

WOAH SRR-SEA capacity building on risk analysis for transboundary animal disease control purposes in Southeast Asia



Australian Government
**Department of Agriculture,
Fisheries and Forestry**

EXTRA UNIT 1

SPATIAL ANALYSIS

Department of Emerging diseases and Global health

Animal Health Research Centre (CISA)

Institute for Agronomic and Food Research (INIA)

Spain's Research Council (CSIC)

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Outline

- Introduction to Spatial Analysis in Veterinary Epidemiology and Basics of Geographic Information Systems (GIS)
- Data visualization in Geographic Information Systems (GIS)
- Exploratory spatial data analysis (ESDA)
- Introduction to SaTScan: Cluster analysis
- Interpolation and spatial smoothing techniques
- Knowledge check questions
- Resources



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PART 1

INTRODUCTION

AND GIS BASICS



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Spatial epidemiology in veterinary science

Spatial epidemiology focuses on the **geographic location of diseases to identify distribution patterns and factors influencing spread.**

This approach is crucial in veterinary medicine for diseases which require constant monitoring and identification of risk areas (such as ASF or HPAI).

Objectives of spatial epidemiological analysis are (*Pfeiffer, 2008*):

- ❖ **the description of spatial patterns,**
- ❖ **the identification of clustering of disease cases**
- ❖ **the description or prediction of disease risk**

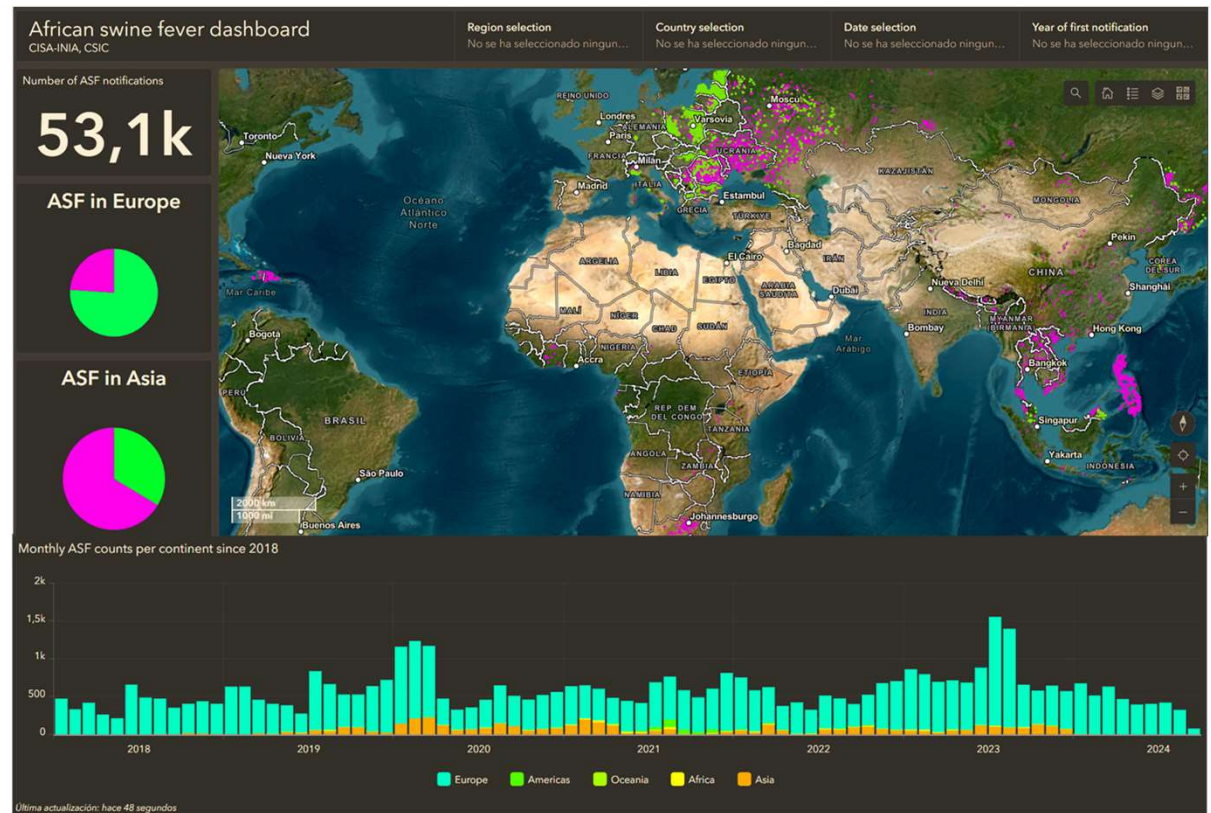


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Spatial epidemiology in veterinary science

Geographic Information Systems (GIS) provide spatial analysis tools that, along with other spatiotemporal cluster analysis tools, enable detailed studies of disease patterns across different areas and time periods, facilitating decision-making in the implementation of control measures, surveillance, and prevention in affected areas.

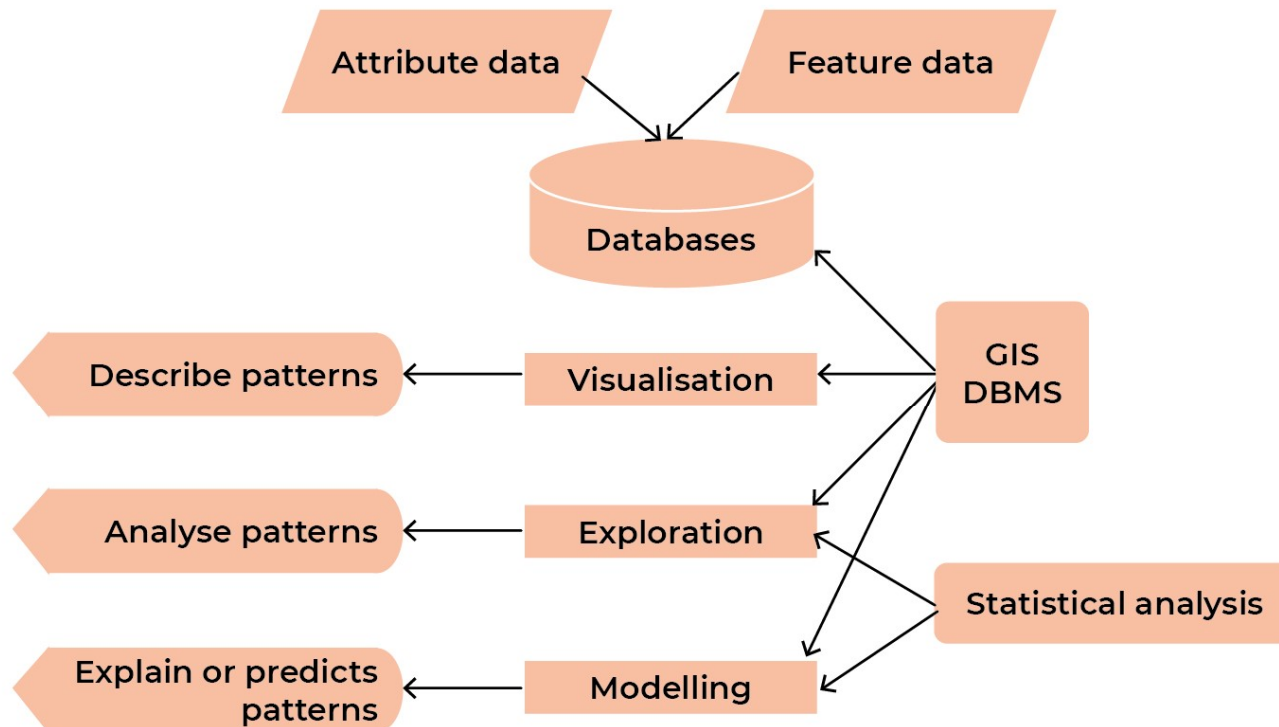


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Spatial epidemiology in veterinary science

The spatial analysis process comprises 3 steps: **visualization**, **exploration** and finally **modelling**. The last steps are helped by statistical methods



Spatial Analysis in Epidemiology,
Pfeiffer et al. 2008



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History of spatial analysis in health science



■ Pumps
● Cholera cases

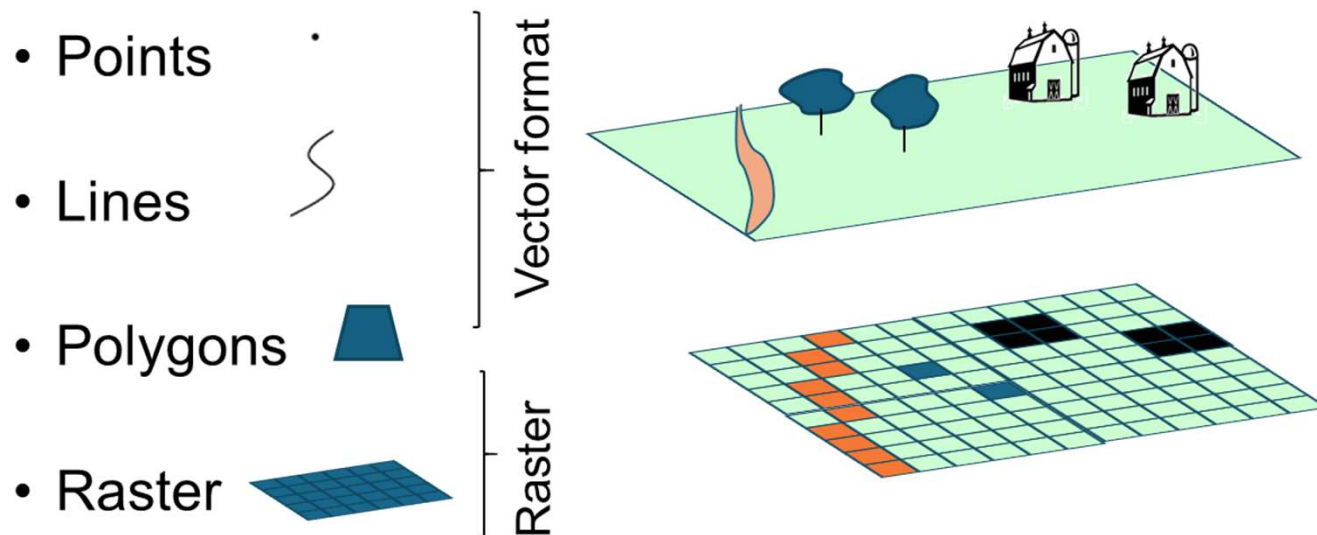


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Geographic Information Systems (GIS): Definition and components

GIS are essential tools in spatial analysis, capable of capturing, storing, managing, analyzing, and visualizing geospatial data. They facilitate understanding of disease distribution and patterns through a wide array of data represented in vector and raster formats.



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GIS Software and applications

GIS software, including paid and free programs like ArcGIS and QGIS, provides powerful tools for spatial analysis. These tools are crucial for detailed studies of disease patterns and aiding in decision-making for control, surveillance, and prevention measures.:



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Exercise 1: Exploring SARS-CoV-2 data in animals using SARS-BOARD

The SARS-BOARD, hosted by INIA-CSIC, Spain, provides an interactive tool for exploring SARS-CoV-2 outbreaks in various types of animals (captive, domestic, wild, and pets).

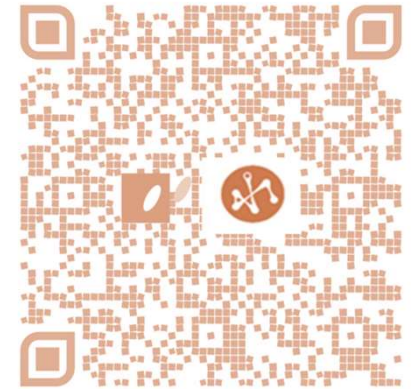
Purpose: To enable detailed examination of outbreak data across different species and regions using a dynamic dashboard.

Dashboard Features:

- Historical records of outbreaks since 2020.
- Time slider for selecting specific periods and visualizing outbreaks.
- Interactive maps and graphics detailing outbreak regions.

Data Sources:

- Outbreak data from the World Animal Health Information System (WAHIS).
- Climate data from Climate Data Online (CDO).
- Socioeconomic factors from World Bank Data.



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DATA VISUALIZATION



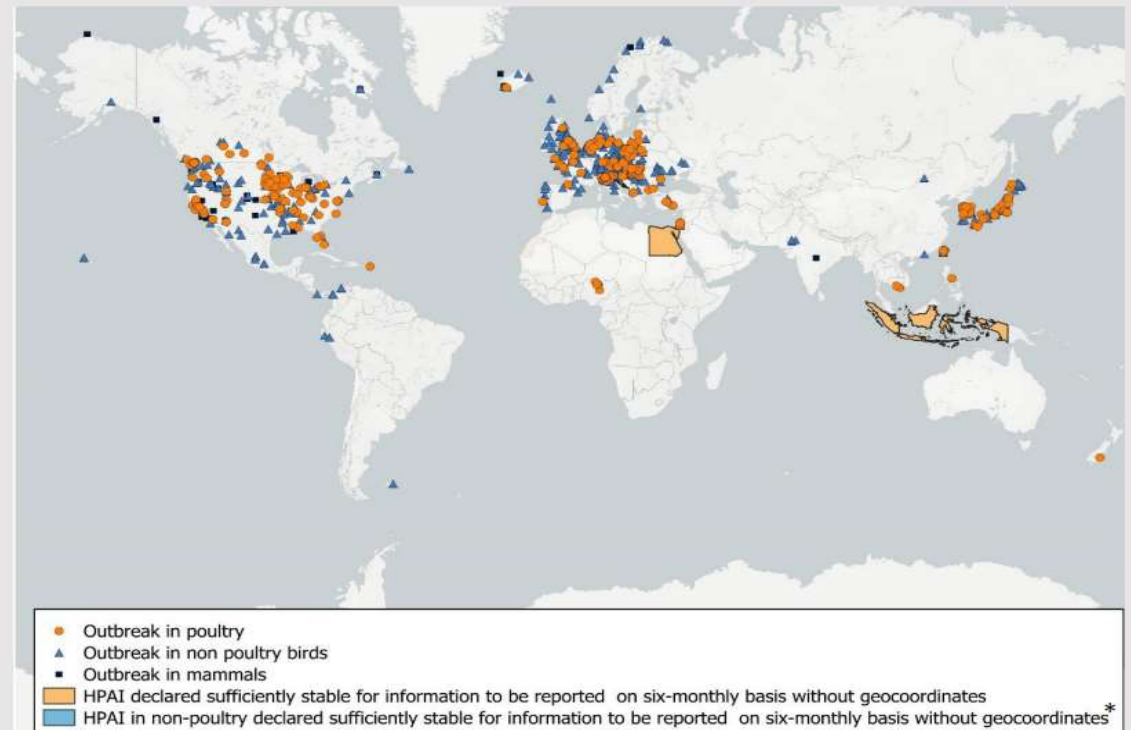
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Data visualization on maps

- ❖ **Thematic maps** are graphical representations that highlight a specific variable (e.g., case density, farm distribution, risk areas) within a geographic area.
- ❖ They are **essential for identifying geographical patterns** of diseases
- ❖ Example: *A thematic map of high pathogenic avian influenza disease presence by region/province can help identify the most affected areas.*

HPAI map for the current seasonal wave (Oct 2024-Sep 2025, as of January 2025)



Source: High Pathogenicity Avian Influenza (HPAI) –
Situation Report 67 WOA. January 2025
<https://www.woah.org/app/uploads/2025/02/hpai-report-67.pdf>



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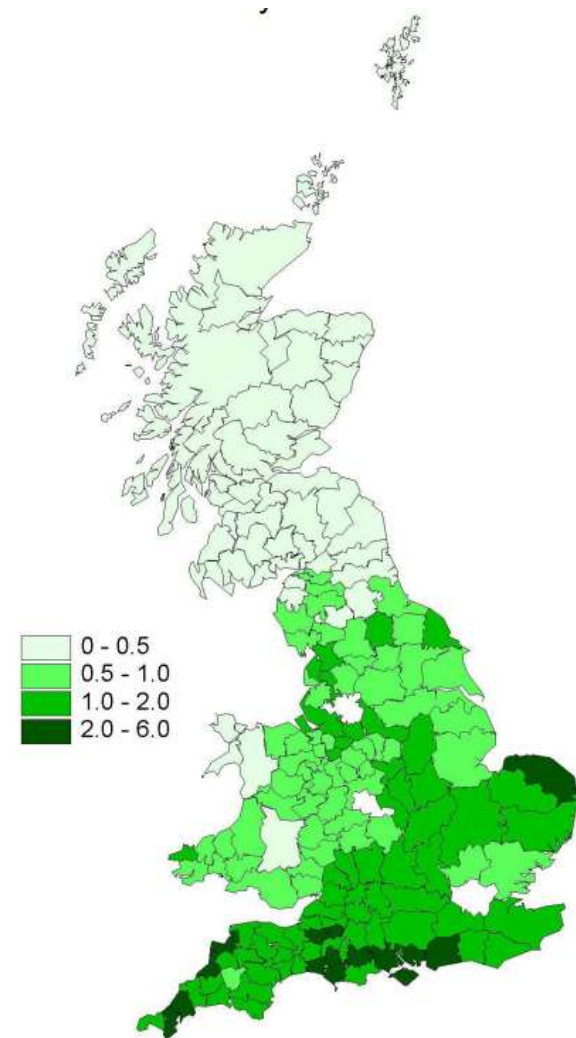


Symbolization in GIS

Symbolization encodes information through colors, sizes, and shapes.

- Colors by area: Could represent outbreak severity

Standardised morbidity ratios for BSE in British cattle born before 30 June 1988. Source: "Analysis of disease count data" of OIE Sub-Regional training on applying Geographic Information Systems (GIS) for advanced spatial analysis of animal health data 16 – 19 October, 2018



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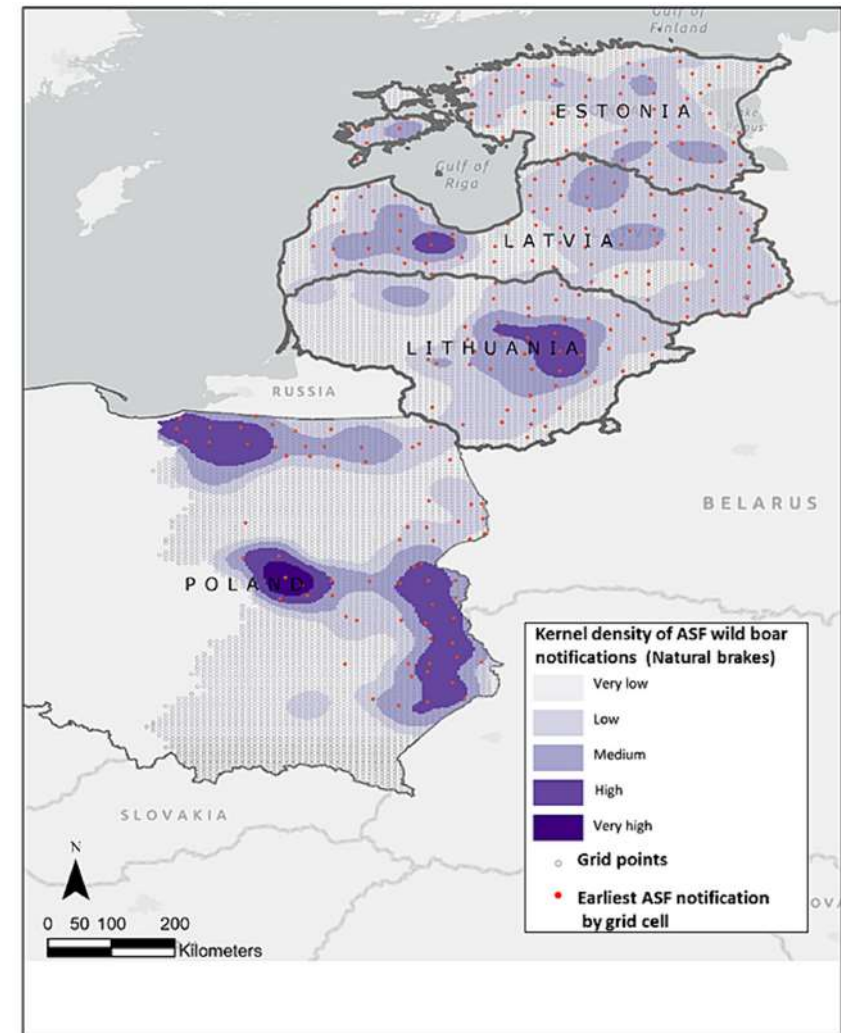
Symbolization in GIS

Symbolization encodes information through colors, sizes, and shapes.

- Colors continuous : Could represent outbreak density

Kernel density of ASF wild boar notifications from January 2014 to January 2022 in Estonia, Latvia, Lithuania and Poland (Europe) Source: Martínez Avilés M, Montes F, Sacristán I, de la Torre A and Iglesias I (2024) Spatial and temporal analysis of African swine fever frontwave velocity in wild boar: implications for surveillance and control strategies.

Front. Vet. Sci. 11:1353983. doi: 10.3389/fvets.2024.1353983



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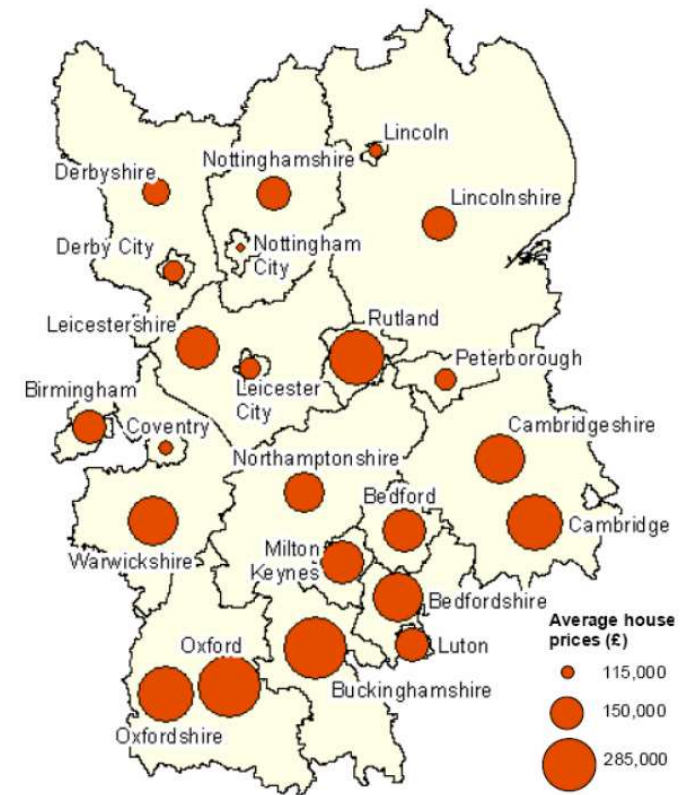


Symbolization in GIS

Symbolization encodes information through colors, sizes, and shapes.

- Point sizes: Could indicate number of infected animals at each location.

Liver fluke in dairy herds in Victoria, Australia. Point map showing the location of study herds around Maffra. The size of each point is proportional to the number of animals tested in each herd. Colour indicates the apparent fluke prevalence in each study herd. *Source: “Analysis of disease count data” of OIE Sub-Regional training on applying Geographic Information Systems (GIS) for advanced spatial analysis of animal health data 16 – 19 October, 2018*



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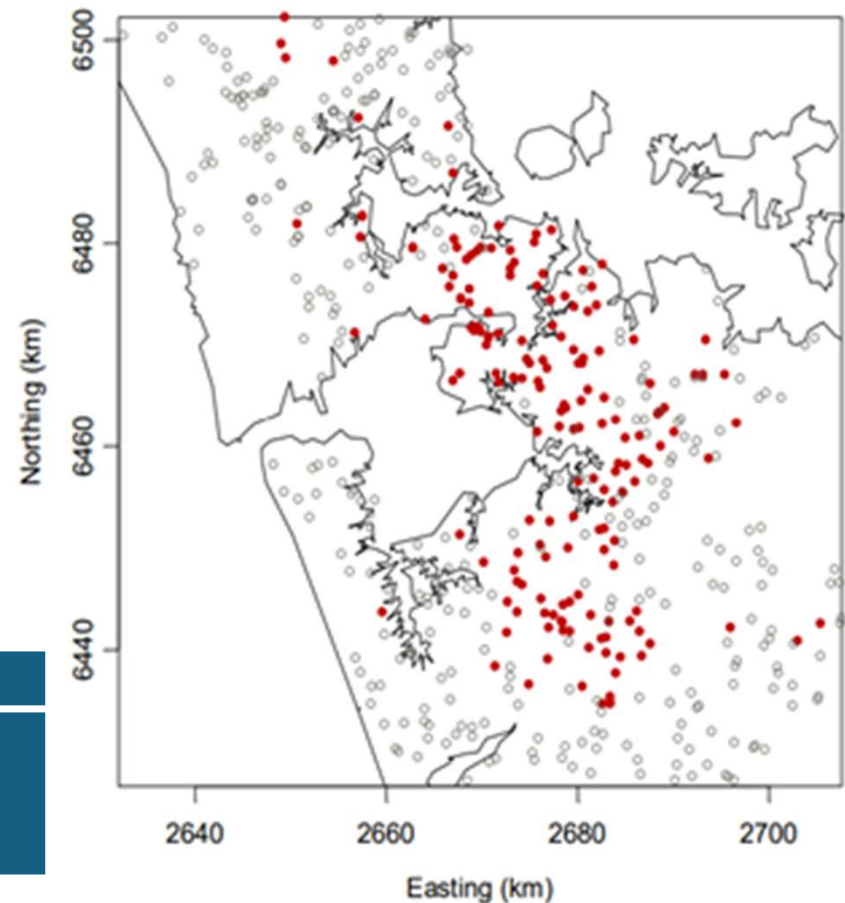


Symbolization in GIS

Symbolization encodes information through colors, sizes, and shapes.

- Point color : Could indicate type of outbreaks , presence of disease..etc

Varroa destructor in honey bees in the greater Auckland area of New Zealand.
Source: “Analysis of disease count data” of OIE Sub-Regional training on applying Geographic Information Systems (GIS) for advanced spatial analysis of animal health data 16 – 19 October, 2018



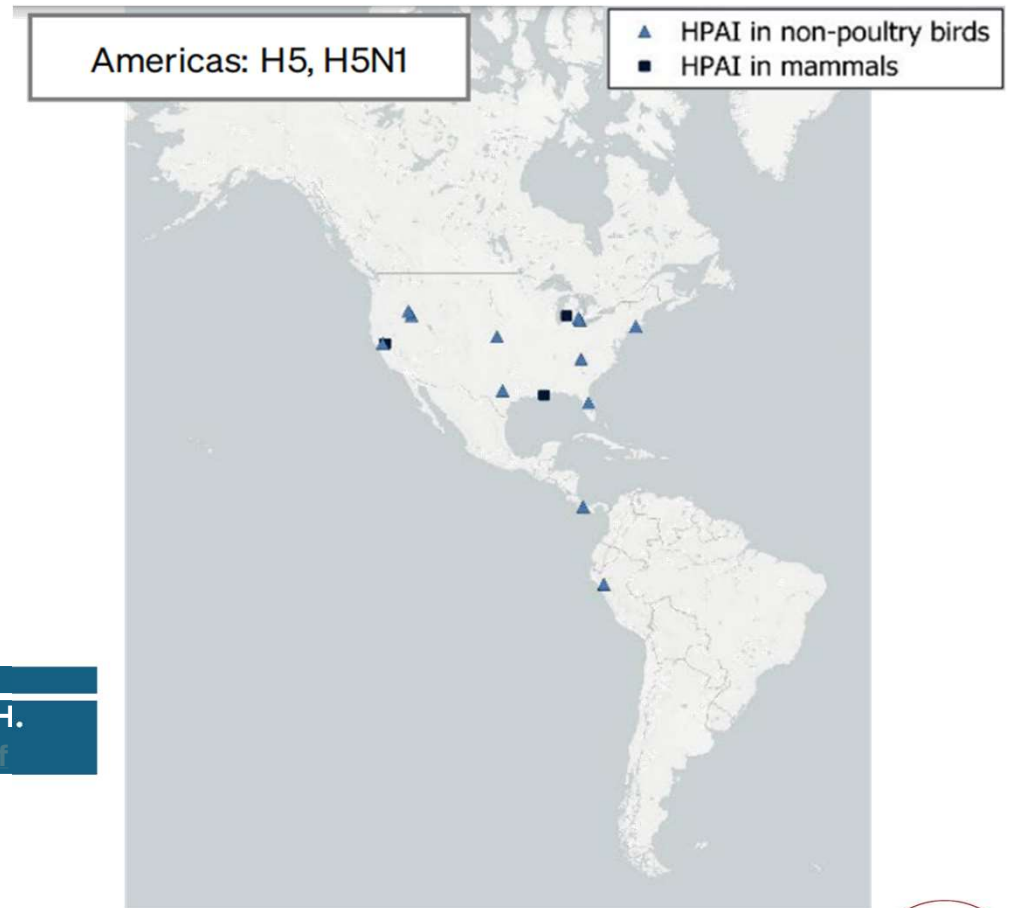
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Symbolization in GIS

Symbolization encodes information through colors, sizes, and shapes.

- Point shape : Could indicate type of outbreaks (species, diseases, etc)



Source: High Pathogenicity Avian Influenza (HPAI) – Situation Report 67 WOA. January 2025 <https://www.woah.org/app/uploads/2025/02/hpai-report-67.pdf>



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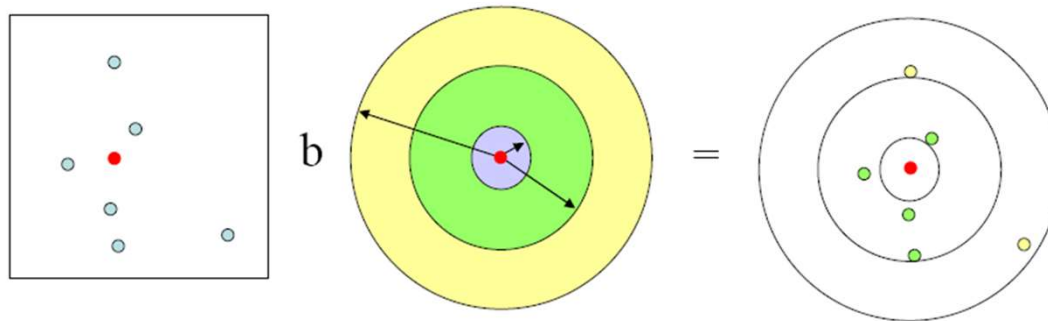
Proximity tools - Distances and buffers

❖ Distance calculation:

- Measures distances between points (e.g., infected farms) or between geographic elements (e.g., wetlands, roads, rivers) and animal population areas (e.g., farms or live animal markets).
- Essential for assessing potential disease transmission pathways.

❖ Buffers:

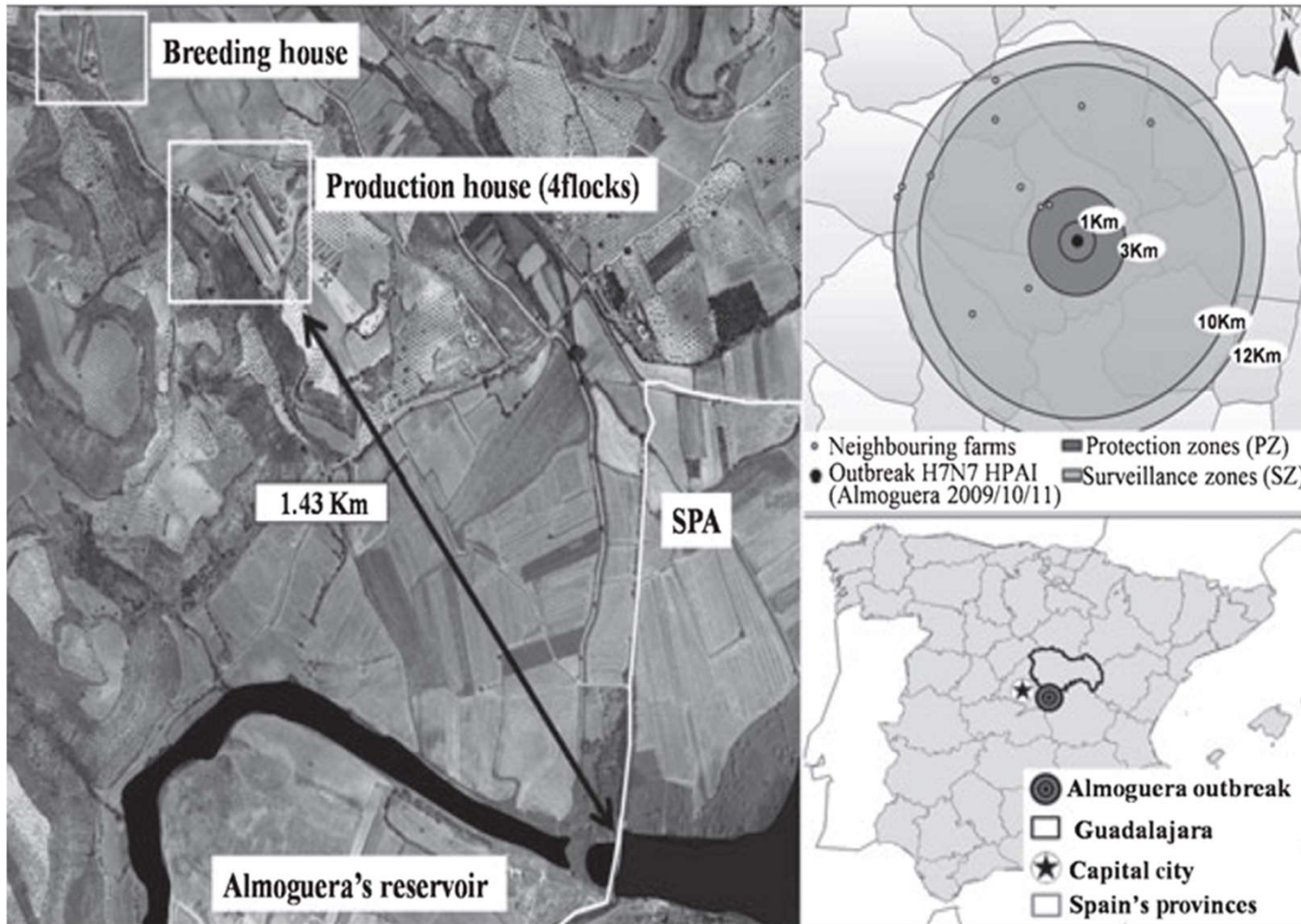
- Buffer zones are areas of influence created around a point, line, or polygon at a specified distance.
- They help identify which geographic features lie within a set proximity to an outbreak.



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Proximity tools - Distances and buffers



Left :Ortophoto of HPAI-affected holding (production house) and **distance** to the nearest reservoir, located within a SPA (Special Protection Area for birds, delimited with a white line).

Right : Neighboring farms (white dots) within the **buffers** of protection and surveillance zones (top) and the location of the HPAI outbreak in Spain (bottom).

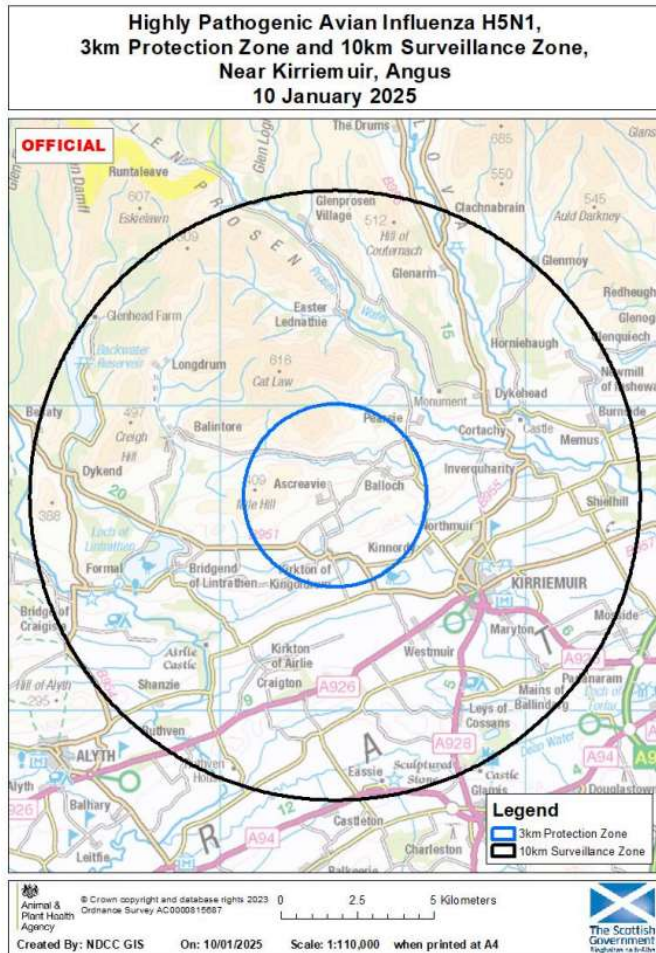
Source: Iglesias, I., Martínez, M., Muñoz, M. J., De La Torre, A., & Sánchez-Vizcaíno, J. M. (2010). First case of highly pathogenic avian influenza in poultry in Spain. *Transboundary and emerging diseases*, 57(4), 282-285.



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Application of buffers in veterinary epidemiology



Map Showing the HPAI Protection Zone and Surveillance Zone in Kirriemuir.
Source: [Scottish Government's website](#) (January 2025)



Animal Diseases | Avian Influenza | The Animal Echo | SEARCH

WHO WE ARE | WHAT WE DO | WHAT WE OFFER | MEDIA | WAHIS 7

Inicio • What we do • Standards • Codes and Manuals • Terrestrial Code Online Access

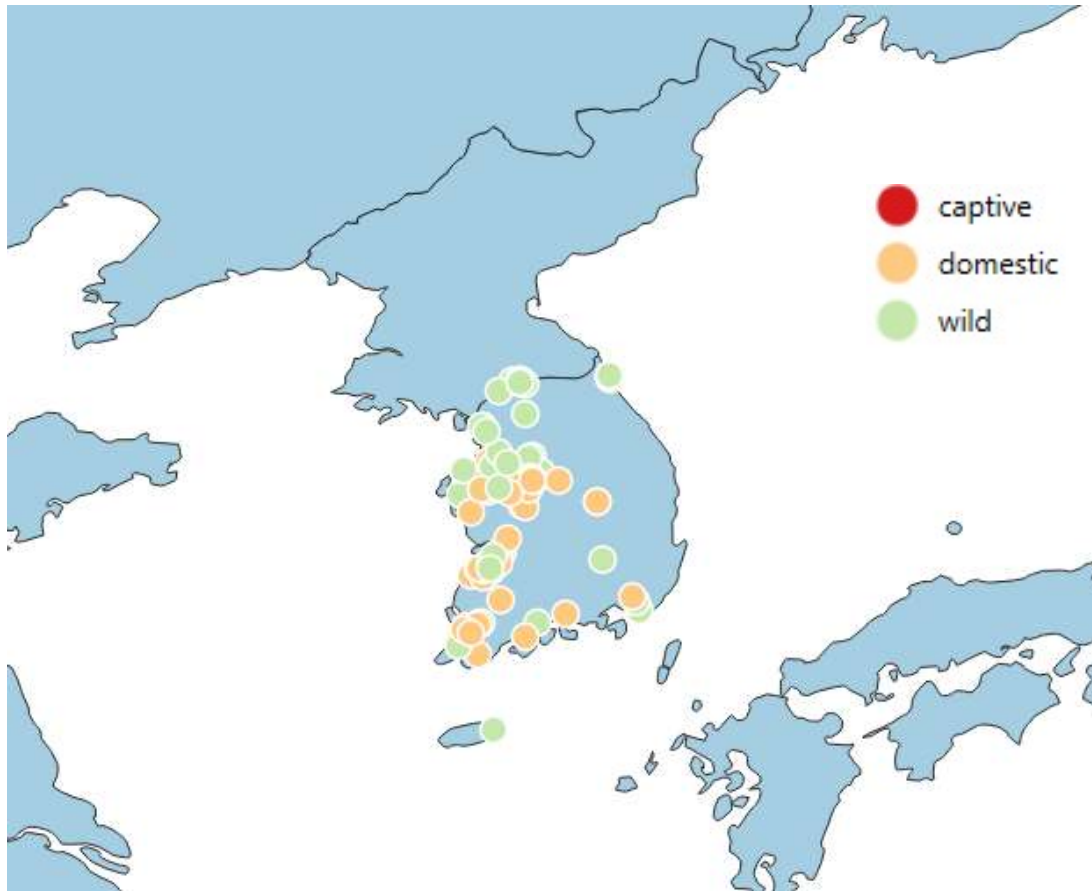
Terrestrial Code Online Access



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Exercise 1: Simbology



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DATASET

DATASET: Download Link: <https://saco.csic.es/s/bcYcx8oAqoymPyd>

The dataset consists of **two spatial layers**:

1) Countries Layer (Shapefile "**countries**"): polygons

A global shapefile containing the geographical boundaries of all countries worldwide.

Used as a reference layer for spatial analysis.

2) HPAI H5N1 Outbreaks Layer (Shapefile "**Outbreaks**"): points

Contains 396 reported outbreaks of Highly Pathogenic Avian Influenza (HPAI) H5N1 in five Asian countries (Cambodia, South Korea, Laos, Philippines, Vietnam) during 2021 and 2022. The data includes outbreak notifications from the World Organisation for Animal Health (OIE). Each outbreak point is georeferenced and represents a reported case of HPAI H5N1 in poultry or wild birds.

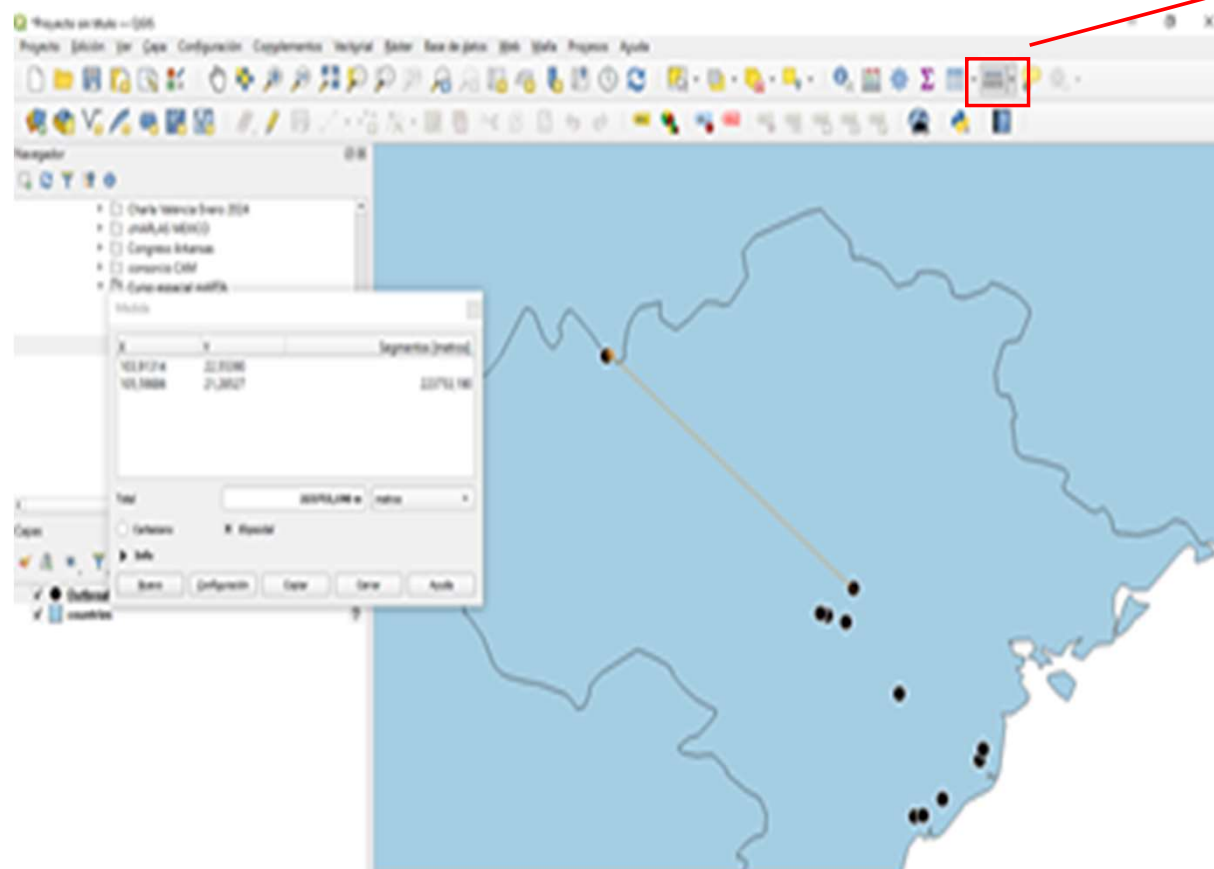
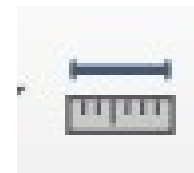
This dataset can be used for Exercises



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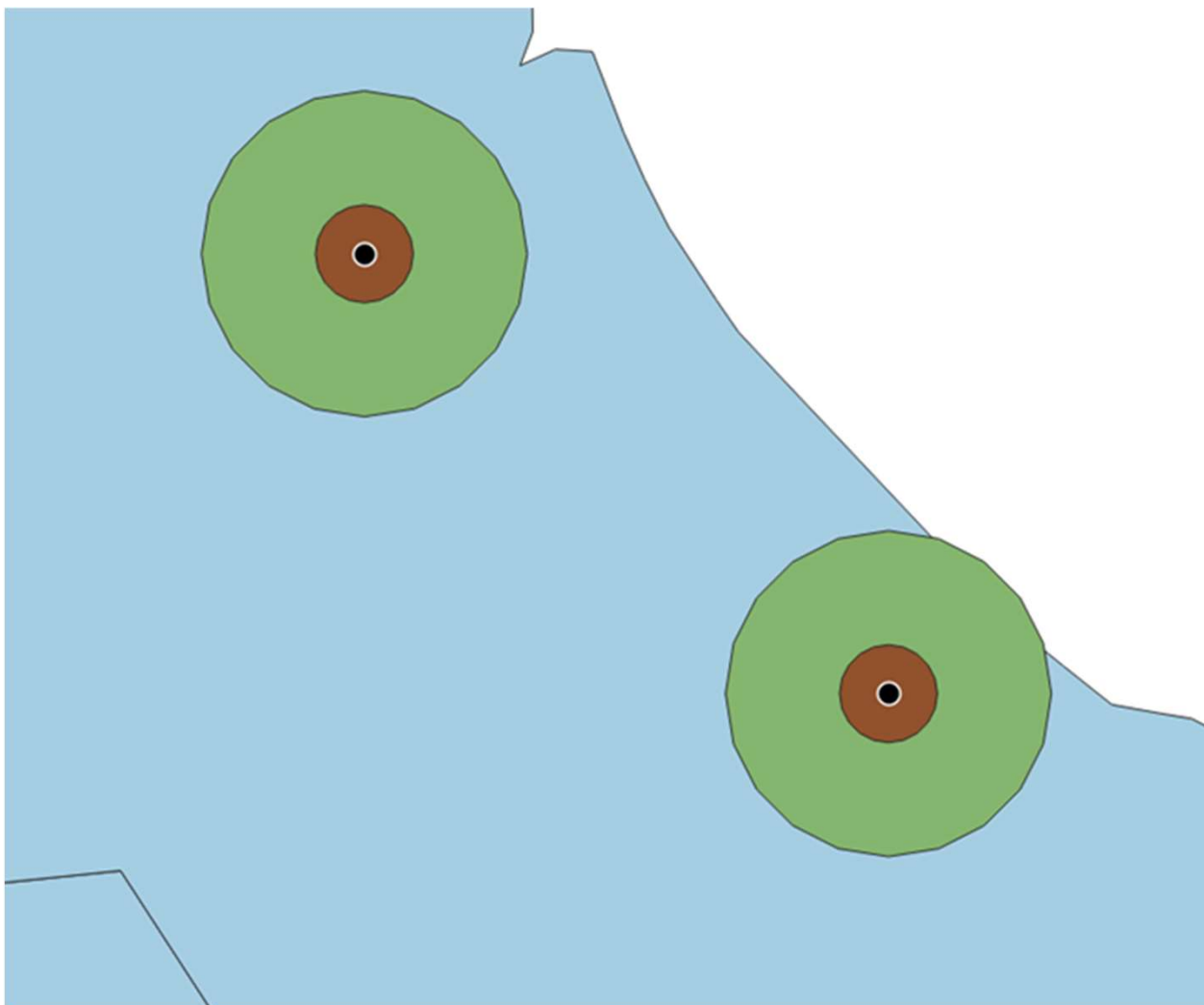
Exercise 2: Distance



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Exercise 3: Buffer



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PART 3

EXPLORATORY DATA ANALYSIS



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Introduction ESDA

Exploratory

Questions that ESDA helps to answer

Spatial

Data

Analysis

- Is the variable I am looking at concentrated in space?
- Do similar values tend to be located close to each other?
- Can I identify a specific area where certain values cluster together?



What is behind this pattern?

What could be generating the process?

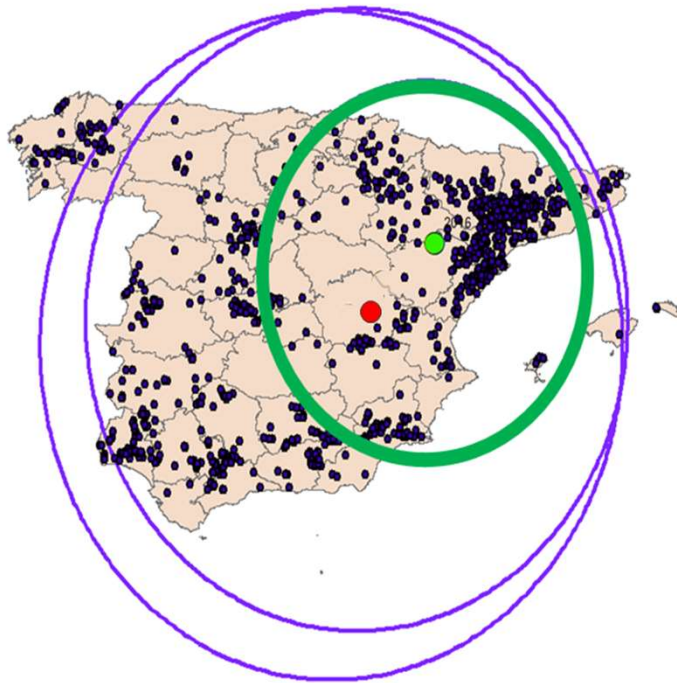
Why do certain clusters appear in space?



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Descriptive spatial statistics:



- Poultry farms in Spain

Mean center

$$\bar{X} = \sum_{i=1}^N \frac{X_i}{N}$$
$$\bar{Y} = \sum_{i=1}^N \frac{Y_i}{N}$$

Spatial Standard Deviation

$$SD_{x,y} = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{N-1} + \frac{\sum_{i=1}^n (Y_i - \bar{Y})^2}{N-1}}$$

Weighted by census
Mean Center

$$\bar{X} = \frac{\sum_{i=1}^n w_i x_i}{\sum_{i=1}^n w_i}$$
$$\bar{Y} = \frac{\sum_{i=1}^n w_i y_i}{\sum_{i=1}^n w_i}$$

Weighted by census
Spatial Standard Deviation

$$WSD = \sqrt{\frac{\sum_{i=1}^n w_i [(x_i - \bar{x}_w)^2 + (y_i - \bar{y}_w)^2]}{\sum_{i=1}^n w_i}}$$



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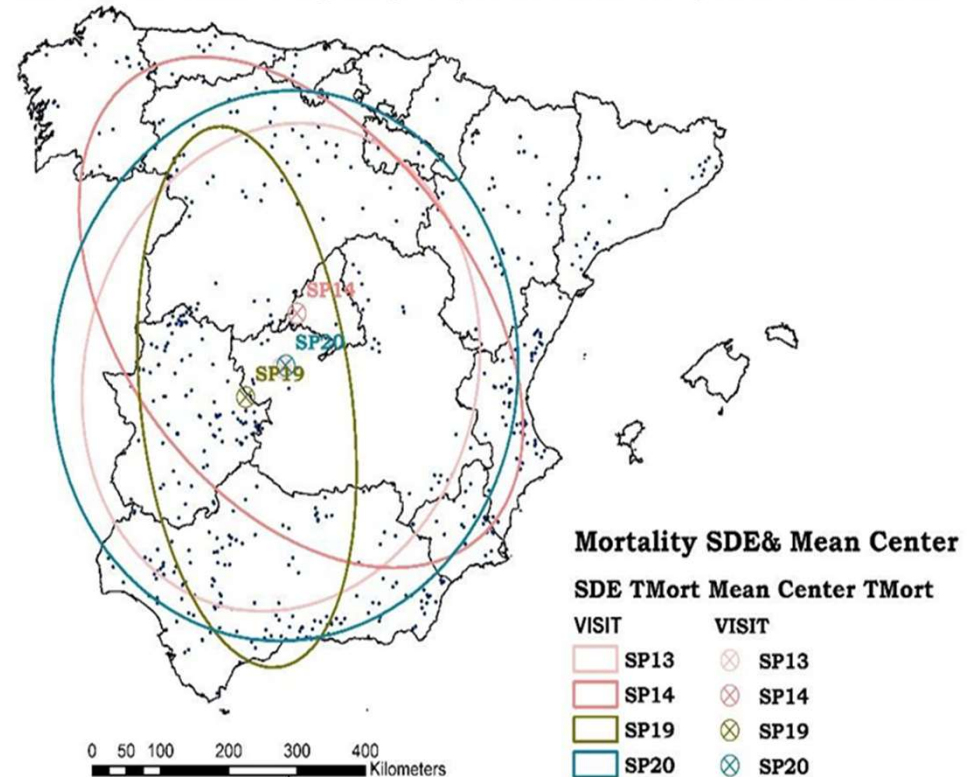
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Descriptive spatial statistics:

Standard deviation ellipses (SDEs) and mean center (MC) of apiary winter mortality (SP) occurring between the springs of 2013-14 and 2019-2020 reflect a pronounced change of pattern, showing a shift to a North-South orientation in the western region of Spain in SP19. Each ellipse is drawn from data collected during the annual spring visits (SP).

Source: [Perez-Cobo et al, 2025](#)

Directional distribution of winter mortality:
Standard Deviation Ellipses (SDE) & Mean Center (2013-2014; 2019-2020)

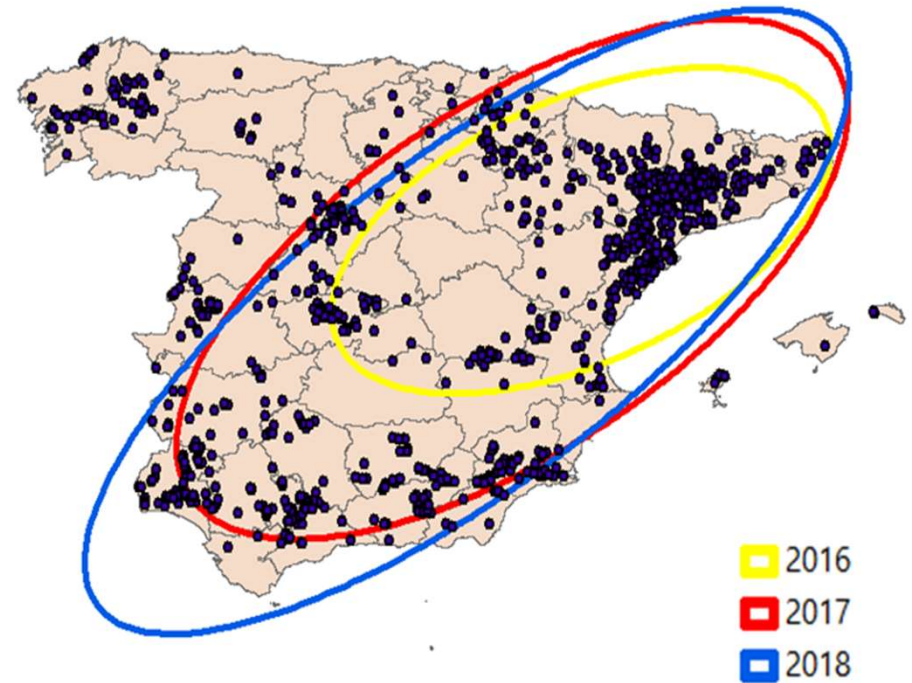


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Descriptive spatial statistics:

Example of Standard deviation ellipses (SDEs) by year using simulated annual data on poultry census variation in farms in Spain over three years (2016-2018)



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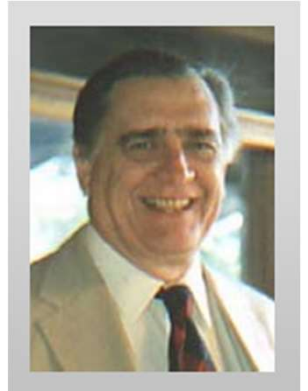


Spatial autocorrelation

The definition of spatial autocorrelation measures the extent to which nearby objects are similar.

Why is spatial autocorrelation important?

One of the main reasons why **spatial autocorrelation** is important is that **statistical analyses rely on the assumption of independent observations**. When spatial autocorrelation is present in a map, this violates the assumption that observations are **independent from one another**, potentially leading to **biased results and incorrect inferences**.



Spatial autocorrelation

Tobler

Statistical representation of Tobler's Law

In traditional statistics is equivalent to correlation.

To measure spatial autocorrelation, we use Moran's I test.



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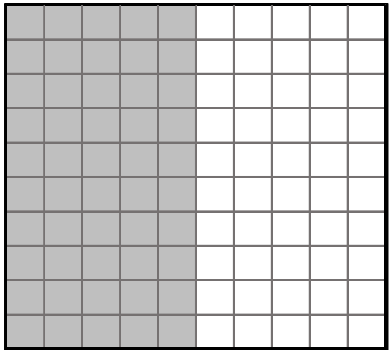
Spatial autocorrelation

Moran's I can be classified as positive, negative, or with no spatial autocorrelation.

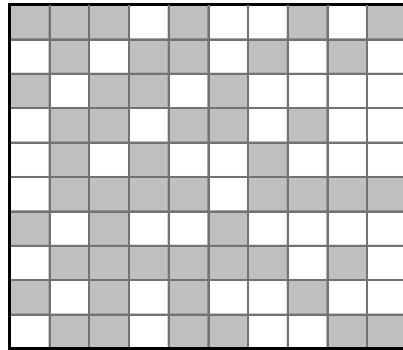
- Positive spatial autocorrelation occurs when similar values cluster together on a map. →
- No spatial autocorrelation happens when similar values are randomly distributed.
- Negative spatial autocorrelation occurs when similar values are far apart from each other. →

Income
Poverty
Vegetation
Temperature

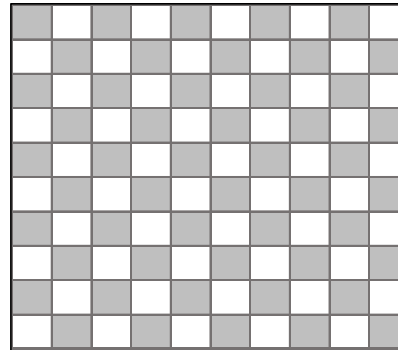
Supermarkets
Police Stations
Fire Stations
Hospitals



Positive autocorrelation



Negative autocorrelation



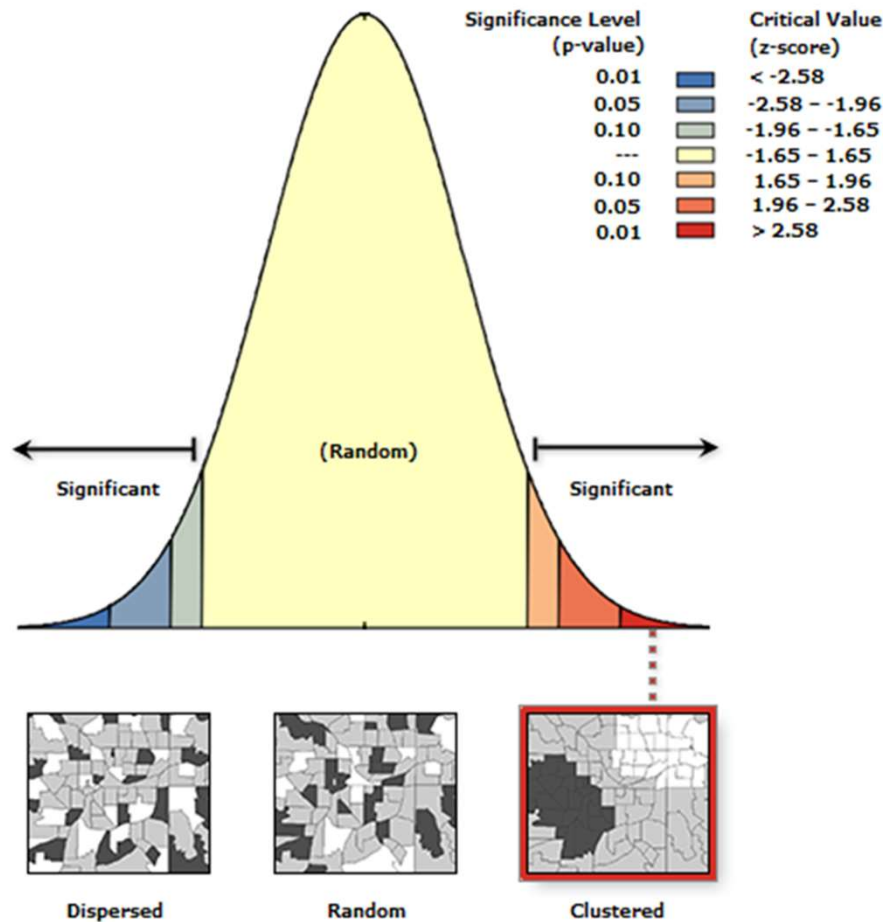
No spatial autocorrelation



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Spatial autocorrelation



$$I = \frac{N}{W} \times \frac{\sum_i \sum_j w_{ij} (X_i - \bar{X})(X_j - \bar{X})}{\sum_i (X_i - \bar{X})^2}$$

Where:

- I = Moran's I index
- N = Total number of spatial units (observations)
- X_i = Value of the variable at location i
- \bar{X} = Mean of the variable
- w_{ij} = Spatial weight between locations i and j
- W = Sum of all spatial weights ($W = \sum_i \sum_j w_{ij}$)

The null hypothesis for spatial pattern analysis tools is complete spatial randomness. The null hypothesis is typically rejected when the p-value is less than 0.1.



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Hot Spot analysis (Getis-Ord)

Measures spatial autocorrelation at a local level (as if locally aggregating intensity values).

Indicates areas of high and low clustering.

Requires an intensity level of the event, for example, the number of cases per province. An input field such as **year** can be used for temporal analysis.

The *Gi* statistic → *Z-score interpretation**: If *Gi* is significant*:

- **$Z > 1$** → The larger the Z-score, the stronger the clustering of high values (**hot spot**).
- **$Z < 1$** → The smaller the Z-score, the stronger the clustering of low values (**cold spot**).



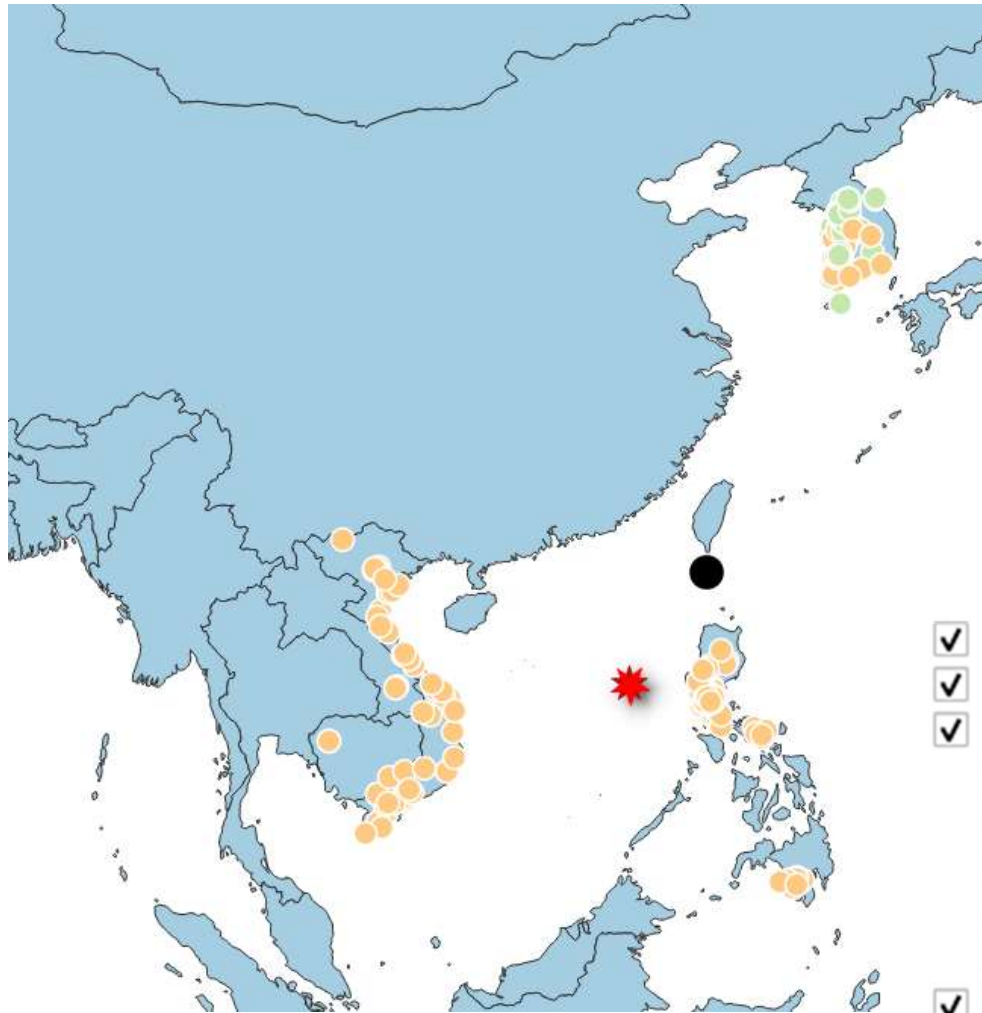
<https://desktop.arcgis.com/es/arcmap/latest/tools/spatial-statistics-toolbox/hot-spot-analysis-with-rendering.htm>



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Exercise 3 (Optional): Perform descriptive spatial statistics



Perform descriptive spatial statistics in QGIS:
Mean Center and Weighted Mean Center



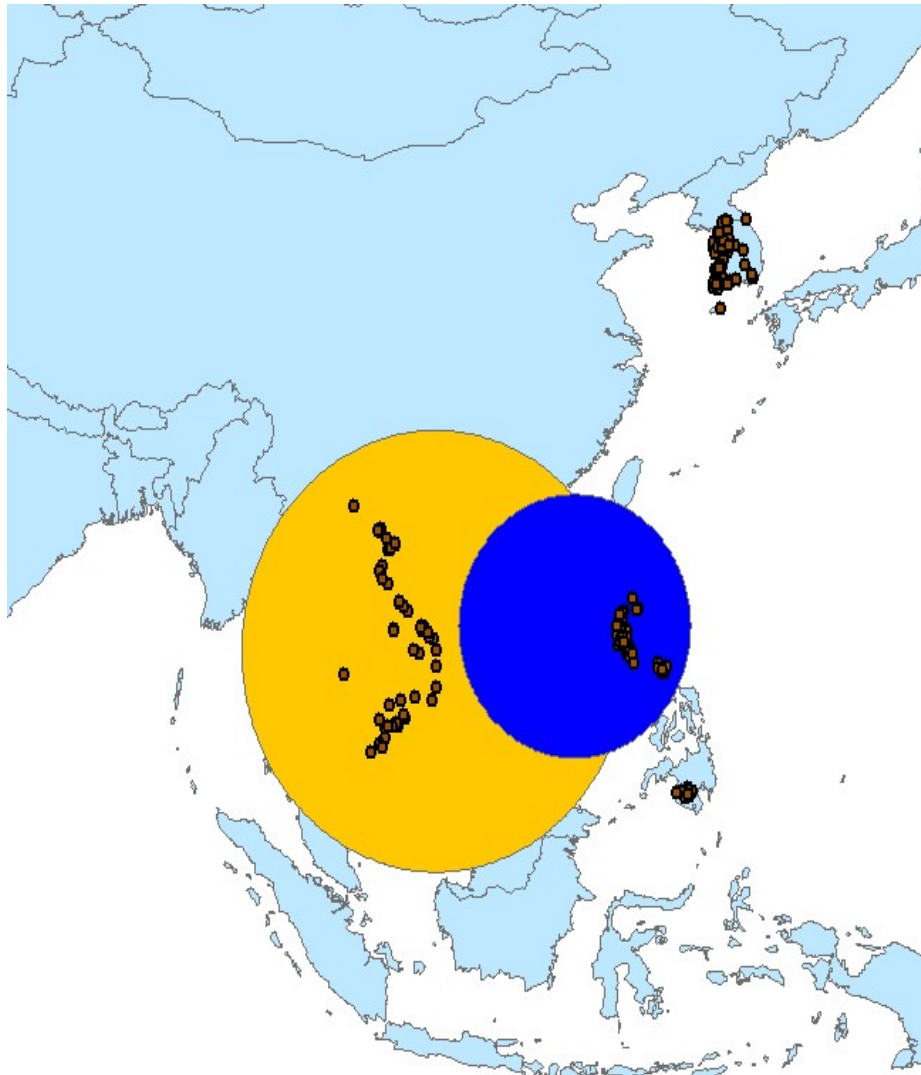
- ☒  **Weighted Mean Center**
- ☒  **Mean center**
- ☒  **Outbreaks**
- ☒  **captive**
- ☒  **domestic**
- ☒  **wild**
- ☒  **countries**



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Exercise 3 (Optional): Perform descriptive spatial statistics



Perform descriptive spatial statistics
Standard deviation (ArcGIS)

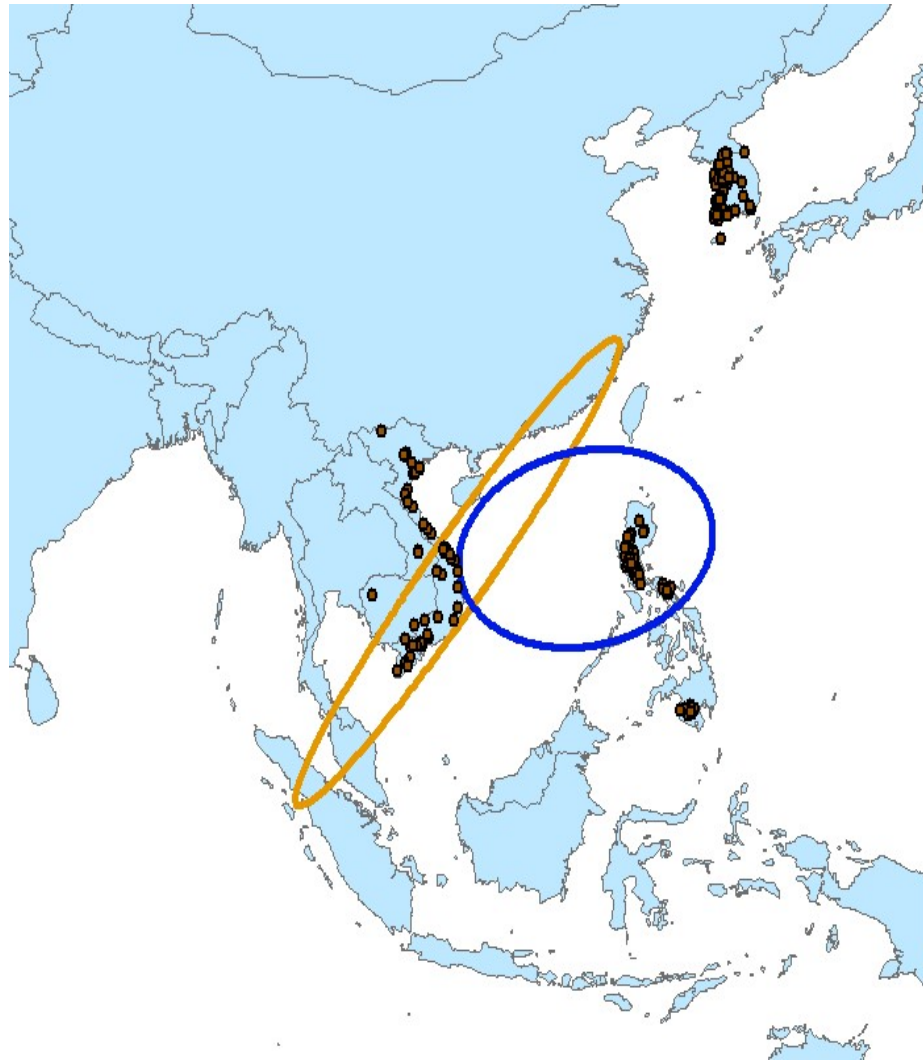
- Weight field : Cases
- Case field: year



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Exercise 3 (Optional): Perform descriptive spatial statistics



**Perform descriptive spatial statistics:
Standard Deviation Ellipse (SDE) (ArcGIS)**

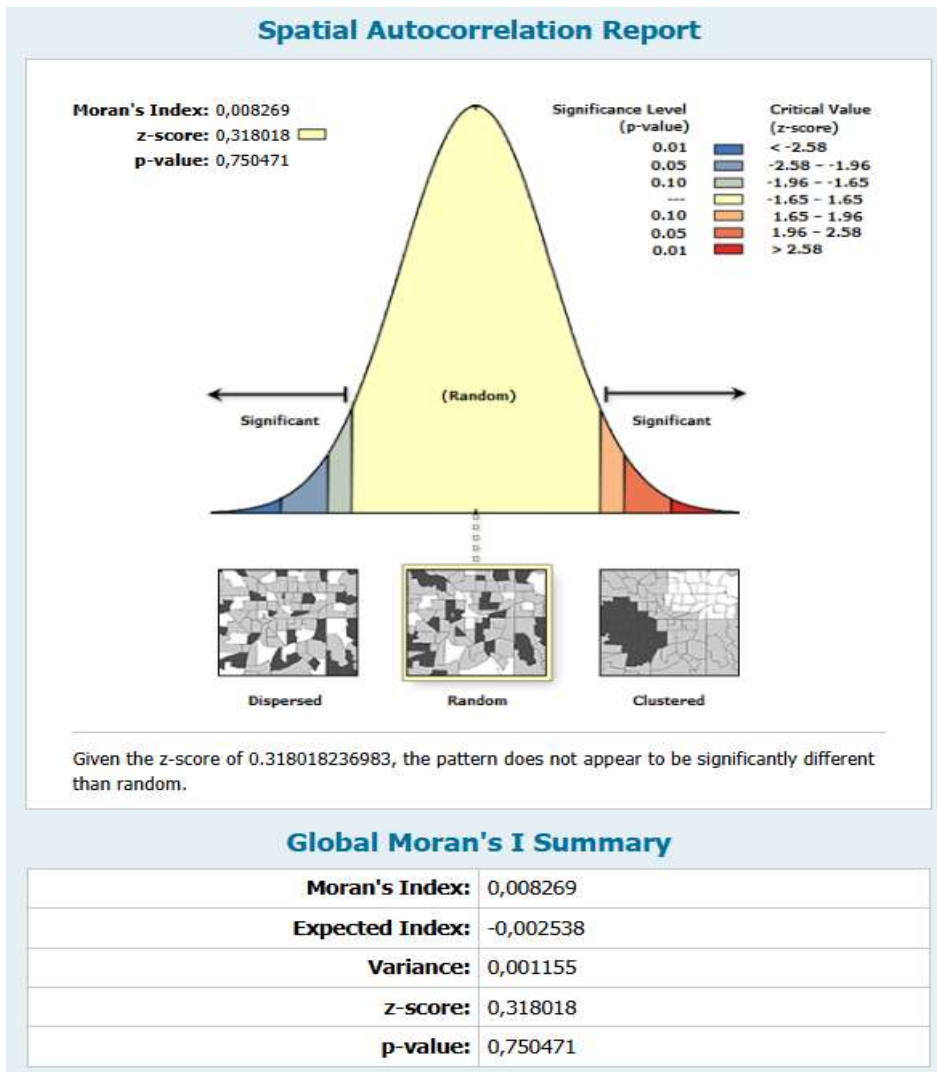
- **Weight field : Cases**
- **Case field: year**



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Exercise 3 (Optional): Autocorrelation and pattern analysis



Autocorrelation and pattern analysis measures (ArcGIS):

Moran's I - Global Spatial Autocorrelation



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Exercise 3 (Optional): Autocorrelation and pattern analysis



Autocorrelation and pattern analysis measures (ArcGIS):

Moran's I Local (Anselin)



Outbreaks_ClustersOutliers

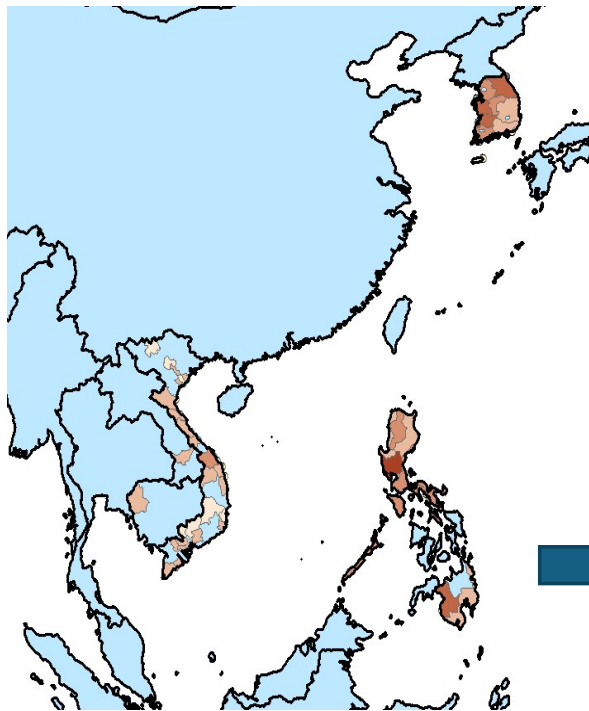
- Not Significant
- Cluster: High
- High Outlier
- Low Outlier
- Cluster: Low



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Exercise 3 (Optional): Autocorrelation and pattern analysis

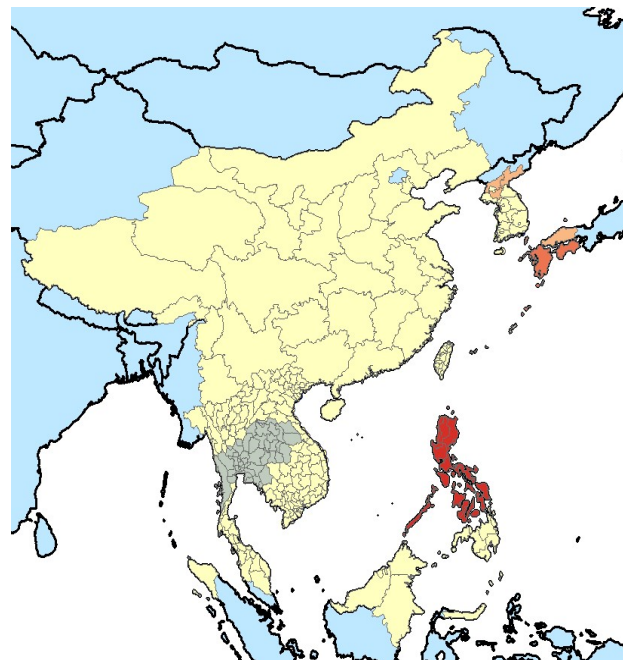


Number outbreaks by province

- 0 - 1
- 2 - 5
- 6 - 15
- 16 - 27
- 28 - 153

Autocorrelation and pattern analysis measures (ArcGIS):

Hot Spot Analysis (Getis-Ord G_i^*)



- HotSpots N° Cases/province
Gi_Bin
- Cold Spot - 99% Confidence
 - Cold Spot - 95% Confidence
 - Cold Spot - 90% Confidence
 - Not Significant
 - Hot Spot - 90% Confidence
 - Hot Spot - 95% Confidence
 - Hot Spot - 99% Confidence



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PART 4

CLUSTER ANALYSIS



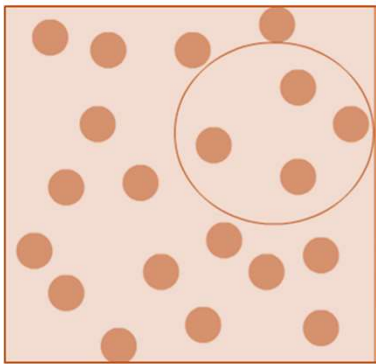
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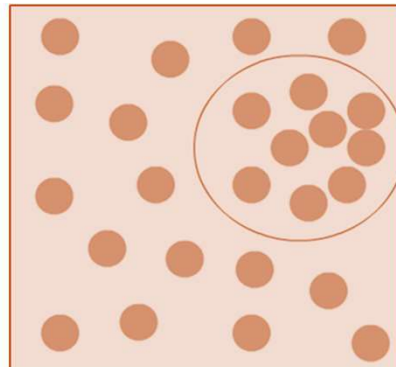
Introduction to SaTScan



- Detects the most probable and secondary clusters
- Uses Monte Carlo simulation to generate the p-Value
- Allows the identification of spatial, temporal, and spatiotemporal clusters



**Observed = Expected
NO CLUSTER**



**Observed > Expected
CLUSTER**



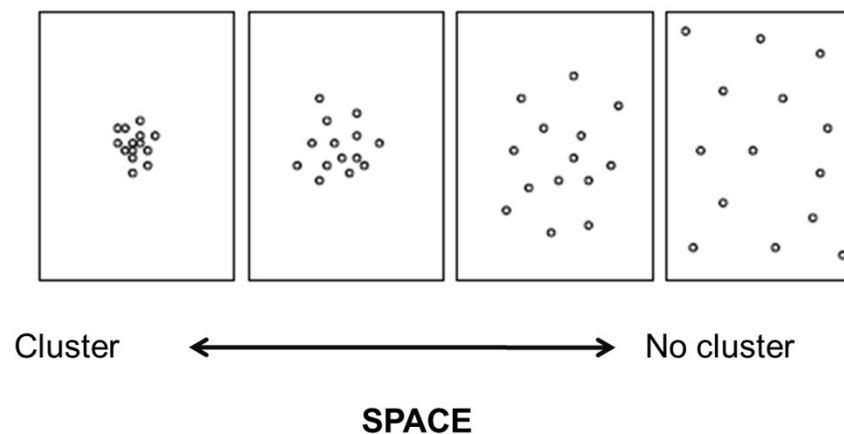
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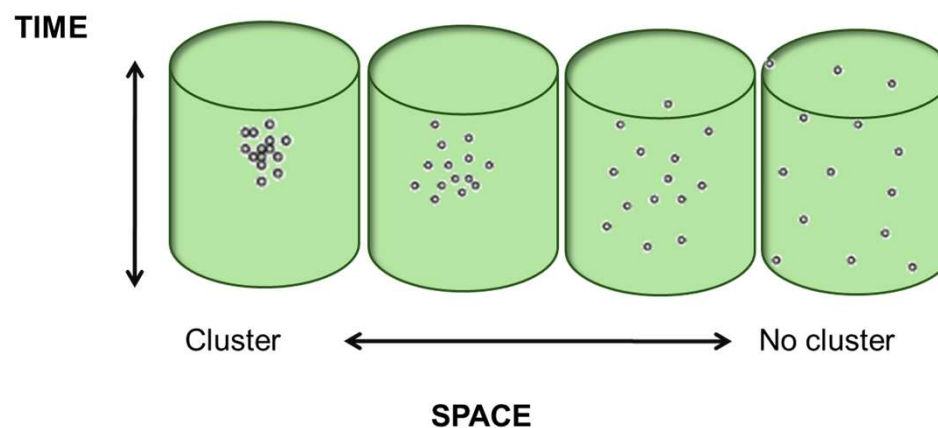
Introduction to SaTScan



Spatial analysis



Spatiotemporal analysis



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Main statistical models in SaTScan

Poisson Model

- Cases / Total Population
- Requires: Case counts & population data
- Used when population-at-risk is available
- Spatial, temporal and spatiotemporal

Bernoulli Model

- Cases / Total Controls (1 = case, 0 = control)
- Requires: Case-control data
- Used in clinical & epidemiological studies
- Spatial, temporal and spatiotemporal

Permutation Model

- Cases per unit area/time
- Assumes uniform distribution
- Used when no population data is available
- Spatiotemporal

Other Models

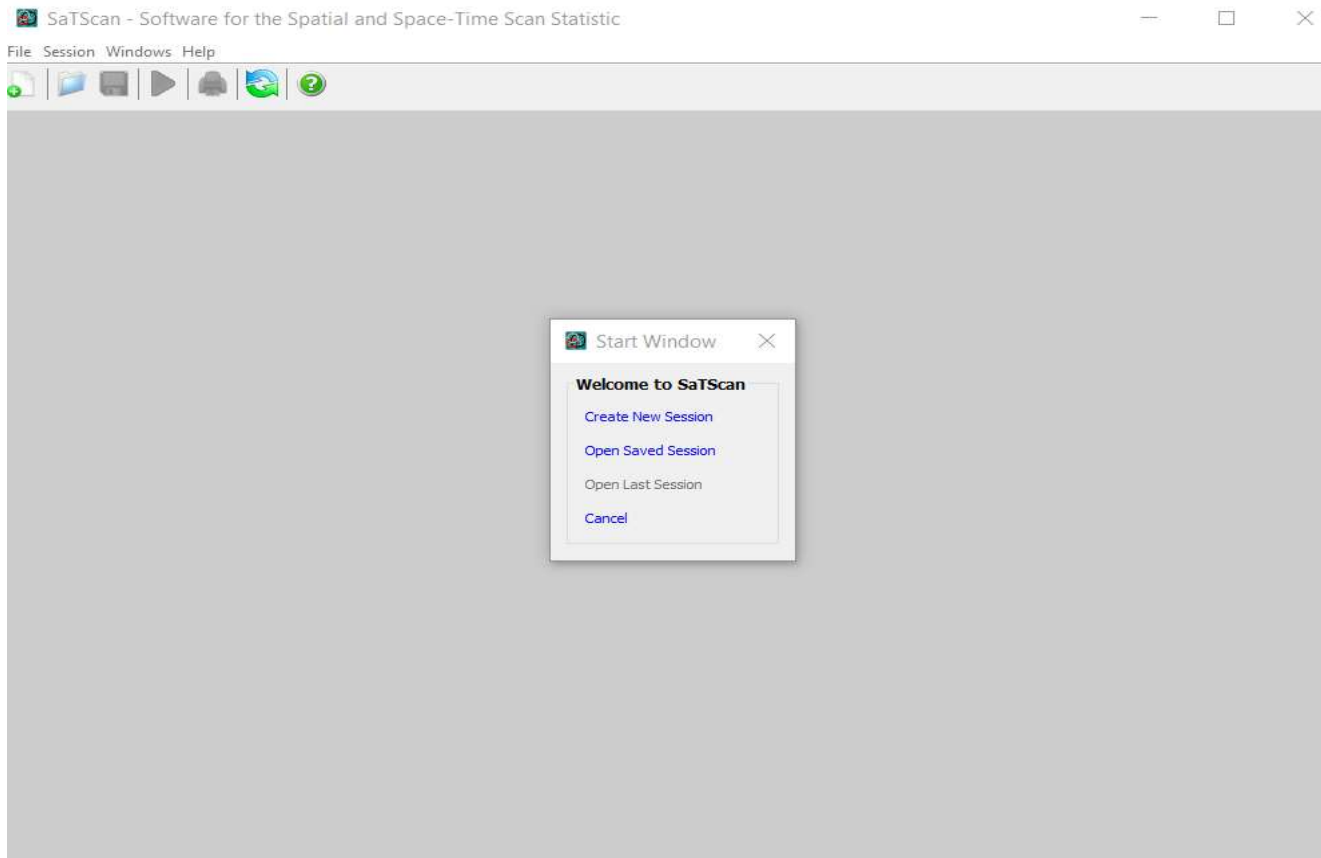
- Normal: Continuous data (e.g., weight gain)
- Exponential: Time-to-event (e.g., disease detection)
- Ordinal: Ordered categories (e.g., mortality levels)
- Multinomial: Multiple categories without ranking



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Data configuration and spatial-temporal scanning Windows



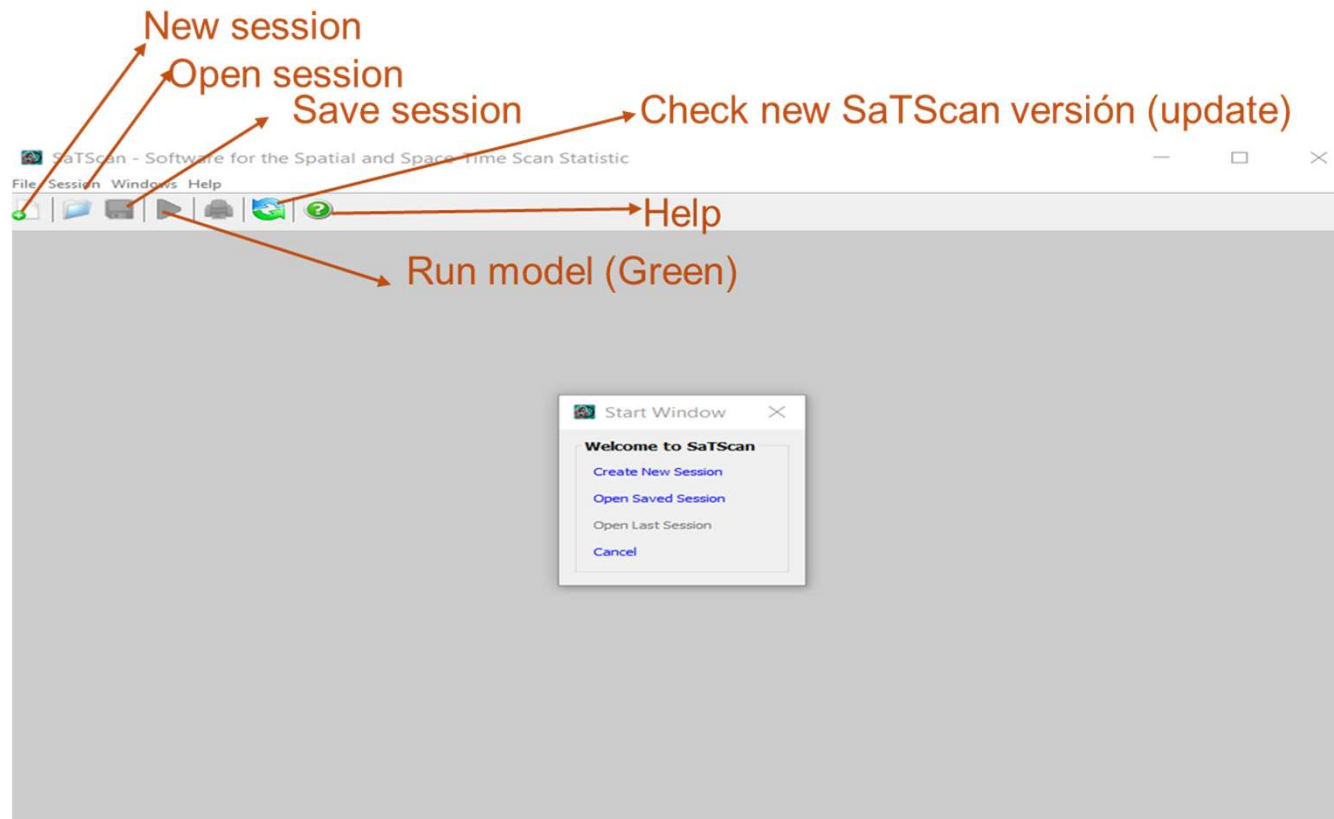
Interface



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Data configuration and spatial-temporal scanning Windows



Interface



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Data configuration and spatial-temporal scanning Windows

Input data

The screenshot shows a software window with three tabs: 'Input', 'Analysis', and 'Output'. The 'Input' tab is active and contains the following fields and options:

- Case File:** A text input field with a browse button (...).
- Control File:** A text input field with the text '(Bernoulli Model)' and a browse button (...).
- Time Precision:** A group box containing four radio buttons: 'None', 'Year' (selected), 'Month', and 'Day'. There is also a 'Generic' radio button below them.
- Study Period:** A group box containing two date pickers. The 'Start Date' is set to Year: 2000, Month: 1, Day: 1. The 'End Date' is set to Year: 2000, Month: 12, Day: 31.
- Population File:** A text input field with the text '(Poisson Model)' and a browse button (...).
- Coordinates File:** A text input field with a browse button (...).
- Grid File:** A text input field with the text '(optional)' and a browse button (...).
- Coordinates:** A group box containing two radio buttons: 'Cartesian' and 'Lat/Long' (selected).

An 'Advanced >>' button is located at the bottom right of the window.



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Data configuration and spatial-temporal scanning Windows

Input data

The screenshot shows a software window with three tabs: 'Input', 'Analysis', and 'Output'. The 'Input' tab is active, displaying the following fields:

- Case File:** A text input field with a browse button (...).
- Control File:** A text input field containing '(Bernoulli Model)' with a browse button (...).
- Time Precision:** A group box containing four radio buttons: 'None', 'Year' (selected), 'Month', and 'Day'. There is also a 'Generic' radio button below them.
- Study Period:** A section with two sets of date pickers, each labeled 'Year', 'Month', and 'Day'.

Below the form fields is a table with the following data:

Id	source	latitude	longitude	region	country	admin1	Satscan	dom_silv	sumCases
278641	National auth	52,09	14,66	Europe	Germany	Brandenburg	2020/9/18	wild boar	6
278618	OIE	53,257791	50,084607	Europe	Russian Feder	Samarskaya C	2020/9/11	domestic	1
278617	OIE	53,2486	49,5708	Europe	Russian Feder	Samarskaya C	2020/9/11	wild boar	1
278616	OIE	53,263896	49,280197	Europe	Russian Feder	Samarskaya C	2020/9/11	wild boar	1
278615	OIE	53,376765	49,35858	Europe	Russian Feder	Samarskaya C	2020/9/11	wild boar	1
278588	OIE	50,468611	22,744167	Europe	Poland	Lubeiskie	2020/9/15	domestic	1
278587	OIE	50,668611	23,6375	Europe	Poland	Lubeiskie	2020/9/15	domestic	1
278586	OIE	50,439722	22,729722	Europe	Poland	Lubeiskie	2020/9/15	domestic	2
278585	OIE	53,736395	20,578624	Europe	Poland	Warminsko-M	2020/9/15	domestic	34
278584	OIE	50,569722	23,644722	Europe	Poland	Lubeiskie	2020/9/15	domestic	5
278583	OIE	50,4475	23,261667	Europe	Poland	Lubeiskie	2020/9/15	domestic	1
278582	OIE	50,531718	23,673204	Europe	Poland	Lubeiskie	2020/9/15	domestic	2
278581	OIE	51,530278	22,391667	Europe	Poland	Lubeiskie	2020/9/15	domestic	5
278580	OIE	50,344167	22,9875	Europe	Poland	Lubeiskie	2020/9/15	domestic	10
278579	OIE	50,447222	23,266389	Europe	Poland	Lubeiskie	2020/9/15	domestic	13

Attention! Check date format: YY/MM/DD



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Data configuration and spatial-temporal scanning Windows

Analysis

The screenshot shows a software window titled 'Analysis' with three tabs: 'Input', 'Analysis', and 'Output'. The 'Analysis' tab is active. It contains three main sections:

- Type of Analysis:**
 - Retrospective Analyses:**
 - ☒ Purely Spatial
 - ☐ Purely Temporal
 - ☐ Space-Time
 - ☐ Seasonal
 - ☐ Spatial Variation in Temporal Trends
 - Prospective Analyses:**
 - ☐ Purely Temporal
 - ☐ Space-Time
- Probability Model:**
 - Discrete Scan Statistics:**
 - ☒ Poisson
 - ☐ Bernoulli
 - ☐ Space-Time Permutation
 - ☐ Multinomial
 - ☐ Ordinal
 - ☐ Exponential
 - ☐ Normal
 - Continuous Scan Statistics:**
 - ☐ Poisson
- Scan For Areas With:**
 - ☒ High Rates
 - ☐ Low Rates
 - ☐ High or Low Rates
- Time Aggregation:**
 - Units: ☒ Year, ☐ Month, ☐ Day
 - Length: Years

An 'Advanced >>' button is located at the bottom right of the window, highlighted with a red rectangle.



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Data configuration and spatial-temporal scanning Windows

Spatial window

Advanced Analysis Features

Space and Time Adjustments Inference Border Analysis Power Evaluation

Spatial Window Temporal Window Cluster Restrictions

Maximum Spatial Cluster Size

percent of the population at risk ($\leq 50\%$, default = 50%)

☐ percent of the population defined in the max circle size file ($\leq 50\%$)

☒ is a circle with a kilometer radius

☐ Include Purely Temporal Clusters (Spatial Size = 100%)

Spatial Window Shape

☒ Circular

☐ Elliptic Non-Compactness Penalty:

☐ Use Isotonic Spatial Scan Statistic

Set Defaults Close



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Data configuration and spatial-temporal scanning Windows

Temporal window

Advanced Analysis Features

Space and Time Adjustments Inference Border Analysis Power Evaluation

Spatial Window Temporal Window Cluster Restrictions

Maximum Temporal Cluster Size

☐ is 50.0 percent of the study period ($\leq 50\%$, default = 50%)

☒ is 30 days

Minimum Temporal Cluster Size

1 days

☐ Include Purely Spatial Clusters (Temporal Size = 100%)

Flexible Temporal Window Definition

☐ Include only windows with:

Start time in range: 2000 1 1 to 2000 12 31

End time in range: 2000 1 1 to 2000 12 31

Set Defaults Close



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Data configuration and spatial-temporal scanning Windows

Cluster restrictions

Advanced Analysis Features

Space and Time Adjustments	Inference	Border Analysis	Power Evaluation
Spatial Window	Temporal Window	Cluster Restrictions	

Minimum Number of Cases

Restrict high rate clusters to have at least cases.

Boscoe's Limit on Clusters by Risk Level

☐ Restrict high rate clusters to observed/expected greater than or equal to:

☐ Restrict low rate clusters to observed/expected less than or equal to:

Set Defaults Close



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Data configuration and spatial-temporal scanning Windows

**Outputs:
check all of them**

Input Analysis **Output**

Text Output Format

Main Results File:

Geographical Output

- ☐ HTML file for Google Map
- ☐ KML file for Google Earth
- ☐ Shapefile for GIS software
- ☐ HTML file for Cartesian map

Column Output Format

	ASCII	dBase
Cluster Information	<input type="checkbox"/>	<input type="checkbox"/>
Stratified Cluster Information	<input type="checkbox"/>	<input type="checkbox"/>
Location Information	<input type="checkbox"/>	<input type="checkbox"/>
Risk Estimates for Each Location	<input type="checkbox"/>	<input type="checkbox"/>
Simulated Log Likelihood Ratios/Test Statistics	<input type="checkbox"/>	<input type="checkbox"/>

Advanced >>



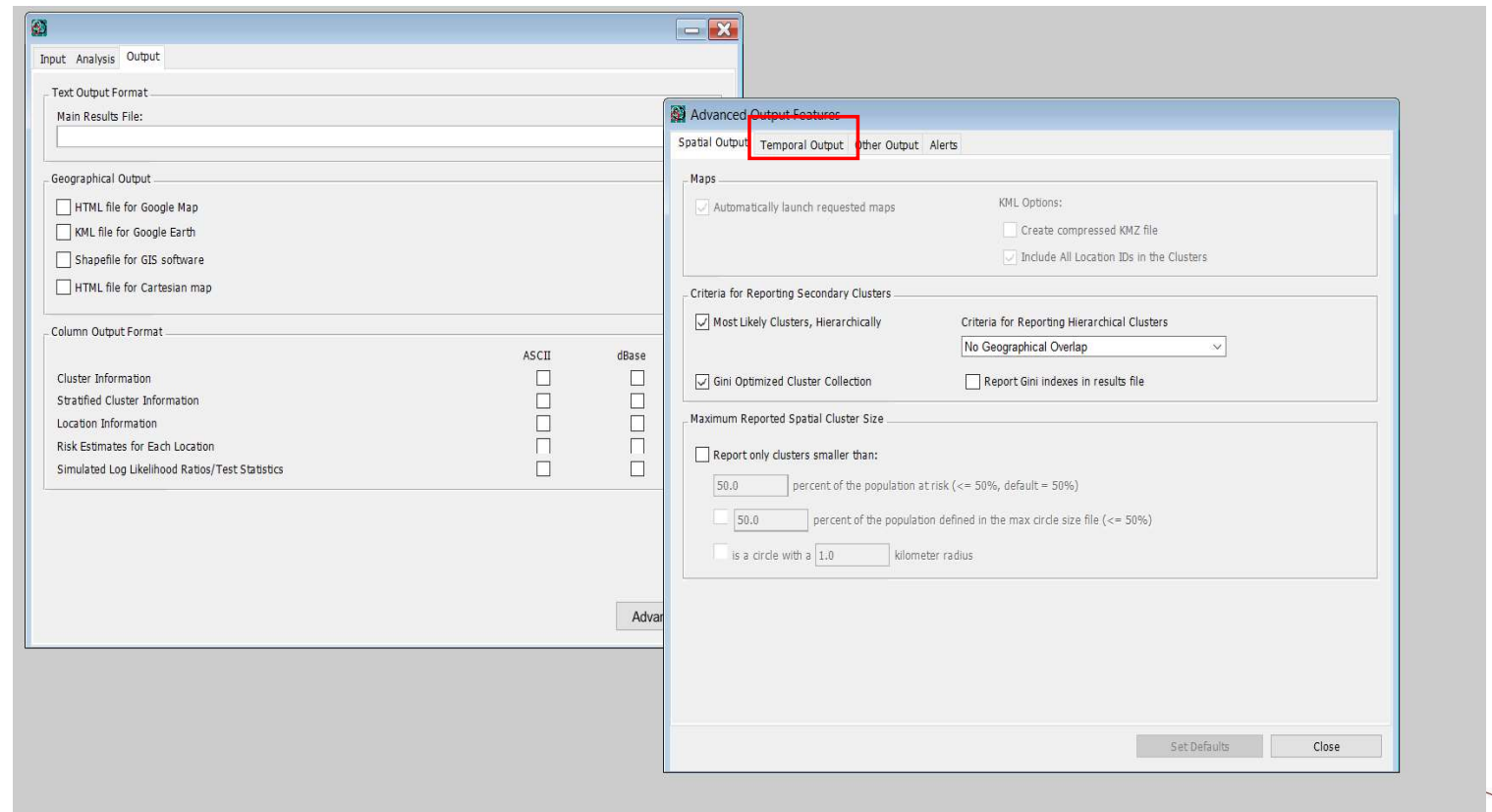
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Data configuration and spatial-temporal scanning Windows

**Outputs:
check all of them..**

**..including temporal
output**



Data configuration and spatial-temporal scanning Windows

Results
Txt

```
C:\Users\igles\OneDrive\Desktop\Satscan\results_2020

SaTS

SaTScan v9.6

Program run on: Mon Sep 21 13:24:30 2020

Retrospective Space-Time analysis
scanning for clusters with high rates
using the Space-Time Permutation model.

SUMMARY OF DATA
< [Progress Bar]

Warnings/Errors:
No Warnings or Errors.

Program run on: Mon Sep 21 13:37:15 2020

Retrospective Space-Time analysis
scanning for clusters with high rates
using the Space-Time Permutation model.

SUMMARY OF DATA

Study period.....: 2020/1/1 to 2020/12/31
Number of locations.....: 3197
Total number of cases.....: 3629
```



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Data configuration and spatial-temporal scanning Windows

Results Txt

PARAMETER SETTINGS

Input

Case File : C:\Users\igles\OneDrive\Desktop\Satscan\Cases_2020
Time Precision : Day
Start Time : 2020/1/1
End Time : 2020/12/31
Coordinates File : C:\Users\igles\OneDrive\Desktop\Satscan\Coordinates_2020
Coordinates : Latitude/Longitude

Analysis

Type of Analysis : Retrospective Space-Time
Probability Model : Space-Time Permutation
Scan for Areas with : High Rates
Time Aggregation Units : Day
Time Aggregation Length : 7

Output

Main Results File : C:\Users\igles\OneDrive\Desktop\Satscan\results_2020
Google Earth File : C:\Users\igles\OneDrive\Desktop\Satscan\results_2020.kml
Google Maps File : C:\Users\igles\OneDrive\Desktop\Satscan\results_2020.clustermap.html
Shapefile : C:\Users\igles\OneDrive\Desktop\Satscan\results_2020.clustermap.col.shp
Cartesian Graph File : C:\Users\igles\OneDrive\Desktop\Satscan\results_2020.cluster.html
Cluster File : C:\Users\igles\OneDrive\Desktop\Satscan\results_2020.cluster.col.dbf
Stratified Cluster File : C:\Users\igles\OneDrive\Desktop\Satscan\results_2020.cluster.sci.dbf
Location File : C:\Users\igles\OneDrive\Desktop\Satscan\results_2020.cluster.gis.dbf
Simulated LLRs File : C:\Users\igles\OneDrive\Desktop\Satscan\results_2020.cluster.llr.dbf

Spatial Window

Maximum Spatial Cluster Size : 50 percent of population at risk
Maximum Spatial Cluster Size : 30 km
Window Shape : Circular

Temporal Window

Minimum Temporal Cluster Size : 1 Day
Maximum Temporal Cluster Size : 30 Days

Cluster Restrictions

Minimum Cases in Cluster for High Rates : 5
Restrict High Rate Clusters : No

Space And Time Adjustments

Adjust for Weekly Trends, Nonparametric : No

Inference

P-Value Reporting : Default Combination
Number of Replications : 999
Adjusting for More Likely Clusters : No



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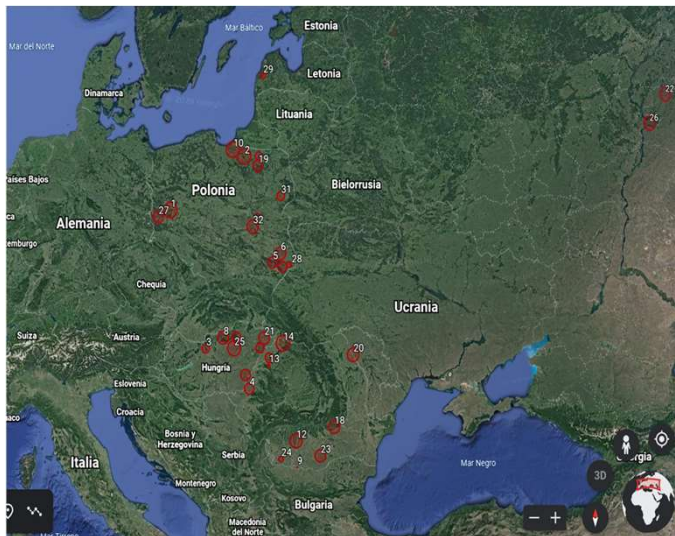
RESEARCH
CENTER

CSIC

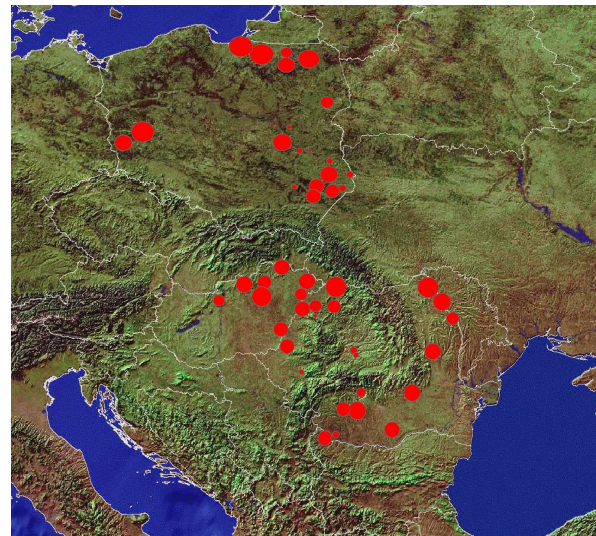
Data configuration and spatial-temporal scanning Windows



Results:



KML



Shapefile

- Number of Clusters
- Duration
- Time of occurrence
- Radius
- Number of Cases per Cluster
- Observed/Expected Ratio
- P-Value

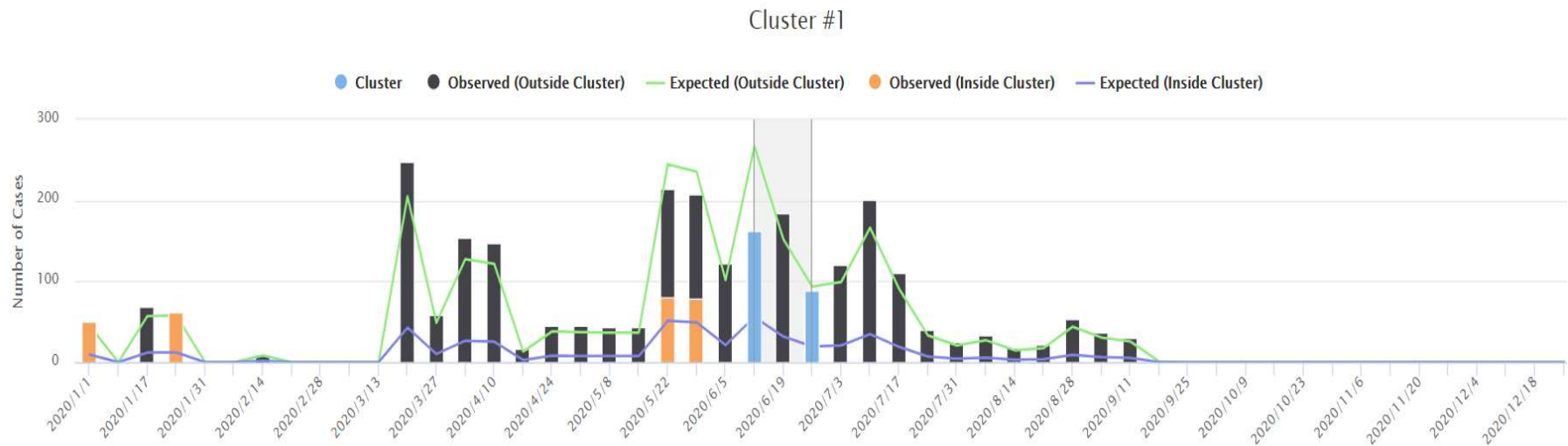


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Data configuration and spatial-temporal scanning Windows

Temporal
Results
Html

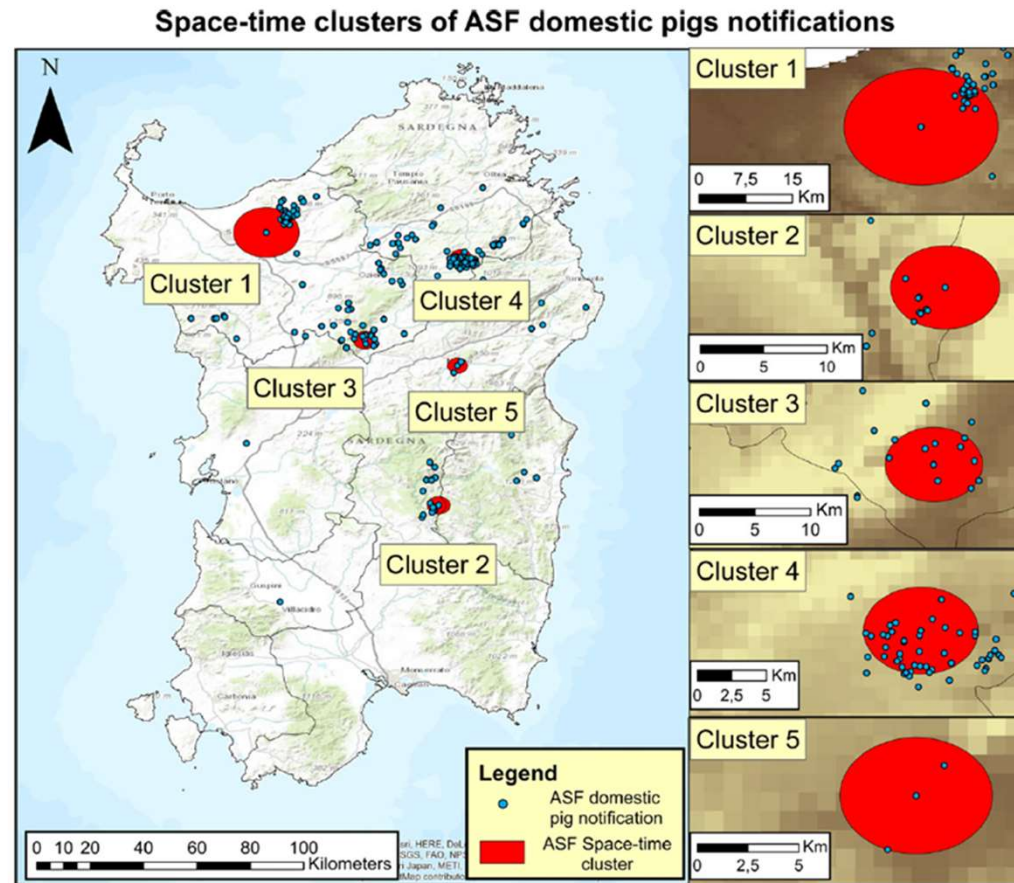


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Examples of use in animal health disease analysis

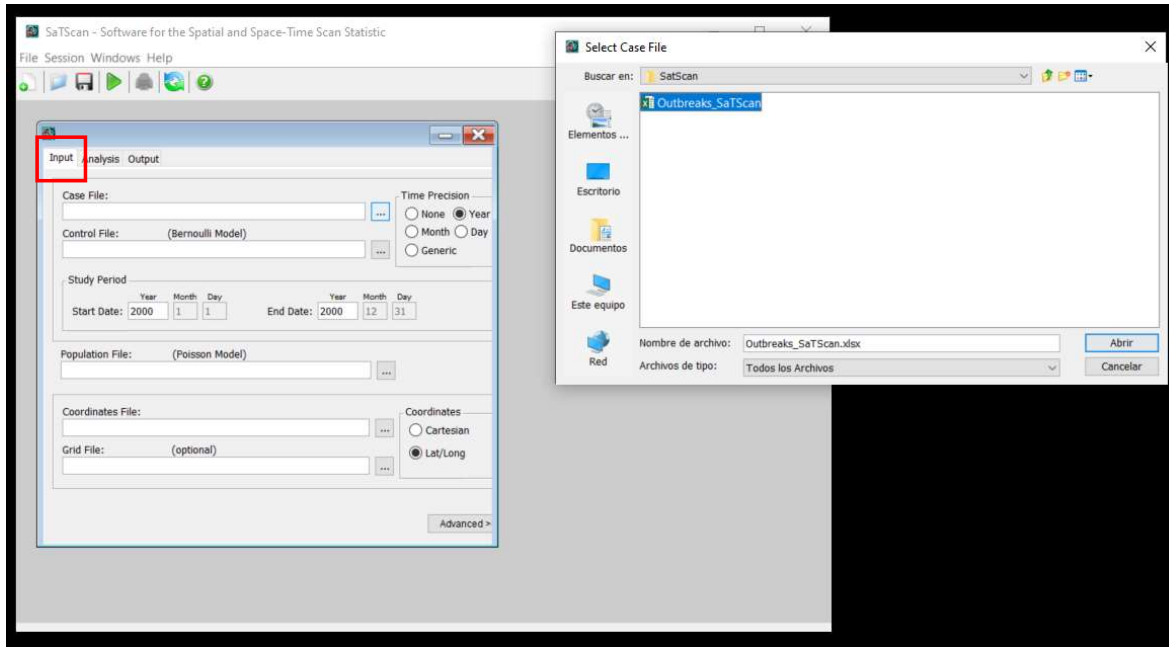
Space-time clusters of domestic pig African swine fever (ASF) notifications detected with the space-time permutation statistic (Kulldorff et al., 2005) in Sardinia (Italy) Significant clusters have a P-value <0.05. Source: Iglesias, I., Rodríguez, A., Feliziani, F., Rolesu, S., & De la Torre, A. (2017). Spatio-temporal analysis of African Swine Fever in Sardinia (2012–2014): trends in domestic pigs and wild boar. *Transboundary and emerging diseases*, 64(2), 656-662.



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Exercise: Conducting a Space-Time Permutation Cluster Analysis of ASF Outbreaks in SaTScan



Import case file from excel

SaTScan Folder  Download Link: <https://saco.csic.es/s/bcYcx8oAqoymPyd>

 All exercise steps and results are included in this folder.



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Exercise

Import File Wizard

Display SaTScan Variables For: space-time permutation model

SaTScan Variable	Source File Variable
Location ID	Generated Id
Number of Cases	One Count
Date/Time (optional)	SaTScan_date
Covariate1 (optional)	unassigned
Covariate2 (optional)	unassigned
Covariate3 (optional)	unassigned

Clear

Generated Id #	One Count #	ID	sero_sub_genotype_eng	disease_
location2	1	1	H5N1	High path
location3	1	2	H5N1	High path
location4	1	3	H5N1	High path
location5	1	4	H5N1	High path
location6	1	5	H5N1	High path
location7	1	6	H5N1	High path

< >

= Column is not actually defined in file but can be used as SaTScan variable.

< Previous Next >

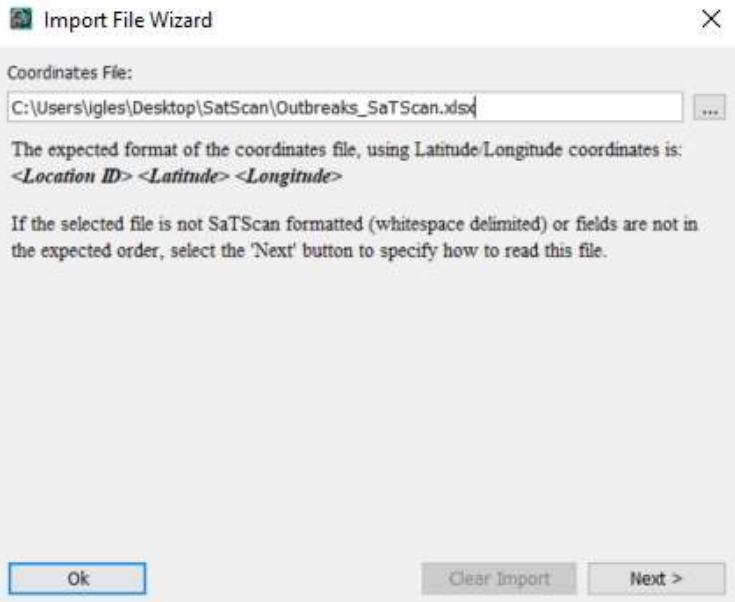
- Import case file from excel
Outbreaks SaTScan
- Model space-time permutation



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Exercise



Import File Wizard

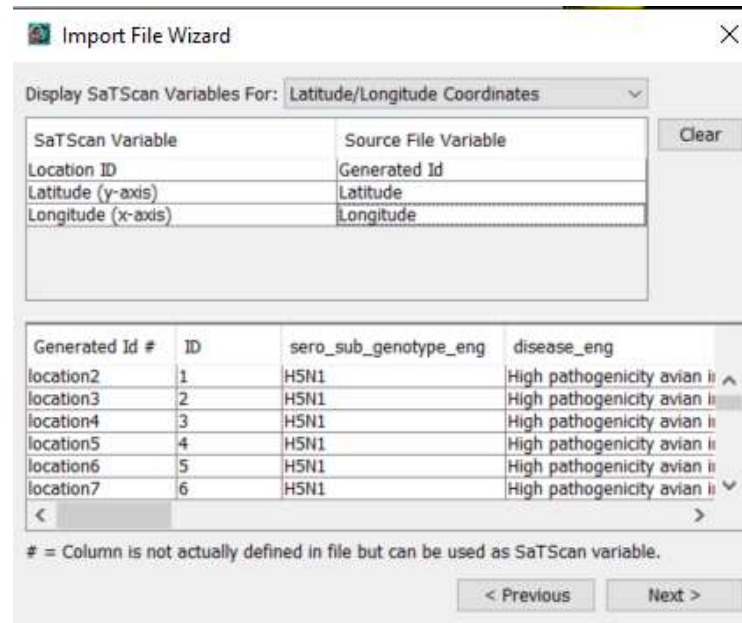
Coordinates File:
C:\Users\jgles\Desktop\SatScan\Outbreaks_SaTScan.xlsx

The expected format of the coordinates file, using Latitude/Longitude coordinates is:
<Location ID> <Latitude> <Longitude>

If the selected file is not SaTScan formatted (whitespace delimited) or fields are not in the expected order, select the 'Next' button to specify how to read this file.

Ok Clear Import Next >

- Import coordinates file from excel Outbreaks SaTScan
- Model space-time permutation



Import File Wizard

Display SaTScan Variables For: Latitude/Longitude Coordinates

SaTScan Variable	Source File Variable
Location ID	Generated Id
Latitude (y-axis)	Latitude
Longitude (x-axis)	Longitude

Clear

Generated Id #	ID	sero_sub_genotype_eng	disease_eng
location2	1	H5N1	High pathogenicity avian i
location3	2	H5N1	High pathogenicity avian i
location4	3	H5N1	High pathogenicity avian i
location5	4	H5N1	High pathogenicity avian i
location6	5	H5N1	High pathogenicity avian i
location7	6	H5N1	High pathogenicity avian i

< >

= Column is not actually defined in file but can be used as SaTScan variable.

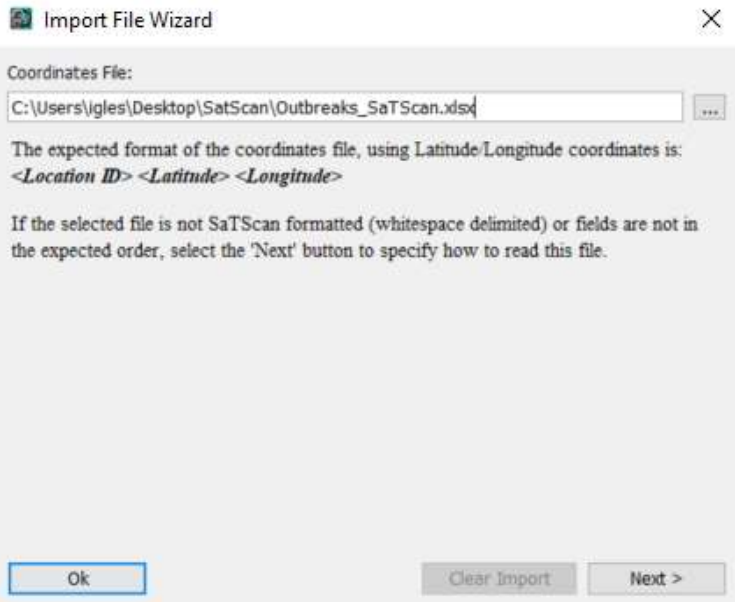
< Previous Next >



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Exercise



Import File Wizard

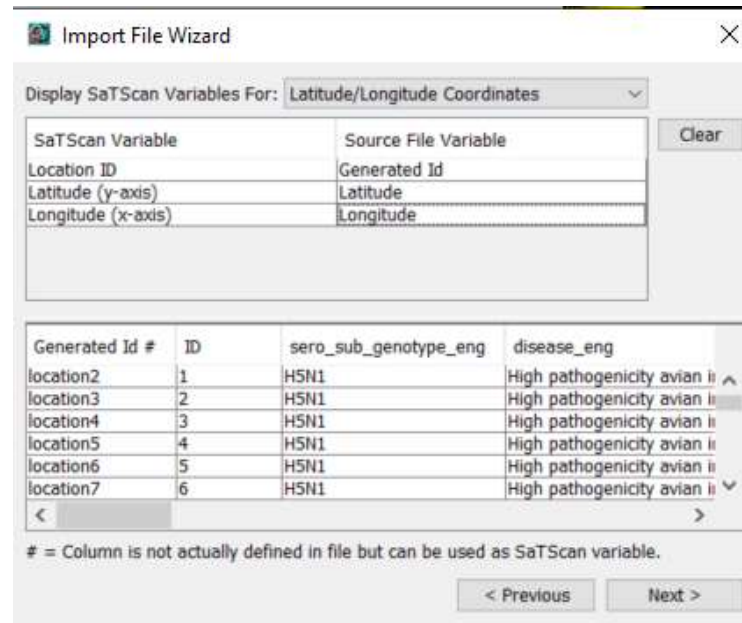
Coordinates File:
C:\Users\jgles\Desktop\SatScan\Outbreaks_SatScan.xlsx

The expected format of the coordinates file, using Latitude/Longitude coordinates is:
<Location ID> <Latitude> <Longitude>

If the selected file is not SaTScan formatted (whitespace delimited) or fields are not in the expected order, select the 'Next' button to specify how to read this file.

Ok Clear Import Next >

- Import coordinates file from excel Outbreaks SaTScan
- Model space-time permutation



Import File Wizard

Display SaTScan Variables For: Latitude/Longitude Coordinates

SaTScan Variable	Source File Variable
Location ID	Generated Id
Latitude (y-axis)	Latitude
Longitude (x-axis)	Longitude

Clear

Generated Id #	ID	sero_sub_genotype_eng	disease_eng
location2	1	H5N1	High pathogenicity avian i
location3	2	H5N1	High pathogenicity avian i
location4	3	H5N1	High pathogenicity avian i
location5	4	H5N1	High pathogenicity avian i
location6	5	H5N1	High pathogenicity avian i
location7	6	H5N1	High pathogenicity avian i

< >

= Column is not actually defined in file but can be used as SaTScan variable.

< Previous Next >

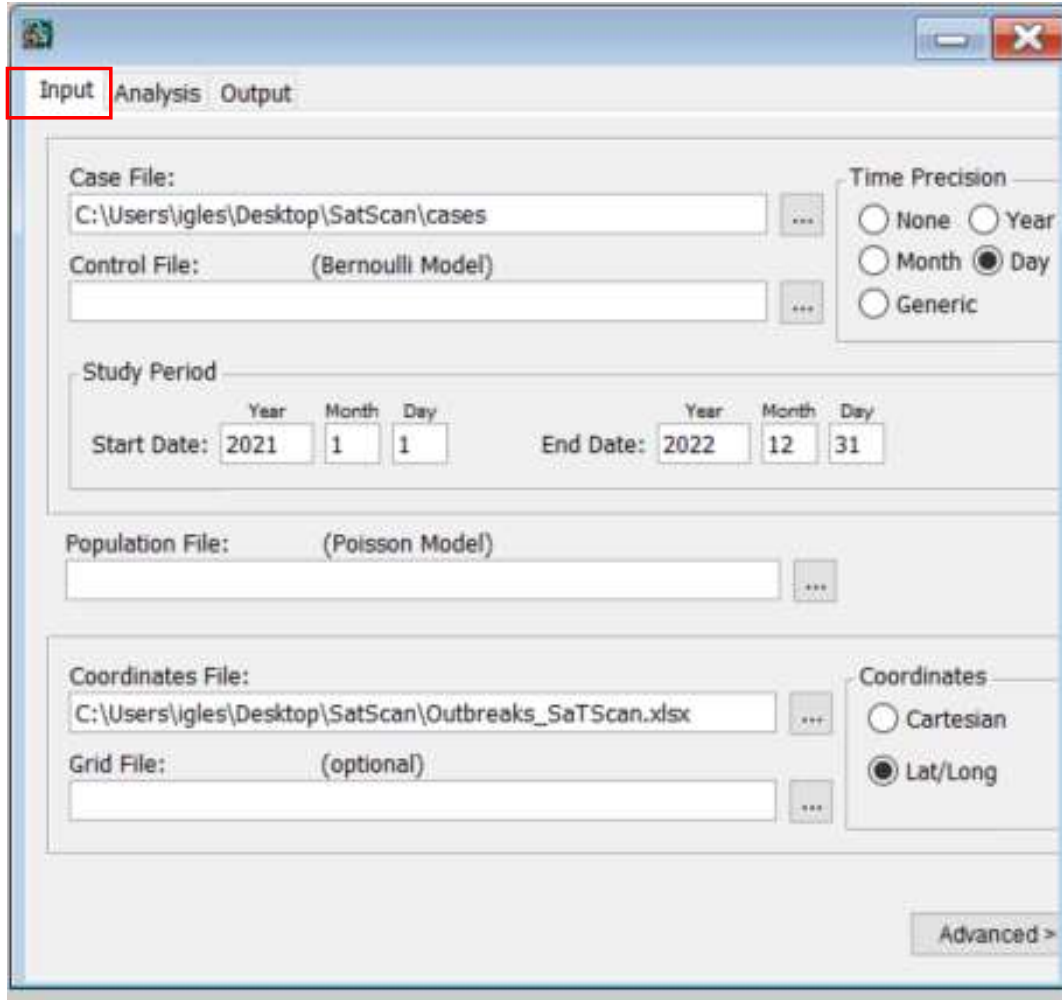


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Exercise



The screenshot shows the 'Input' tab of the SatScan software interface. The 'Case File' is set to 'C:\Users\igles\Desktop\SatScan\cases'. The 'Control File' is set to '(Bernoulli Model)'. The 'Study Period' is defined by 'Start Date: 2021 1 1' and 'End Date: 2022 12 31'. The 'Population File' is set to '(Poisson Model)'. The 'Coordinates File' is set to 'C:\Users\igles\Desktop\SatScan\Outbreaks_SaTScan.xlsx'. The 'Grid File' is set to '(optional)'. The 'Time Precision' is set to 'Day' (selected). The 'Coordinates' are set to 'Lat/Long' (selected). An 'Advanced >' button is visible at the bottom right.

Input Analysis Output

Case File:
C:\Users\igles\Desktop\SatScan\cases ...

Control File: (Bernoulli Model) ...

Study Period

Start Date: Year Month Day
2021 1 1

End Date: Year Month Day
2022 12 31

Population File: (Poisson Model) ...

Coordinates File:
C:\Users\igles\Desktop\SatScan\Outbreaks_SaTScan.xlsx ...

Grid File: (optional) ...

Time Precision
☐ None ☐ Year
☐ Month ☒ Day
☐ Generic

Coordinates
☐ Cartesian
☒ Lat/Long

Advanced >

- Check study period (2021-2022) and time precision



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Exercise

The screenshot shows a software window with three tabs: 'Input', 'Analysis', and 'Output'. The 'Analysis' tab is active. It contains several sections for configuring the analysis:

- Type of Analysis:**
 - Retrospective Analyses:**
 - ☐ Purely Spatial
 - ☐ Purely Temporal
 - ☒ Space-Time
 - ☐ Seasonal
 - ☐ Spatial Variation in Temporal Trends
 - Prospective Analyses:**
 - ☐ Purely Temporal
 - ☐ Space-Time
- Probability Model:**
 - Discrete Scan Statistics:**
 - ☐ Poisson
 - ☐ Bernoulli
 - ☒ Space-Time Permutation
 - ☐ Multinomial
 - ☐ Ordinal
 - ☐ Exponential
 - ☐ Normal
 - Continuous Scan Statistics:**
 - ☐ Poisson
 - ☐ ...
- Scan For Areas With:**
 - ☐ High Rates
 - ☐ Low Rates
 - ☒ High or Low Rates
- Time Aggregation:**
 - Units: ☐ Year, ☐ Month, ☒ Day
 - Length: Days

An 'Advanced >>' button is located at the bottom right of the window.

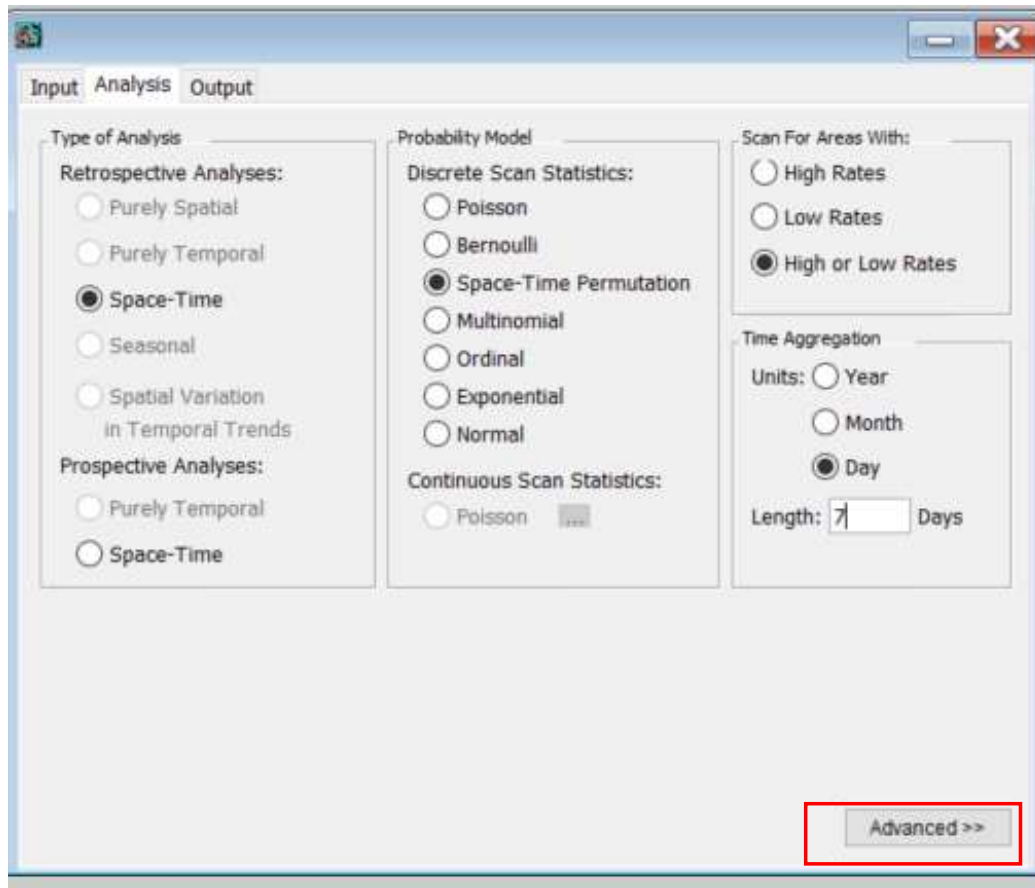
- **Analysis:**
 - **Space-time**
 - **Permutation**
 - **Scan High or Low rates**
 - **Time aggregation 7 days**



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Exercise



The screenshot shows a software window titled 'Analysis' with three tabs: 'Input', 'Analysis', and 'Output'. The 'Analysis' tab is active. It contains several sections for configuring statistical analysis:

- Type of Analysis:**
 - Retrospective Analyses:**
 - ☐ Purely Spatial
 - ☐ Purely Temporal
 - ☒ Space-Time
 - ☐ Seasonal
 - ☐ Spatial Variation in Temporal Trends
 - Prospective Analyses:**
 - ☐ Purely Temporal
 - ☐ Space-Time
- Probability Model:**
 - Discrete Scan Statistics:**
 - ☐ Poisson
 - ☐ Bernoulli
 - ☒ Space-Time Permutation
 - ☐ Multinomial
 - ☐ Ordinal
 - ☐ Exponential
 - ☐ Normal
 - Continuous Scan Statistics:**
 - ☐ Poisson
 - ☐ ...
- Scan For Areas With:**
 - ☐ High Rates
 - ☐ Low Rates
 - ☒ High or Low Rates
- Time Aggregation:**
 - Units:** ☐ Year, ☐ Month, ☒ Day
 - Length:** Days

A red box highlights the 'Advanced >>' button at the bottom right of the window.

- **Analysis:Advanced**



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Exercise

The screenshot shows the 'Advanced Analysis Features' dialog box with the 'Spatial Window' tab selected. The 'Maximum Spatial Cluster Size' section has three options: the first is selected with a value of 50.0, the second is unchecked with a value of 50.0, and the third is checked with a value of 100. The 'Spatial Window Shape' section has 'Circular' selected. The 'Non-Compactness Penalty' is set to 'Medium'. The 'Use Isotonic Spatial Scan Statistic' checkbox is unchecked. At the bottom are 'Set Defaults' and 'Close' buttons.

Advanced Analysis Features

Space and Time Adjustments Inference Border Analysis Power Evaluation
Spatial Window Temporal Window Cluster Restrictions

Maximum Spatial Cluster Size

☒ 50.0 percent of the population at risk ($\leq 50\%$, default = 50%)

☐ 50.0 percent of the population defined in the max circle size file ($\leq 50\%$)

☒ is a circle with a 100 kilometer radius

☐ Include Purely Temporal Clusters (Spatial Size = 100%)

Spatial Window Shape

☒ Circular

☐ Elliptic Non-Compactness Penalty: Medium

☐ Use Isotonic Spatial Scan Statistic

Set Defaults Close

- Analysis:Advanced
- Spatial window 100km



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Exercise

The screenshot shows the 'Advanced Analysis Features' dialog box with the 'Temporal Window' tab selected. The 'Maximum Temporal Cluster Size' section has two radio buttons: 'is 50.0 percent of the study period (<= 50%, default = 50%)' and 'is 90 days'. The 'Minimum Temporal Cluster Size' section has a text box with '1' and the label 'days'. The 'Include Purely Spatial Clusters (Temporal Size = 100%)' checkbox is unchecked. The 'Flexible Temporal Window Definition' section has an unchecked checkbox 'Include only windows with:' followed by two date range inputs. The first input is 'Start time in range: 2000 1 1 to 2000 12 31' and the second is 'End time in range: 2000 1 1 to 2000 12 31'. At the bottom are 'Set Defaults' and 'Close' buttons.

Advanced Analysis Features

Space and Time Adjustments Inference Border Analysis Power Evaluation

Spatial Window Temporal Window Cluster Restrictions

Maximum Temporal Cluster Size

☐ is 50.0 percent of the study period (<= 50%, default = 50%)

☒ is 90 days

Minimum Temporal Cluster Size

1 days

☐ Include Purely Spatial Clusters (Temporal Size = 100%)

Flexible Temporal Window Definition

☐ Include only windows with:

Start time in range: 2000 1 1 to 2000 12 31

End time in range: 2000 1 1 to 2000 12 31

Set Defaults Close

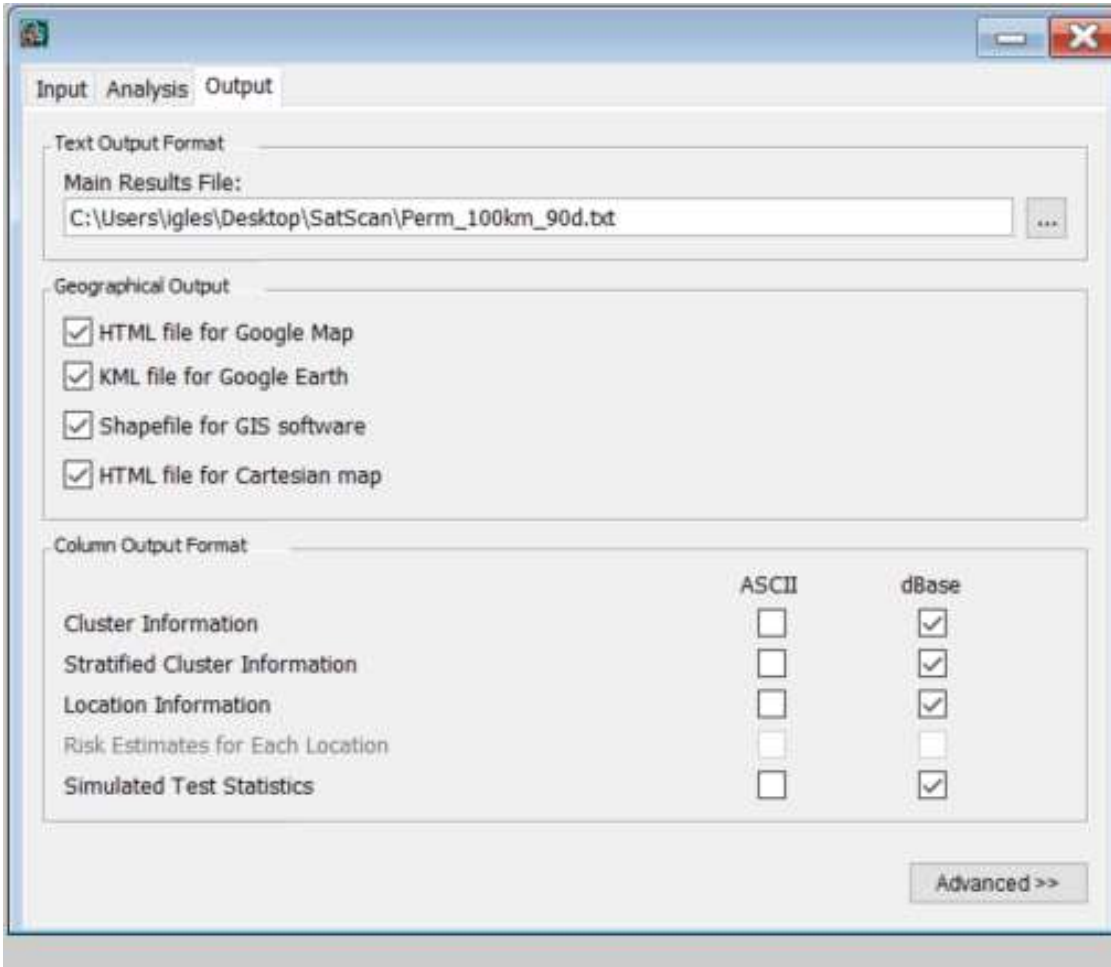
- Analysis:Advanced
- Temporal window 90 days



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Exercise



The screenshot shows the 'Output' tab of the SatScan software. It is divided into three sections: 'Text Output Format', 'Geographical Output', and 'Column Output Format'.

Text Output Format

Main Results File:
C:\Users\igles\Desktop\SatScan\Perm_100km_90d.txt

Geographical Output

- ☒ HTML file for Google Map
- ☒ KML file for Google Earth
- ☒ Shapefile for GIS software
- ☒ HTML file for Cartesian map

Column Output Format

	ASCII	dBase
Cluster Information	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Stratified Cluster Information	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Location Information	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Risk Estimates for Each Location	<input type="checkbox"/>	<input type="checkbox"/>
Simulated Test Statistics	<input type="checkbox"/>	<input checked="" type="checkbox"/>

Advanced >>

Outputs:
check all outputs in dBase
format



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Exercise

Advanced Output Features

Spatial Output: Temporal Output Other Output:

Temporal Graphs

☒ Produce Temporal Graphs

☐ Most likely cluster only

☐ 1 most likely clusters, one graph for each

☒ All significant clusters, one graph for each, with p-value less than: 0.05

Set Defaults Close

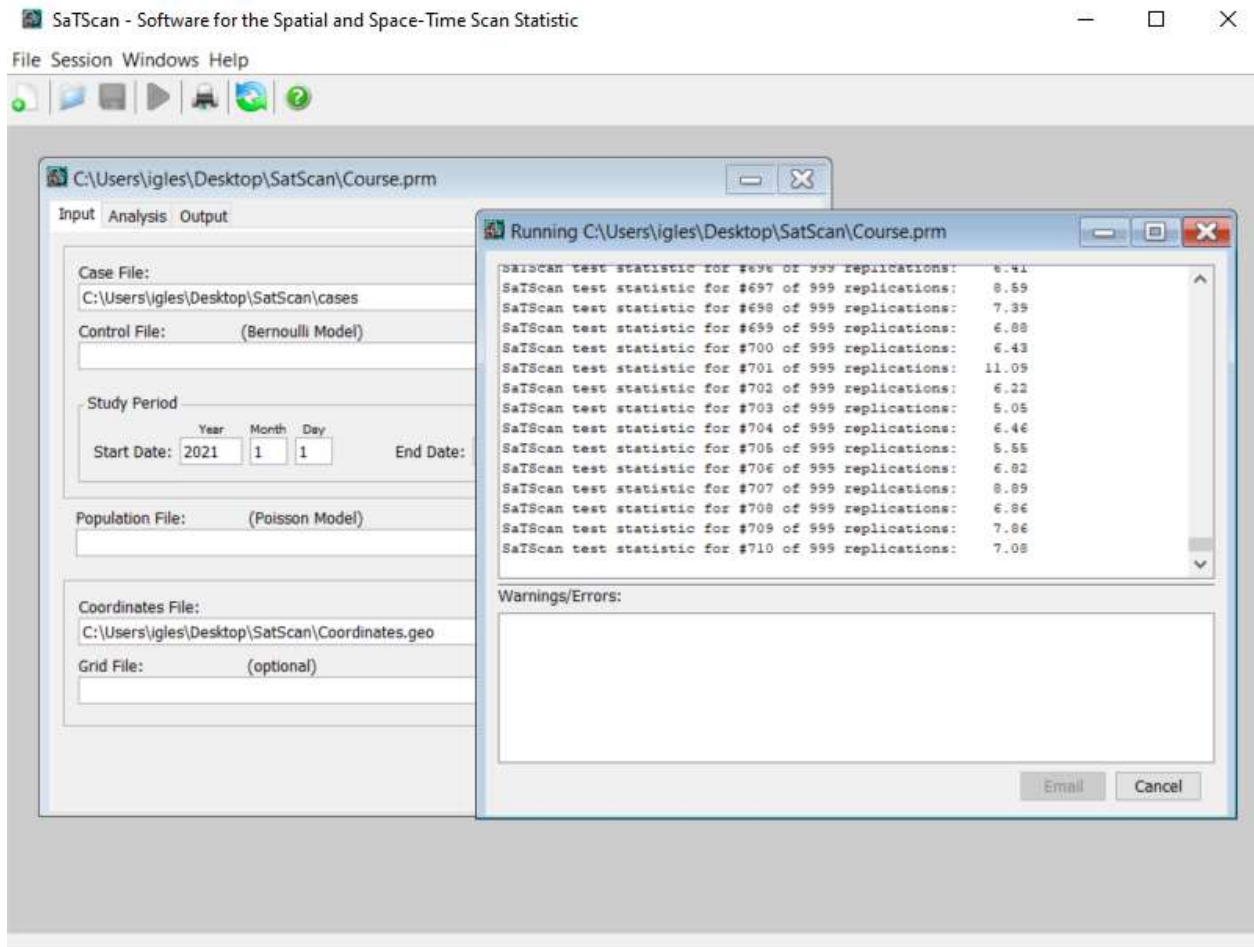
**Outputs: Advanced
Temporal all significant
clusters**



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Exercise



Run model



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Exercise



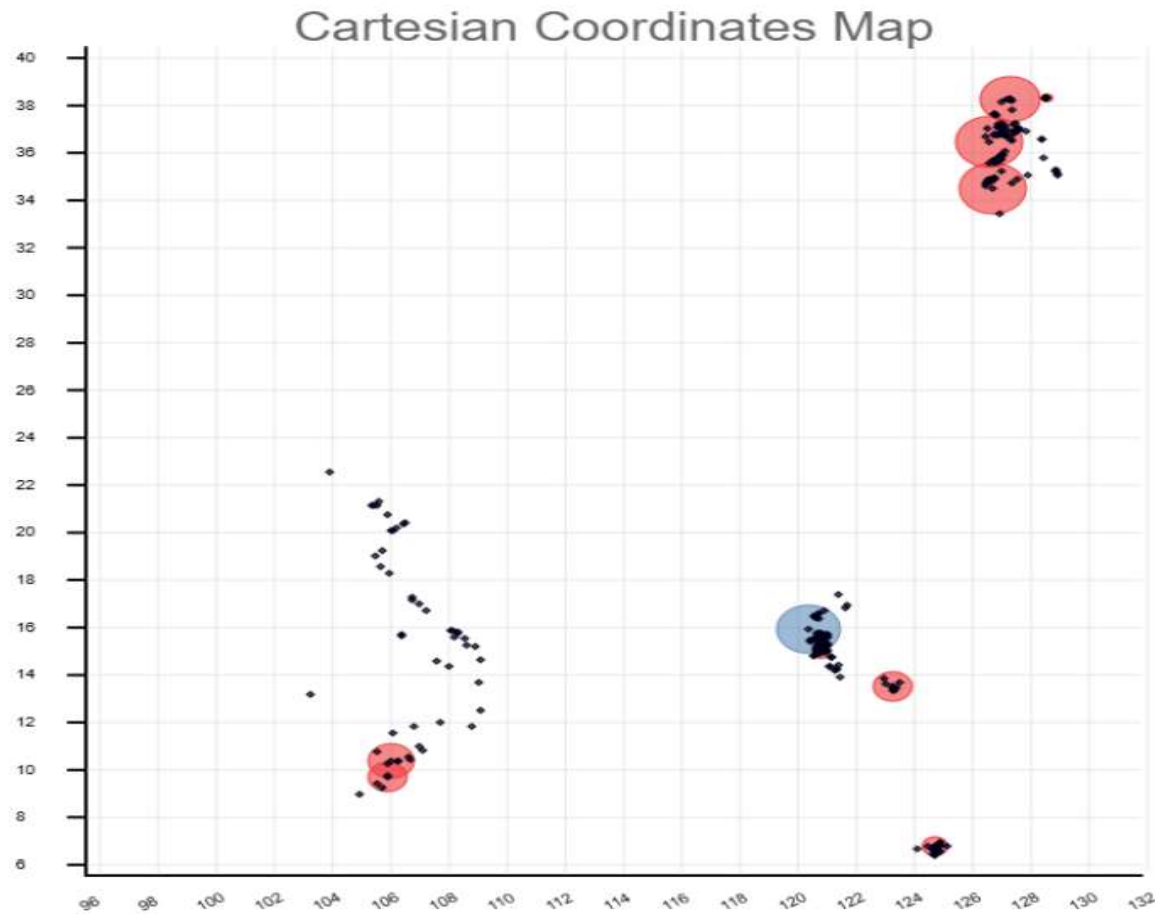
Html map will be open
when the model finish.



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Exercise



**Html map will be open
when the model finish.**



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Exercise Results

Check TXT :

 Perm_100km_90d

15 cluster:

- 10 significatives (p value<0.05)
- 9 observed/expected >1 (Red)
- 1 observed/expected <1 (Blue)

```

SaTScan v9.6

Program run on: Tue Feb 25 08:08:10 2025

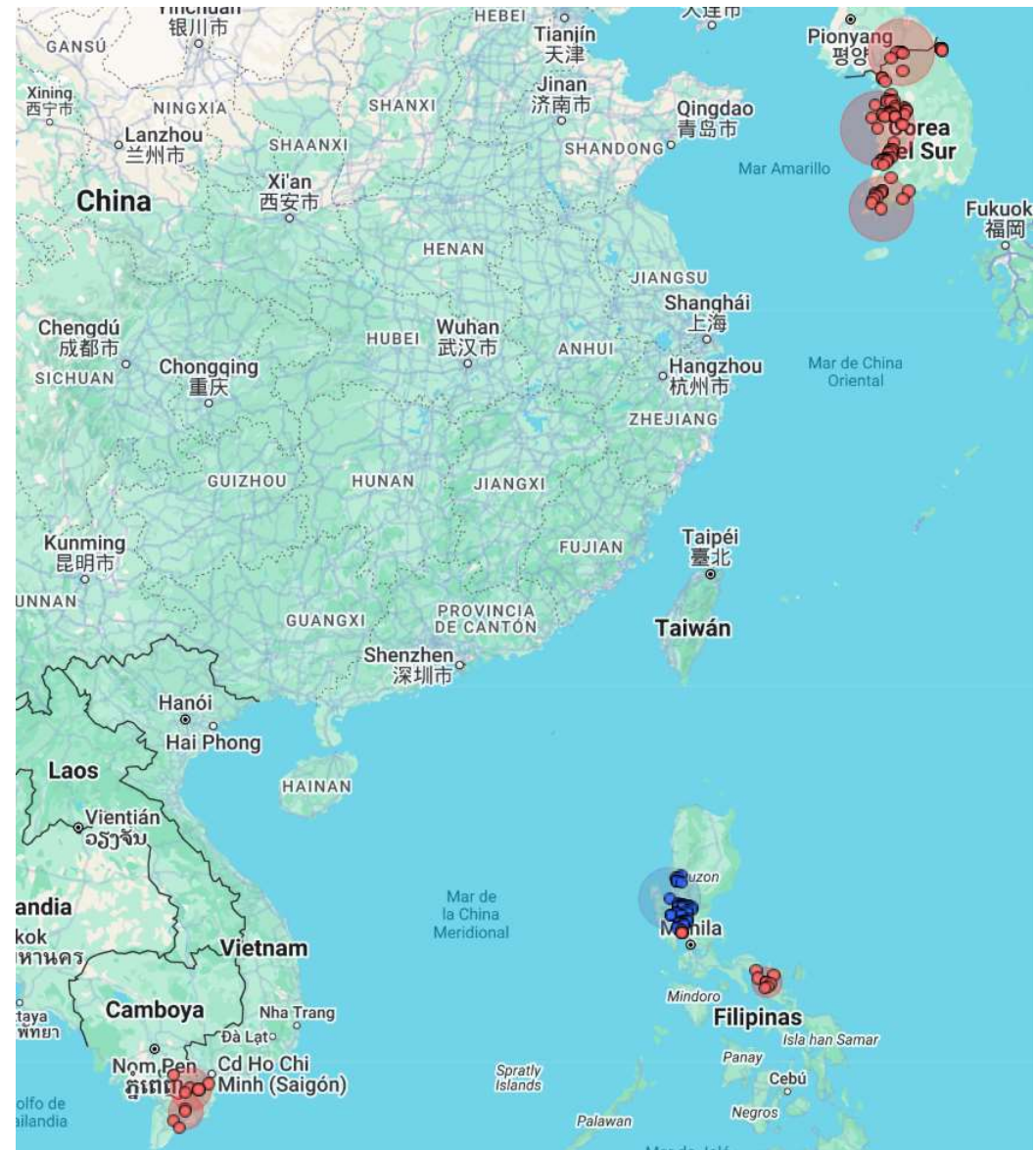
Retrospective Space-Time analysis
scanning for clusters with high or low rates
using the Space-Time Permutation model.

SUMMARY OF DATA
Study period.....: 2021/1/1 to 2022/12/31
Number of locations.....: 311
Total number of cases.....: 395

CLUSTERS DETECTED

1.Location IDs included.: location346, location347, location349, location300, location310,
location311, location320, location329, location330, location331,
location332, location335, location336, location338, location339,
location340, location341, location342, location343, location350,
location351, location352, location353, location363, location309,
location366, location379, location280, location289, location291,
location293, location294, location297, location312, location313,
location314, location315, location316, location317, location318,

```



Exercise Results

Open dbf .col with Excel :

CLUSTER	LOC_ID	LATITUDE	LONGITUDE	RADIUS	START_DATE	END_DATE	NUMBER_LOC	TEST_STAT	P_VALUE	OBSERVED	EXPECTED	ODE	GINI_CLUST
1	location346	14,935704	120,755243	5,83036944	2022/7/31	2022/8/6	6	34,6517011	7,8E-16	33	5,116455696	6,44977734	FALSO
2	location88	36,456	126,5915	99,9501069	2021/12/5	2022/2/19	52	27,4606615	6,177E-12	40	9,741772152	4,10602911	FALSO
3	location123	38,313993	128,531013	3,44750347	2022/3/27	2022/4/2	14	19,5040794	1,2475E-07	11	0,744303798	14,7789116	FALSO
4	location31	34,499518	126,694278	88,5206314	2021/11/7	2022/1/1	14	15,8914703	1,1241E-05	11	1,063291139	10,3452381	FALSO
5	location344	15,940039	120,35265	99,1881234	2021/12/12	2022/3/5	50	15,5923463	1,6318E-05	0	15,28860759	0	FALSO
6	location233	10,385	106,0049	68,8975106	2021/5/23	2021/7/17	6	15,4918114	1,8496E-05	7	0,296202532	23,6324786	FALSO
7	location3	9,7231	105,8607	57,6149362	2021/1/17	2021/1/23	4	12,8289759	0,00051028	4	0,060759494	65,8333333	FALSO
8	location122	38,268104	127,287422	86,7468215	2022/2/27	2022/4/2	18	11,9779573	0,0014726	16	3,511392405	4,55659697	FALSO
9	location187	6,766535	124,705411	22,6528506	2022/4/3	2022/4/9	11	11,3788089	0,00310404	8	0,789873418	10,1282051	FALSO
10	location111	13,51452	123,2652	49,1022647	2022/2/27	2022/3/26	9	10,8650169	0,0058794	10	1,448101266	6,90559441	FALSO
11	location20	15,7227	106,3951	6,66172372	2021/7/11	2021/7/17	2	7,78073206	0,277	2	0,015189873	131,666667	FALSO
12	location229	20,0909	106,0592	74,2339733	2022/10/23	2022/10/29	6	7,70740955	0,296	4	0,227848101	17,5555556	FALSO
13	location382	18,277	105,9759	94,244301	2022/10/23	2022/10/29	3	6,93700316	0,556	3	0,113924051	26,3333333	FALSO
14	location57	11,562	106,0735	84,7604901	2022/1/2	2022/1/8	2	5,84426361	0,957	2	0,040506329	49,375	FALSO
15	location10	11,8076	108,7607	0	2021/5/23	2021/7/3	1	5,40805297	0,992	2	0,050632911	39,5	FALSO



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Exercise Results

Include duration : End_date – Star_Date

CLUSTER	LOC_ID	LATITUDE	LONGITUDE	RADIUS	START_DATE	END_DATE	Duration	NUMBER_LOC	TEST_STAT	P_VALUE	OBSERVED	EXPECTED	ODE	GINI_CLUST
1	location346	14,935704	120,755243	5,83036944	2022/7/31	2022/8/6	6	6	34,6517011	7,8E-16	33	5,116455696	6,44977734	FALSO
2	location88	36,456	126,5915	99,9501069	2021/12/5	2022/2/19	76	52	27,4606615	6,177E-12	40	9,741772152	4,10602911	FALSO
3	location123	38,313993	128,531013	3,44750347	2022/3/27	2022/4/2	6	14	19,5040794	1,2475E-07	11	0,744303798	14,7789116	FALSO
4	location31	34,499518	126,694278	88,5206314	2021/11/7	2022/1/1	55	14	15,8914703	1,1241E-05	11	1,063291139	10,3452381	FALSO
5	location344	15,940039	120,35265	99,1881234	2021/12/12	2022/3/5	83	50	15,5923463	1,6318E-05	0	15,28860759	0	FALSO
6	location233	10,385	106,0049	68,8975106	2021/5/23	2021/7/17	55	6	15,4918114	1,8496E-05	7	0,296202532	23,6324786	FALSO
7	location3	9,7231	105,8607	57,6149362	2021/1/17	2021/1/23	6	4	12,8289759	0,00051028	4	0,060759494	65,8333333	FALSO
8	location122	38,268104	127,287422	86,7468215	2022/2/27	2022/4/2	34	18	11,9779573	0,0014726	16	3,511392405	4,55659697	FALSO
9	location187	6,766535	124,705411	22,6528506	2022/4/3	2022/4/9	6	11	11,3788089	0,00310404	8	0,789873418	10,1282051	FALSO
10	location111	13,51452	123,2652	49,1022647	2022/2/27	2022/3/26	27	9	10,8650169	0,0058794	10	1,448101266	6,90559441	FALSO
11	location20	15,7227	106,3951	6,66172372	2021/7/11	2021/7/17	6	2	7,78073206	0,277	2	0,015189873	131,666667	FALSO
12	location229	20,0909	106,0592	74,2339733	2022/10/23	2022/10/29	6	6	7,70740955	0,296	4	0,227848101	17,5555556	FALSO
13	location382	18,277	105,9759	94,244301	2022/10/23	2022/10/29	6	3	6,93700316	0,556	3	0,113924051	26,3333333	FALSO
14	location57	11,562	106,0735	84,7604901	2022/1/2	2022/1/8	6	2	5,84426361	0,957	2	0,040506329	49,375	FALSO
15	location10	11,8076	108,7607	0	2021/5/23	2021/7/3	41	1	5,40805297	0,992	2	0,050632911	39,5	FALSO



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Exercise Results

Basic Description of SaTScan Results:

- 10 significant clusters detected:
 - 1 cluster with observed cases lower than expected
 - 9 clusters with observed cases higher than expected (Mean O/E ratio = 16)
- Seasonal Distribution:
 - 5/10 clusters occurred in winter
 - 4/10 clusters occurred in spring
 - 1/10 cluster occurred in summer
- Spatial and Temporal Characteristics:
 - Mean radius: 56 km
 - Mean duration: 27.93 days
- High Incidence Clusters:
 - 4 in South Korea
 - 3 in the Philippines
 - 2 in Vietnam
- Low Incidence Cluster:
 - 1 in the Philippines



CLUSTER	LOC_ID	LATITUDE	LONGITUDE	RADIUS	START_DATE	END_DATE	Duration	NUMBER_LOC	TEST_STAT	P_VALUE	OBSERVED	EXPECTED	ODE	GINI_CLUST
1	location346	14,935704	120,755243	5,83036944	2022/7/31	2022/8/6	6	6	34,6517011	7,8E-16	33	5,116455696	6,44977734	FALSO
2	location88	36,456	126,5915	99,9501069	2021/12/5	2022/2/19	76	52	27,4606615	6,177E-12	40	9,741772152	4,10602911	FALSO
3	location123	38,313993	128,531013	3,44750347	2022/3/27	2022/4/2	6	14	19,5040794	1,2475E-07	11	0,744303798	14,7789116	FALSO
4	location31	34,499518	126,694278	88,5206314	2021/11/7	2022/1/1	55	14	15,8914703	1,1241E-05	11	1,063291139	10,3452381	FALSO
5	location344	15,940039	120,35265	99,1881234	2021/12/12	2022/3/5	83	50	15,5923463	1,6318E-05	0	15,28860759	0	FALSO
6	location233	10,385	106,0049	68,8975106	2021/5/23	2021/7/17	55	6	15,4918114	1,8496E-05	7	0,296202532	23,6324786	FALSO
7	location3	9,7231	105,8607	57,6149362	2021/1/17	2021/1/23	6	4	12,8289759	0,00051028	4	0,060759494	65,8333333	FALSO
8	location122	38,268104	127,287422	86,7468215	2022/2/27	2022/4/2	34	18	11,9779573	0,0014726	16	3,511392405	4,55659697	FALSO
9	location187	6,766535	124,705411	22,6528506	2022/4/3	2022/4/9	6	11	11,3788089	0,00310404	8	0,789873418	10,1282051	FALSO
10	location111	13,51452	123,2652	49,1022647	2022/2/27	2022/3/26	27	9	10,8650169	0,0058794	10	1,448101266	6,90559441	FALSO
11	location20	15,7227	106,3951	6,66172372	2021/7/11	2021/7/17	6	2	7,78073206	0,277	2	0,015189873	131,666667	FALSO
12	location229	20,0909	106,0592	74,2339733	2022/10/23	2022/10/29	6	6	7,70740955	0,296	4	0,227848101	17,5555556	FALSO
13	location382	18,277	105,9759	94,244301	2022/10/23	2022/10/29	6	3	6,93700316	0,556	3	0,113924051	26,3333333	FALSO
14	location57	11,562	106,0735	84,7604901	2022/1/2	2022/1/8	6	2	5,84426361	0,957	2	0,040506329	49,375	FALSO
15	location10	11,8076	108,7607	0	2021/5/23	2021/7/3	41	1	5,40805297	0,992	2	0,050632911	39,5	FALSO



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Exercise Results

Basic Description of SaTScan Results: Interpretation

SaTScan analysis identified spatial-temporal clusters of HPAI H5N1 outbreaks, highlighting areas with high and low case densities. The majority of high-incidence clusters were observed in South Korea, the Philippines, and Vietnam, while one low-incidence cluster was detected in the Philippines. Clusters were primarily concentrated in the winter and spring seasons, indicating potential seasonal patterns in outbreak occurrences.



CLUSTER	LOC_ID	LATITUDE	LONGITUDE	RADIUS	START_DATE	END_DATE	Duration	NUMBER_LOC	TEST_STAT	P_VALUE	OBSERVED	EXPECTED	ODE	GINI_CLUST
1	location346	14,935704	120,755243	5,83036944	2022/7/31	2022/8/6	6	6	34,6517011	7,8E-16	33	5,116455696	6,44977734	FALSO
2	location88	36,456	126,5915	99,9501069	2021/12/5	2022/2/19	76	52	27,4606615	6,177E-12	40	9,741772152	4,10602911	FALSO
3	location123	38,313993	128,531013	3,44750347	2022/3/27	2022/4/2	6	14	19,5040794	1,2475E-07	11	0,744303798	14,7789116	FALSO
4	location31	34,499518	126,694278	88,5206314	2021/11/7	2022/1/1	55	14	15,8914703	1,1241E-05	11	1,063291139	10,3452381	FALSO
5	location344	15,940039	120,35265	99,1881234	2021/12/12	2022/3/5	83	50	15,5923463	1,6318E-05	0	15,28860759	0	FALSO
6	location233	10,385	106,0049	68,8975106	2021/5/23	2021/7/17	55	6	15,4918114	1,8496E-05	7	0,296202532	23,6324786	FALSO
7	location3	9,7231	105,8607	57,6149362	2021/1/17	2021/1/23	6	4	12,8289759	0,00051028	4	0,060759494	65,8333333	FALSO
8	location122	38,268104	127,287422	86,7468215	2022/2/27	2022/4/2	34	18	11,9779573	0,0014726	16	3,511392405	4,55659697	FALSO
9	location187	6,766535	124,705411	22,6528506	2022/4/3	2022/4/9	6	11	11,3788089	0,00310404	8	0,789873418	10,1282051	FALSO
10	location111	13,51452	123,2652	49,1022647	2022/2/27	2022/3/26	27	9	10,8650169	0,0058794	10	1,448101266	6,90559441	FALSO
11	location20	15,7227	106,3951	6,66172372	2021/7/11	2021/7/17	6	2	7,78073206	0,277	2	0,015189873	131,666667	FALSO
12	location229	20,0909	106,0592	74,2339733	2022/10/23	2022/10/29	6	6	7,70740955	0,296	4	0,227848101	17,5555556	FALSO
13	location382	18,277	105,9759	94,244301	2022/10/23	2022/10/29	6	3	6,93700316	0,556	3	0,113924051	26,3333333	FALSO
14	location57	11,562	106,0735	84,7604901	2022/1/2	2022/1/8	6	2	5,84426361	0,957	2	0,040506329	49,375	FALSO
15	location10	11,8076	108,7607	0	2021/5/23	2021/7/3	41	1	5,40805297	0,992	2	0,050632911	39,5	FALSO



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Exercise Results

Visualizing SaTScan Results

1. Load the Results in a GIS Software

- Open **QGIS**, **ArcGIS**, or any other GIS software.
- Import the **SaTScan output files .col**

 Perm_100km_90d.gis.shp

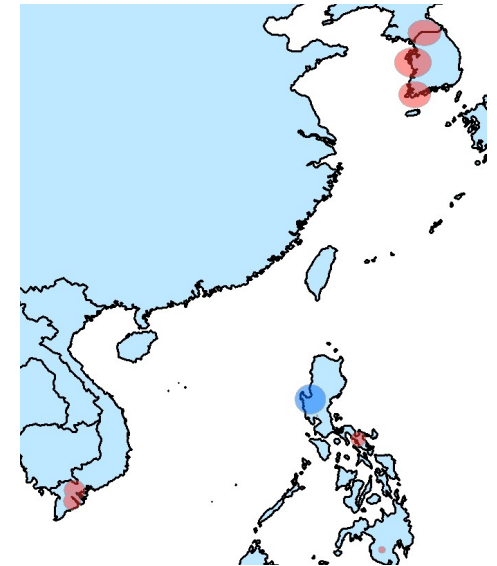
 Perm_100km_90d.col.shp

2. Display the Cluster Data

- Load the **base map** (e.g., "countries" shapefile) for geographic reference.
- Overlay the **clusters layer** and apply a **graduated color scale** to distinguish high and low observed/expected (O/E) ratios.
- Set **symbols** to differentiate:
 - **High-incidence clusters** (Observed > Expected)
 - **Low-incidence clusters** (Observed < Expected)

3. Analyze Spatial Patterns

- Use **symbology settings** to categorize clusters by **season (winter, spring, summer)**.
- Adjust **transparency** to visualize overlapping clusters.

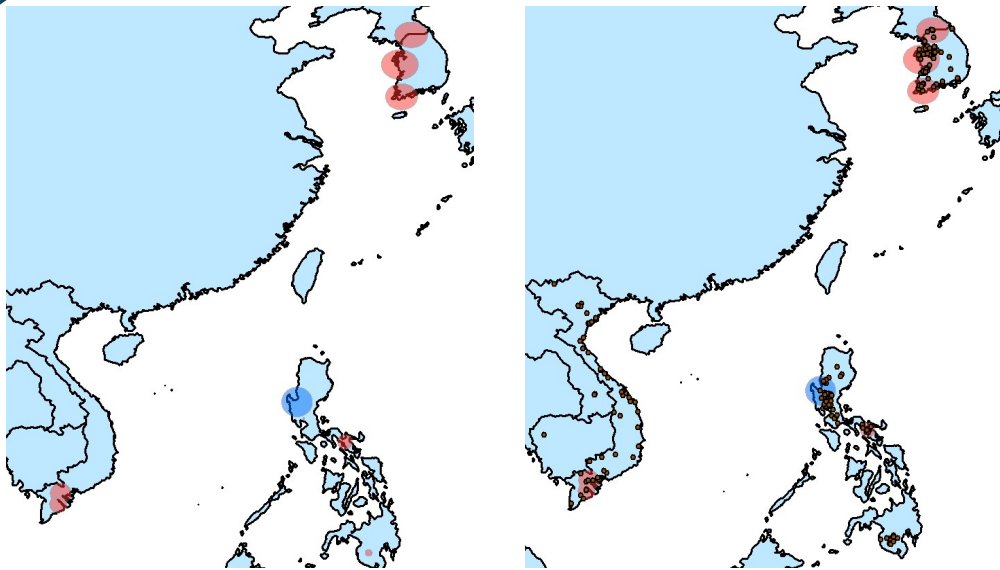


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Exercise Results

Visualizing SaTScan Results



Outbreaks

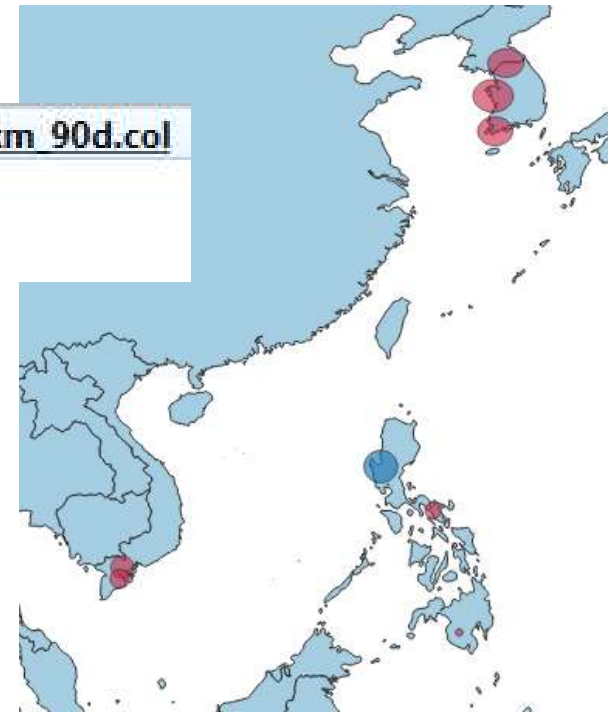
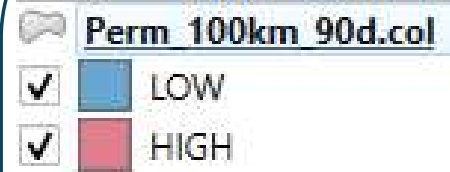


Perm_100km_90d.col

ODE

LOW

HIGH



PART 5

INTERPOLATION AND SMOOTHING



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Concept of Interpolation

- **Objective:** Estimate (predict) the value of a variable at **unsampled locations**, based on known values at sampled points.
- **Main characteristic:**
 - Assumes the existence of a **continuous field or surface** of the variable (e.g., temperature, altitude, contamination levels).
 - Many interpolation methods (e.g., **IDW, Kriging, Splines**) generate surfaces that **pass through or approximate observed values**.
- **Examples of interpolation in GIS**
 - ❖ Estimating **altitude** between known elevation points.
 - ❖ Predicting **temperature** in locations without meteorological stations → survival pathogens.
 - ❖ Estimating **contaminant concentration** based on scattered sampling sites.



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Concept of Spatial Smoothing

- Spatial smoothing techniques, such as **Kernel Density Estimation (KDE)** create a **continuous density surface** based on point distribution.
- **Objective:** Identify **intensity or concentration of events** over a geographic area.
- **Main characteristic:**
 - KDE does **not estimate real values** at unknown locations but calculates how **dense** a set of points (events) is in a given area.
 - Uses a **kernel function** to smooth point concentration over space, creating a **continuous density surface**.
- **Examples of spatial smoothing in GIS**
 - ❖ Mapping **disease hotspots** in study areas.
 - ❖ Identifying **high-risk zones** for disease outbreaks.
 - ❖ Visualizing **wildlife habitat use** based on tracking data.

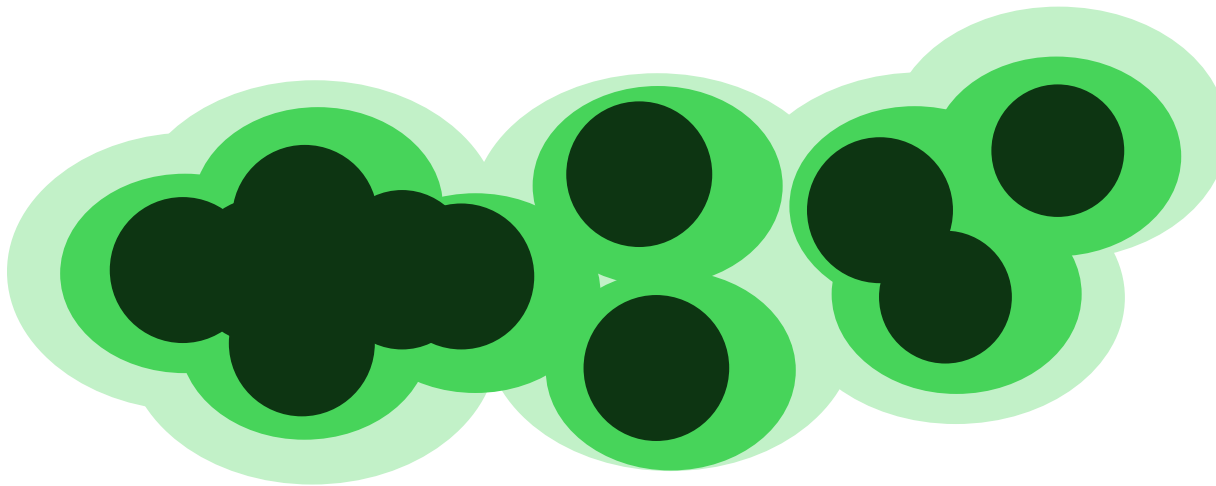


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Concept of Spatial Smoothing: KDE

Transformation of point data into continuous data



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Exercise 1: Self-assessment quiz on IDW vs KDE

Which of the following statements correctly describes the difference between Kernel Density Estimation (KDE) and Inverse Distance Weighting (IDW)?

- A) KDE is an interpolation method that predicts values at unsampled locations, while IDW is a smoothing technique used to estimate event density.
- B) IDW creates a continuous density surface based on point distribution, whereas KDE estimates unknown values using weighted distances to known points.
- C) KDE generates a density surface representing the intensity of point events, while IDW estimates specific values at unknown locations based on weighted distances to known data points.
- D) Both KDE and IDW perform interpolation by estimating missing values in a continuous spatial field.

Correct Answer: C)



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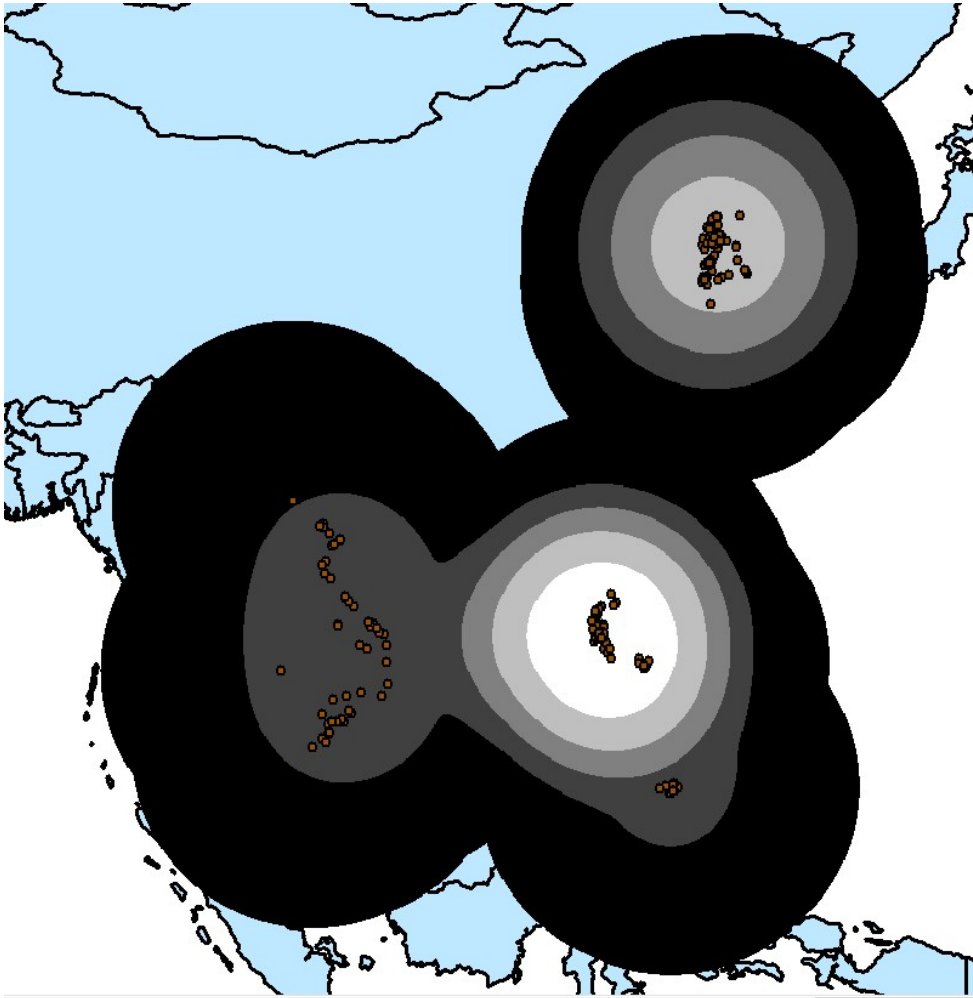
Exercise 2: Spatial Smoothing: KDE QGIS



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Exercise 2: KDE using ArcGIS



Radius 100km

Kernel Density

Input point or polyline features
Outbreaks

Population field
NONE

Output raster
C:\Users\igles\Documents\ArcGIS\Default.gdb\KernelD_shp12

Output cell size (optional)
0,102750752

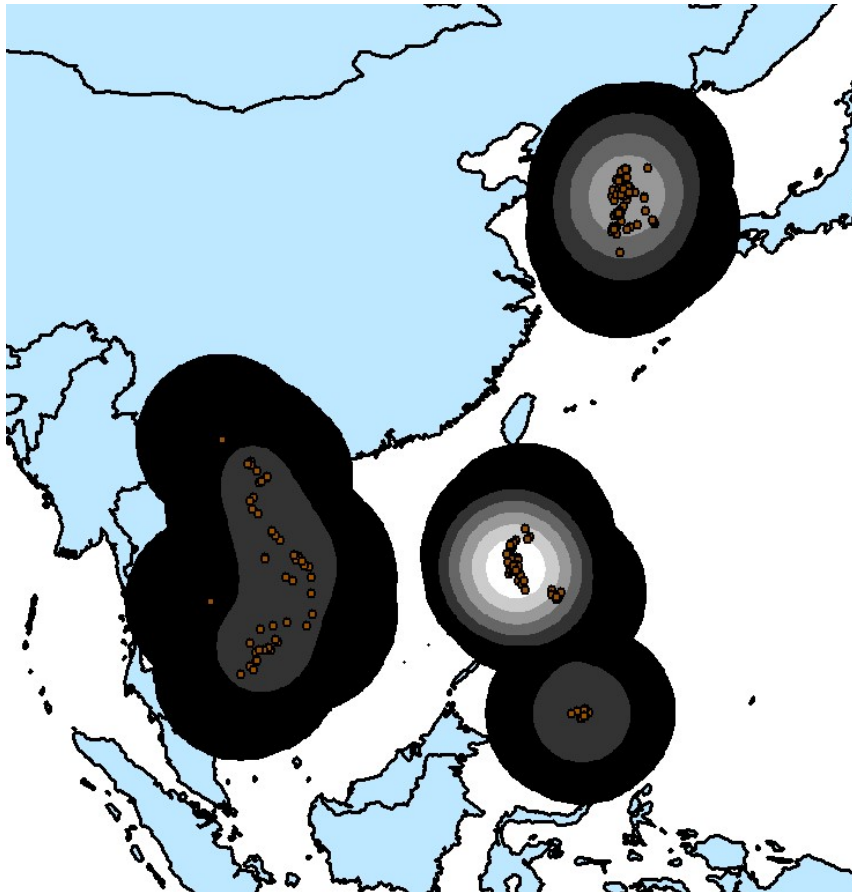
Search radius (optional)
10



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Exercise 2: KDE using ArcGIS



Radius 50km

Kernel Density

Input point or polyline features
Outbreaks

Population field
NONE

Output raster
C:\Users\igles\Documents\ArcGIS\Default.gdb\KernelD_shp15

Output cell size (optional)
0,0602750752

Search radius (optional)
5

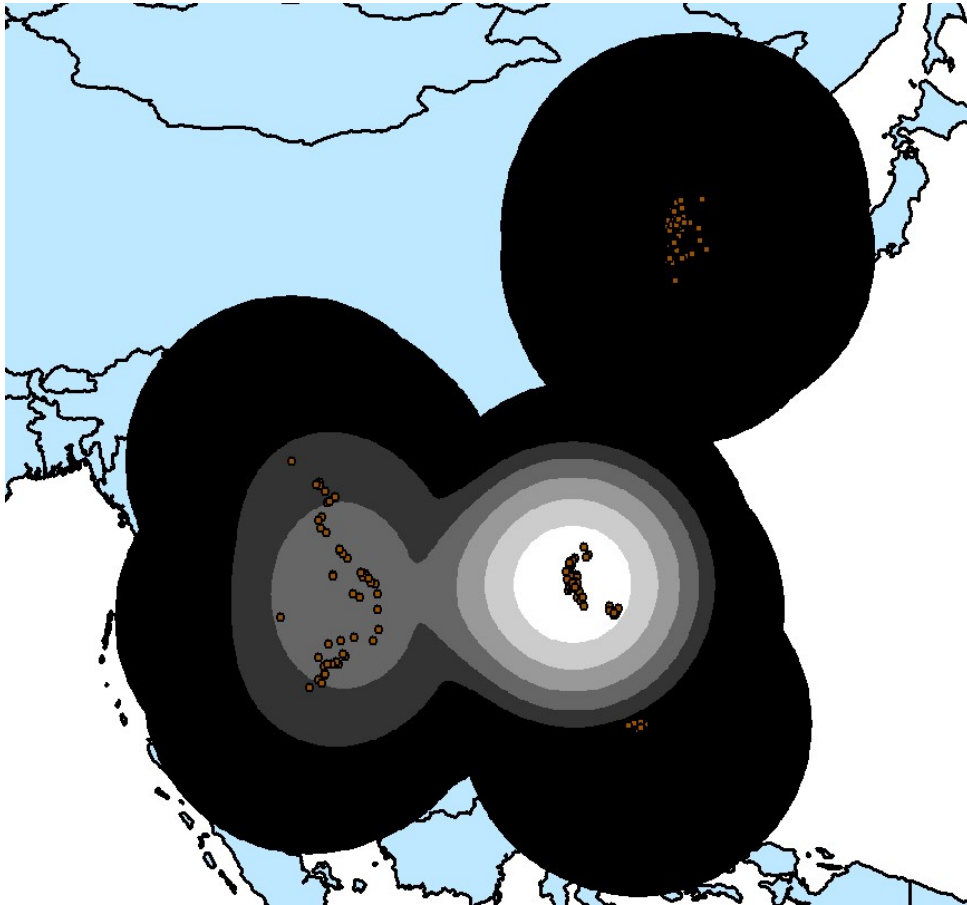
Area units (optional)



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Exercise 2: KDE using ArcGIS



Radius 100km

Weight Field: Number of cases

Kernel Density

Input point or polyline features
Outbreaks

Population field
cases

Output raster
C:\Users\igles\Documents\ArcGIS\Default.gdb\KernelD_shp10

Output cell size (optional)
0,06

Search radius (optional)
10

Area units (optional)



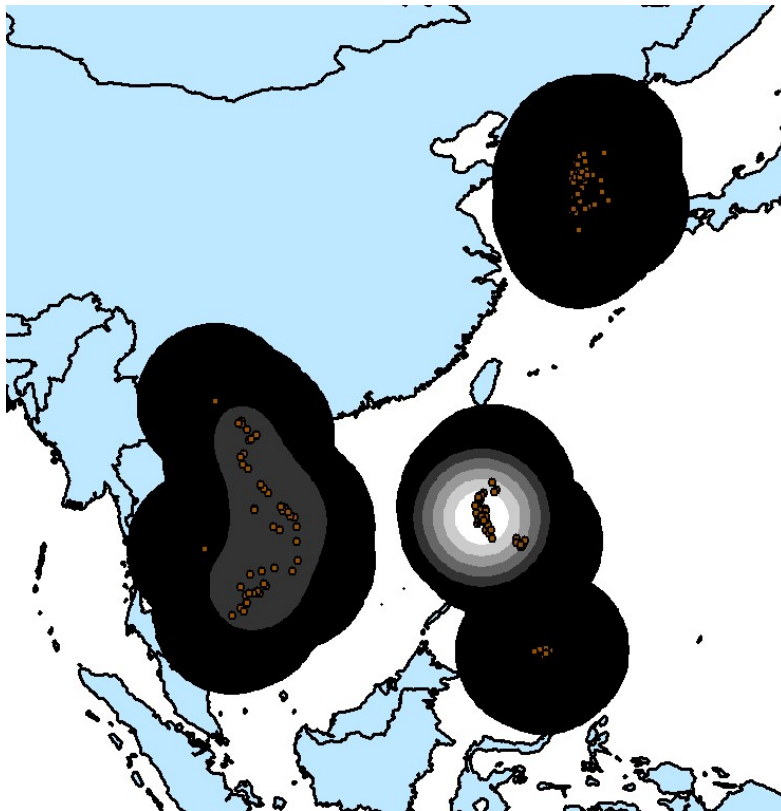
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Exercise 2: KDE using ArcGIS

Radius 50km

Weight Field: Number of cases



Kernel Density

Input point or polyline features
Outbreaks

Population field
cases

Output raster
C:\Users\igles\Documents\ArcGIS\Default.gdb\KernelD_shp10

Output cell size (optional)
0,06

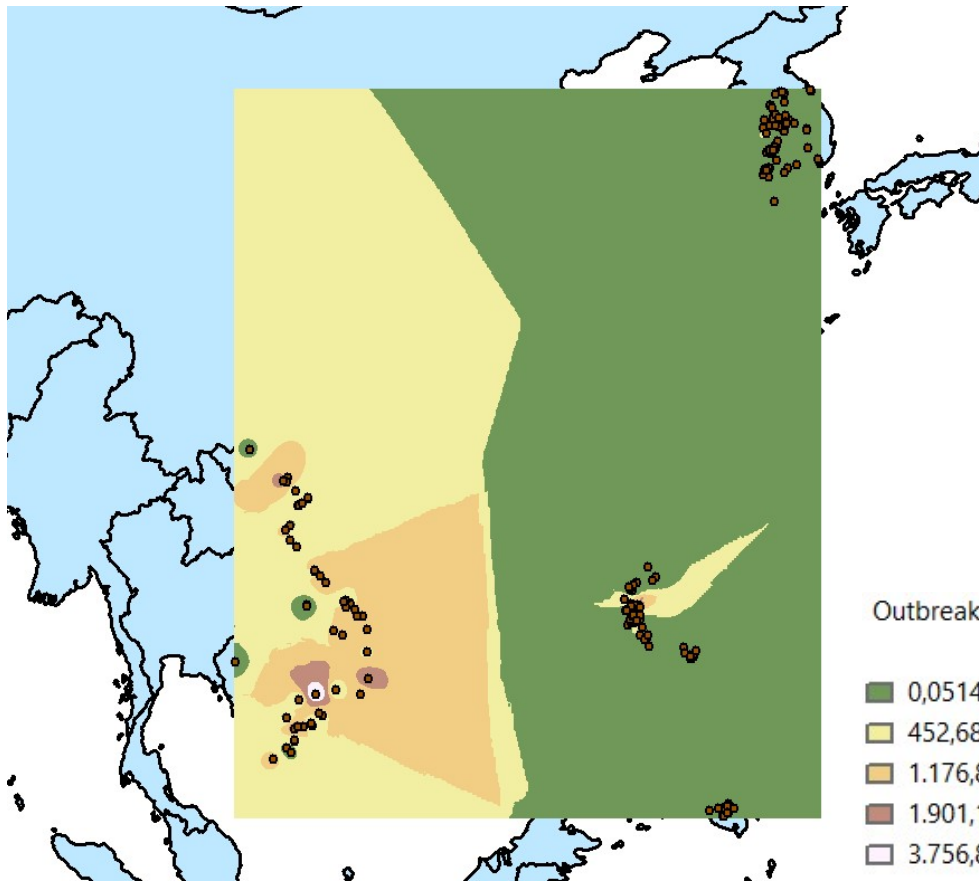
Search radius (optional)
5



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Exercise 2: KDE



Outbreaks IDW

■	0,051444594 - 452,6835034
■	452,6835035 - 1.176,894798
■	1.176,894799 - 1.901,106092
■	1.901,106093 - 3.756,897533
■	3.756,897534 - 11.542,16895

"IDW of outbreaks using ArcGIS" → **INCORRECT**

Inverse Distance Weighting is an interpolation method, meaning it is used to estimate unknown values at unsampled locations based on known data points.

However, disease outbreaks are discrete events, not continuous variables.



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