Suitable habitats for Palearctic *Ornithodoros* soft ticks

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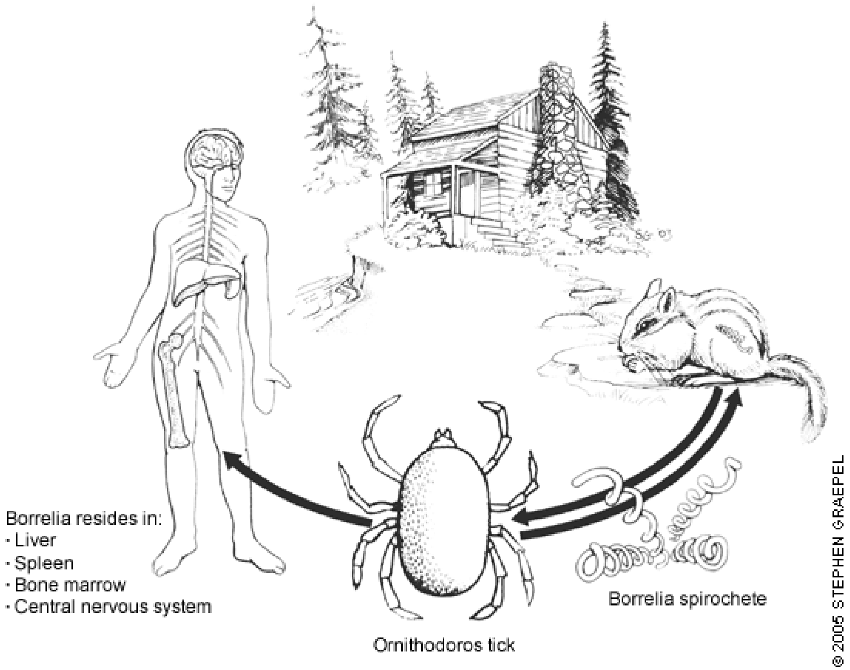
Ornithodoros

Wikipedia

- Soft tick
- Vector of
  - African Swine Fever
  - Tick-borne Relapsing Fever

Tick-borne Relapsing fever

- TBRF
- Borrelia bacteria
- Human disease:
  - Recurring episodes of fever
  - abdominal pain, vomiting & altered sensorium
  - ocular, encephalitic, arthritic and pregnancy complications
- Outbreaks in
  - Spain (2002-2012)
  - USA: California, Washington, Colorado (1990-2010)



African Swine Fever

- ASF
- Double-stranded DNA virus
- Domestic and wild pigs
  - Highly contagious, haemorrhagic disease
  - Usually deadly
- Transmission
  - Direct contact
  - Contaminated items
  - *Ornithodoros* ticks
- Distribution
  - African countries
  - Sardinia
  - Georgia
  - Western & Southern Russia
- Outbreaks in Ukraine & Belarus (2013)

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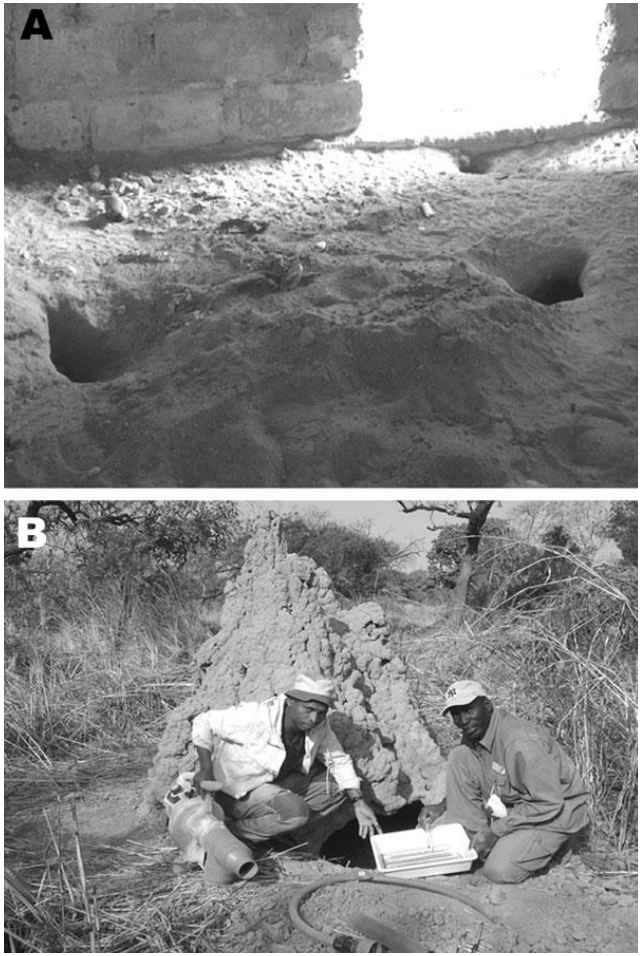
Ornithodoros field sampling

underground and sheltered habitats like nests, burrows, caves or cracks in buildings

- Limited data on absence/presence
- Mostly opportunistic sampling



L. Vial *& al* (2007)

MCDA methodology

- Multi-criteria decision analysis
  - structuring and solving decision and planning problems involving multiple criteria
  - Fuzzy sets for vagueness
  - AHP

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The **analytic hierarchy process** (**AHP**) is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. It was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. (Wikipedia)

Decision space with multiple criteria

- Words → expressions
- 2 criteria:
  - Warm
  - Semi-arid

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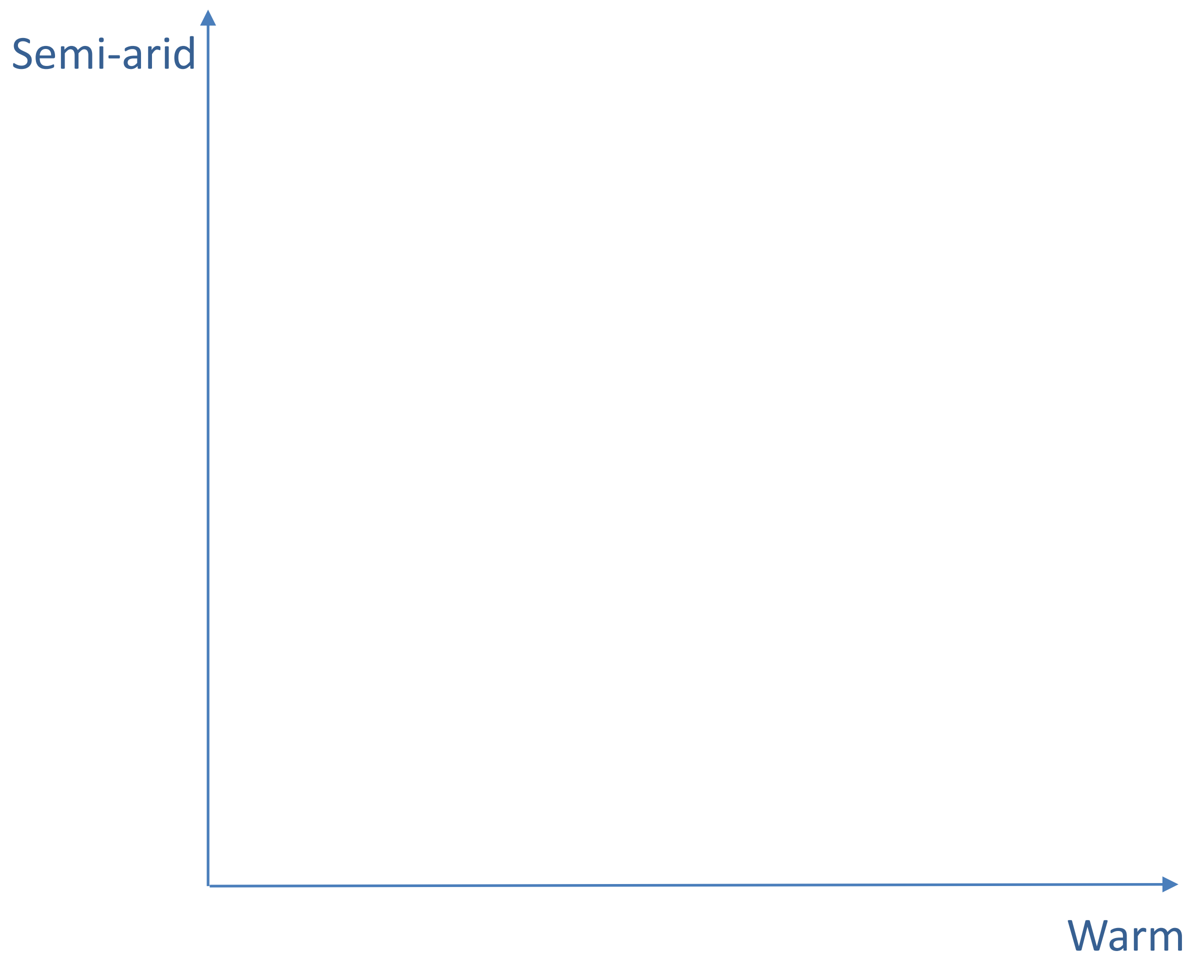

Decision space with multiple criteria

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- 2 criteria:
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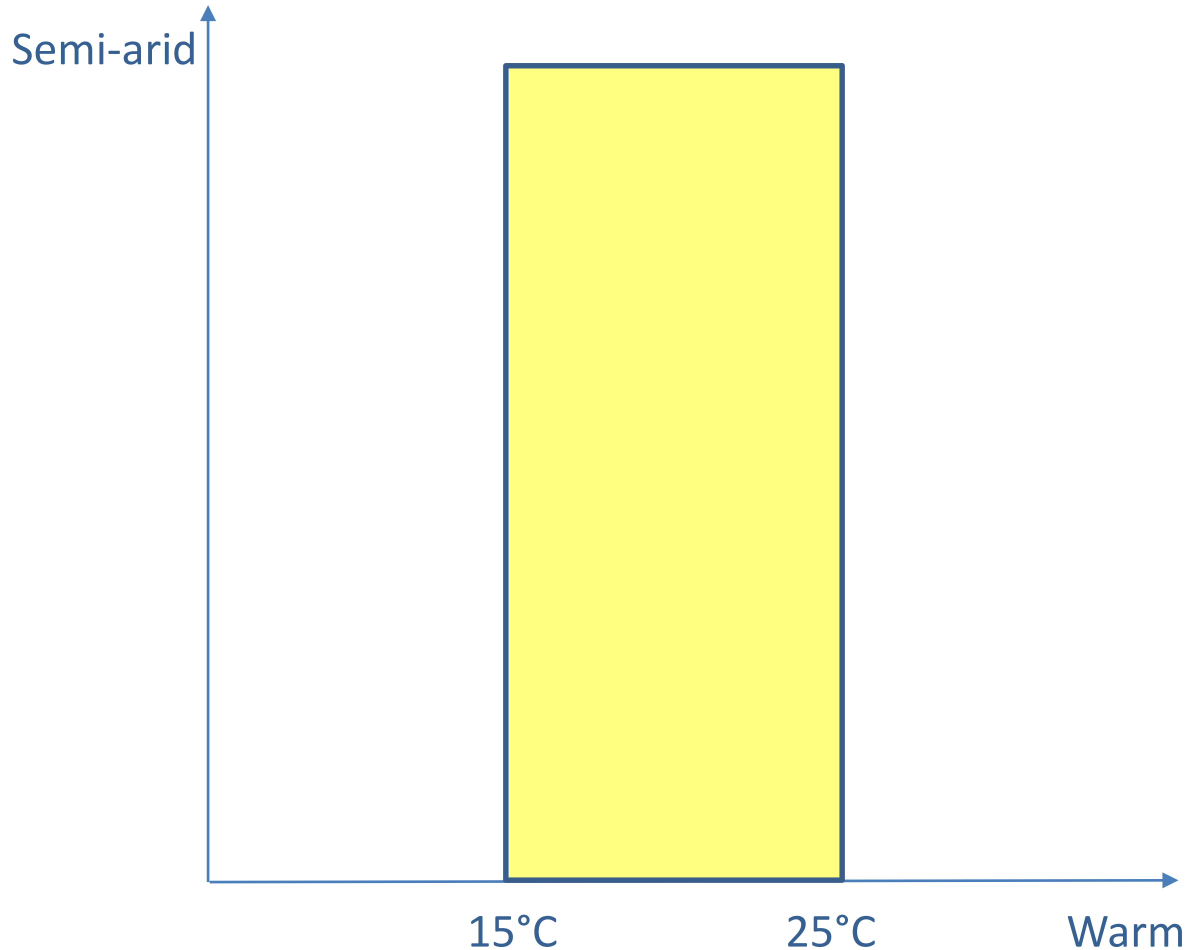
  - Semi-arid



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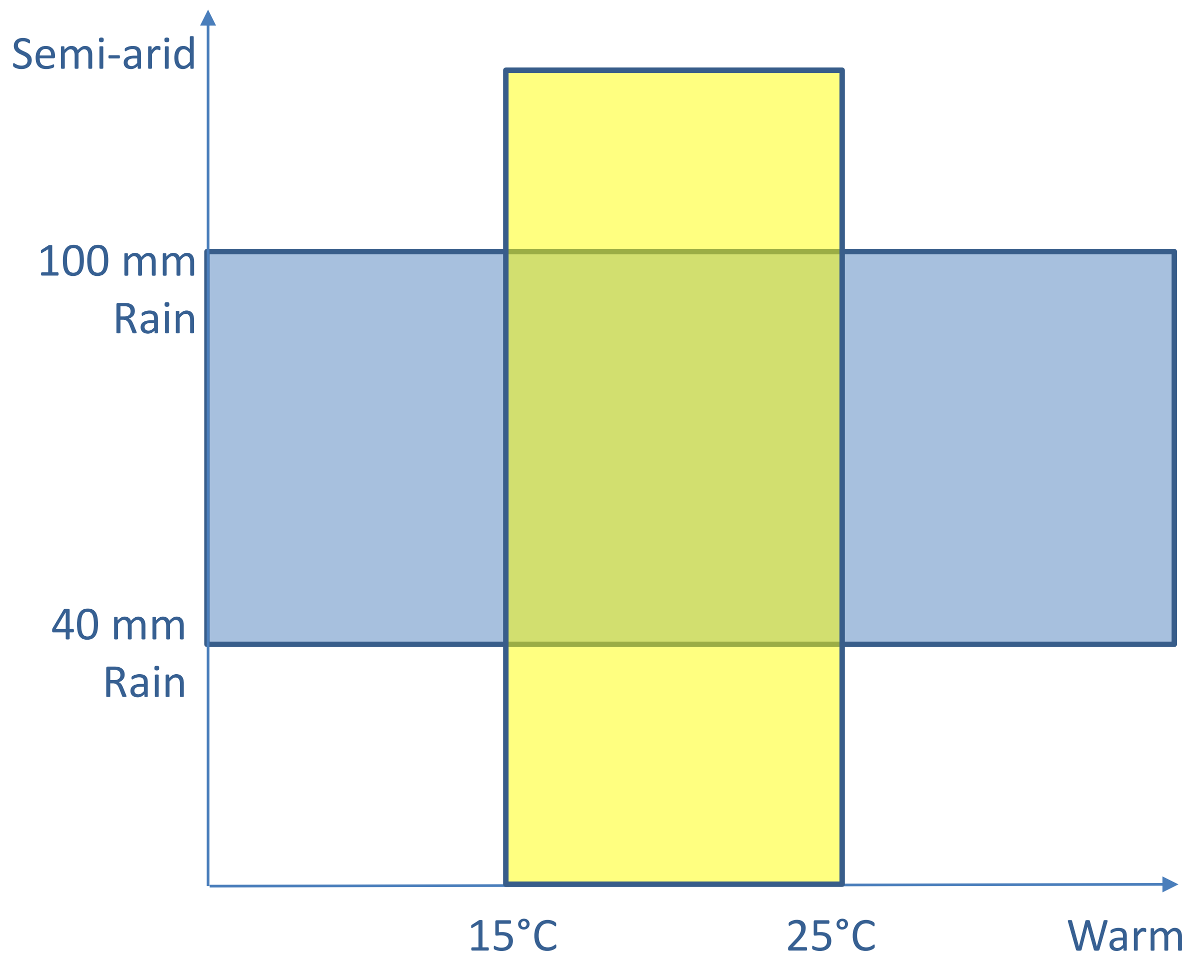
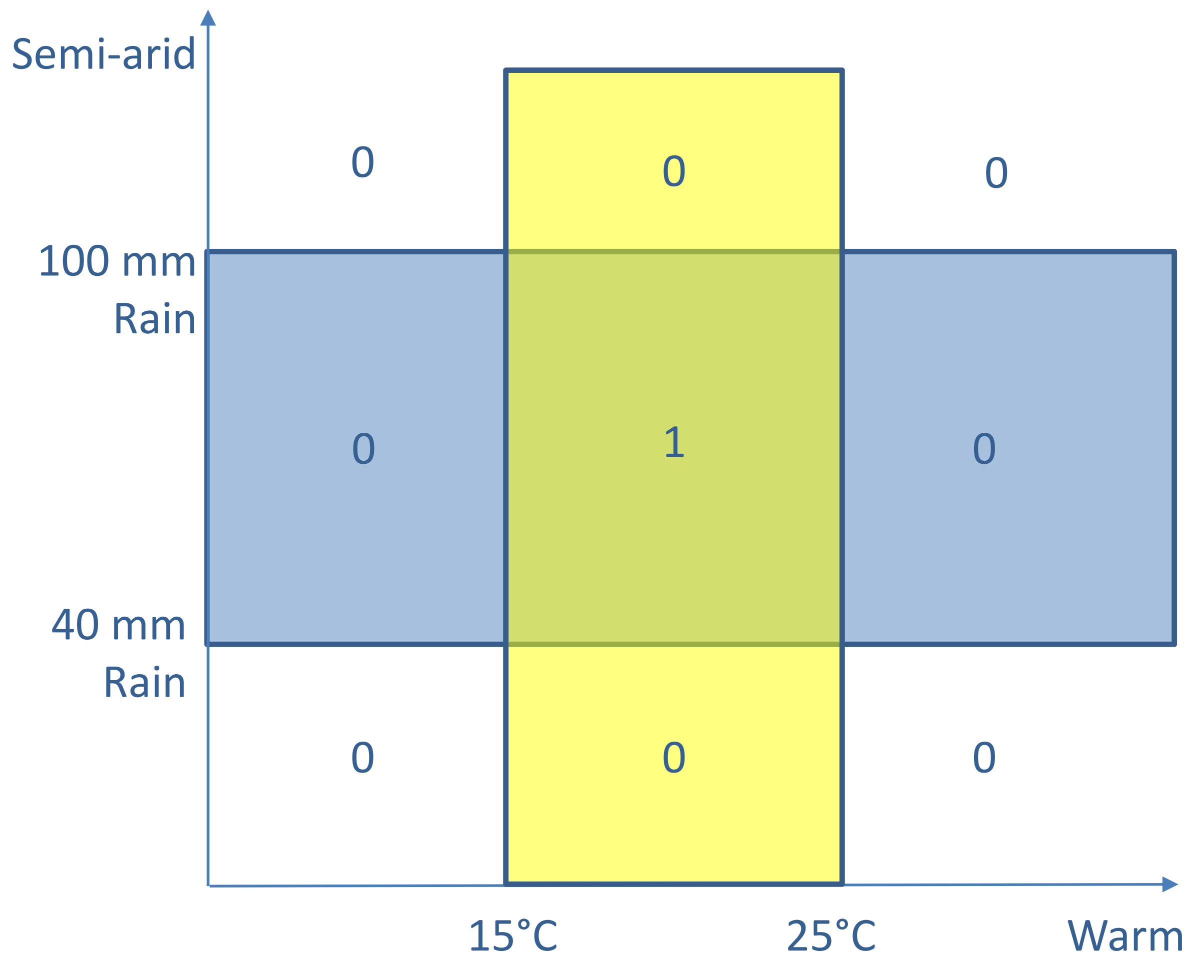
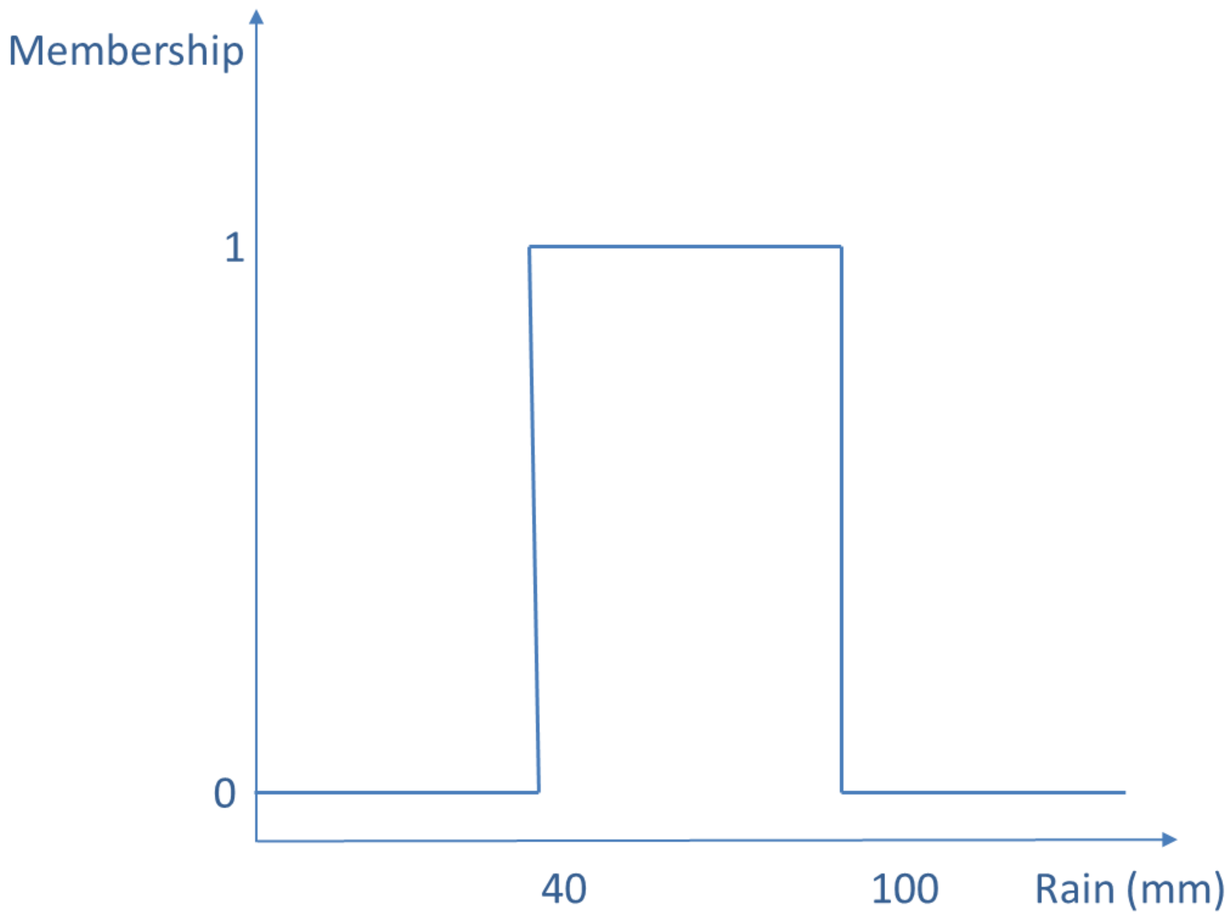


Decision space with multiple criteria

- Words ➔ expressions
- 2 criteria:
  - Warm
  - Semi-arid



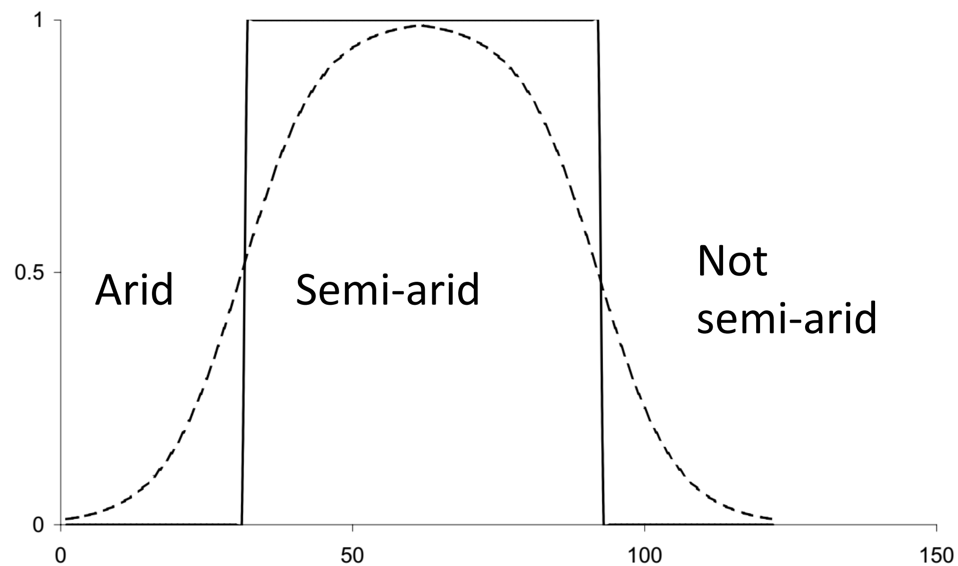
Semi-arid: Crisp sets



Fuzzy sets

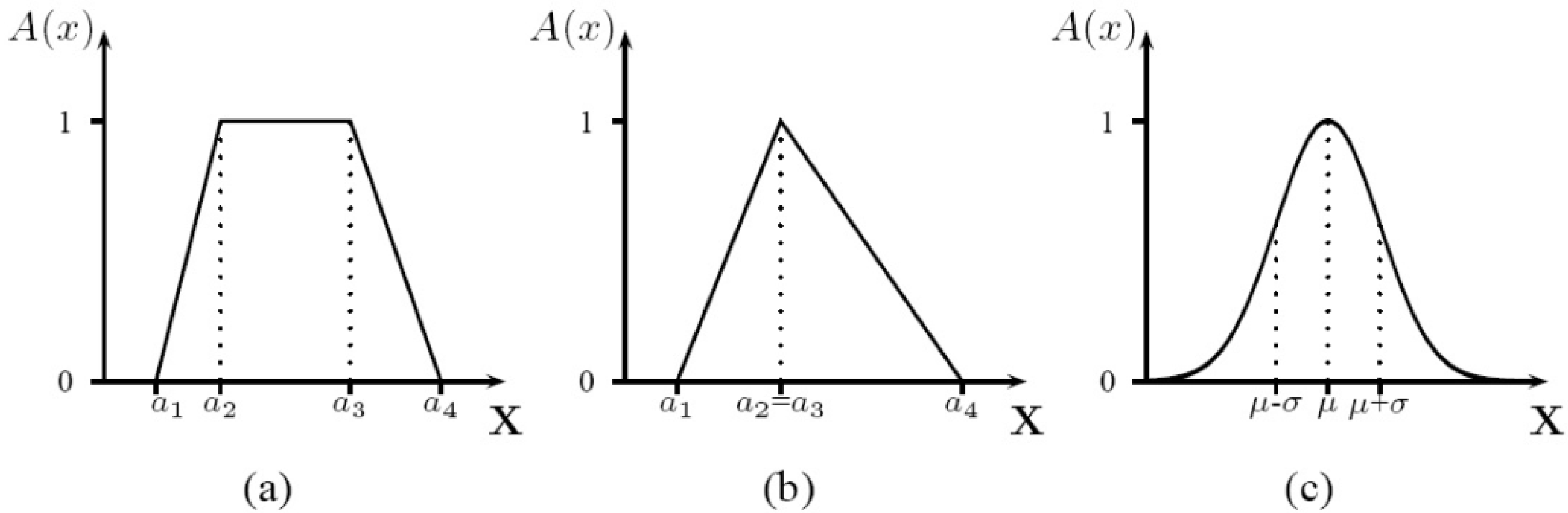
A fuzzy set is a pair (U, m) where U is a set and $m: U \rightarrow [0, 1]$ a membership function.

(Wikipedia)



- Interpretation of the original crisp data
- Degree of membership
- For vagueness & uncertainty

Membership functions



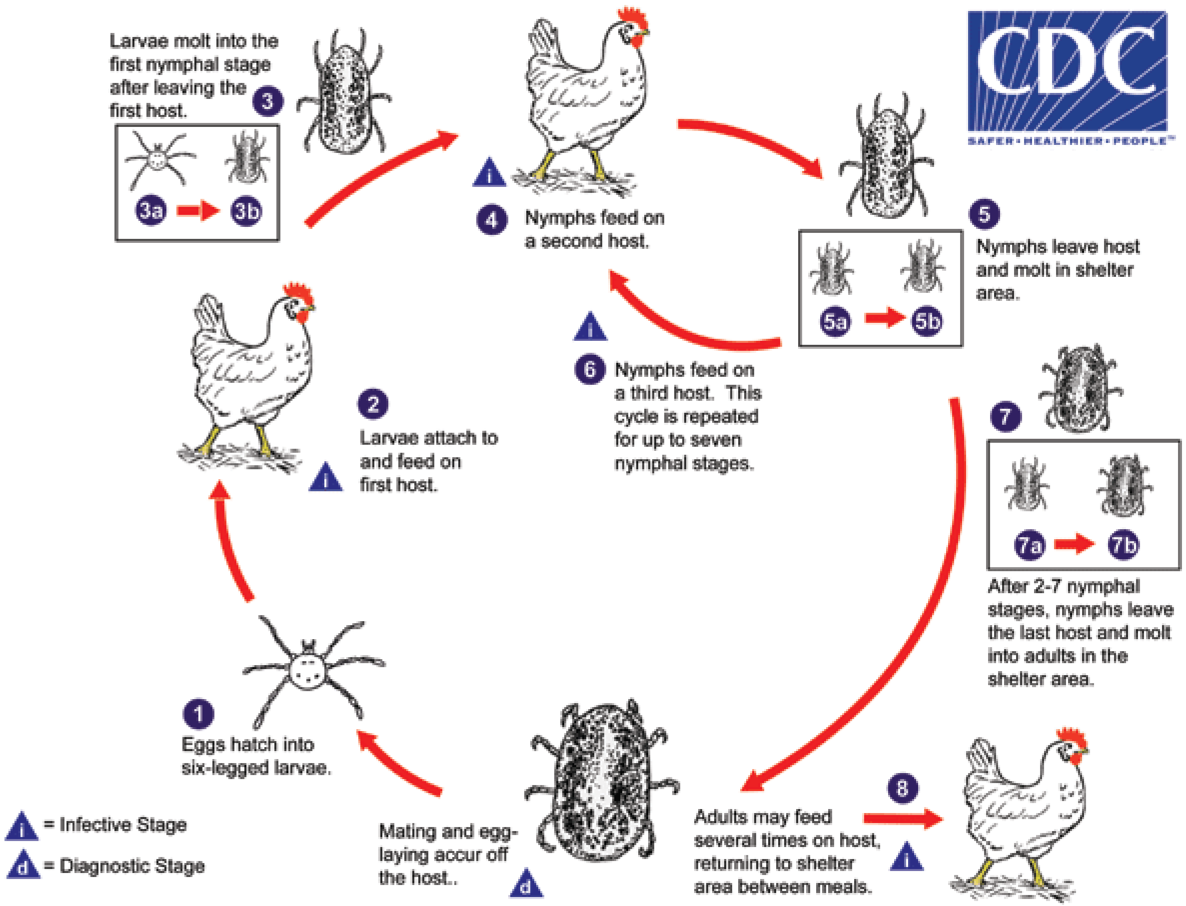
Ecological niche

“each species or homogeneous group of species is found within a specific range of environmental conditions enabling individuals to survive, grow and reproduce”

Membership function ➔

Degree of (habitat/environmental) suitability for any given area

Ecological study: Factors favouring development



CDC.gov

METHODS

Focus group discussion
➔ environmental criteria

- Relatively high spring temperatures to get out of diapauze
- High summer temperatures to complete life cycle
- Occurring in (semi)arid climates
- Occurring in (hyper)arid climates due to small dry season rain spells
- Presence of a large river in arid regions

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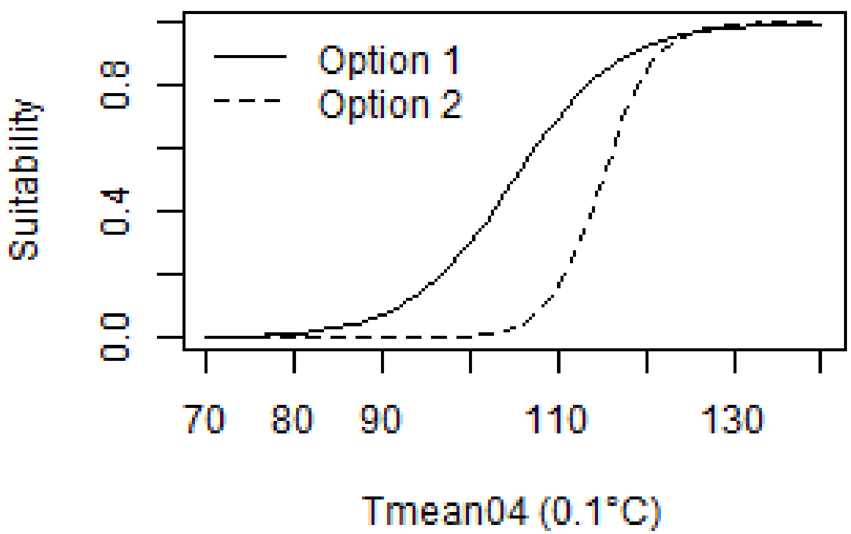
Criterion 1

- End of diapause and begin of development cycle
- Mean temperature (°C) in April



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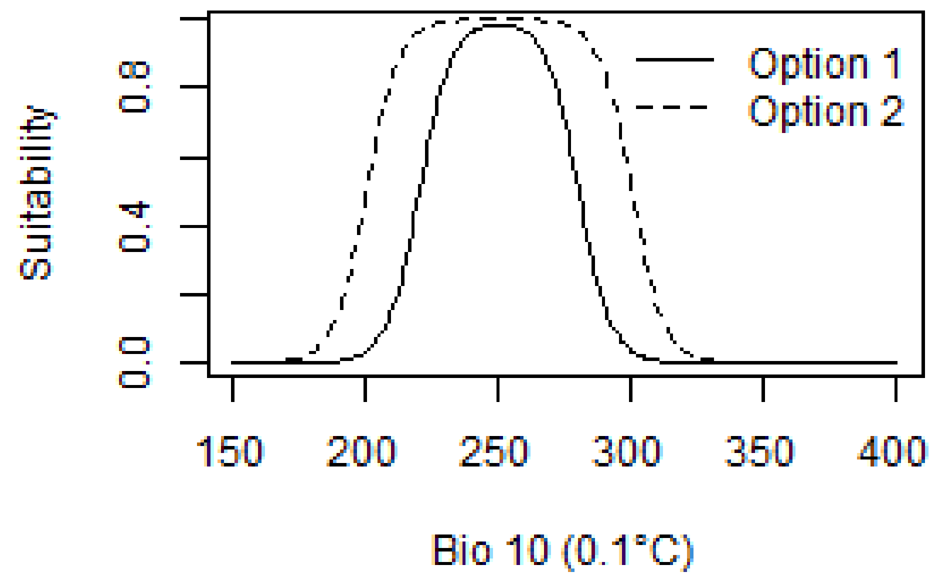
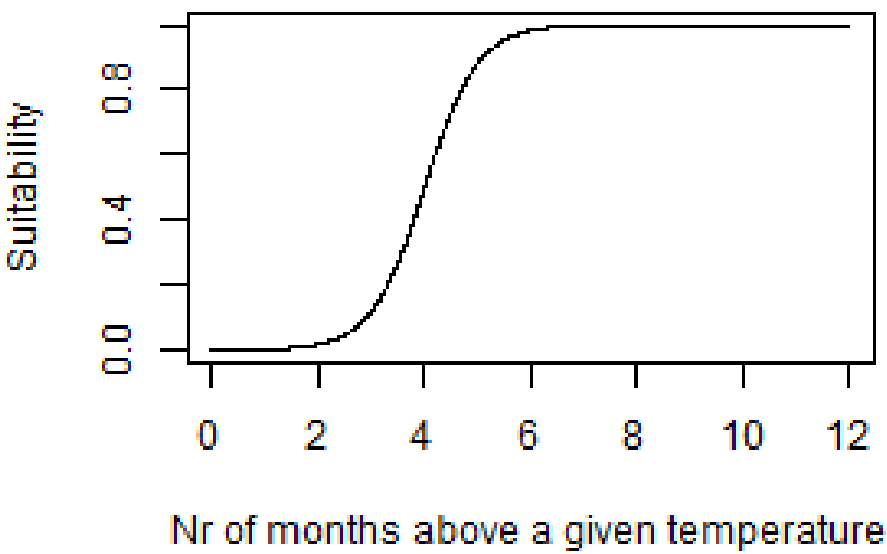
Criterion 2

- Sufficient warm temperatures to complete at least one cycle a year
- Mean temperature (°C) during the warmest quarter



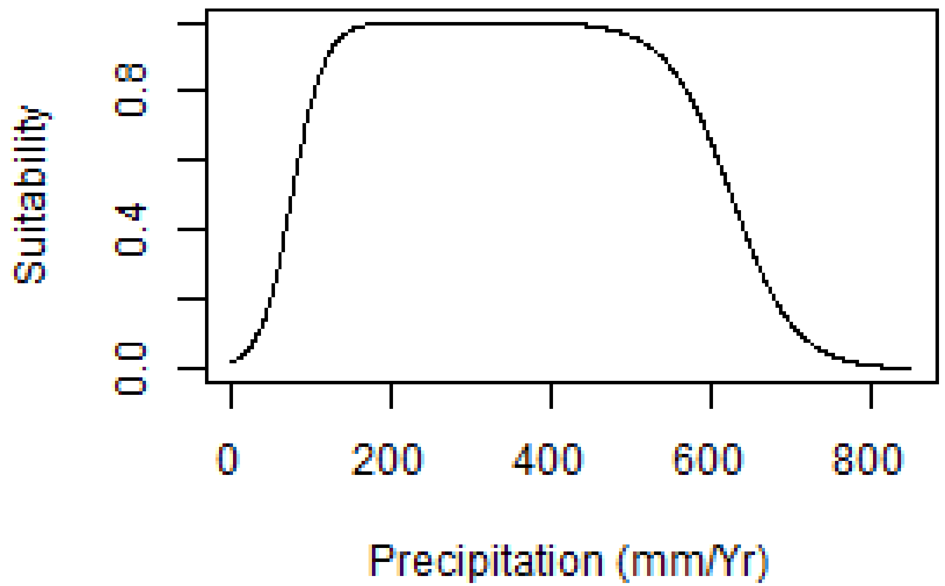
Criterion 2 … Cntd

- Sufficient warm temperatures to complete at least one cycle a year
- Nr of months per year with a mean temperature above
  - 18°C
  - 20°C
  - 22°C



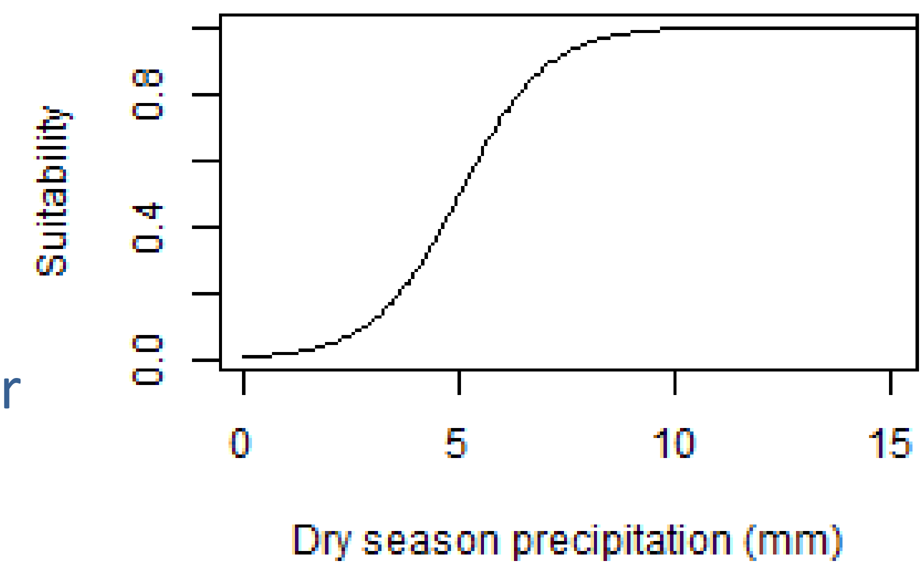
Criterion 3

- Suitable humidity for the habitat
- Annual precipitation (mm)



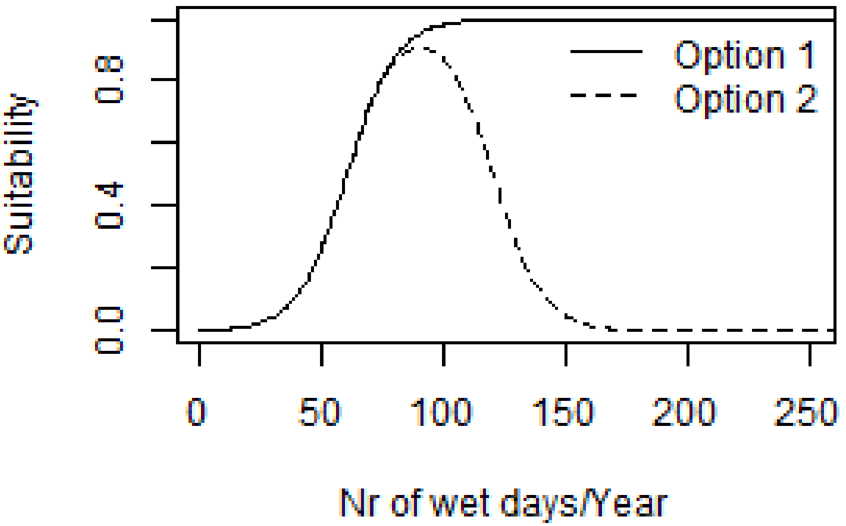
Criterion 4 v1

- Protection against desiccation during the dry season
  - Precipitation (mm) during the driest quarter



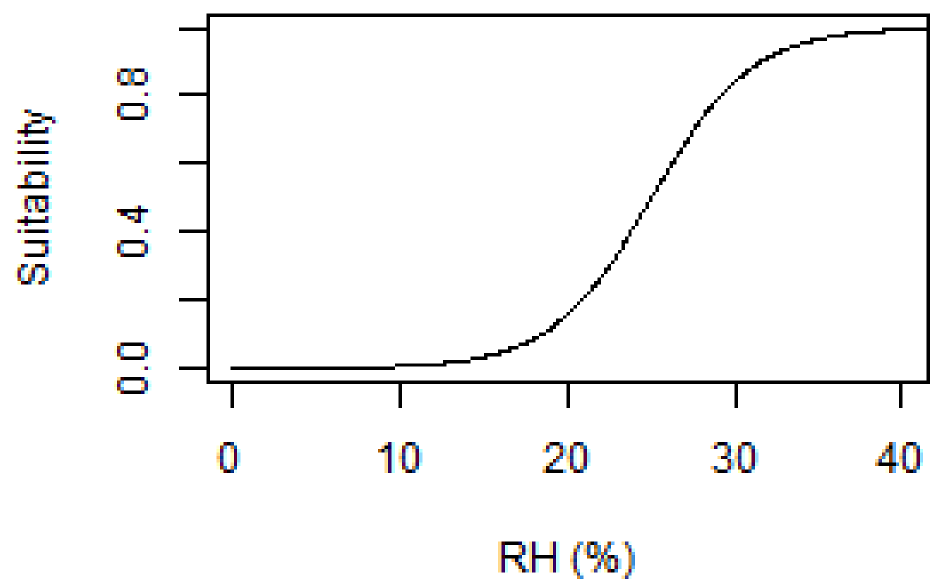
Criterion 4 v2

- Protection against desiccation during the dry season
  - Nr of wet days during the year



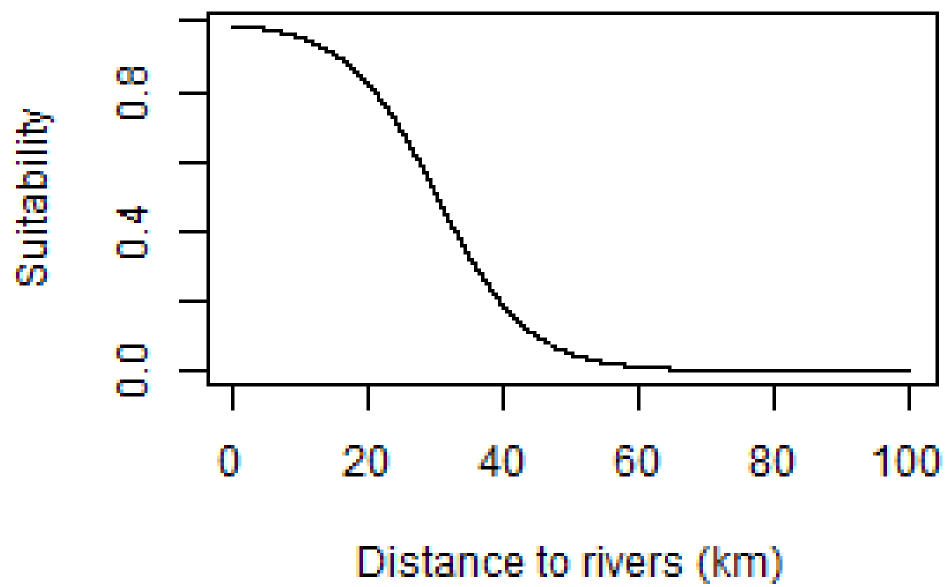
Criterion 4

- Protection against desiccation during the dry season
  - Minimum relative humidity (%) over the year



Criterion 5

- Protection against desiccation by river bank
  - Distance to perennial rivers in arid regions



Data sources

- WorldClim
  - 1950-1990
  - Monthly Precipitation, Tmin, Tmean, Tmax
  - 19 derived variables
  - 1 km^2
- Climate Research Unit (CRU TS)
  - 1900 - 2015 : Vapor pressures, Wet days, …
  - 5 km^2

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Combining criteria

- Weighted sum (OR)
  - Equal weigth per criterion
  - Equal weight per group of criteria
  - AHP
- Weighted product (AND)
  - Per group of criteria

	C1	C2	C3	C4	C5	w
C1	1					0,24
C2	1	1				0,276
C3	1	1	1			0,288
C4	1	1/3	1/3	1		0,142
C5	1/5	¼	1/5	1/3	1	0,054

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Summary on weights

Option	C1	C2	C3	C4	C5
ADD1	0.2	0.2	0.2	0.2	0.2
ADD2	0.25	0.25	0.17	0.17	0.17
ADD3	0.24	0.276	0.288	0.142	0.054
MULT	0.5	0.5	0.333	0.333	0.333

Combination of factors: 160 models

Weights	C1	C2	C3	C4	C5
ADD1	0.2	0.2	0.2	0.2	0.2
ADD2	0.25	0.25	0.17	0.17	0.17
ADD3	0.24	0.276	0.288	0.142	0.054
MULT	0.5	0.5	0.333	0.333	0.333

Options	C1	C2	C3	C4	C5
	C1V1O1	C2V1O1	C3V1O1	C4V1O1	C5V1O1
	C1V1O2	C2V1O2		C4V2O1	
		C2V2O1		C4V2O2	
		C2V3O1		C4V3O1	
		C2V4O1			

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Ensemble modelling

- 160 models
- Individually low accuracy
- Running different models & synthetizing the outcome
  – Improve accuracy of the predictions
- In machine learning
  – Random Forest etcetera

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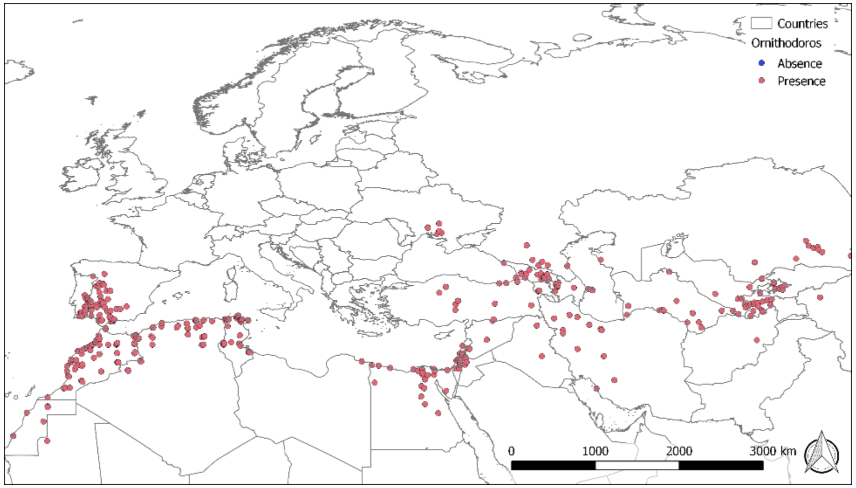
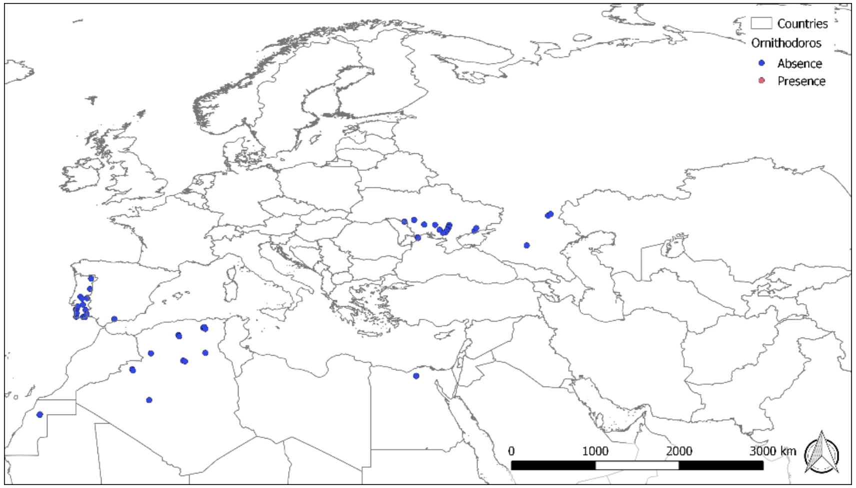
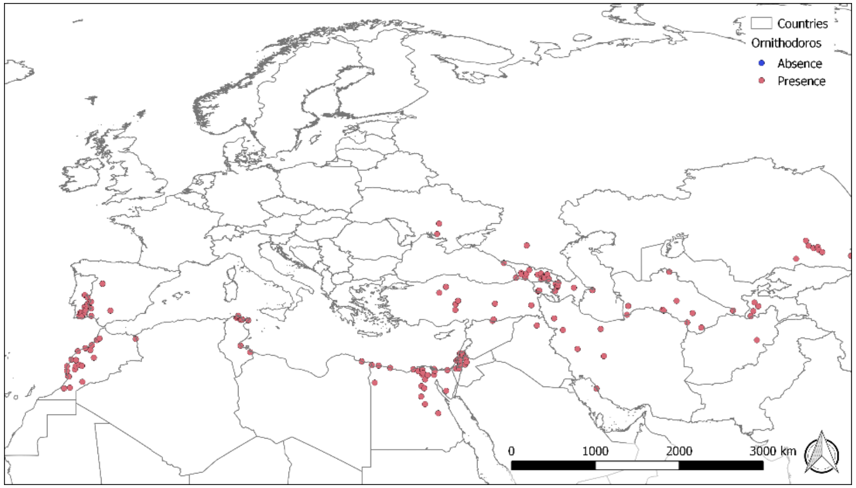
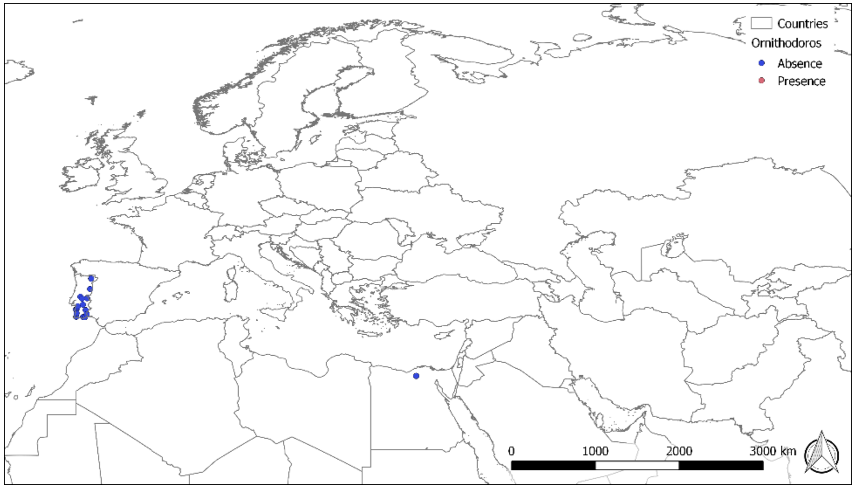
Validation


Countries
Ornithodoros
Absence
Presence
0
1000
2000
3000 km


Countries
Ornithodoros
Absence
Presence
0
1000
2000
3000 km

Synchronic data (1950-2000)





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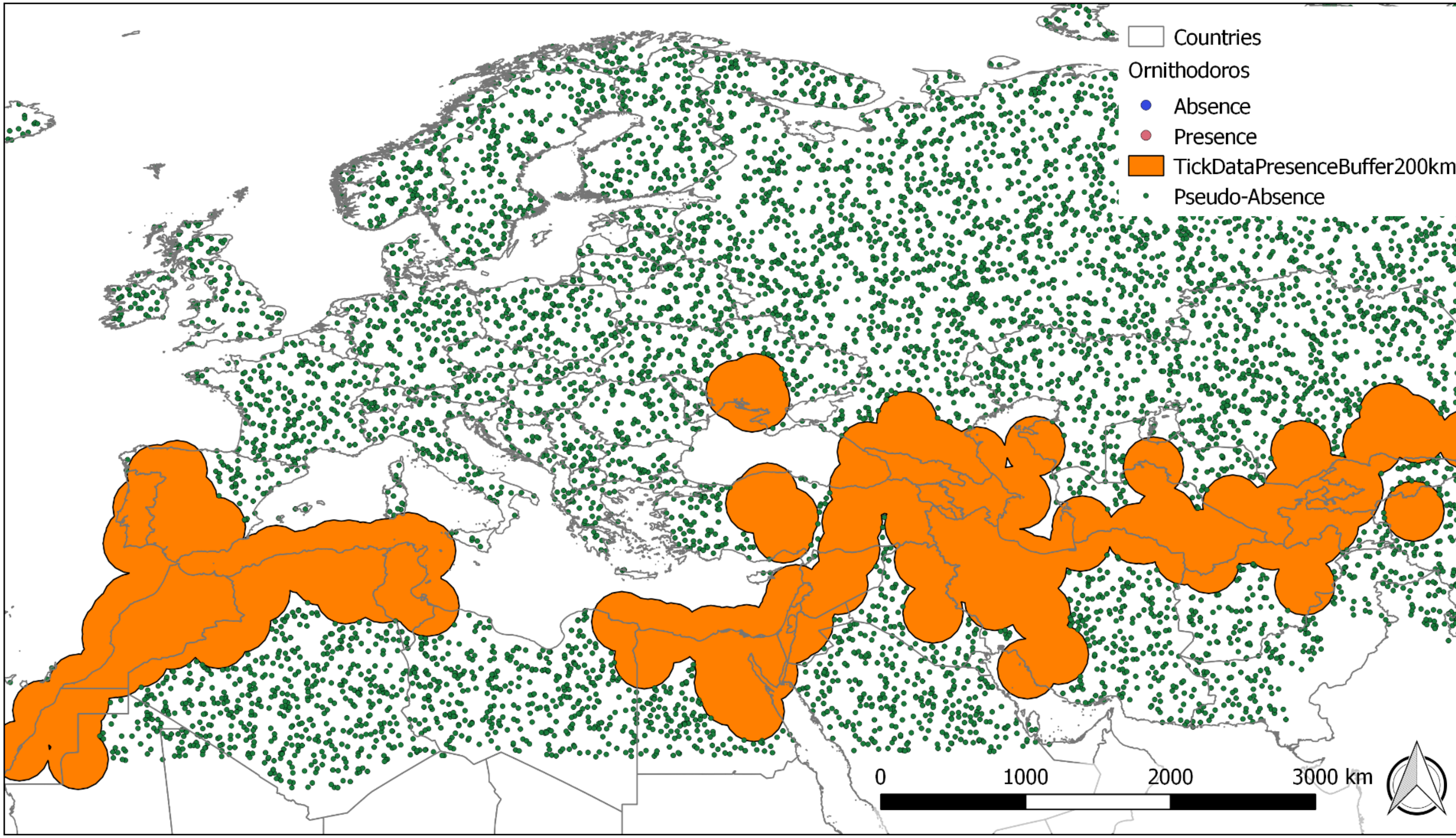
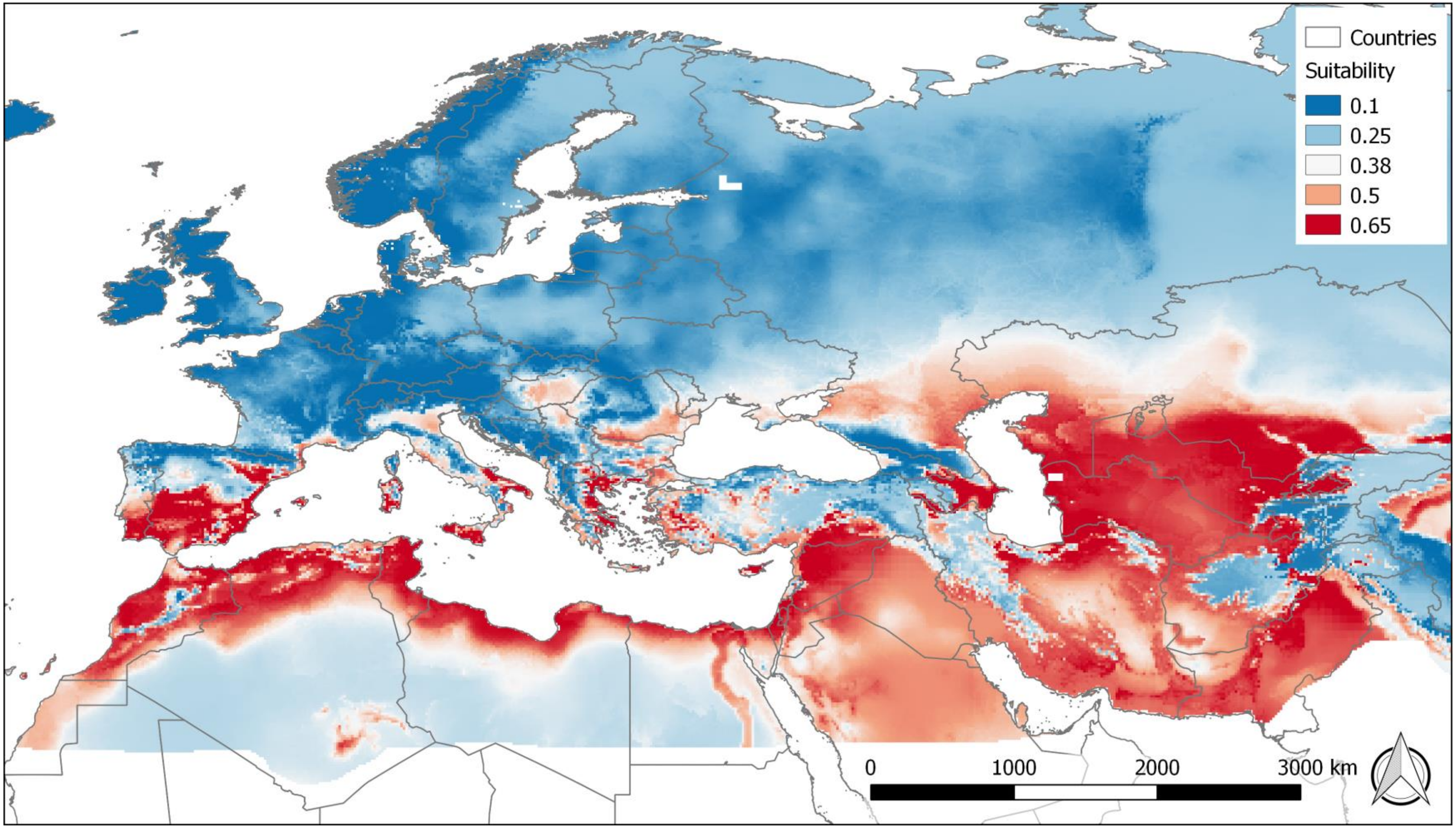
Pseudo-absences (200 km buffer)



RESULTS

Mean



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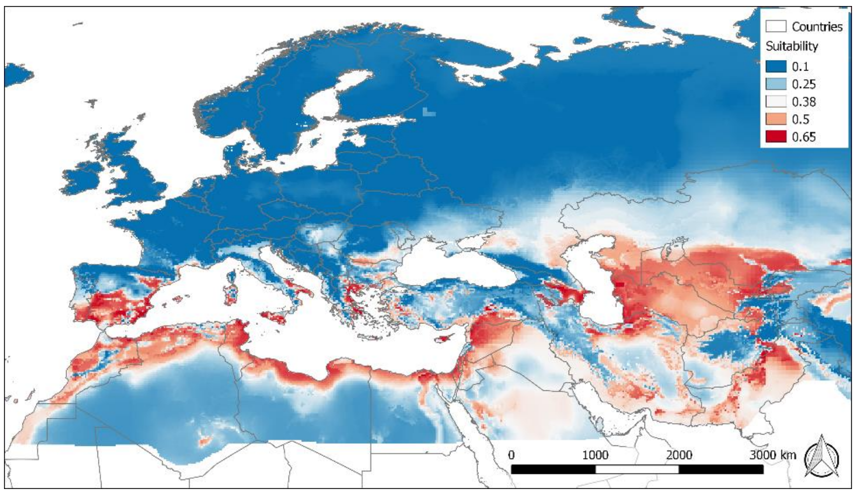
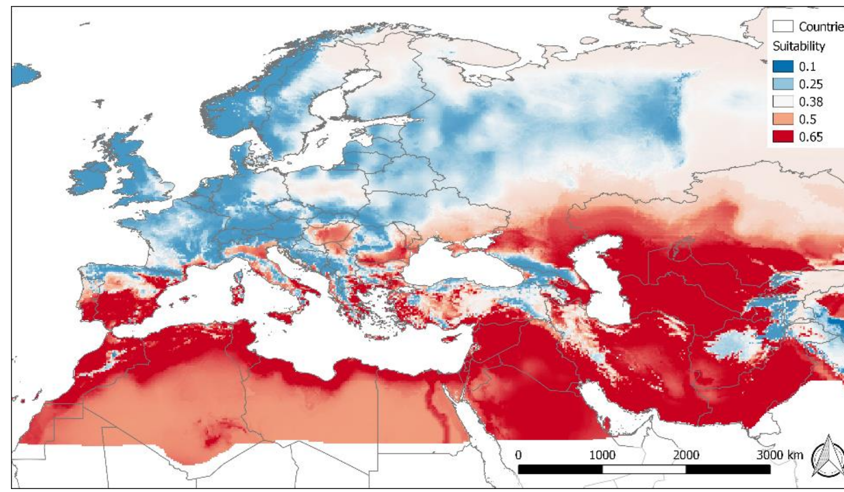
Sensitivity analysis (25- & 75 percentile)





Accuracy assessment

Models	AUC using all points	Optimal threshold (Sens=Spec)	AUC with synchronous points	Optimal threshold (Sens=Spec)
ALL	0,861 (0,037)	0,409 (0,16)	0,856 (0,035)	0,4 (0,163)
ADD1	0,855 (0,031)	0,452 (0,038)	0,852 (0,03)	0,449 (0,041)
ADD2	0,854 (0,04)	0,491 (0,044)	0,85 (0,038)	0,483 (0,046)
ADD3	0,844 (0,036)	0,544 (0,04)	0,838 (0,035)	0,533 (0,046)
MULT	0,893 (0,014)	0,15 (0,052)	0,885 (0,015)	0,136 (0,066)

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Weighted sum

Models	AUC using all points	Optimal threshold (Sens=Spec)	AUC with synchronous points	Optimal threshold (Sens=Spec)
ALL ADD	0,851 (0,036)	0,496 (0,055)	0,847 (0,035)	0,488 (0,056)
C1V1O1	0,848 (0,038)	0,486 (0,055)	0,843 (0,037)	0,476 (0,055)
C1V1O2	0,854 (0,034)	0,506 (0,054)	0,85 (0,033)	0,501 (0,054)
C2V1O1	0,88 (0,011)	0,454 (0,043)	0,876 (0,012)	0,447 (0,036)
C2V1O2	0,891 (0,009)	0,547 (0,049)	0,889 (0,01)	0,548 (0,046)
C2V2O1	0,854 (0,013)	0,516 (0,043)	0,843 (0,013)	0,504 (0,044)
C2V3O1	0,832 (0,015)	0,499 (0,043)	0,828 (0,014)	0,491 (0,044)
C2V4O1	0,798 (0,018)	0,463 (0,041)	0,798 (0,016)	0,452 (0,043)
C4V1O1	0,852 (0,031)	0,505 (0,055)	0,838 (0,032)	0,493 (0,054)
C4V2O1	0,849 (0,037)	0,491 (0,055)	0,849 (0,036)	0,488 (0,056)
C4V2O2	0,866 (0,033)	0,476 (0,054)	0,861 (0,032)	0,466 (0,054)
C4V3O1	0,837 (0,039)	0,512 (0,052)	0,839 (0,037)	0,507 (0,054)

Weighted sum

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C2V1O1	0,88 (0,011)	0,454 (0,043)	0,876 (0,012)	0,447 (0,036)
C2V1O2	0,891 (0,009)	0,547 (0,049)	0,889 (0,01)	0,548 (0,046)
C2V2O1	0,854 (0,013)	0,516 (0,043)	0,843 (0,013)	0,504 (0,044)
C2V3O1	0,832 (0,015)	0,499 (0,043)	0,828 (0,014)	0,491 (0,044)
C2V4O1	0,798 (0,018)	0,463 (0,041)	0,798 (0,016)	0,452 (0,043)
C4V1O1	0,852 (0,031)	0,505 (0,055)	0,838 (0,032)	0,493 (0,054)
C4V2O1	0,849 (0,037)	0,491 (0,055)	0,849 (0,036)	0,488 (0,056)
C4V2O2	0,866 (0,033)	0,476 (0,054)	0,861 (0,032)	0,466 (0,054)
C4V3O1	0,837 (0,039)	0,512 (0,052)	0,839 (0,037)	0,507 (0,054)

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Weighted product

Models	AUC using all points	Optimal threshold (Sens=Spec)	AUC with synchronous points	Optimal threshold (Sens=Spec)
ALL MULT	0,893 (0,014)	0,15 (0,052)	0,885 (0,015)	0,136 (0,066)
C1V1O1	0,89 (0,017)	0,131 (0,054)	0,882 (0,017)	0,109 (0,068)
C1V1O2	0,895 (0,011)	0,169 (0,044)	0,888 (0,013)	0,163 (0,053)
C2V1O1	0,906 (0,001)	0,157 (0,019)	0,898 (0,006)	0,152 (0,022)
C2V1O2	0,905 (0,003)	0,223 (0,034)	0,901 (0,009)	0,235 (0,034)
C2V2O1	0,893 (0,006)	0,15 (0,033)	0,884 (0,007)	0,116 (0,043)
C2V3O1	0,888 (0,008)	0,12 (0,037)	0,88 (0,008)	0,096 (0,046)
C2V4O1	0,871 (0,01)	0,1 (0,037)	0,863 (0,008)	0,081 (0,041)
C4V1O1	0,893 (0,012)	0,16 (0,059)	0,876 (0,012)	0,137 (0,067)
C4V2O1	0,895 (0,013)	0,14 (0,047)	0,891 (0,014)	0,136 (0,069)
C4V2O2	0,897 (0,012)	0,122 (0,044)	0,888 (0,014)	0,107 (0,058)
C4V3O1	0,885 (0,018)	0,179 (0,048)	0,887 (0,019)	0,165 (0,065)

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Weighted product

Models	AUC using all points	Optimal threshold (Sens=Spec)	AUC with synchronous points	Optimal threshold (Sens=Spec)
ALL MULT	0,893 (0,014)	0,15 (0,052)	0,885 (0,015)	0,136 (0,066)
C1V1O1	0,89 (0,017)	0,131 (0,054)	0,882 (0,017)	0,109 (0,068)
C1V1O2	0,895 (0,011)	0,169 (0,044)	0,888 (0,013)	0,163 (0,053)
C2V1O1	0,906 (0,001)	0,157 (0,019)	0,898 (0,006)	0,152 (0,022)
C2V1O2	0,905 (0,003)	0,223 (0,034)	0,901 (0,009)	0,235 (0,034)
C2V2O1	0,893 (0,006)	0,15 (0,033)	0,884 (0,007)	0,116 (0,043)
C2V3O1	0,888 (0,008)	0,12 (0,037)	0,88 (0,008)	0,096 (0,046)
C2V4O1	0,871 (0,01)	0,1 (0,037)	0,863 (0,008)	0,081 (0,041)
C4V1O1	0,893 (0,012)	0,16 (0,059)	0,876 (0,012)	0,137 (0,067)
C4V2O1	0,895 (0,013)	0,14 (0,047)	0,891 (0,014)	0,136 (0,069)
C4V2O2	0,897 (0,012)	0,122 (0,044)	0,888 (0,014)	0,107 (0,058)
C4V3O1	0,885 (0,018)	0,179 (0,048)	0,887 (0,019)	0,165 (0,065)

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Weighted product

Models	AUC using all points	Optimal threshold (Sens=Spec)	AUC with synchronous points	Optimal threshold (Sens=Spec)
ALL MULT	0,893 (0,014)	0,15 (0,052)	0,885 (0,015)	0,136 (0,066)
C1V1O1	0,89 (0,017)	0,131 (0,054)	0,882 (0,017)	0,109 (0,068)
C1V1O2	0,895 (0,011)	0,169 (0,044)	0,888 (0,013)	0,163 (0,053)
C2V1O1	0,906 (0,001)	0,157 (0,019)	0,898 (0,006)	0,152 (0,022)
C2V1O2	0,905 (0,003)	0,223 (0,034)	0,901 (0,009)	0,235 (0,034)
C2V2O1	0,893 (0,006)	0,15 (0,033)	0,884 (0,007)	0,116 (0,043)
C2V3O1	0,888 (0,008)	0,12 (0,037)	0,88 (0,008)	0,096 (0,046)
C2V4O1	0,871 (0,01)	0,1 (0,037)	0,863 (0,008)	0,081 (0,041)
C4V1O1	0,893 (0,012)	0,16 (0,059)	0,876 (0,012)	0,137 (0,067)
C4V2O1	0,895 (0,013)	0,14 (0,047)	0,891 (0,014)	0,136 (0,069)
C4V2O2	0,897 (0,012)	0,122 (0,044)	0,888 (0,014)	0,107 (0,058)
C4V3O1	0,885 (0,018)	0,179 (0,048)	0,887 (0,019)	0,165 (0,065)

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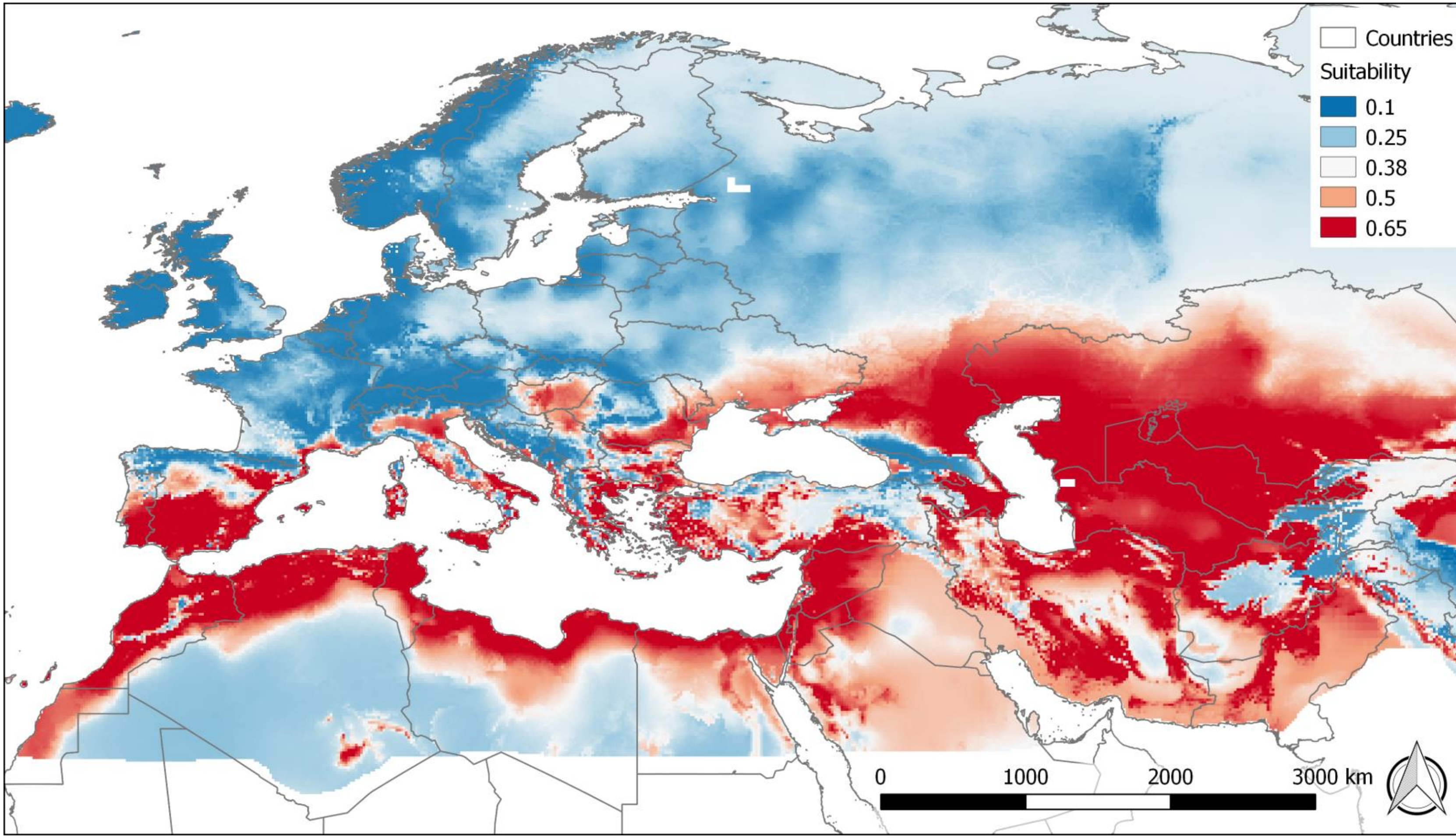
Weighted sum



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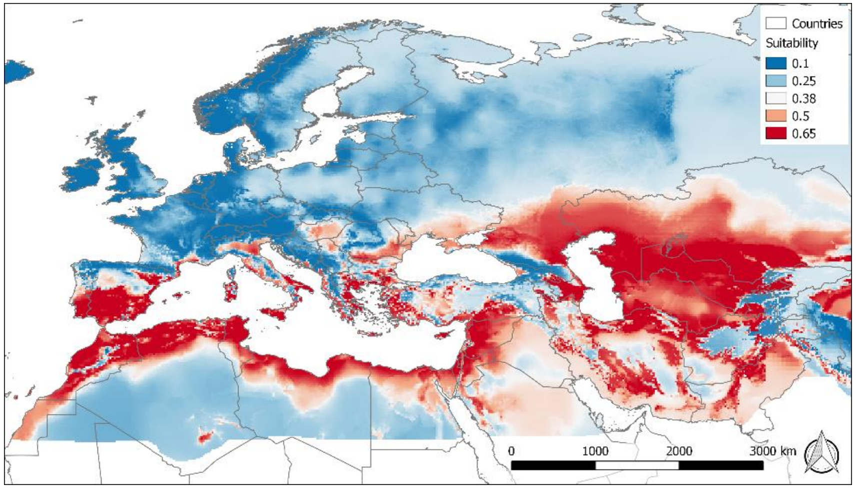
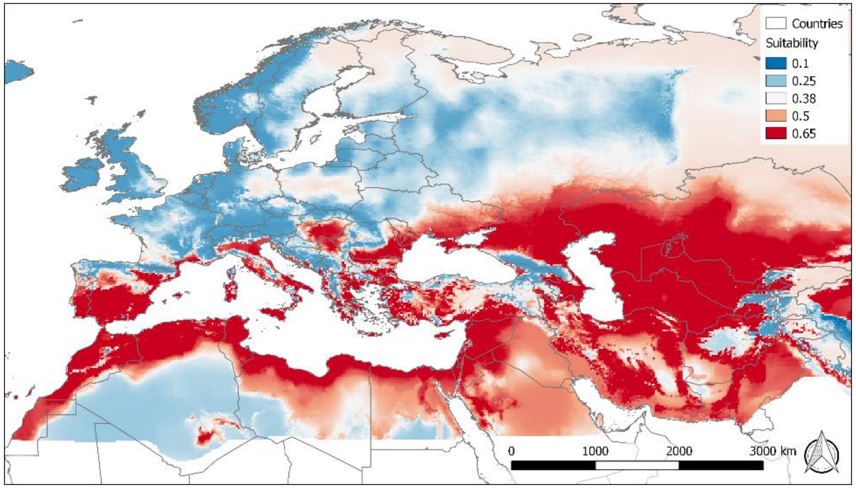
Weighted sum Confidence interval (25- & 75 percentile)





fnrs
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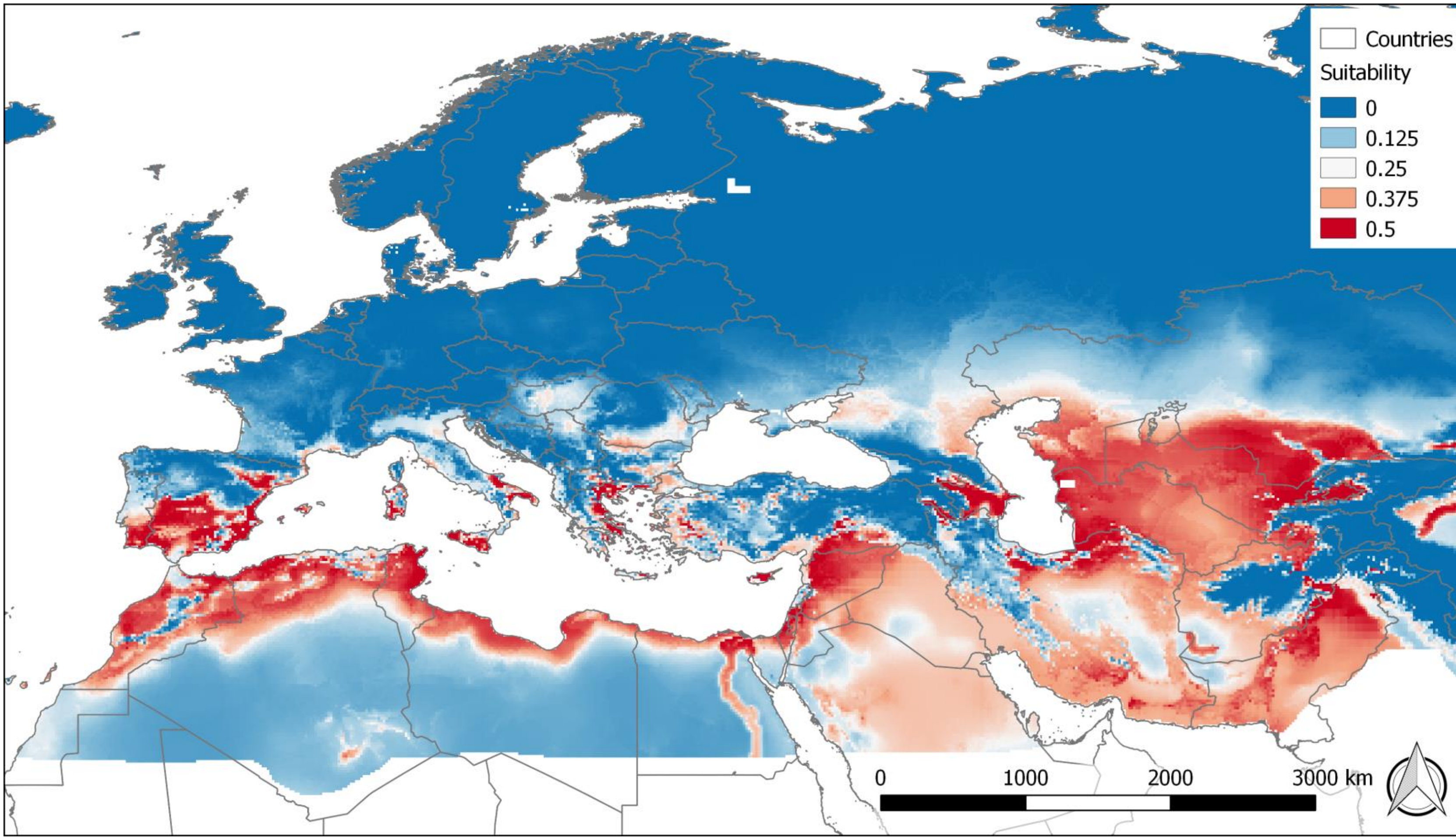
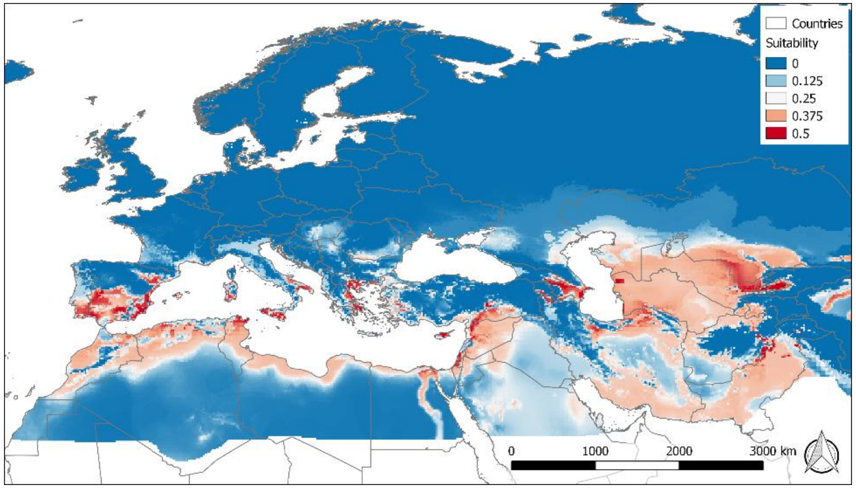
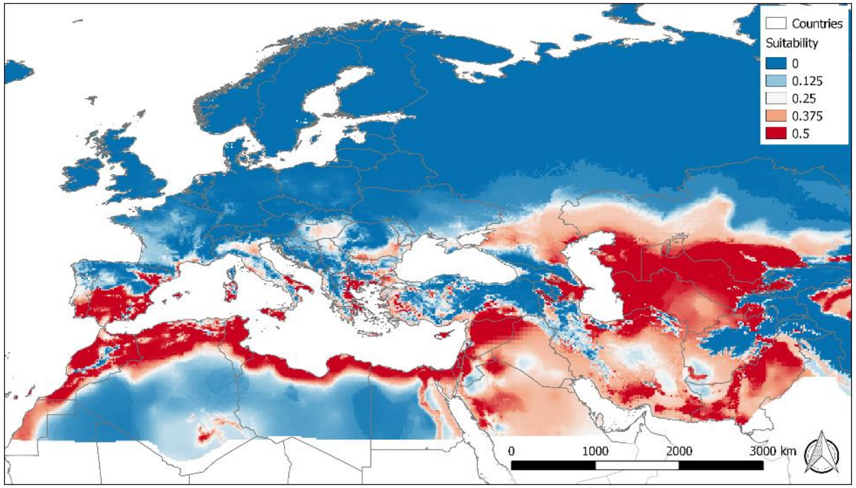
Weighted product



Weighted product
Confidence interval (25- & 75 percentile)





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Comparison with data driven models

- Maximum entropy
- Data on
  - Presence
  - Pseudo-absence
- Fit to the data (Auto-Features)
- WorldClim/CRU as explanatory variables

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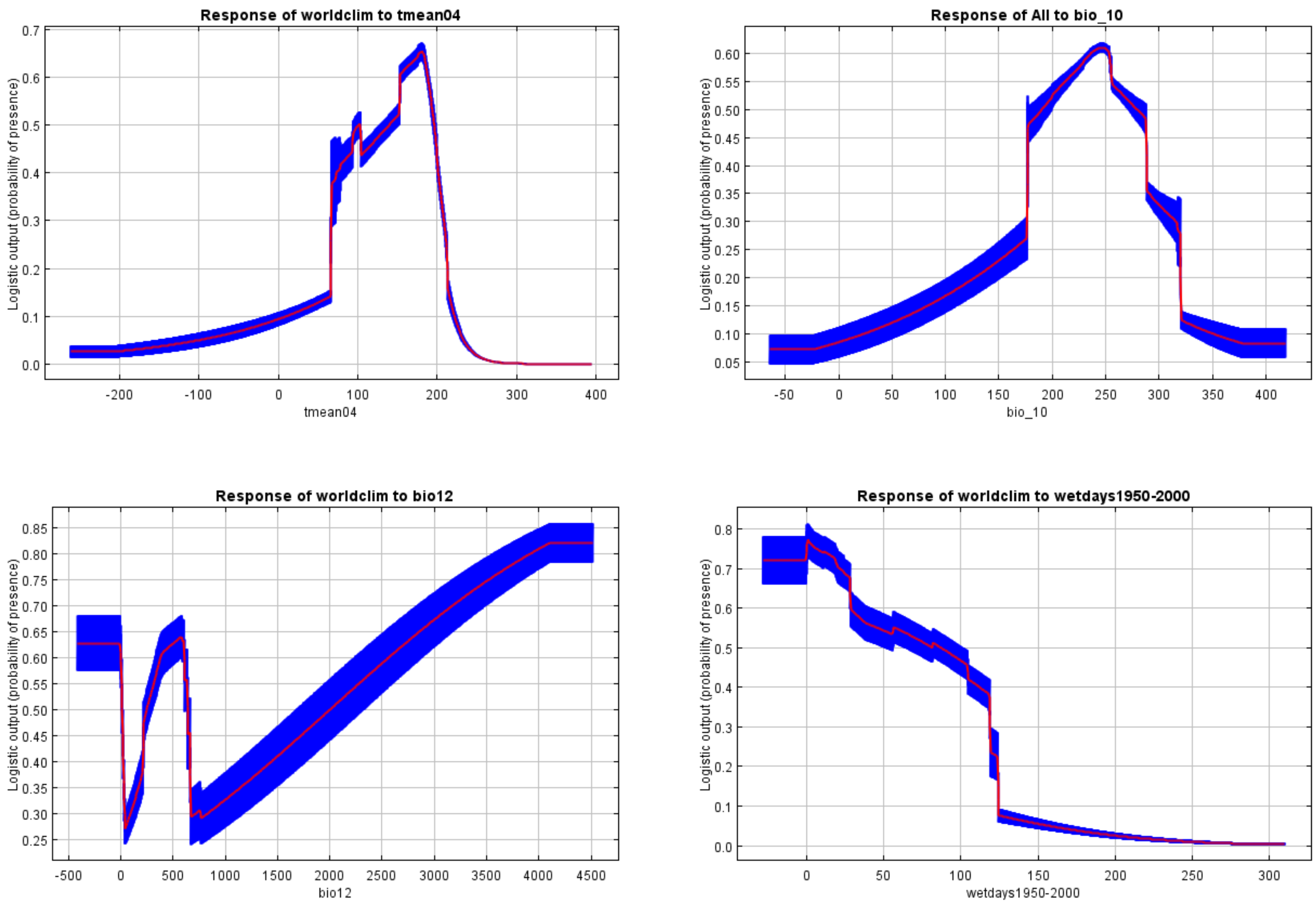
Response curves



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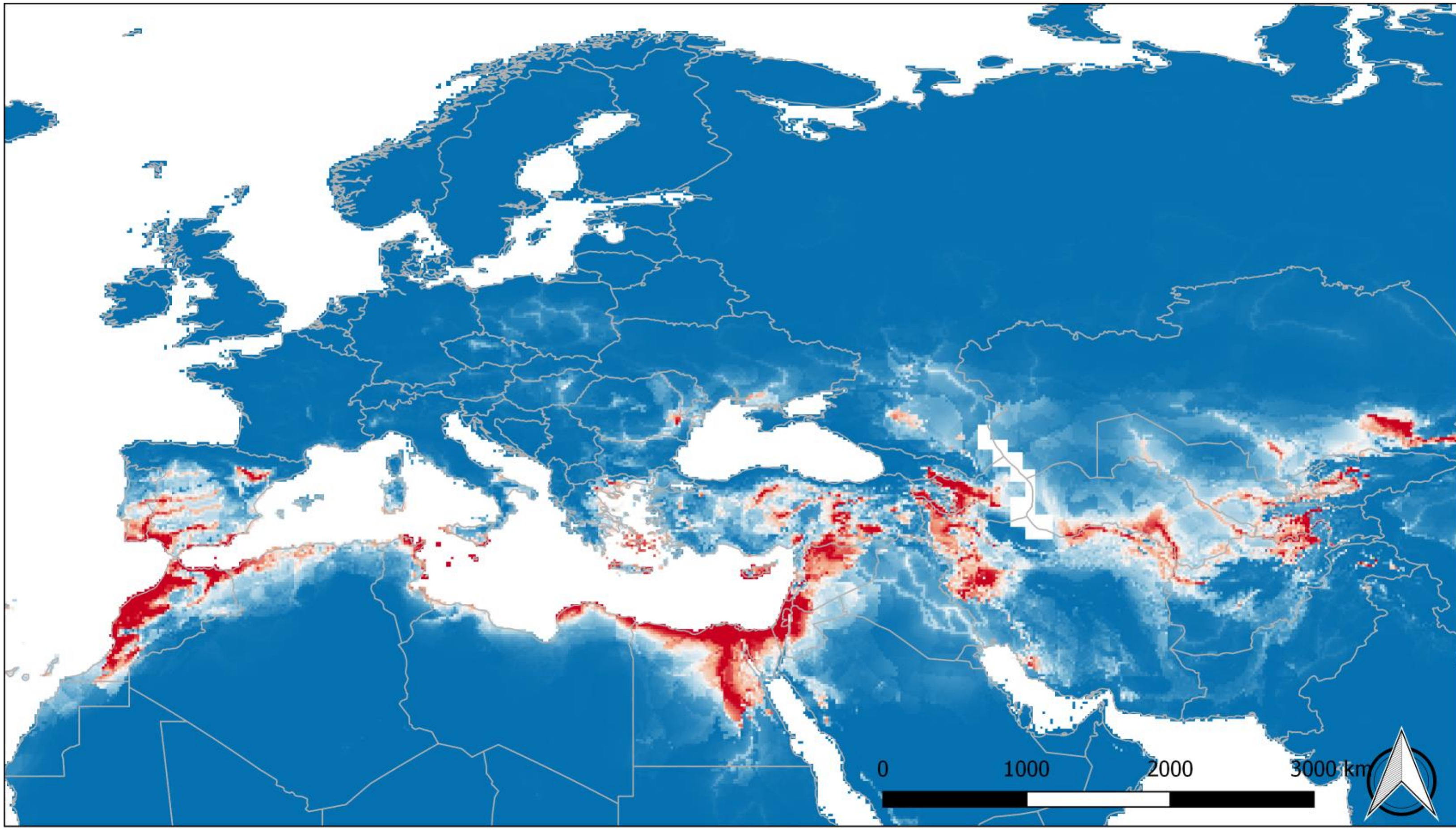
Predictions



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Conclusions & Outlook

- Very useful/fast to estimate global distribution
- Accepted by decision makers
- Target surveillance countries/counties: sensitivity more important than specificity
- Based on climatic factors ; not for local distribution
- Paves the road for data-driven models

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Acknowledgements

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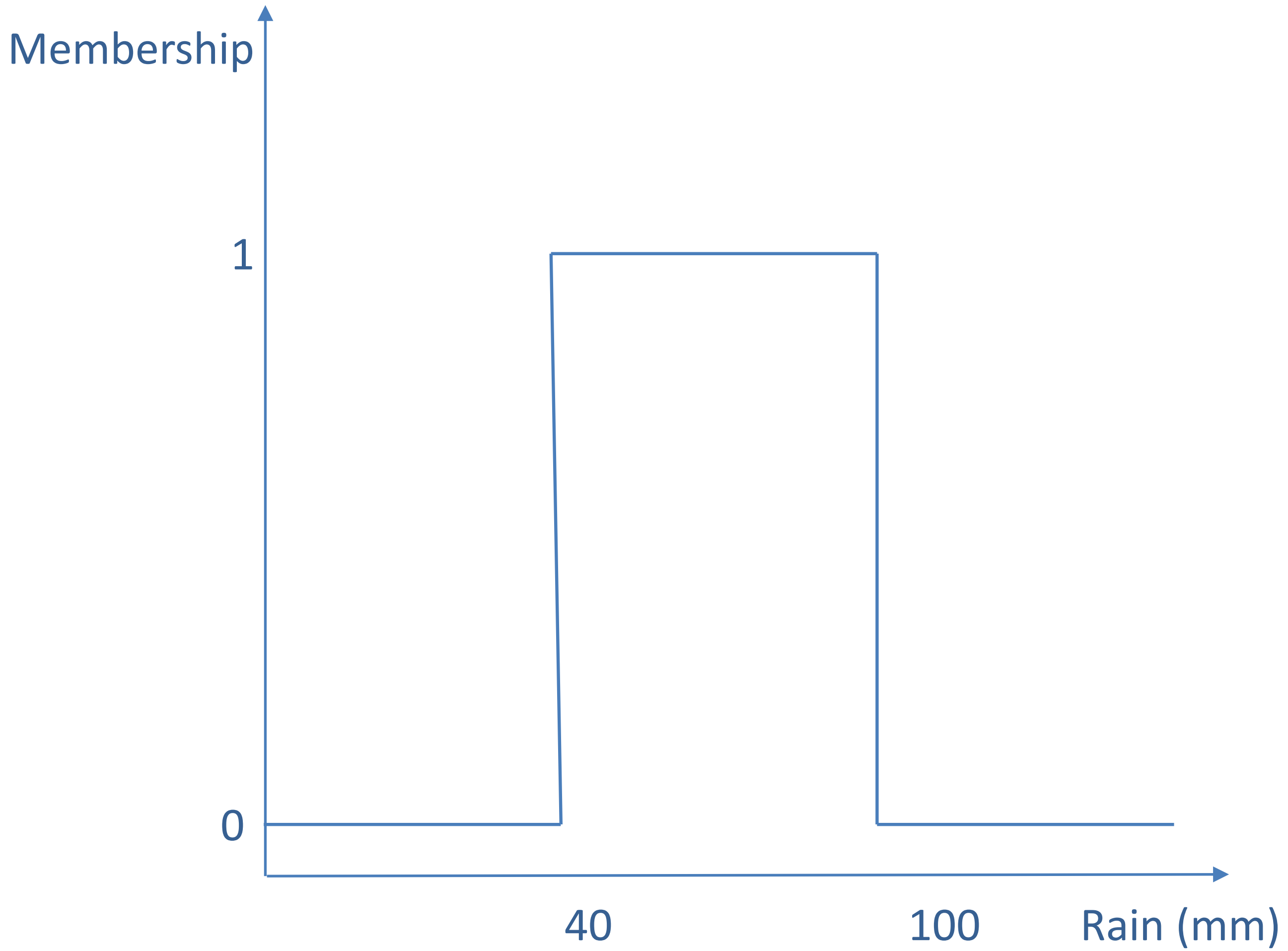
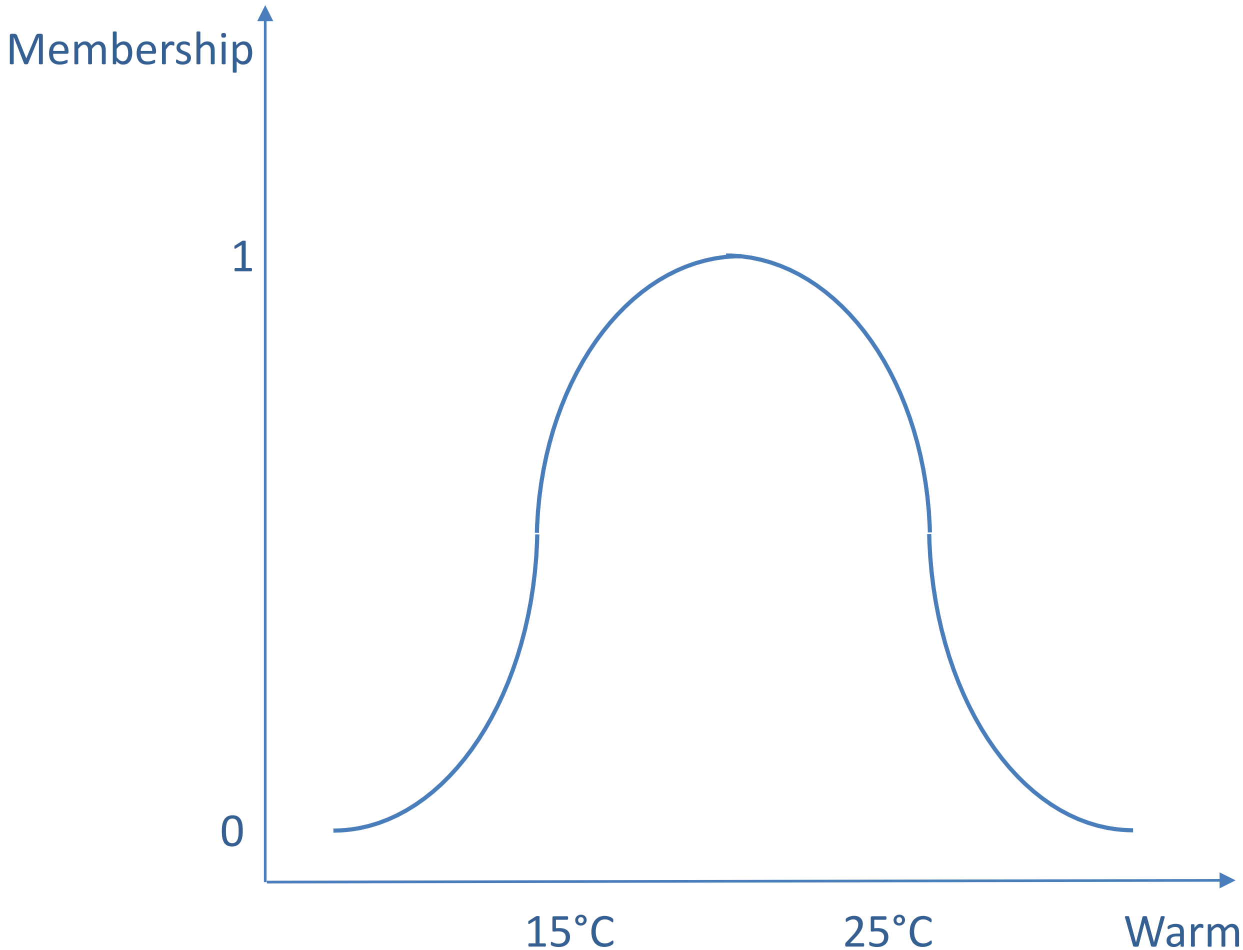

Membership
1
0
40
100
Rain (mm)


Membership
1
0
15°C
25°C
Warm