Fuzzy sets and species distributions

Quick review

presence-(pseudo)absence models

(GLM, GAM, RF, BRT, ANN…)

presence probability

favourability

together with species prevalence in the **modelled sample**

keep the values continuous!

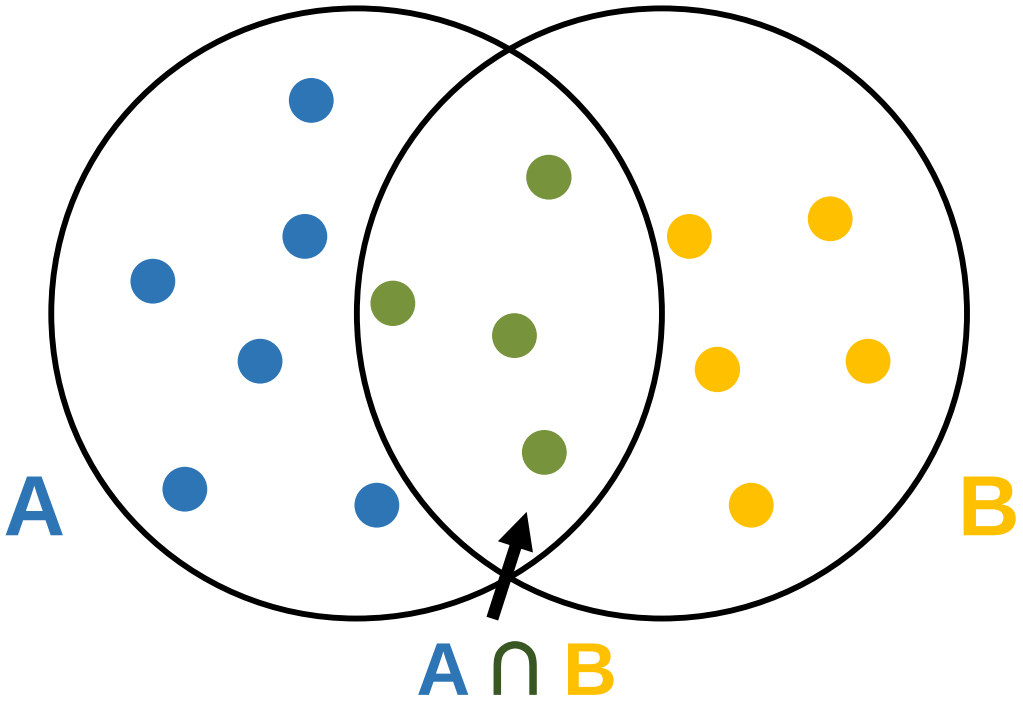
can be **formally** combined across species

Classical sets

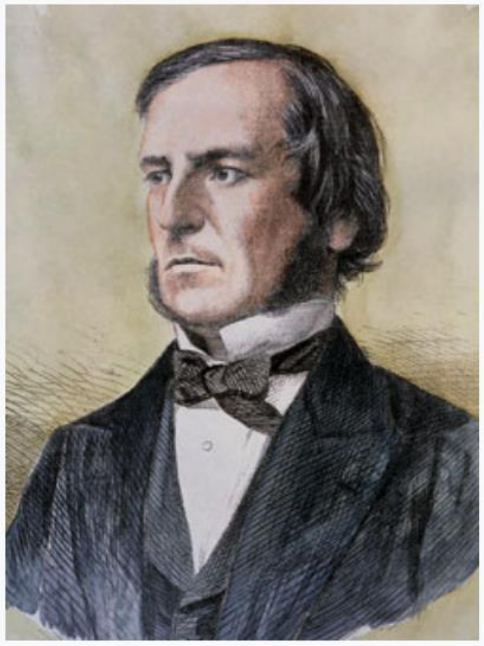
under **classical (Boolean, binary) logic**,

there are only 2 possible outcomes: **TRUE** or **FALSE**

an object either **does** or **doesn't** belong to a set

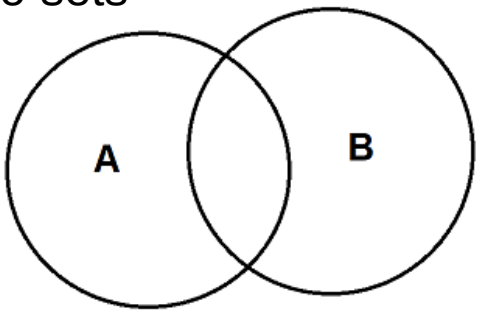


George Boole

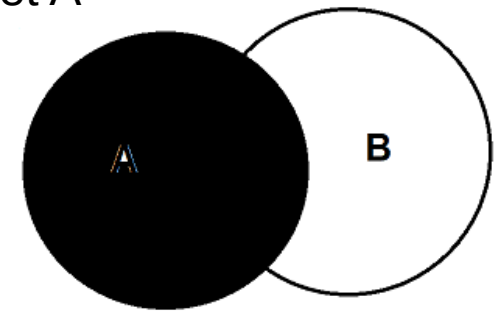


Classical sets

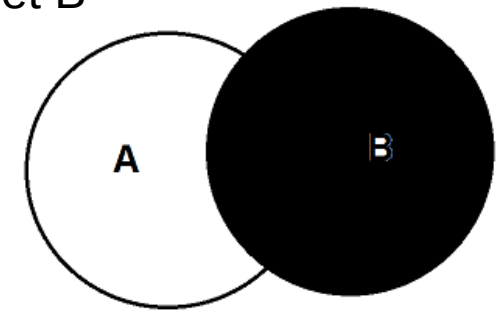
two sets



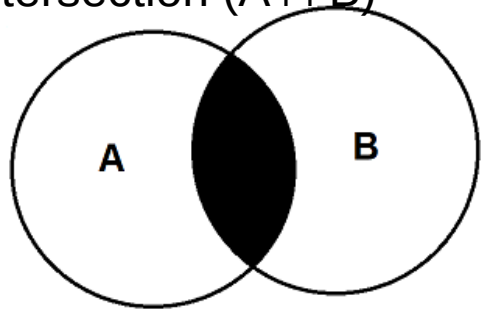
set A



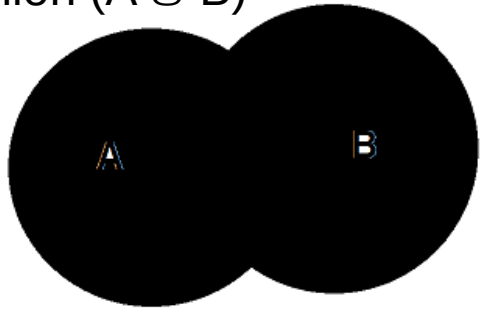
set B



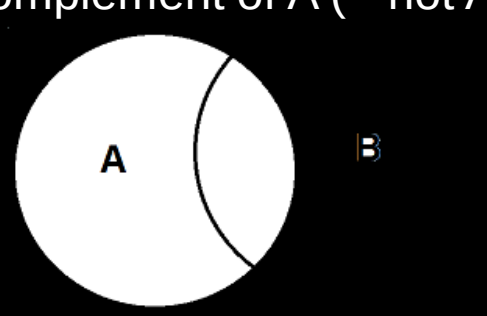
intersection (A ∩ B)



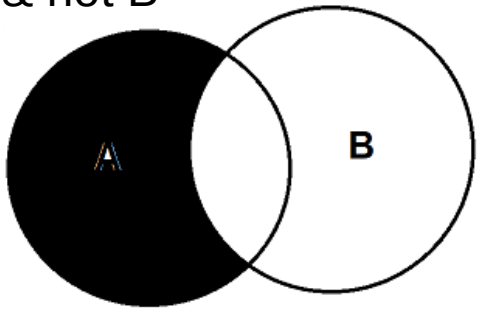
union (A ∪ B)



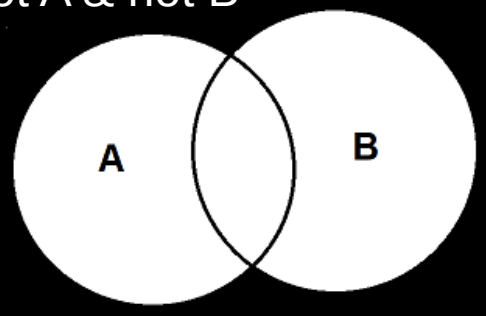
complement of A (~ not A)



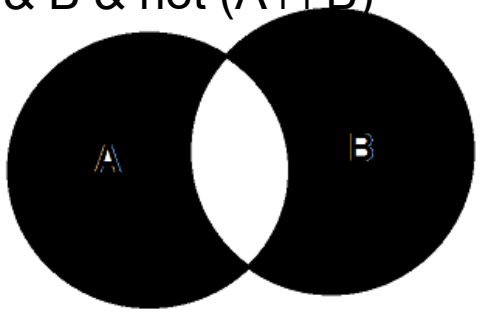
A & not B



not A & not B



A & B & not (A ∩ B)

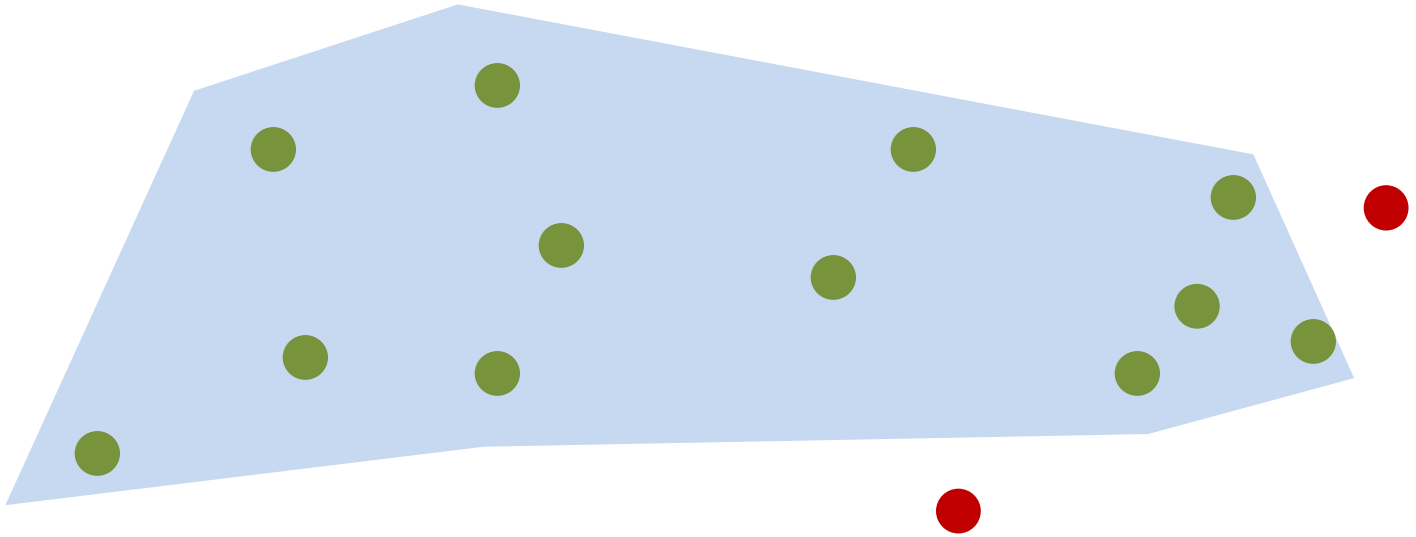


Classical sets

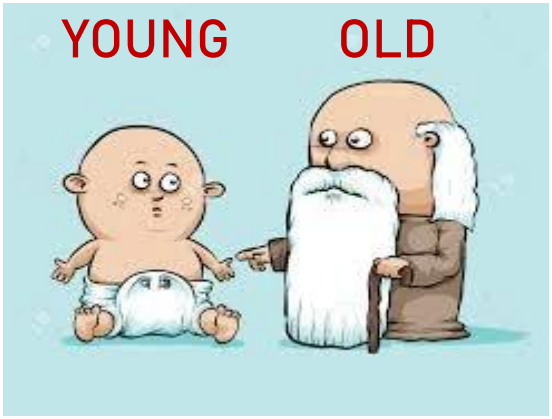
under **classical (Boolean, binary) logic**,

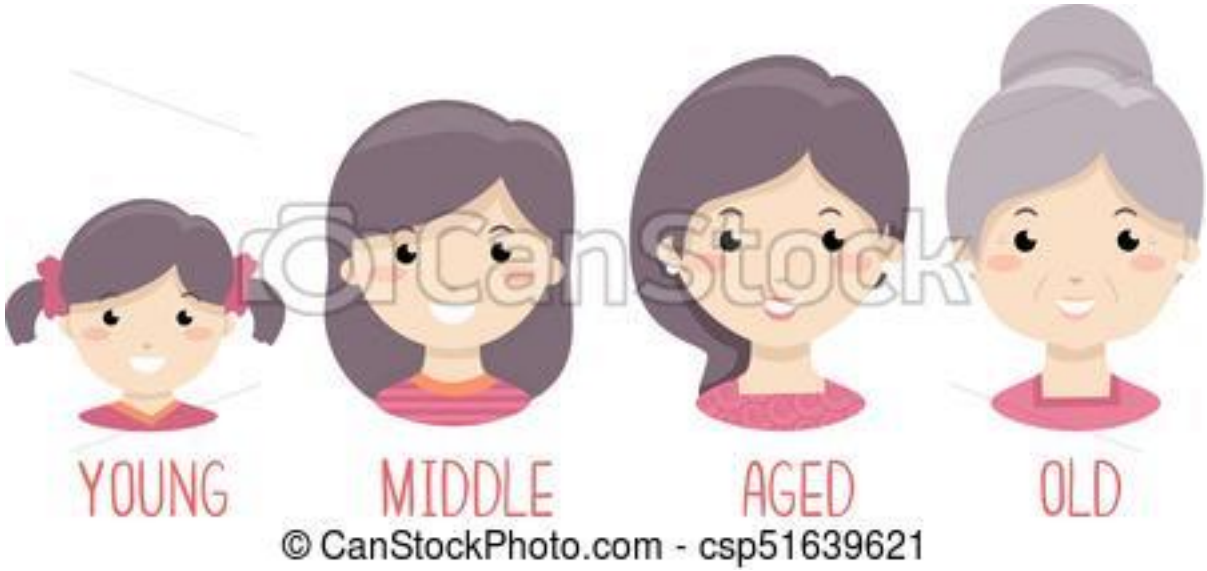
a species is either **present or absent** in a region

a site either **does** or **doesn't belong** to a species' distribution area

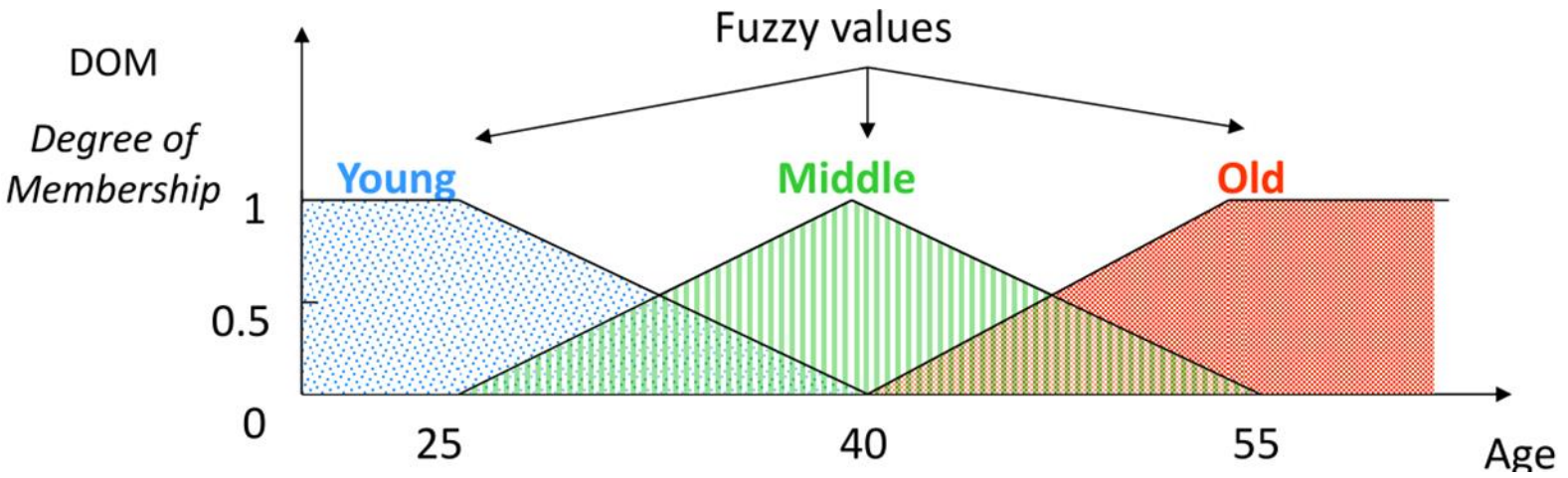


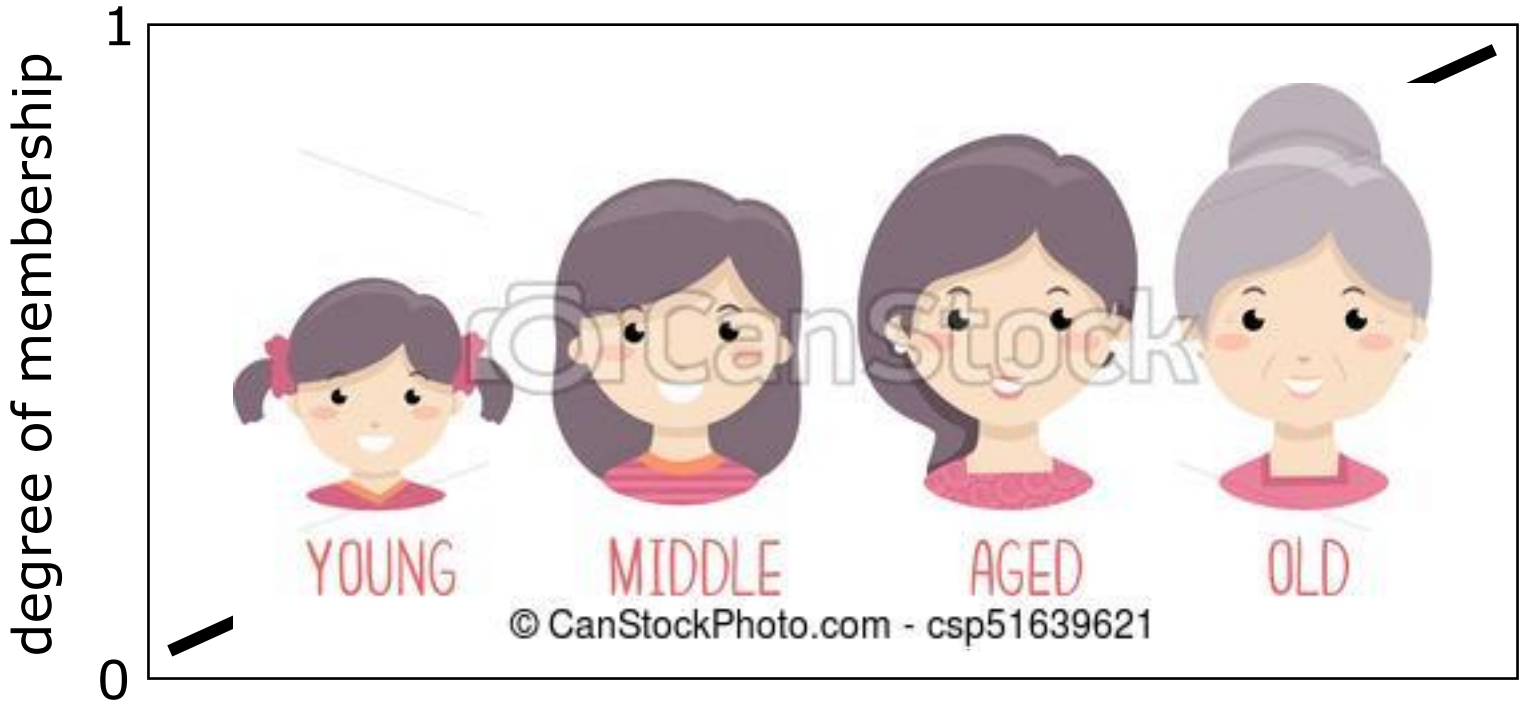
Classical sets





Fuzzy sets


Fuzzy values
DOM
Degree of Membership
Young
Middle
Old
1
0.5
0
25
40
55
Age


degree of membership
1
0
YOUNG
MIDDLE
AGED
OLD
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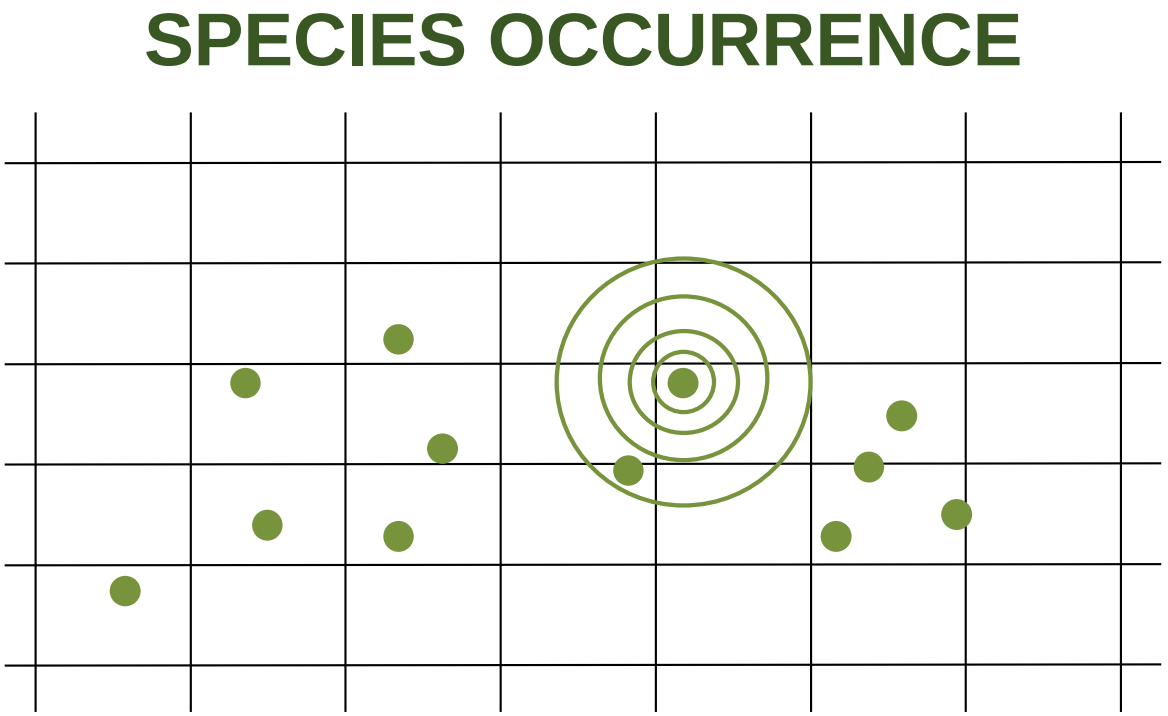
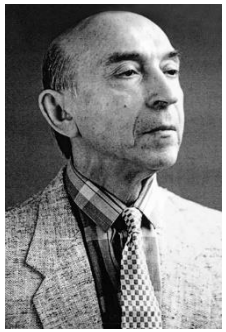
Fuzzy sets

in the real world, the simple division between TRUE and FALSE does not exist: any value in the middle is possible, from completely true to completely false

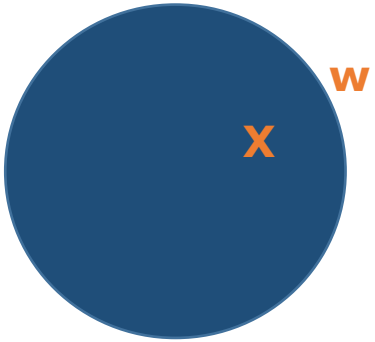


Fuzzy sets

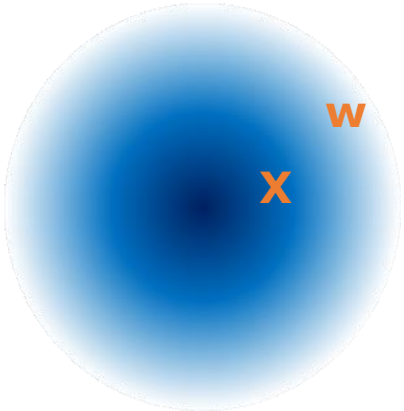


A fuzzy set is a class of objects with a continuum of grades of membership […] The notions of inclusion, union, intersection, complement, relation, convexity, etc., are extended to such sets […]

classical set



fuzzy set



Fuzzy membership vs. probability

The degree of membership is **not the probability** that an item is in a set, but the **extent to which** the item is in the set – e.g., the degree to which a pixel is in the set of potential occurrence areas of a species.

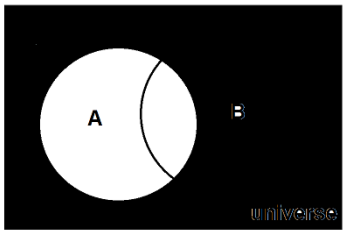
Classical vs. fuzzy sets

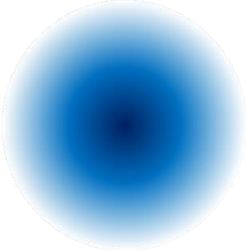
classical sets:

- each element is either in or out of a set
- cardinal of a set is the number of elements it contains

fuzzy sets:

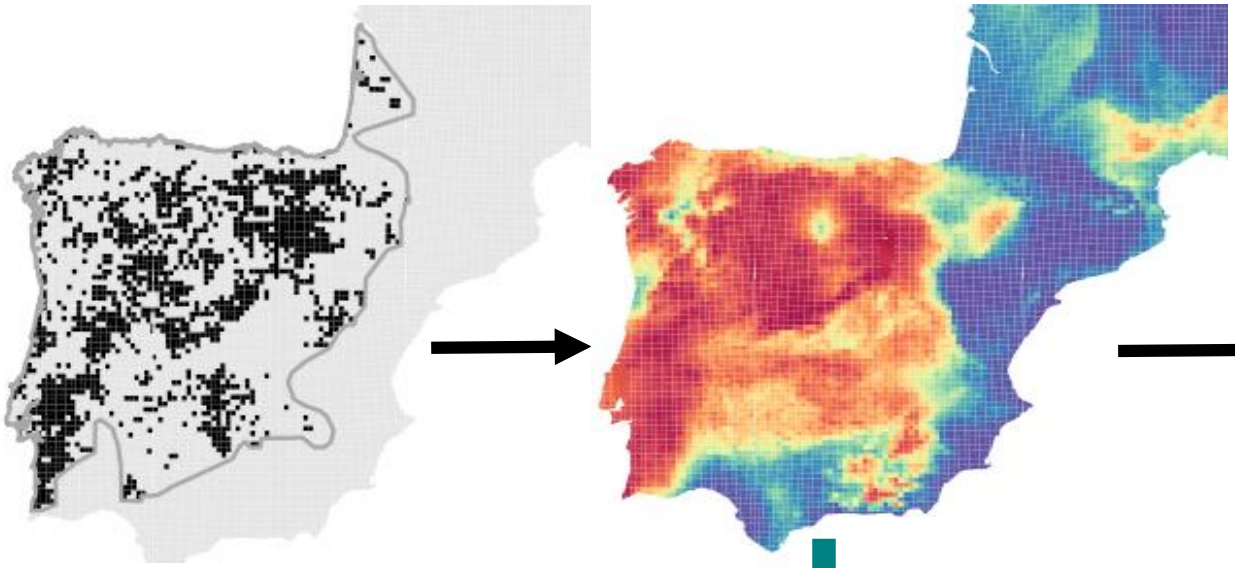
- every element belongs to every set to a certain degree
- cardinal of a fuzzy set is the sum of the degrees of membership of all elements
- intersection between a set and its complement is not null





Fuzzy species distribution

observations **favourability**



convert to binary prediction?!

degree of membership of each site to the potential occurrence area of the species

since we have fuzzy logic, we don't need to binarize model predictions to be able to operate with them and calculate e.g. potential species richness, co-occurrence, exclusion…

Classical vs. fuzzy logic

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British Ecological Society

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APPLICATION

fuzzySim: applying fuzzy logic to binary similarity indices in ecology

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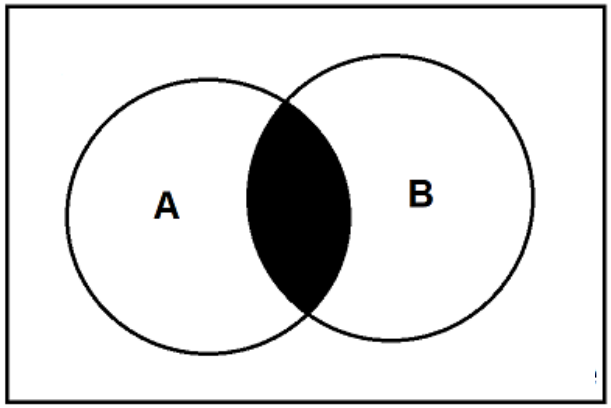
Table 1. Correspondence between the terms in the formulas of binary similarity indices for a given pair of species (sp1 and sp2) and their equivalent expressions in classical and fuzzy set theory (Zadeh 1965)

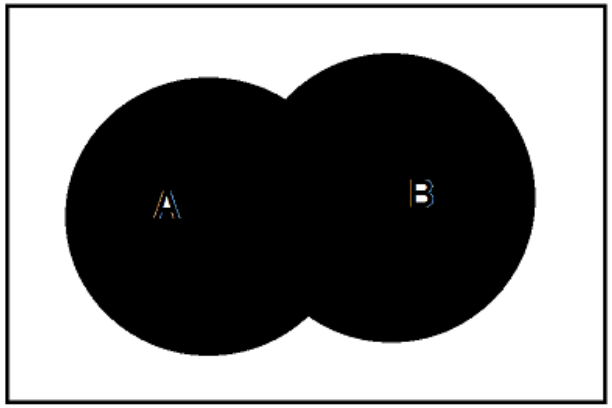
Term	Boolean logic	Classical sets	Fuzzy sets
A	sp1	sp1	sum(sp1)
B	sp2	sp2	sum(sp2)
C	sp1 AND sp2	sp1 ∩ sp2	sum(minimum(sp1, sp2))
D	NOT sp1 AND NOT sp2	complement (sp1 U sp2)	sum(1 – maximum (sp1, sp2))

Classical vs. fuzzy logic

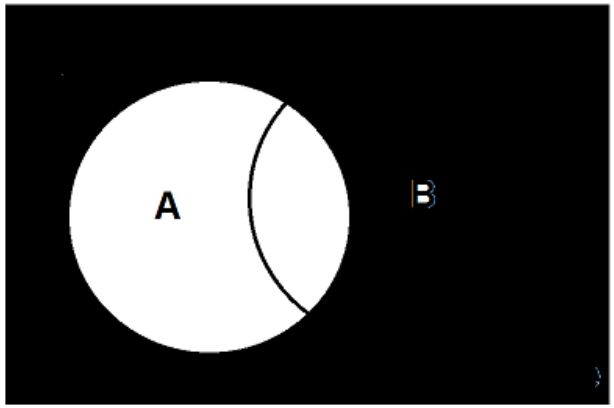
AND / INTERSECTION: minimum



OR / UNION: maximum



NOT / COMPLEMENT: 1 - value



Classical vs. fuzzy logic

Site A	Site B	A ∩ B	A ∪ B	cA	cB
0	0	0	0	1	1
0	1	0	1	1	0
1	1	1	1	0	0

Site A	Site B	A ∩ B	A ∪ B	cA	cB
0.2	0.2	0.2	0.2	0.8	0.8
0.2	0.7	0.2	0.7	0.8	0.3
0.7	0.7	0.7	0.7	0.3	0.3

PRACTICAL

```
dat$intersection <- fuzzyOverlay(data = dat,
overlay.cols = spp_cols, op = "intersection")

dat$intersection_fuzzy <- fuzzyOverlay(data = dat,
overlay.cols = fav_cols, op = "intersection")



dat$union_fuzzy <- fuzzyOverlay(data = dat, overlay.cols
= fav_cols, op = "union")



dat$LLnotNV_fuzzy <- fuzzyOverlay(data = dat,
overlay.cols = c("Lutlut_F", "Neovis_F"), op = "AnotB")
```