APPLIED LANDSCAPE ECOLOGY

Ecologia da Paisagem Aplicada 2024

Class Schedule

Date	Theoretical	Practical
21 February	Course presentation	Preparation of practical class and group assignments
28 February	Patterns of points in the landscape; the scale effect	Practical example: analysis of fire ignitions with quadrat approach. Distribution, quantification and aggregation index;
6 March	Analysis of landscape selectivity for points and polygons	Practical example: wildfire (ignitions points and burned areas) selectivity per land cover class; Quantification of fire extent and burned area; wildfire selectivity per land cover class; comparing with data on fire ignitions; discussion of results.
13 March	Polygon Shape patterns. Conclusion of the previous exercises	Practical example: Fire extent and burned scars, shape index analysis and discussion. Example of other applications (wildlife management)
20 March	Line patterns; distributions, density and other attributes	Practical example: Hedgerow typology in agricultural landscape matrix. Implications for management; Preparing first group presentation; doubts clarification
27 April	**Férias da PÁSCOA -- Easter holidays**	**Férias da PÁSCOA -- Easter holidays**
3 April	Landscape composition and structure; fragmentation and connectivity	Practical example: composition quantification (e.g., richness, diversity) and configuration metrics (patch size, shape, edges etc..); scale and grain or resolution effects; Preparing first group presentation; doubts clarification
10 April	First Assignment – Group presentation and discussion	First Assignment – Group presentation and discussion
17 April	Classes, academic break	
24 April	Landscape composition and dynamics; Evaluation of landscape changes using Markov transition matrices;	Practical example: landscape composition in different periods; fire as a driver of landscape dynamics;
1 May	Holiday, day off – Labour day	
8 May	Landscape dynamics; Forecasting and Backcasting	Practical examples for land management and planning; preparing data for the next class exercises
15 May	Linking landscape dynamics with ecosystem services and landscape resilience	Practical examples: comparing Ecosystem services provided by a study area in different periods; management and planning implications; Preparing second group presentation;
22 May	Second Assignment – Group presentation and discussion	Second Assignment – Group presentation and discussion
29 May	Examples of landscape ecology applications – invited speakers	Preparation of individual assignments
5 june	Individual assignment – presentation and discussion – semester evaluation	

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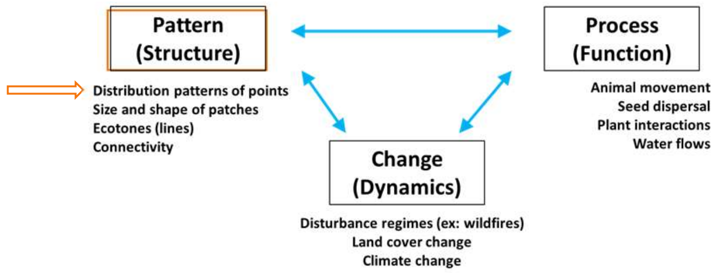
TODAY….



MODULE 1 - ANALYSIS OF PATTERNS TO UNDERSTAND PROCESSES

- Pattern distribution of points, using square grid analysis (distribution, quantification and aggregation indices; scale effect)

Wildfires:
- **Are a landscape driver,**

and
- **Explore Resources (e.g., vegetation, habitats, food) as many animal species**

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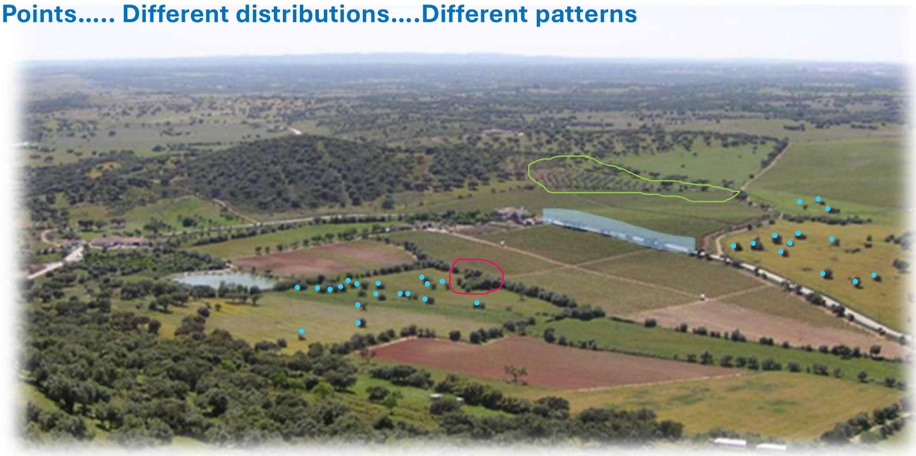
Points..... Different distributions....Different patterns



- **Point – are** landscape elements, with a geographic location, but where area is not relevant for the study of a particular organism or process

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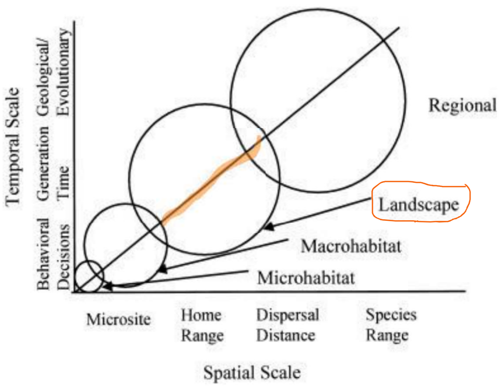
Habitats and patterns depend on the scale of analysis

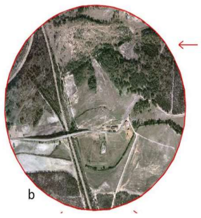


George, T. L., & Zack, S. (2001). Spatial and temporal considerations in restoring habitat for wildlife. *Restoration Ecology*, 9(3), 272-279.

Examples of scale dependency

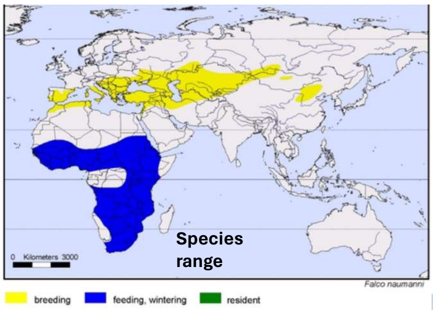
Regional (species range)
Temperature and precipitation

Landscape (metapopulation)
Land cover by tall and moist herbaceous vegetation, patch density, cover by agricultural land.



Macrohabitat (subpopulations)
Patches with tall and moist herbaceous vegetation in, e.g., temporary ponds, humid depressions, road verges.

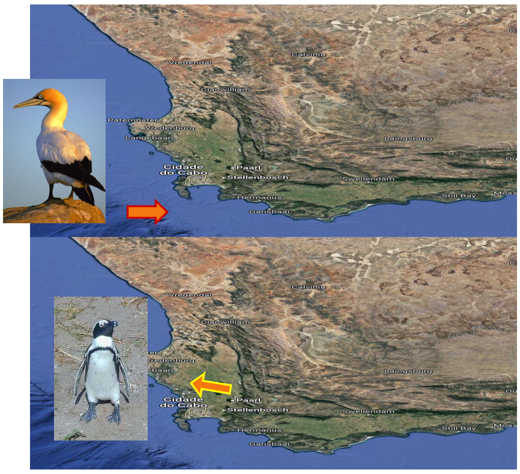
Meso/micro habitat (Home Range/Core Area)
Cover by tall grasses, sedges, rushes, reeds and shrubs.



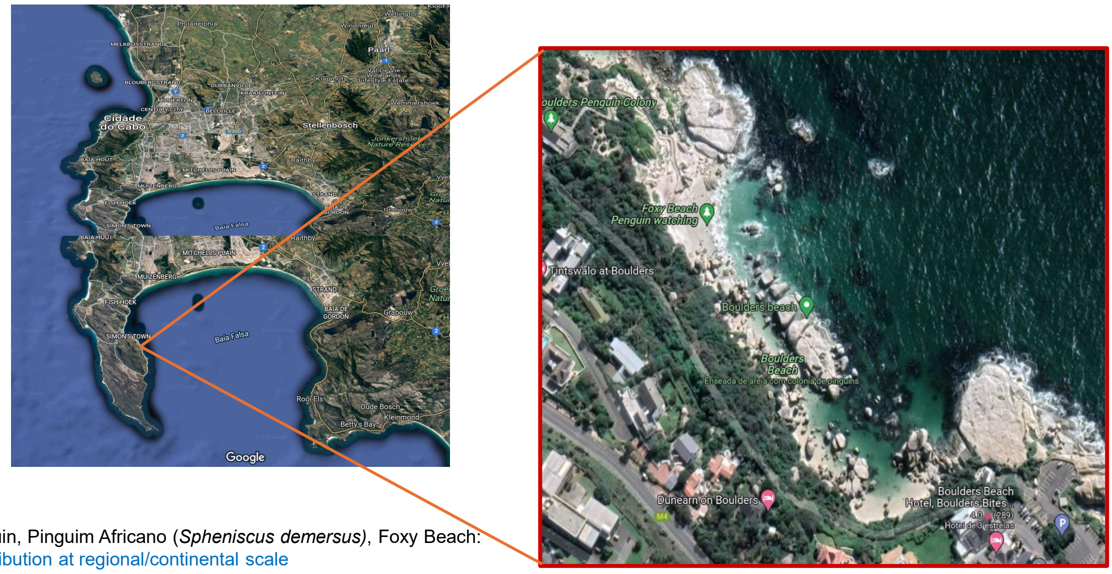
Landscape:
Feeding areas– Random distribution
Breeding area – Clustered distribution

Micro-habitat – breeding site
home range - Regular pattern

Examples of scale dependency



- ➤ Jackass penguin, Pinguim Africano (*Spheniscus demersus)*, 41000 individuos, Em perigo, LD (largely depleted)
- ➤ Cape gannet, Ganso-patola do Cabo (*Morus capensis*), Lambert's Bay, South Africa, 270 000 individuos, Em perigo, (Decreasing)



Jackass penguin, Pinguim Africano (*Spheniscus demersus)*, Foxy Beach:
Clustered distribution at regional/continental scale

Jackass penguin, Pinguim Africano (*Spheniscus demersus)*, 41000 individuals, Endangered, LD (Largely Depleted, IUCN, 2021)

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A question of scale of analysis:

Jackass penguin, distribuição:
- Africa (all Range) - few populations: clusters/ agregada,
- Foxy beach – distribuição aleatória

[Google Maps]

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A question of scale of analysis:

Jackass penguin, distribution pattern

- sandy areas, breeding territories: regular distribution; pattern dependent of the distance between nests

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A question of scale of analysis:

Cape gannet (*Morus capensis*), Ganso-patola, Lambert's Bay, South Africa (Bird Island Nature Reserve)

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A question of scale of analysis:

Cape gannet, distribution pattern

- rocky shores: random distribution pattern;

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A question of scale of analysis:

Cape gannet, ganso patola – padrão de distribuição

- Rocky substrate: regular distribution according to the distance between nests

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Key points

❖ Patterns where some important underlying factors with no random spatial variation are in place:

- **A regular pattern** is created by processes where the placement of a point has a negative influence on the nearby placement of any other point (corresponds to an antagonistic relation, or competition for limiting factors

- **Clustered pattern** is created by processes where the placement of a point has a positive influence on the nearby placement of any other point (corresponds to a symbiotic, synergistic relation, gregarious behaviour, contagium processes)

❖ In the absence on important causal factors or when there is a random variation of underlying factors:

- A random distribution and pattern, can be created if the placement of any point has no influence on the placement of any other point. It may depict homogenous environmental conditions (e.g. sufficient feeding resources, or habitat); no selective behaviour between individuals

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Key points

The detection of the pattern can be determined by two sampling methods:

Both compare the Observed pattern with a known distribution

1. The **nearest neighbour (distance) method** (método da distância ao vizinho mais próximo), is a comparison between the distances measured between points and their nearest neighbours, with the distances that would be expected if the points were randomly placed)

   Uses the concept of area per point

2. The **quadrat method (**método das quadrículas **)**assess the variance/mean ratio of the number of points per quadrat as an index of clustering (Agregation Index, AI)

   Applies the concept of point per area

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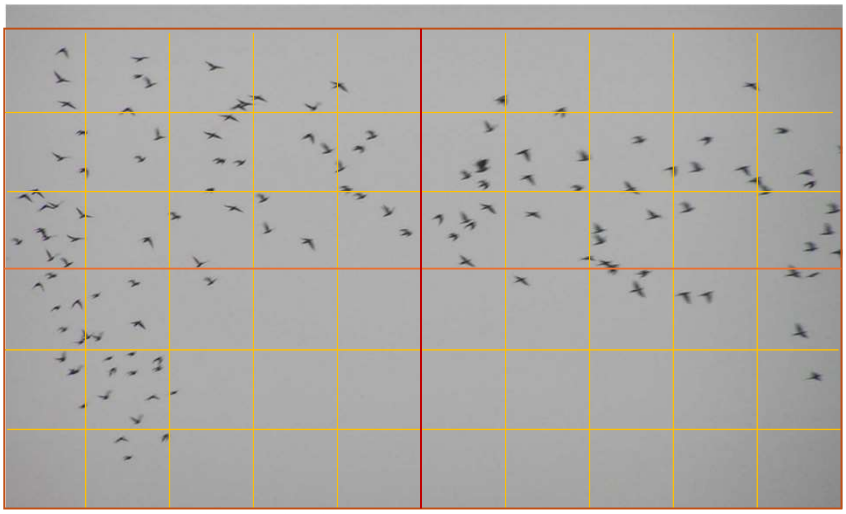
➢ How to decide about the pattern type?

- We can make a grid (quadrat grid) and analyse the point distribution (taking into consideration the number and its variability and dispersion across the grid)



Flock of pigeons during winter migration migration (bando de Pombo-torcaz) durante as migrações invernais

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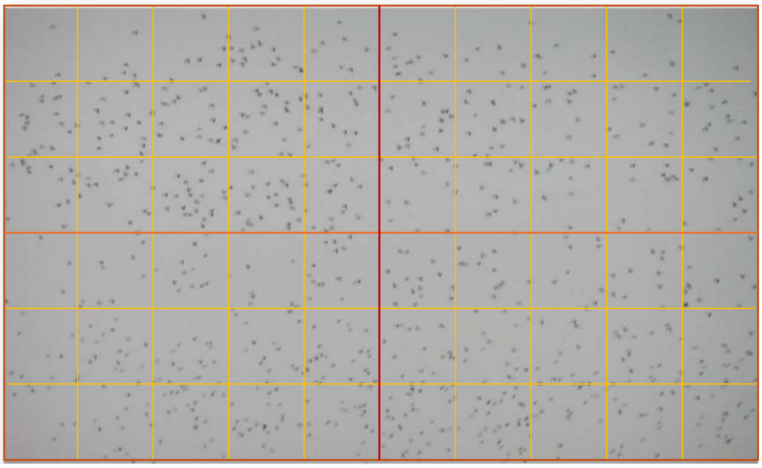
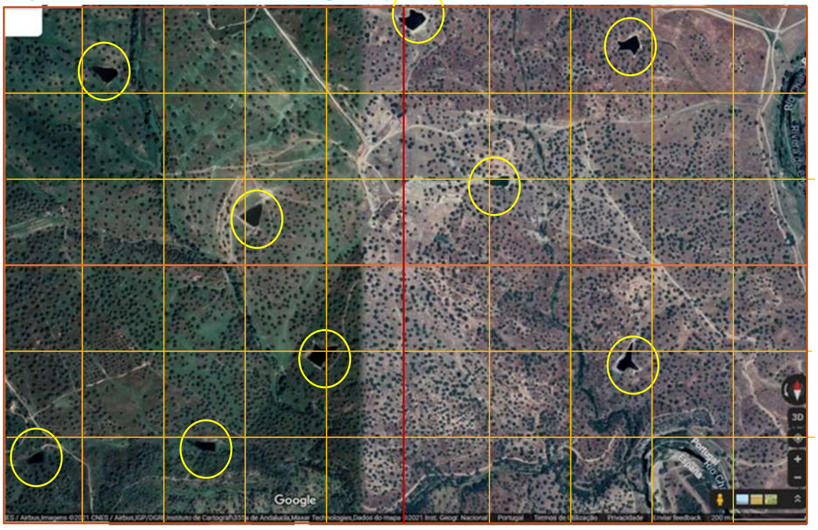
➢ How to decide about the pattern type?

- Compare the observed results with a typical random distribution and see if they differ (e.g., if there is a distribution pattern or not) – we will use a statistical approach with the Poisson distribution



Flock of pigeons during winter migration (bando de Pombo-torcaz) durante as migrações invernais

- **Water points in the landscape:** a random or regular distribution?
- **Holm oak trees in the landscape:** random, clustered or regular pattern?



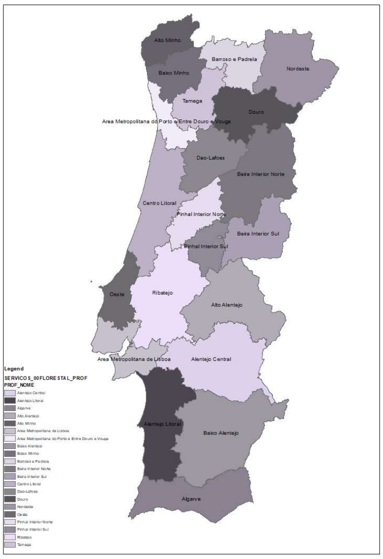
Part 2 – Practical exercises

SELECTION OF STUDY AREA TO PERFORM COURSE EXERCISES

Regiões PROF (Programas Regionais de Ordenamento Florestal)
(Administrative Regions for Forest Planning and management)
http://www2.icnf.pt/portal/florestas/profs

7 Active PROFs (after a revision in 2019 of the 21 former PROFs):
EDM - Entre Douro e Minho;
TMAD - Trás-os-Montes e Alto Douro;
CI - Centro Interior;
CL - Centro Litoral;
LVT - Lisboa e Vale do Tejo;
ALT - Alentejo;
ALG – Algarve

Each working group needs to select one region
(among the former 21)



PROF - sub-regiões (icnf.pt)

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Part 2 – Practical exercises

Working in groups (of 4 students)
Trabalho de grupo (4 elementos)

Distribution by groups

Student Name	Group	PROF selected
Carolina Gonçalves	1	Alto Alentejo
Joana Rodrigues	1	Alto Alentejo
Marlene Rebelo	1	Alto Alentejo
Satoshi Senda	1	Alto Alentejo
Emilly Goedert	2	Beira Interior Norte
Irakli Gabunia	2	Beira Interior Norte
Evelina Ståhl	2	Beira Interior Norte
Rafael Carvalho	2	Beira Interior Norte
Hugo Ferreira	3	Centro Litoral
Madalena Branco	3	Centro Litoral
Pashmi Shurendra	3	Centro Litoral
Sofia Berlanda	3	Centro Litoral
Joanna Hubka	4	Algarve
Wiktoria Stachura	4	Algarve
Mariana Gomes	4	Algarve
Giovanna Silva	4	Algarve

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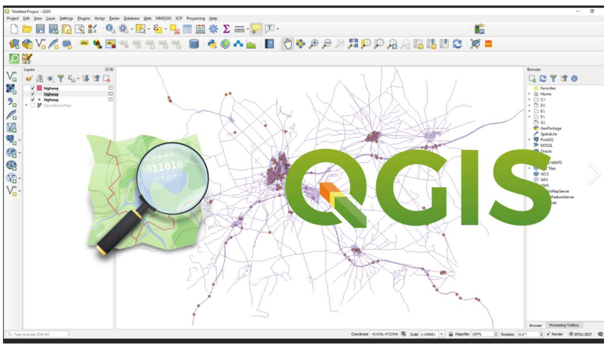
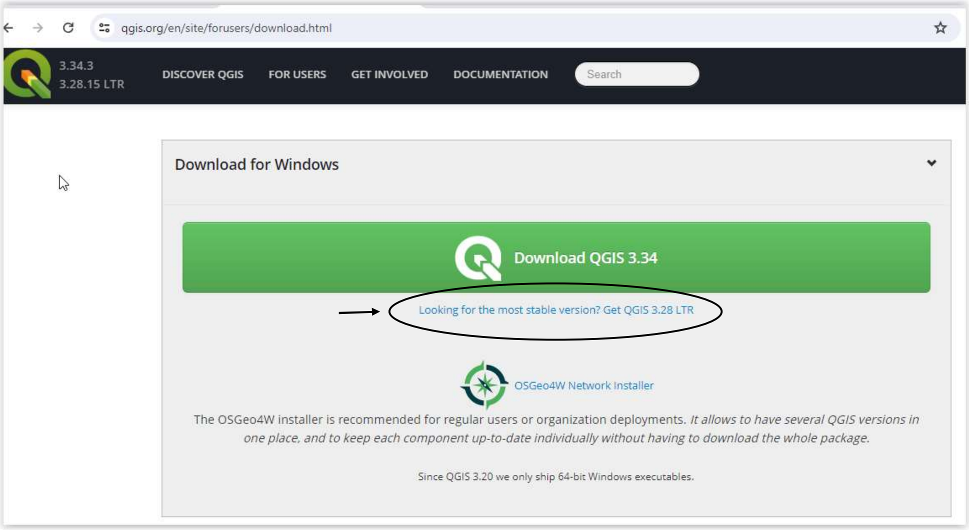
DOWNLOAD AND INSTALL QGIS
https://www.qgis.org/en/site/forusers/download.html

- Computer
- GIS software (preferably QGIS; ArcGIS can also be used, if preferred)





2 – Practical exercise - **Pattern of points distribution**

We will use fire ignition as point elements to analyse its spatial distribution

Objectives:

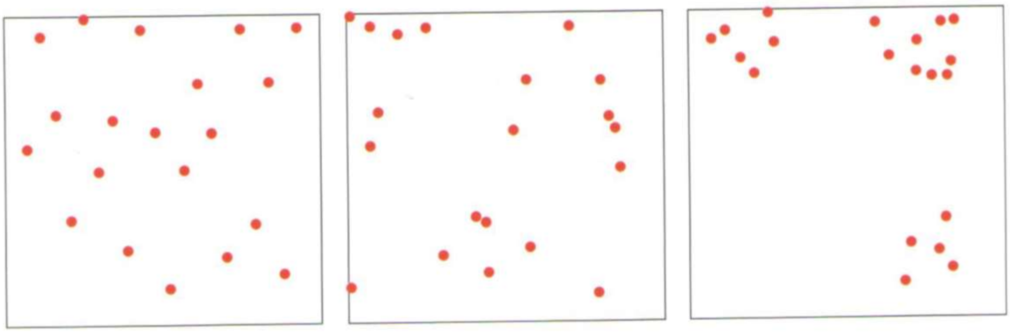
- Analysis of the pattern of fire ignition points in the landscape, using the quadrat method;
- Quantify and evaluate an Aggregation index;
- Use the *Poisson* distribution to estimate expected frequencies of points (if the process involved was random) and compare with observed frequencies;
- Evaluate the scale effect in the distribution pattern analysis.

Questions:

- Does the distribution of fire ignitions follow a pattern?
- How is the scale of analysis affecting the observed pattern?

Fire ignition points: analysis with the quadrat method

- Three types of distribution points



Regular | **Aleatório,** random | **Agrupada, agregada;** clustered or aggregated

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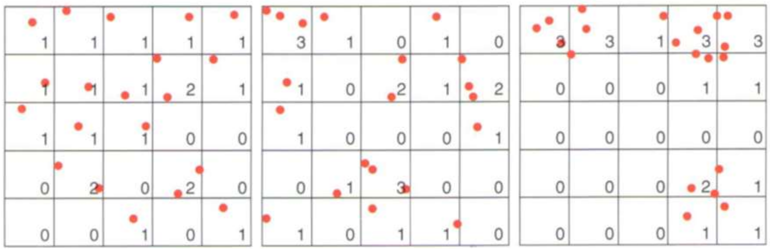
Fire ignition points: analysis with the quadrat method



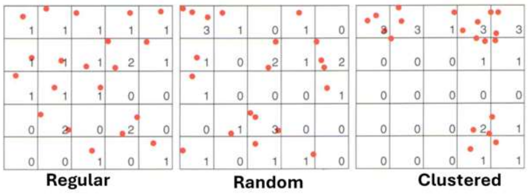
Regular | **Random** | **Clustered**

Total number of ignition points = n (= 20 in the above figure)
Total number of squares= Q (= 25 in the figure above)

Mean = n / Q = 0.8
Variance = $\sum (x_i - \text{Mean})^2 / Q$, with x_i *number of points in the square i*

The mean is the same for the 3 square grids, but variance is different. Thus, higher aggregations corresponds to higher variability in the distribution of points (thus, higher variance)

Fire ignition points: analysis with the quadrat method



Variance/Mean can be used as an Aggregation Index (AI)

$$(AI) = \frac{Variance}{Mean}$$

- If point distribution fallows a **regular pattern, uniform AI < 1**
- If point distribution fallows **random pattern AI = 1**
- If point distribution fallows **a clustered pattern AI > 1**

Comparing with the Poisson distribution (which describe a random process)

We can compare the observed distribution of points with the expected distribution, if the pattern is random, but with the same mean value.

This approach, uses the *Poisson* distribution, a statistical distribution for describing random processes; for estimate the number of expected square grids with x points (see previous examples). The *Poisson* distribution is frequently used to estimate frequencies in time and/or space.

- **Observed square grids frequency:** number of square grids with a given number (x_i) of ignition points
- **Expected frequency of square grids if all ignition points where random distributed:** estimated number of grid cells with a given number of ignitions (x_i) , according to the *Poisson distribution*

Other statistical tests can be done to analyze and check the observed patterns (see suggested references).

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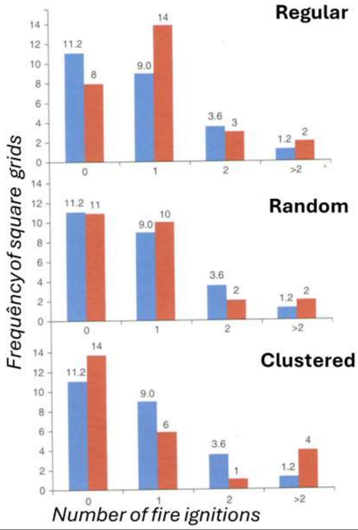
Comparing data results with the Poisson distribution (random process)



$$\textbf{Poisson (x)} = \frac{e^{-\mu}\,\mu^{x}}{x!}$$

$$\textbf{Poisson f(x)} = \sum f(x) * \frac{e^{-\dot{X}}\,\dot{X}^{x}}{x!}$$

μ = mean for Poisson distribution
Ẋ = mean for observed dstribution
x = number of observed ignitions
f(x) = frequency (number of quare grids)

Observed frequency of squares

Expected frequency of square grids, according to the Poisson distribution

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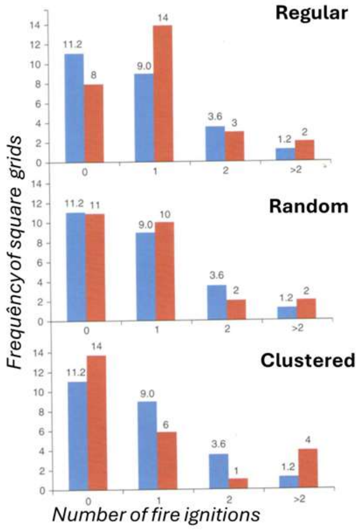
Comparing data results with the Poisson distribution (random process)



Regular: Empty grid cells (zero ignitions) is lower than expected;

The number of observed grid cells with 1 ignition is higher than expected

Random: Expected and observed frequencies are similar

Clustered: More extreme values, with observed grid cells empty and others with high number of ignition points (>2) more common than expected

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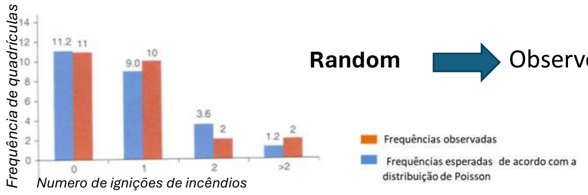
How to find statistical significance of your results (if your data have a pattern or not?)



Random ➡ Observed and Expected frequencies are similar

For each region you can perform a frequency test - Chi-square test (Qui-quadrado = χ^2) to evaluate the statistical significance, robustness of each conclusion):

i.e., comparing observed frequencies of each study area with the expected frequencies, if the process was random (obtained using the Poisson distribution)

$$X^2 = \sum_{i=1}^{n} \frac{(o_i - e_i)^2}{e_i}$$

We will test:

How good the sample fits to Poisson distribution type? i.e. if there is a sigificant fit, then we can say that ignition points are randomly distributed in the landscape, with no specific pattern

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1. **Fill the table**
2. **Count the number of square grids with 0, 1, 2 and >2 ignitions**

$$X^2 = \sum_{i=1}^{n} \frac{(o_i - e_i)^2}{e_i}$$

nr of ignitions per cell grid	Observed values (o_i)	Expected values (e_i) - Poisson	Chi-square X^2 (observed –expected)²/expected
0			
1			
2			
>2			
TOTAL (∑)			

3. **Use the Chi square test - Qui-quadrado = χ^2**

Para cada categoria (i.e., intervalo de valores) de numero de ignições, obter a diferença entre o número observado e o esperado, elevar ao quadrado e dividir pelo numero (a frequência) esperado; o X^2 é o somatório dos valores obtidos para todas as categorias.

4 – Compare the total value obtained with the value in the table according to the Chi-square function and degrees of freedom

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$$X^2 = \sum_{i=1}^{n} \frac{(o_i - e_i)^2}{e_i}$$

Degree of freedom (df): Number of categories (n) -1.

Obtenha os valores do $\chi 2$ nas tabelas desta estatística (próximo slide) ou no Excel para graus de liberdade = nº de categorias-1 e 95% de confiança (i.e., probabilidade de erro de 5%, p=0,05).
Compare com os valores obtidos nas tabelas dos exercicios mediante as seguintes hipóteses:

H_0, se $\chi 2$(exercício) < $\chi 2$ (tabelado), não existem diferenças significativas entre a distribuição de frequências do numero de ignições e a distribuição aleatória (random) com a Poisson

H_1, se $\chi 2$(exercício) > $\chi 2$(tabelado), existem diferenças entre a distribuição de frequências do numero de ignições e a distribuição aleatória (random) com a Poisson – logo não é aleatória e existe um padrão

Chi-square : your data
Critical value of Chi-square: check the table

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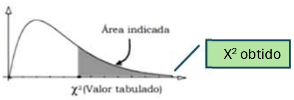
Example for a study region

Tabela Distribuição qui-quadrado.



gl	Área na cauda superior								
	0,25	0,10	0,05	0,025	0,01	0,005	0,0025	0,001	0,0005
1	1,32	2,71	3,84	5,02	6,63	7,88	9,14	10,83	12,12
2	2,77	4,61	5,99	7,38	9,21	10,60	11,98	13,82	15,20
3	4,11	6,25	7,81	9,35	11,34	12,84	14,32	16,27	17,73
4	5,39	7,78	9,49	11,14	13,28	14,86	16,42	18,47	20,00
5	6,63	9,24	11,07	12,83	15,09	16,75	18,39	20,51	22,11
6	7,84	10,64	12,59	14,45	16,81	18,55	20,25	22,46	24,10
7	9,04	12,02	14,07	16,01	18,48	20,28	22,04	24,32	26,02
8	10,22	13,36	15,51	17,53	20,09	21,95	23,77	26,12	27,87
9	11,39	14,68	16,92	19,02	21,67	23,59	25,46	27,88	29,67
10	12,55	15,99	18,31	20,48	23,21	25,19	27,11	29,59	31,42
11	13,70	17,28	19,68	21,92	24,73	26,76	28,73	31,26	33,14
12	14,85	18,55	21,03	23,34	26,22	28,30	30,32	32,91	34,82
13	15,98	19,81	22,36	24,74	27,69	29,82	31,88	34,53	36,48
14	17,12	21,06	23,68	26,12	29,14	31,32	33,43	36,12	38,11
15	18,25	22,31	25,00	27,49	30,58	32,80	34,95	37,70	39,72
16	19,37	23,54	26,30	28,85	32,00	34,27	36,46	39,25	41,31
17	20,49	24,77	27,59	30,19	33,41	35,72	37,95	40,79	42,88
18	21,60	25,99	28,87	31,53	34,81	37,16	39,42	42,31	44,43
19	22,72	27,20	30,14	32,85	36,19	38,58	40,88	43,82	45,97
20	23,83	28,41	31,41	34,17	37,57	40,00	42,34	45,31	47,50
21	24,93	29,62	32,67	35,48	38,93	41,40	43,77	46,80	49,01
22	26,04	30,81	33,92	36,78	40,29	42,80	45,20	48,27	50,51
23	27,14	32,01	35,17	38,08	41,64	44,18	46,62	49,73	52,00
24	28,24	33,20	36,42	39,36	42,98	45,56	48,03	51,18	53,48
25	29,34	34,38	37,65	40,65	44,31	46,93	49,44	52,62	54,95
26	30,43	35,56	38,89	41,92	45,64	48,29	50,83	54,05	56,41
27	31,53	36,74	40,11	43,19	46,96	49,65	52,22	55,48	57,86
28	32,62	37,92	41,34	44,46	48,28	50,99	53,59	56,89	59,30
29	33,71	39,09	42,56	45,72	49,59	52,34	54,97	58,30	60,73
30	34,80	40,26	43,77	46,98	50,89	53,67	56,33	59,70	62,16
35	40,22	46,06	49,80	53,20	57,34	60,27	63,08	66,62	69,20
40	45,62	51,81	55,76	59,34	63,69	66,77	69,70	73,40	76,10
45	50,98	57,51	61,66	65,41	69,96	73,17	76,22	80,08	82,87
50	56,33	63,17	67,50	71,42	76,15	79,49	82,66	86,66	89,56
100	109,1	118,5	124,3	129,6	135,8	140,2	144,3	149,4	153,2

Nota: A coluna em destaque é a mais usada.

$$X^2 = \sum_{i=1}^{n} \frac{(o_i - e_i)^2}{e_i}$$

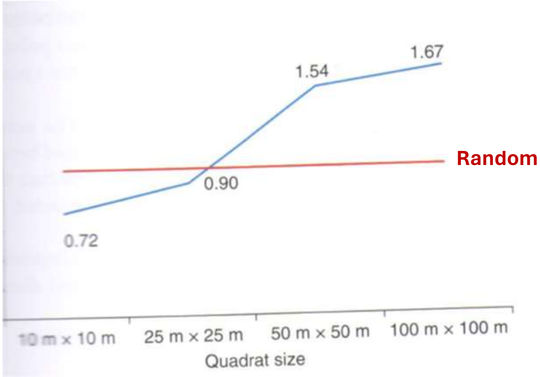
Procurar na tabela o valor para 3 gl (=4 categorias -1) e 0,05 (= 1-95% de probabilidade dos valores para a região serem semelhantes ao esperado):
Ex: O valor tabelado 3 gl =7,81
O valor obtido =204,47

Então, X^2 =204,27>> que X^2 = 7,81

há diferença entre o observado e a distribuição aleatória (a de Poisson)

logo há um padrão (para p ≤0,05)

Scale effect on the pattern of point distribution



Aggregation Index (Variance/Mean) varies according to the grid

The graph illustrates a change in the distribution pattern: from a regular distribution at short distances (AI <1 up 10m) to a clustered distribution at larger distances of analyses (IA > 1 up to 50 m), and near a random distribution at intermediate distances (IA near de 1 up to 25 m).

The detection of pattern at different scales can help clarifying about processes affecting points in the landscape.

Scale effect on the distribution pattern of fire ignitions

Square grid size	MEAN	VARIANCE	Ratio Variance/Mean (Aggregation Index)
10 m x 10 m	0.55	0.40	0.72
25 m x 25 m	3.42	3.08	0.90
50 m x 50 m	13.66	21.04	1.54
100 m x 100 m	54.63	91.23	1.67

Using different square grid sizes to measure the number of points, implies a change in the aggregation index. Thus, the scale of analysis determine the distribution pattern.

According to the above example, the point pattern is regular (AI < 1) when the analysis is made with smaller size grid cells, whereas, the pattern is considered clustered, when using larger grid cells (AI > 1).

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Influence of scale on the distribution pattern of points

Results from study regions – practical exercise

PROF Region	Quadrat Size	Mean	Aggregation Index
Alto Minho	1000x1000 m	0,56	2,67
	2000x2000 m	2,25	4,40
Centro Litoral	1000x1000 m	0,33	3,10
	2000x2000 m	1,37	4,70
Beira Interior Norte	1000x1000 m	0,15	1,53
	2000x2000 m	0,60	2,02
Alto Alentejo	1000x1000 m	0,06	1,90
	2000x2000 m	0,20	2,76
Algarve	1000x1000 m	0,07	1,50
	2000x2000 m	0,29	1,94

Recall that: Mean = n / Q

n = total number of points
Q = total number of quadrats

For the Grid 1000m x 1000m, quadrat area = 1 km^2

For the Grid 2000m x 2000 m, quadrat area = 4 km^2

Therefore, there about four times more quadrats in the Grid 1000x1000 m

The mean in Grid 2000 m x 2000 m is about 4 times larger than the mean in Grid 1000 m x 1000 m

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Results from study regions – practical exercise

We can now use the results to answer our initial questions

Does the distribution of fire ignitions follow a pattern?

- Yes, fire ignitions are aggregated for all studied regions.

- Some study regions have higher aggregation of fire ignitions. Why?

(the process underlying aggregation of fire ignitions will be analyzed in class 3)

How does the distribution pattern change with the scale of analysis?

- Aggregation increases with quadrat size.

- When the quadrat area is 4 km^2 the aggregation is higher. Why? What is causing higher aggregation at 4km^2 than at 1km^2? (the process underlying aggregation of fire ignitions will be analyzed in class 3)

Influence of scale on the distribution pattern of points

Results from study regions – practical exercise

Suggestion for further analysis

Aggregation pattern (AI) can be quantified to other grid sizes and depicted in a graph as a function of grid size. Example: 3000 m x 3000 m, 4000 m x 4000 m, etc.

- Which distribution patters can we see in our results?
- Does pattern change with scale?
- Is there a scale (quadrat size) with maximum aggregation (that is, maximum value of AI)? Detection of scale of maximum aggregation can give us useful information on underlying landscape processes