

# MODELLING INVASION RISK MAPS FOR ALIEN PLANTS

Application in Mediterranean sea cliffs with endemic  
species

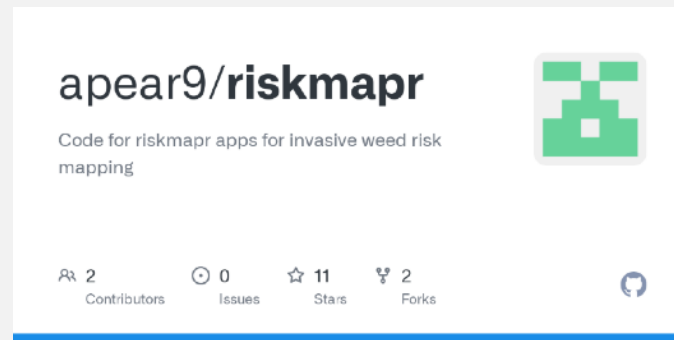


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# RISKMAPR

- Mapping tool that allows land managers to identify priority areas with limited data to monitor and quickly manage weed invasions

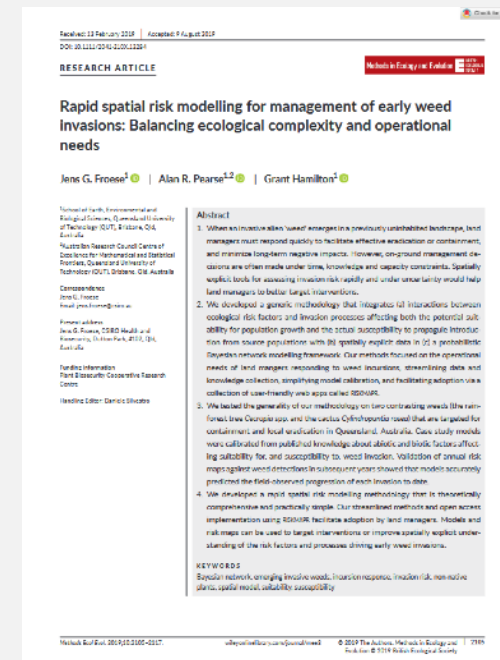


apear9/riskmapr

Code for riskmapr apps for invasive weed risk mapping

Contributors: 2 | Issues: 0 | Stars: 11 | Forks: 2

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RESEARCH ARTICLE

**Rapid spatial risk modelling for management of early weed invasions: Balancing ecological complexity and operational needs**

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**Abstract**

1. When an introduced alien 'weed' emerges in a previously uncolonized landscape, land managers must respond quickly to facilitate effective eradication or containment, and minimize long-term negative impacts. However, operational management decisions are often made under time, knowledge and capacity constraints. Spatially explicit tools for assessing invasion risk rapidly and under uncertainty would help land managers to better target interventions.
2. We developed a generic methodology that integrates (a) interactions between ecological risk factors and invasion processes affecting both the potential suitability for population growth and the actual susceptibility to propagule introduction from source populations with (b) spatially explicit data in (c) a probabilistic Bayesian network modelling framework. Our methods focused on the operational needs of land managers: recording its weed invasions, streamlining data and knowledge collection, simplifying model calibration, and facilitating adoption via a collection of user-friendly web apps called RSDiRR.
3. We tested the generality of our methodology on two contrasting weeds (the rainforest tree *Casuarina* spp. and the tussock *Cyrtopogon* weed) that are targeted for containment and local eradication in Queensland, Australia. Case study models were calibrated from published knowledge about abiotic and biotic factors affecting suitability for, and susceptibility to, weed invasion. Validation of annual risk maps against weed distributions in subsequent years showed that models accurately predicted the 6468 observed progression of each invasion to date.
4. We developed a novel spatial risk modelling methodology that is theoretically comprehensive and practically simple. Our streamlined methods and open access implementation using RSDiRR facilitate adoption by land managers. Models and risk maps can be used to target interventions or improve spatially explicit understanding of the risk factors and processes driving early weed invasions.

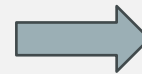
**KEYWORDS**  
Bayesian network, emerging invasive weeds, invasion response, invasion risk, non-native plants, spatial model, suitability, susceptibility

Methods Ecol. Evol. 2018, 9, 1105–1117

# INVASION RISK MODELING

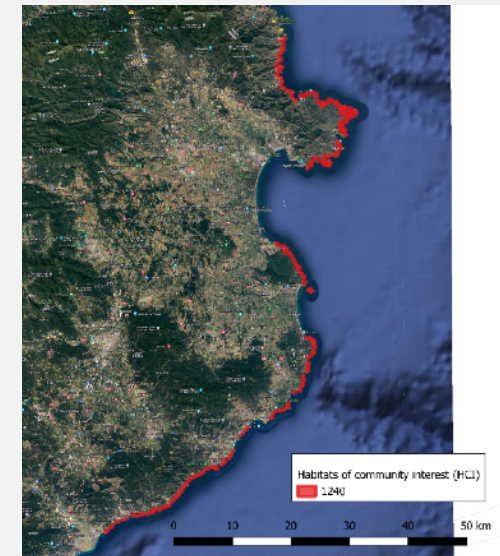
## A Theoretical models of 33 invasive species

1. Identify risk factors
2. Build a conceptual model
3. Obtain spatial data and calibrate the model



## B Risk maps with "riskmapr": Land management

4. Link spatial data
5. Prepare propagule supply and dispersal models
6. Prepare risk maps with "RISKMAPR"



# THEORETICAL MODELS

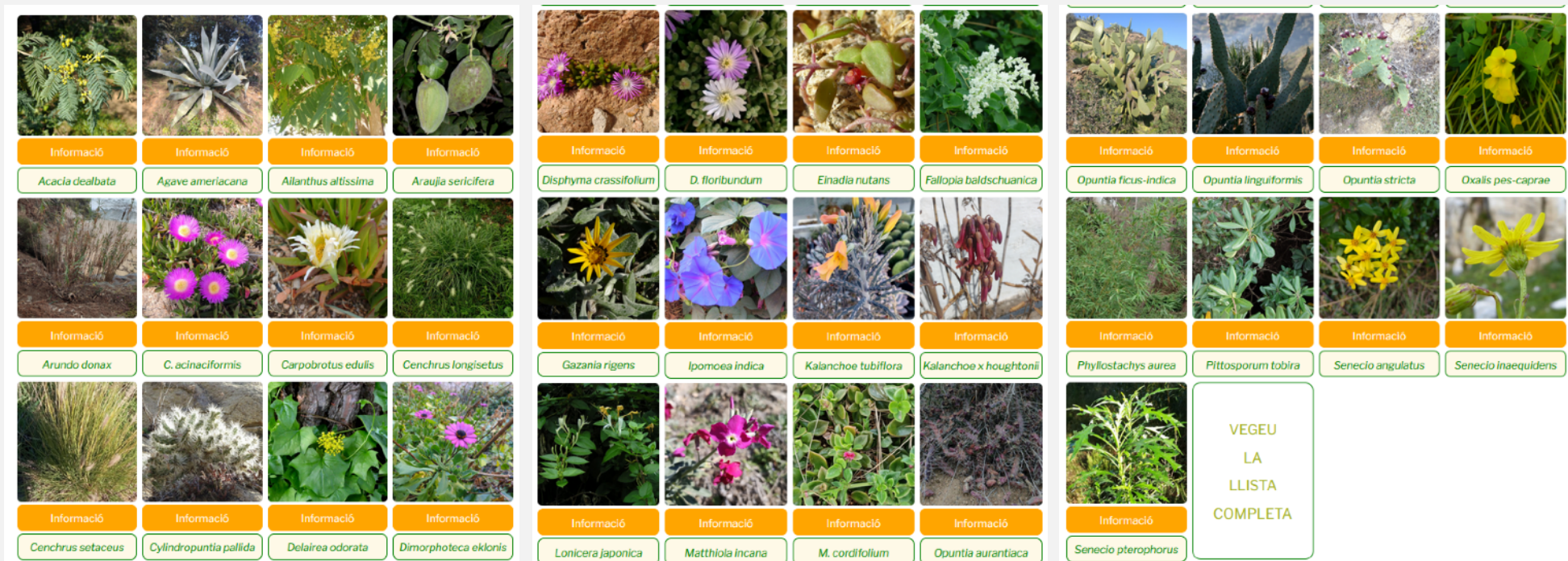
## 33 INVASIVE SPECIES

### RISK FACTORS AND SPATIAL REPRESENTATION

Factor de risc & definició	Mapa utilitzat	Classificació dels atributs espacials	Valor de risc	Establiment	Idoneïtat	Persistència	Dispersió
<b>Pendent</b> Si els fragments són capaços d'establir-se en diferents vessants	Mapa derivat del Model d'Elevació del Terreny de Catalunya 5x5 metres (MET-5) v1	<b>Apte:</b> 0-25 <b>Òptim:</b> 25 – 50 <b>Apte:</b> 50-75 <b>Molt poc apte:</b> >75	50 100 50 25				
<b>Humitat</b> Si el drenatge del sòl dona suport al creixement i la supervivència de les plantes	Inclòs al mapa de sòls de Catalunya a escala 1:250.000 (MSC250M).	<b>Apte:</b> Sòls ben drenats, ràpidament drenats i molt ràpidament drenats <b>Poc apte:</b> Imperfectament drenats <b>No apte:</b> Saturats	100 50 0				
<b>Tipus d'usos del sòl</b> Si els usos del sòl admeten el reclutament dens de plàntules	Mapa d'Usos del Sòl de Catalunya (MSCS) v1.0 – 2018 (ICGC)	<b>Principal habitat:</b> Conreus en transformació, roquissars i congestes <b>Ben tolerat:</b> Matollar, sòl nu forestal <b>Tolerat:</b> Boscos clars d'escleròfil·les i laurifolis, boscos clars d'aciculifolis, prats i herbassars, etc. <b>Habitat inadequat:</b> Altres conreus llenyosos, boscos clars de caducifolis, platges, vinyes, zones verdes, etc <b>No habitat:</b> basses; bosc de ribera; boscos densos de caducifolis, planifolis; casc urbà; cursos d'aigua, etc.	100 75 50 25 0				
<b>Temperatura mínima</b> Si les plantes estan exposades a temperatures adverses durant el mes més fred	Fick, S.E. and R.J. Hijmans, 2017. WorldClim 2: new 1km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37 (12): 4302-4315.	<b>Òptim:</b> >3°C <b>Apte:</b> ≤3°C i >-5°C <b>No apte:</b> ≤ -5°C	100 50 0				
<b>Presència de <i>Dactylopius opuntiae</i></b> Si les inoculacions i la presència de <i>Dactylopius opuntiae</i> poden empitjorar el creixement i la supervivència de les plantes	Llocs d'inoculació de <i>Dactylopius opuntiae</i> a <i>Opuntia ficus-indica</i> i identificacions de <i>D. opuntiae</i> per part de voluntaris al lloc iNaturalist	Distància a un punt d'inoculació de <i>D. opuntiae</i> o observació d'una planta afectada amb <i>D. opuntiae</i> <b>Poc apte:</b> 0 - 50 m <b>Moderada:</b> 50 - 500 m <b>Apte:</b> 500 - 1000 m <b>Molt apte:</b> >1000 m	25 50 75 100				
<b>Subministrament de propàguls</b> Quantitat de segments potencialment dispersats de poblacions font	Mapa derivat de les observacions de voluntaris i observadors a la plataforma iNaturalist	Àrea de la població amb individus madurs <b>Molt alt:</b> ≥20 m2 <b>Alt:</b> 10-20 m2 <b>Moderat:</b> 1-10 m2 <b>Baix:</b> ≤1 m2; poblacions d'inmadurs; poblacions de senescents	100 75 50 25				
<b>Dispersió animal (epi-/endozoocòria)</b> Freqüència i densitat dels segments dispersats de poblacions font per animals terrestres i voladors	Mapa derivat de les observacions de voluntaris i observadors a la plataforma iNaturalist	Distància euclidiana radial calculada des de la font més propera <b>Òptim:</b> 0 a 200 m <b>Moderat:</b> 200 a 750 m <b>Poc adequat:</b> 750 a 2250 m <b>Inadequat:</b> > 2250 m	100 50 25 0				
<b>Dispersió hortícola i jardineria</b> Quants segments poden arribar de possibles fonts de dispersió antropogèniques com jardins privats o àrees particulars	Mapa derivat del Mapa d'Usos del Sòl de Catalunya (MSCS) v1.0 – 2018 (ICGC)	Distància de possibles fonts de dispersió antropogèniques com jardins privats o àrees particulars. <b>Òptim:</b> 0 a 10 m <b>Moderat:</b> 10 a 20 m <b>Poc adequat:</b> 20 a 50 m <b>Inadequat:</b> >50 m	100 50 25 0				

# 33 CALIBRATED INVASIVE PLANT MODELS

- The aim of the LIFE medCLIFFS project is to prepare and calibrate the models for the 33 invasive plants targeted by the project



## 33 CALIBRATED INVASIVE PLANT MODELS

- The aim of the LIFE medCLIFFS project is to prepare and calibrate the models for the 33 invasive plants targeted by the project
- Most time-consuming process while applying RISKMAPR
- These models can be extrapolated to other regions of the Mediterranean (possibility of making adjustments if needed)
- We will create guidelines on how to use and modify these models, with recommendations on where to obtain the necessary spatial proxies

## Example: *Opuntia ficus-indica*

		Risk factor & definition	Map used	Classification of spatial attributes	Risk value
Susceptibility	Suitability	<b>Slope</b> If fragments are able to be established on different slopes	Map derived from the Terrain Elevation Model of Catalonia 5x5 meters (MET-5) v1	<b>Suitable</b> : 0-25 <b>Optimum</b> : 25 – 50 <b>Suitable</b> : 50-75 <b>Very unfit</b> : >75	50 100 50 25
		<b>Soil humidity</b> If soil drainage supports plant growth and survival	Included in the soil map of Catalonia at a scale of 1:250,000 (MSC250M).	<b>Suitable</b> : Well-drained, quickly drained and very quickly drained soils <b>Unsuitable</b> : Imperfectly drained <b>Not suitable</b> : Saturated	100 50 0
		<b>Types of land uses</b> If land use support dense seedling recruitment	Land Use Map of Catalonia (MSCS) v1.0 – 2018 (ICGC)	<b>Main habitat</b> : Crops in transformation, rocky areas and congested areas <b>Well tolerated</b> : Scrub, bare forest floor <b>Tolerated</b> : Clear forests of sclerophylls and laurifolias, clear forests of aciculifolias, meadows and grasslands, etc. <b>Inappropriate habitat</b> : Other woody crops, clear deciduous forests, beaches, vineyards, green areas, etc. <b>Uninhabited</b> : ponds; riparian forest; dense forests of deciduous, planifolia; urban helmet; watercourses; etc.	100 75 50 25 0
		<b>Minimum temperature</b> If plants are exposed to adverse temperatures during the coldest month	Fick , SE and RJ Hijmans , 2017. WorldClim 2: new 1km spatial resolution weather surfaces for global land areas _ International Journal of Climatology 37 (12): 4302-4315.	<b>Optimum</b> : >3°C <b>Suitable</b> : ≤3°C and >-5°C <b>Not suitable</b> : ≤ -5°C	100 50 0
		<b>Presence of <i>Dactylopius opuntia</i></b> If inoculations and presence of <i>Dactylopius opuntiae</i> can affect plant growth and survival	<i>Dactylopius</i> inoculation sites <i>opuntiae</i> to <i>Opuntia ficus-indica</i> and identifications of <i>D. opuntiae</i> by volunteers on the iNaturalist site	<i>D. opuntiae</i> inoculation point or observation of a plant affected with <i>D. opuntiae</i> <b>Not suitable</b> : 0 - 50 m <b>Moderate</b> : 50 - 500 m <b>Suitable</b> : 500 - 1000 m <b>Very suitable</b> : >1000 m	25 50 75 100
		<b>Supply of propagules</b> Number of potentially dispersed segments of source infestation	Map derived from the observations of volunteers and observers on the iNaturalist platform	Area of the population with mature individuals <b>Very high</b> : ≥20 m2 <b>Height</b> : 10-20 m2 <b>Moderate</b> : 1-10 m2 <b>Low</b> : ≤1 m2; populations of immatures or senescent	100 75 50 25
	Dispersion	<b>Animal dispersal ( epi -/ endozoochory )</b> Frequency and density of dispersed segments of source infestations by terrestrial and flying animals	Map derived from the observations of volunteers and observers on the iNaturalist platform	Radial Euclidean distance calculated from the nearest source <b>Optimum</b> : 0 to 200 m <b>Moderate</b> : 200 to 750 m <b>Not suitable</b> : 750 to 2250 m <b>Unsuitable</b> : > 2250 m	100 50 25 0
		<b>Horticultural dispersal and gardening</b> How many segments can to arrive of possible sources of anthropogenic dispersion such as private gardens or private areas	Map derived from the Land Use Map of Catalonia (MSCS) v1.0 – 2018 (ICGC)	Distance from possible sources of anthropogenic dispersion such as private gardens or private areas. <b>Optimum</b> : 0 to 10 m <b>Moderate</b> : 10 to 20 m <b>Not suitable</b> : 20 to 50 m <b>Inappropriate</b> : >50 m	100 50 25 0

Highly x 3 = Very important

Weighting x 2 = Moderately important

Weighting x 1 = Somewhat important

## STEP 3. OBTAIN SPATIAL DATA AND CALIBRATE THE MODEL

For each identified risk factor:

- Search spatial proxies represent them
- A classification is assigned, composed of several discrete and mutually exclusive states
- Each discrete state is assigned a risk value [0 to 100]

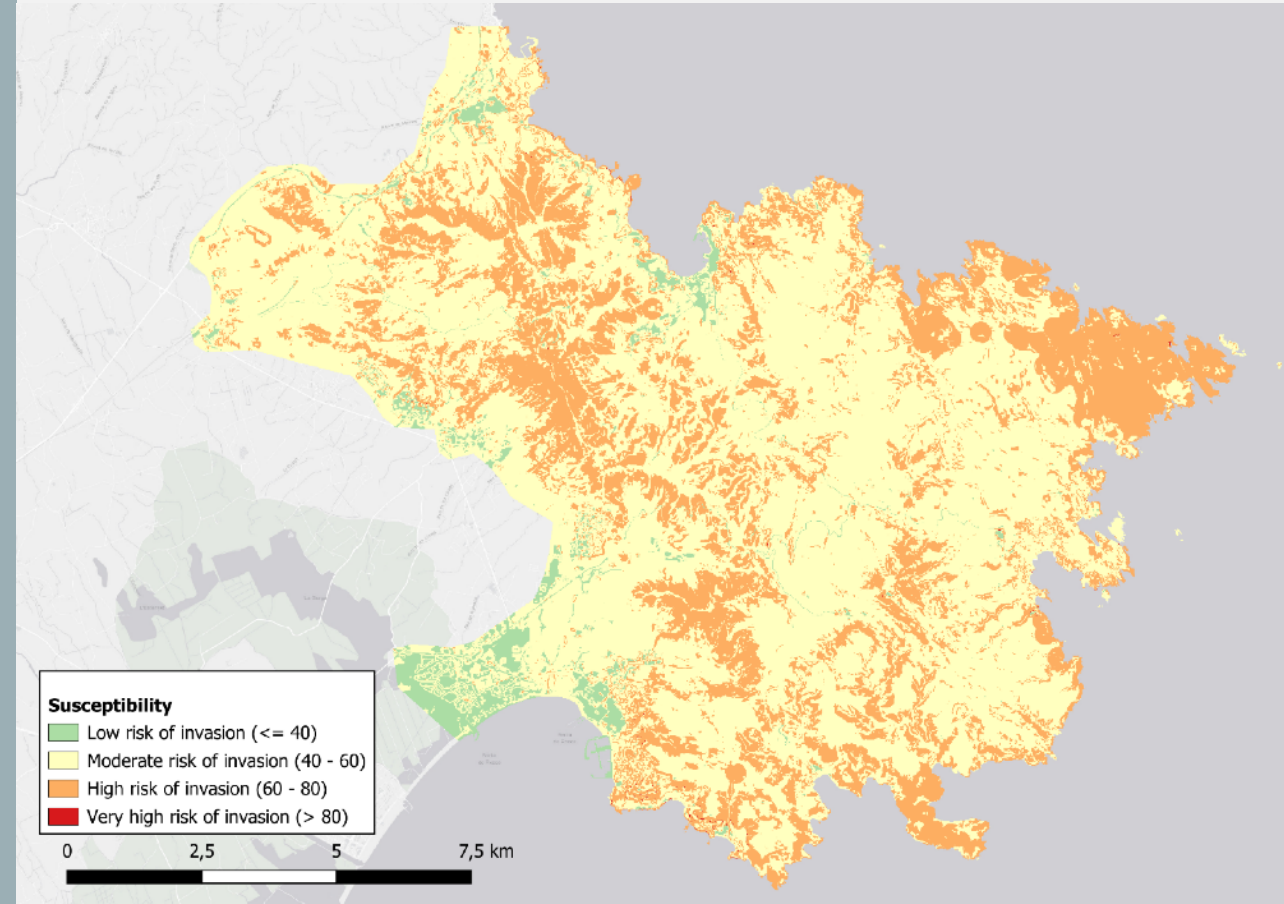
EXAMPLE

Risk factor & definition	Spatial proxy	Classification of spatial attributes in discrete states	Risk value
<i>Minimum temperature</i> If the plants are exposed to adverse minimum temperatures during the coldest month of the year	BIO6 = Minimum temperature of the coldest month	Optimum: $>3^{\circ}\text{C}$ Suitable: $\leq 3^{\circ}\text{C}$ and $> -5^{\circ}\text{C}$ Not suitable: $\leq -5^{\circ}\text{C}$	100 50 0



# RISK MAPS

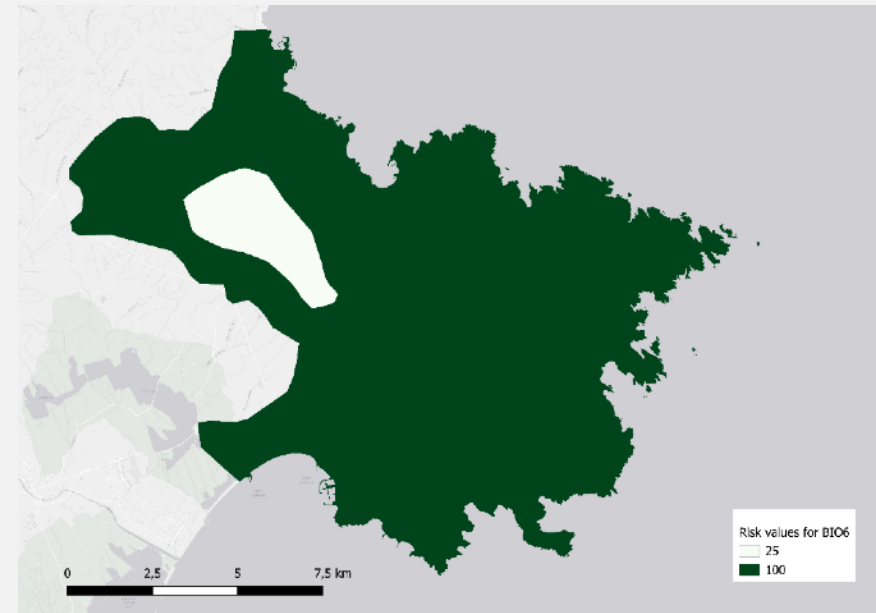
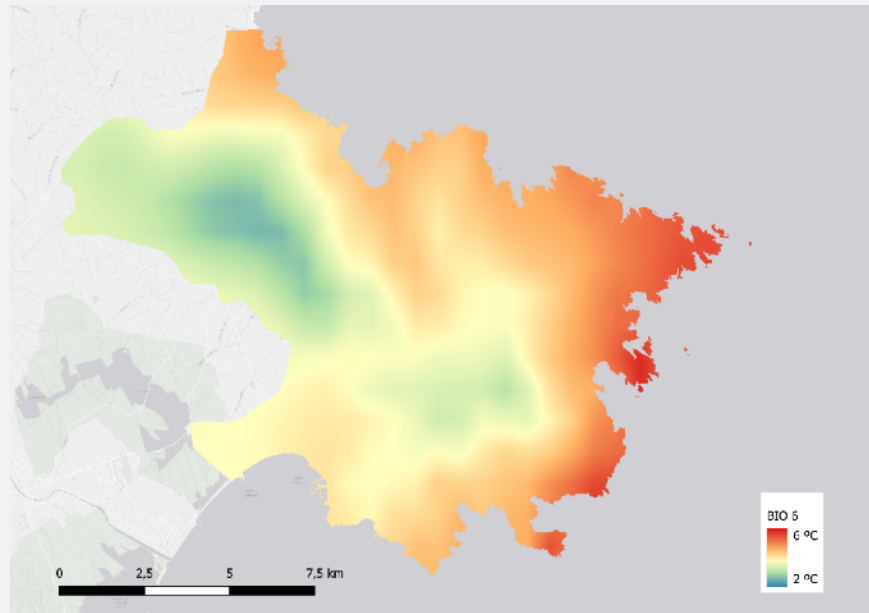
LAND MANAGEMENT WITH RISKMAPR



## STEP 4. LINK SPATIAL DATA

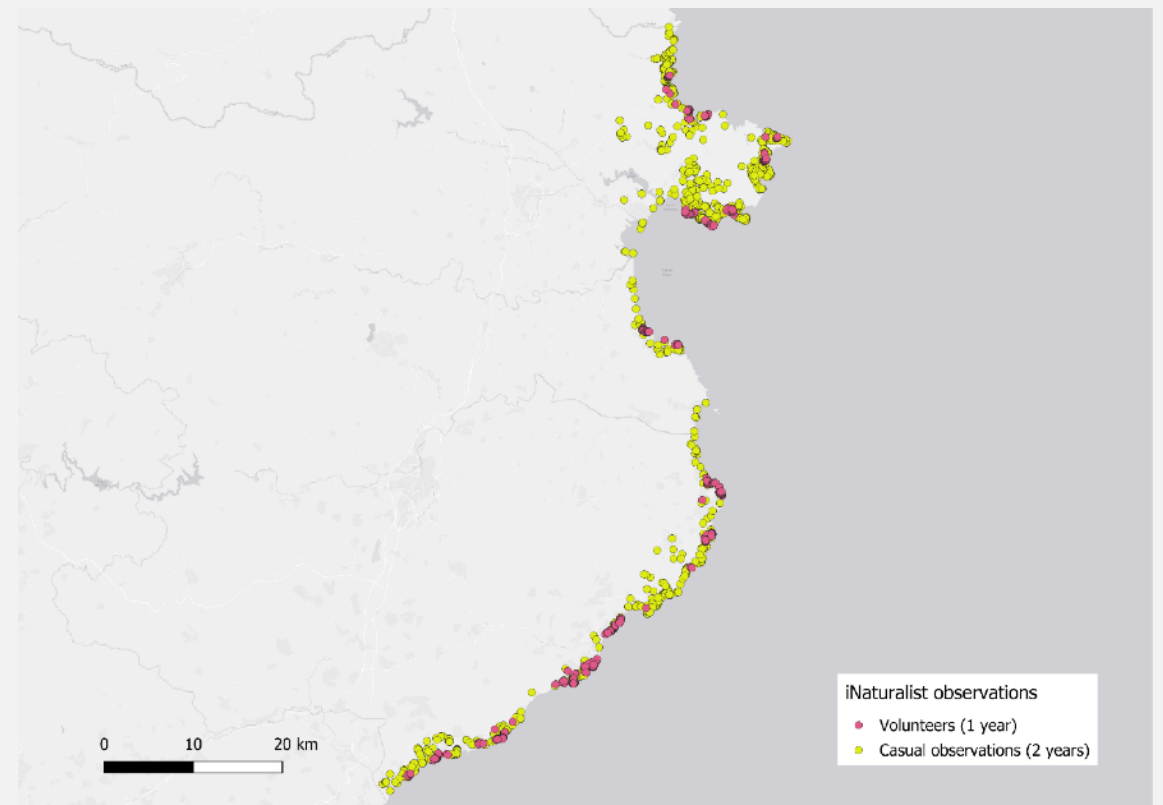
EXAMPLE

Risk factor & definition	Spatial proxy	Classification of spatial attributes in discrete states	Risk value
<i>Minimum temperature</i> If the plants are exposed to adverse minimum temperatures during the coldest month of the year	BIO6 = Minimum temperature of the coldest month	Optimum: $>3^{\circ}\text{C}$ Suitable: $\leq 3^{\circ}\text{C}$ and $> -5^{\circ}\text{C}$ Not suitable: $\leq -5^{\circ}\text{C}$	100 50 0



## STEP 5. PROPAGULE SUPPLY AND DISPERSAL MODELS

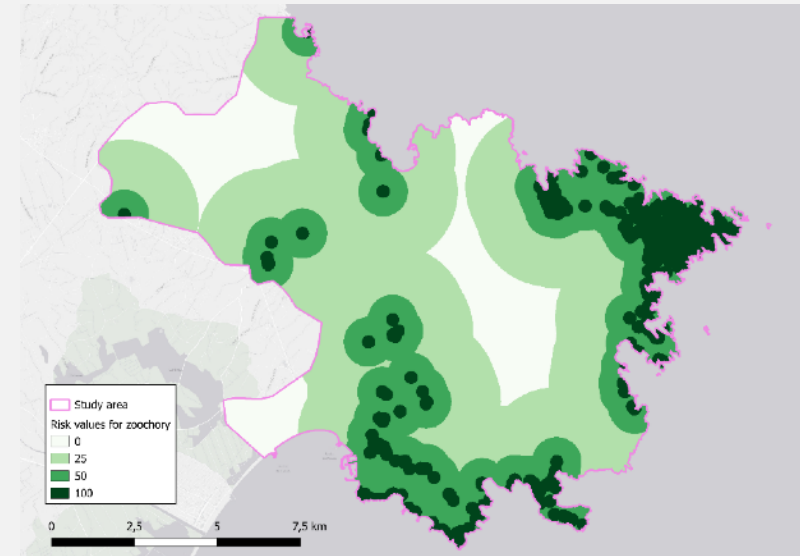
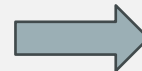
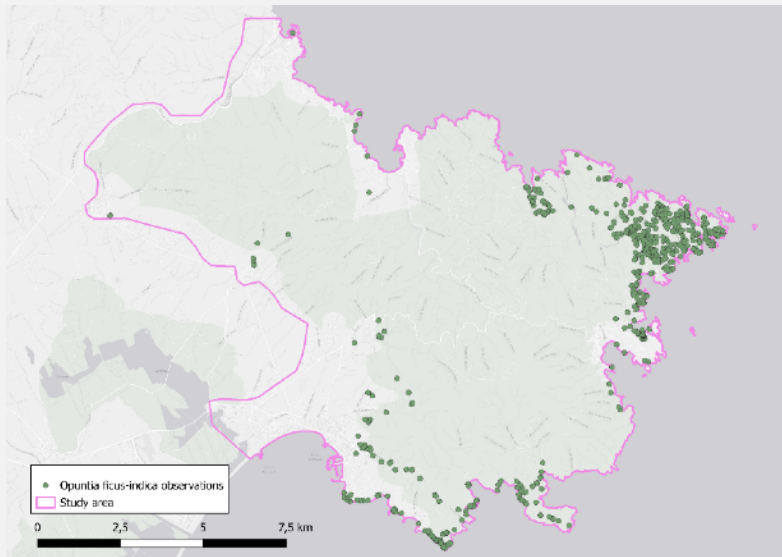
- To create the propagule pressure maps:
  - Supply of propagules
  - Dispersal over short or long distances (animals, wind, water, etc.)
- "Riskmapr" features a functionality to generate propagation and dispersion pressure maps using species location data and additional information
- Data from a volunteer network and casual observations collected via the iNaturalist provides up-to-date data on the presence of invasive plants



## STEP 5. PROPAGULE SUPPLY AND DISPERSAL MODELS

EXAMPLE

Risk factor & definition	Spatial proxy	Classification of spatial attributes in discrete states	Risk value
<i>Animal dispersal ( epi- / endozoochory )</i> Frequency and density of dispersed segments of source populations by terrestrial and flying animals	Map derived from the observations of volunteers and observers on the iNaturalist platform	Radial Euclidean distance calculated from the nearest source  <b>Optimum</b> : 0 to 200 m <b>Moderate</b> : 200 to 750 m <b>Not suitable</b> : 750 to 2250 m <b>Unsuitable</b> : > 2250 m	100 75 25 0



## STEP 6. CREATE RISK MAPS WITH " RISKMAPR "

### Rapid weed riskmapr - susceptibility model

#### Upload spatial proxies for risk factors (establishment) (.tif extension, allows multiple)

Browse... No file selected

Select spatial proxies for all identified risk factors affecting plant establishment at once and click 'Open'. Files are automatically uploaded in alphabetical order. Upload limit is 50MB, but app functionality has only been confirmed for total upload sizes < 15MB.

#### Risk factor weights (establishment)

Enter numerical weights for all identified risk factors affecting plant establishment. Weights must equal '1', '2' or '3', be separated by commas and ordered alphabetically by spatial proxy name.

#### Standard deviation (establishment)

15

Enter the standard deviation used for computing the CPT of plant establishment from its weighted risk factors. The default is '15'. This may be changed to any reasonable value in the range [0,1,100] where appropriate.

#### Upload spatial proxies for risk factors (persistence) (.tif extension, allows multiple)

Browse... No file selected

Select spatial proxies for all identified risk factors affecting plant persistence at once and click 'Open'. For details, see above.

#### Risk factor weights (persistence)

Enter numerical weights for all identified risk factors affecting plant persistence. For details, see above.

#### Standard deviation (persistence)

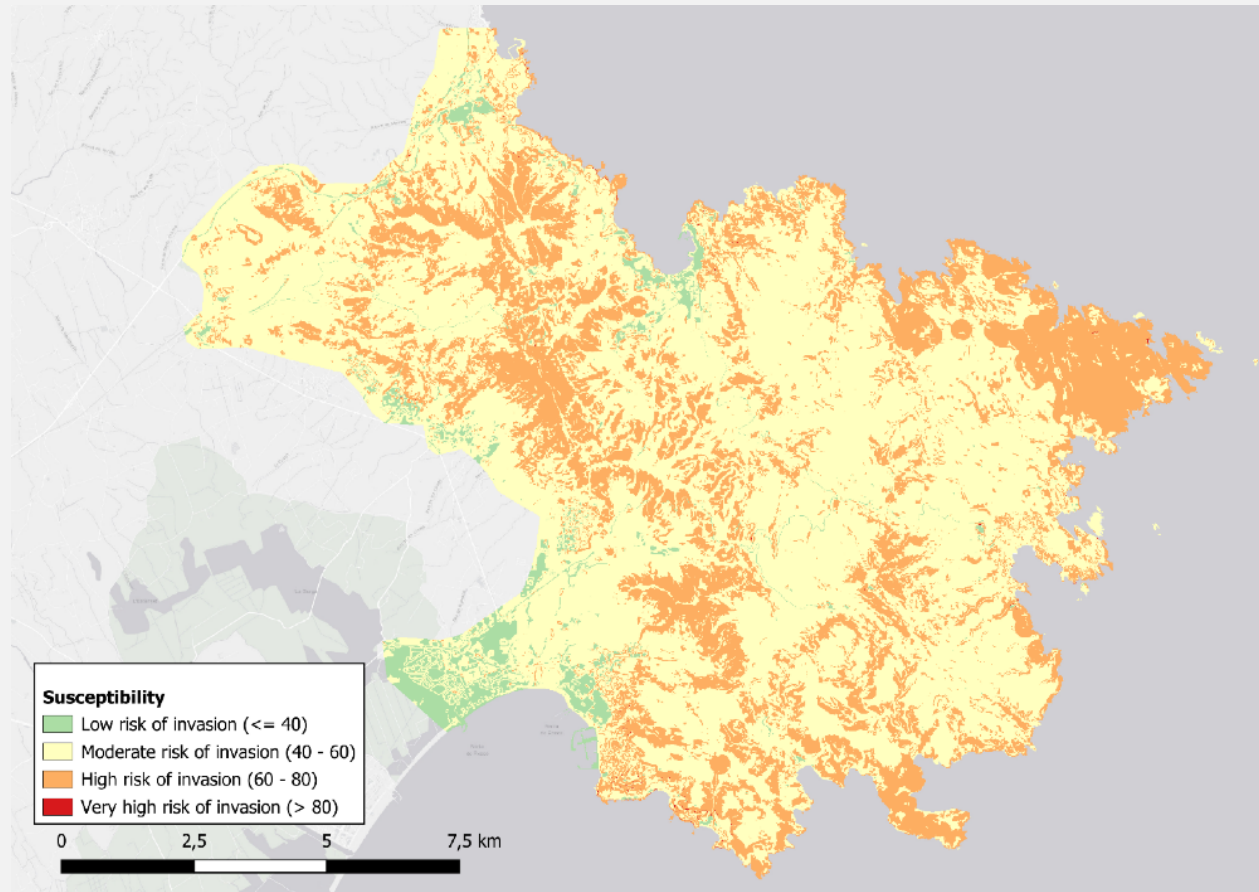
15

Enter the standard deviation used for computing the CPT of plant persistence. For details, see above.

expected values), and uncertainty maps for each (the standard deviations) This should take no longer than 1-2 minutes, depending on the size of spatial proxies. Once completed, the risk map is displayed on the right-hand panel.

- Use the RISKMAPR application for the invasive plant (ex: *O. ficus-indica*)
- **Inputs:**
  - a. Maps of each risk factor associated with the models of each plant
  - b. Weighting of risk factors [1,3]
  - c. Standard Deviations (SD)
- **Outputs:**
  - a. Concept map of the model
  - b. "Suitability" and "Susceptibility to Invasion" Index Maps
  - c. Uncertainty maps of for the two maps above

# RESULTS RISKMAPR

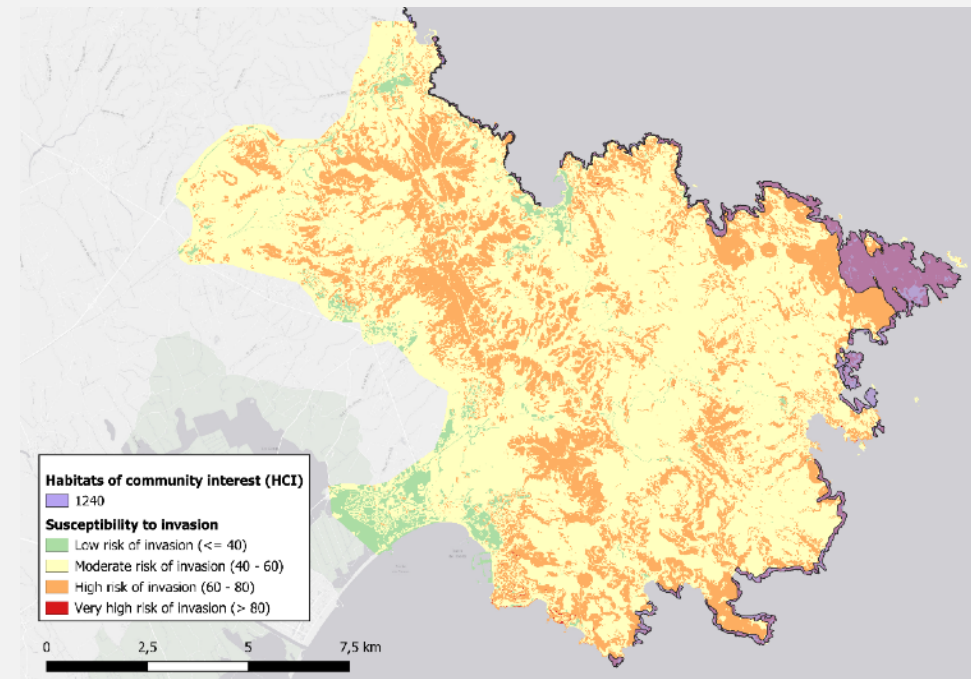
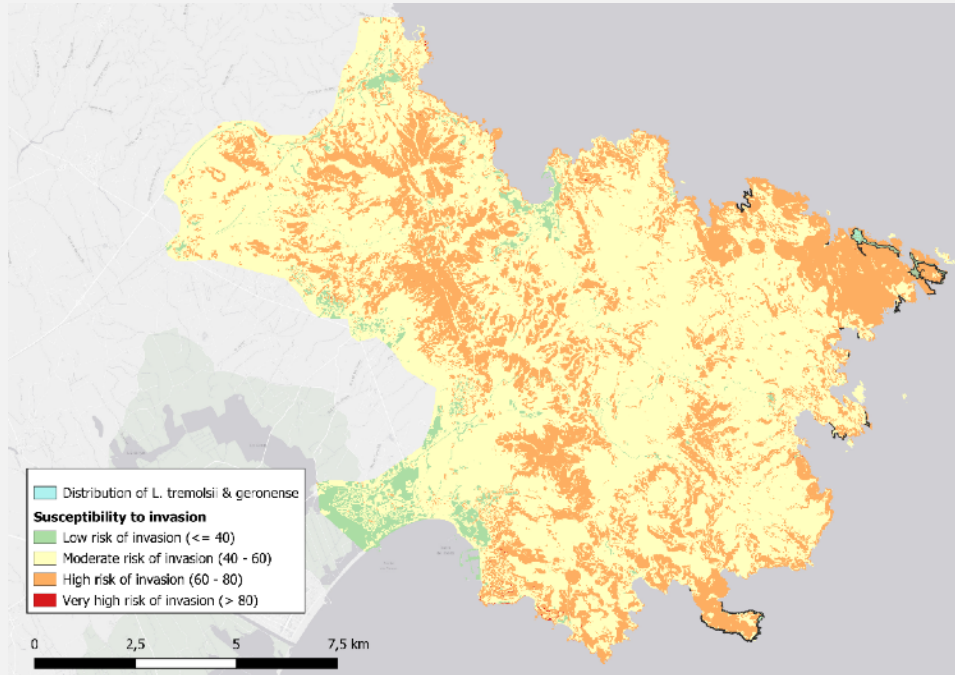


## Susceptibility of the territory to an invasion (ex: *Opuntia ficus-indica*)

- Know the state and general risk of invasion by an invasive plant
- Useful for predicting where the invasive plant will spread
- Where to focus efforts to eradicate or contain the invasive species

# PRACTICAL FUNCTION OF RISK MAPS

- Overlapping data on the distribution of species or habitats that want to be protected to find the priority areas for eradication or containment



# CONCLUSIONS

- The results you have seen are preliminary (limited study area and species in an advanced invasive state)
- The use of citizen science has potential to target larger areas and a wider range of species
- The application is an innovative tool that allows to:
  - Balance ecological complexity with the practical needs of land managers
  - Minimize long-term cost management and impacts



# THANK YOU

- If you want more information about our project:

[www.lifemedcliffs.org](http://www.lifemedcliffs.org)

- Or reach us to:

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