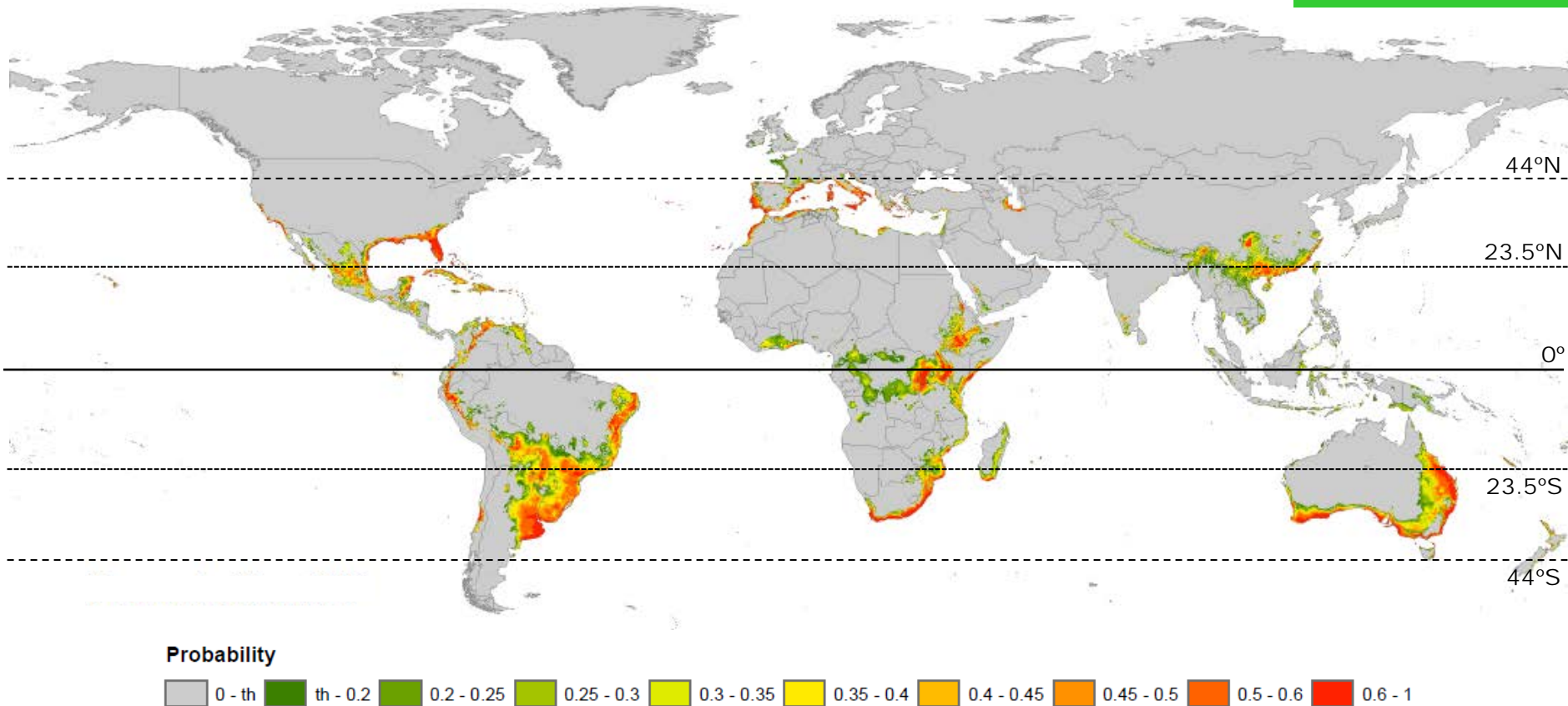


Occurrences until 2019 (67.4%)

- The species spread to the Indian Subcontinent, and to several countries of Asia.
- Expanded to Sub-Saharan Africa.
- Expanded to other parts of South America (Brazil and Peru) as well as to Mexico.

3. Potential distribution

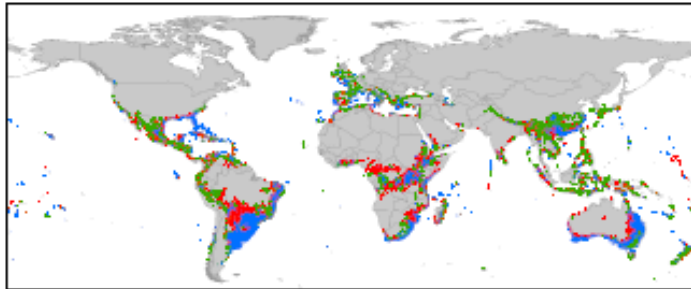
Software employed:
MaxEnt v.3.3.3k



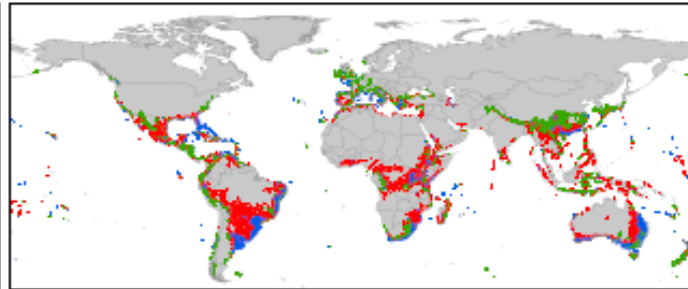
- Suitable areas mainly around Mediterranean and subtropical regions, from 20° to 40° of both northern and southern latitudes.
- Some tropical latitudes are also suitable.

4. Predictions in future scenarios

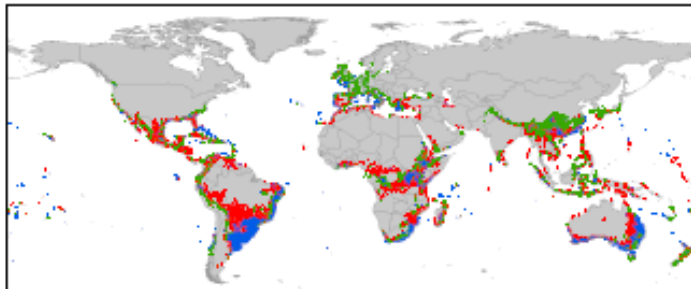
(A) Present / Year 2070 CCSM RCP 2.6



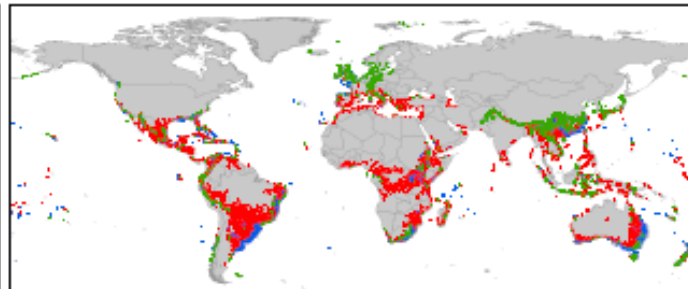
(B) Present / Year 2070 CCSM RCP 8.5



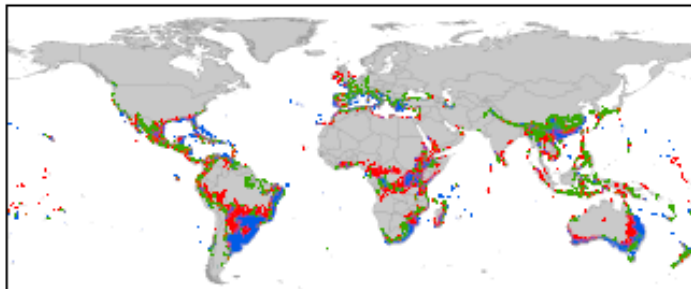
(C) Present / Year 2070 GFDL RCP 2.6



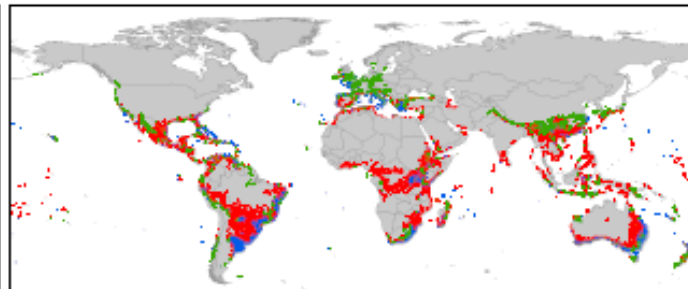
(D) Present / Year 2070 GFDL RCP 8.5



(E) Present / Year 2070 MPI RCP 2.6



(F) Present / Year 2070 MPI RCP 8.5



Comparative between present and future models

■ Gained area ■ Lost area ■ Overlap area

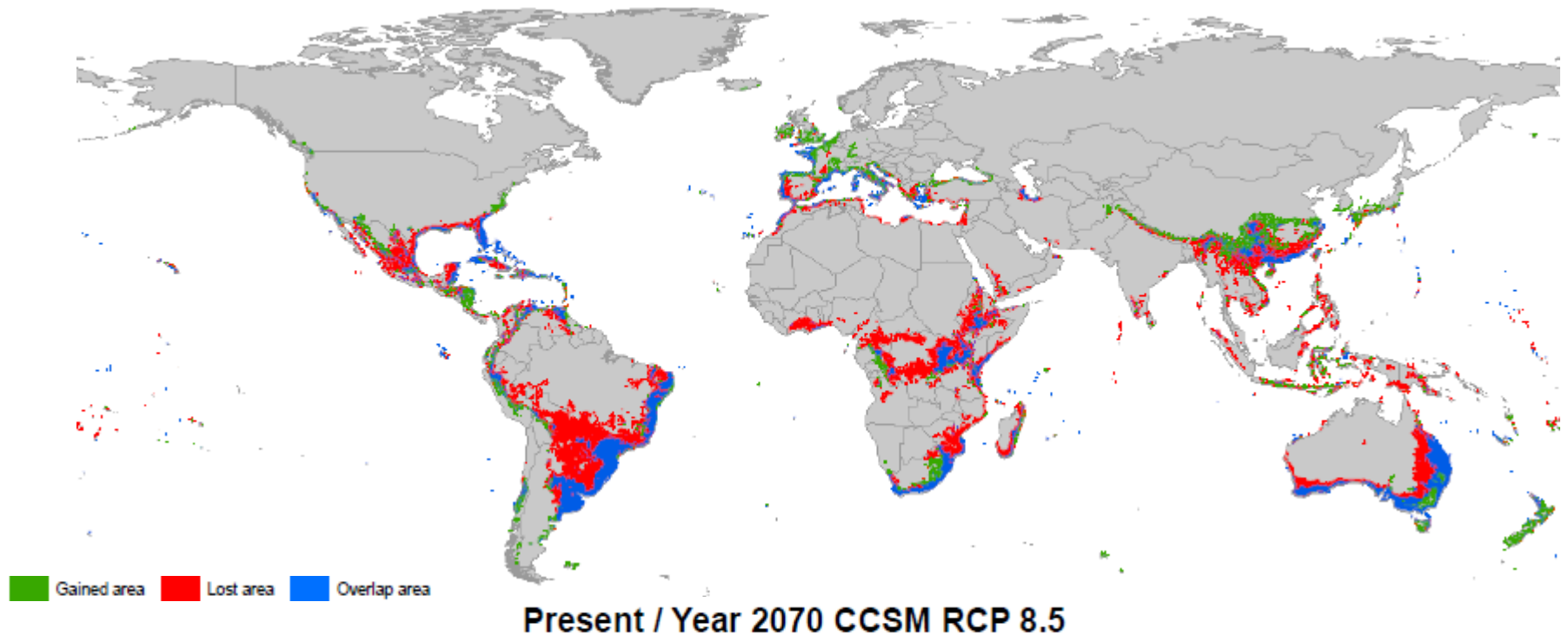


*EMISSION SCENARIOS

RCP 2.6: Most optimistic (+0.3–1.7°C for 2081–2100)
RCP 8.5: Most pessimistic (+2.6–4.8°C for 2081–2100)

- We got 6 predictions (3 climatic models with 2 emission scenarios*)
- All models estimate a considerable **reduction** in the potential distribution, with an average of **33.5%** ($\pm 17.0\%$)
- The reduction is lower under RCP 2.6 (average = **20.05%**) than under RCP 8.5 (average = **46.84%**)

4. Predictions in future scenarios



- **Lost areas** for the year 2070 (in red): mostly at low latitudes
- **Gained areas** for the year 2070 (in green): mostly at high latitudes
- Many continental areas are lost, whereas coastal areas are generally maintained
⇒ continental areas would undergo more severe climatic changes than coastlines (as reported in other studies; [O'Donnell et al., 2012](#); [Allen & Bradley, 2016](#))

Conclusions

The distribution range of mother of millions (*K. × houghtonii*) is delimited with precision for the first time. As one may anticipate, it has already reached a global distribution (although mostly focused on Mediterranean and subtropical regions).

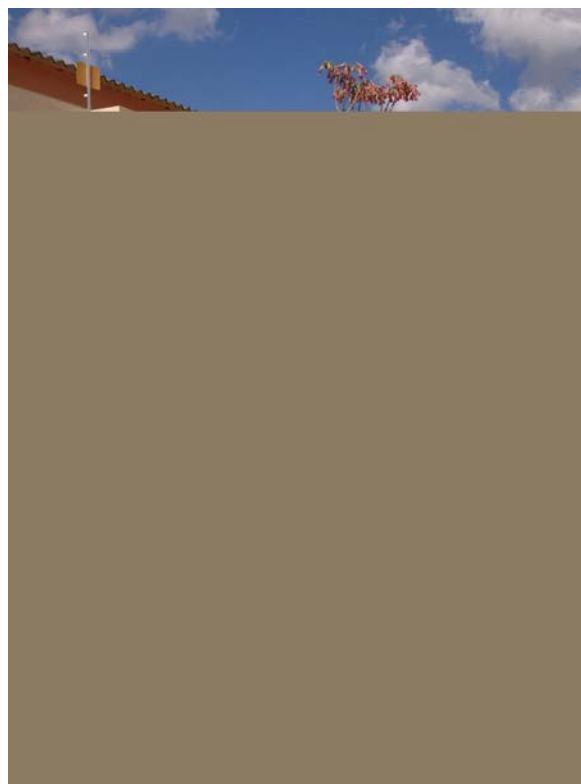
There is a somewhat unexpected reduction of the potential distribution area in *K. × houghtonii*, which might be related to its eco-physiological traits (succulent plant with CAM metabolism)

⇒ THE RISE IN EXTREME PERIODS OF PROLONGED WET CYCLES ESTIMATED FOR THE YEAR 2070 (IPCC, 2014) IS PROBABLY BEHIND THIS RESULT.



It would be interesting to test whether a decrease in potential habitats might constitute a general pattern for Crassulaceae and CAM plants.

THANK YOU !! -- ευχαριστώ



VERY IMPORTANT NOTE:

Any observation of *Kalanchoe* × *houghtonii* (or any of their parentals) will be very welcomed. Please contact me at jlopezpu@gmail.com or jlopez@ibb.csic