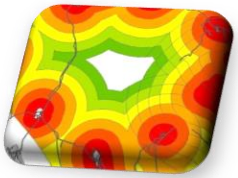


SPATIAL ANALYSIS

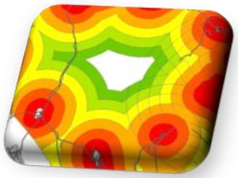
EGS 2310

Spatial analysis: An introduction

Lecture No. 01

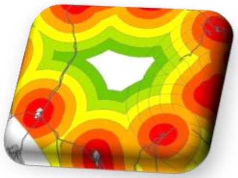
Felix Mutua, Ph. D

Monday, January 23, 2023



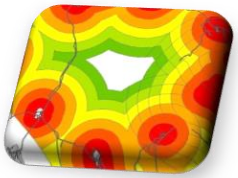
Content

- Course outline
- Spatial analysis concept
- Dimensions of spatial analysis
- Spatial Analysis: the basic primitives



Course Structure

- **Objective :** To gain in-depth knowledge and skills on advanced spatial analysis techniques.
- **Course assessment:**
  - Assignment (many) – 20%
    - Failure to submit = -10 marks
    - Copying from each other = -10 marks
  - CAT(2) – 5%
  - Practical - 5%
  - Exam – 70%



References(1)

Course Journals

- International Journal of Geographical Information Science
- Transactions of GIS

Reference Journals

- Geography Compass
- International Journal of Geomatics and Geosciences

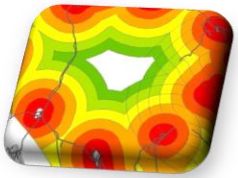
References(2)

Main Reference

http://www.spatialanalysisonline.com/HTML/index.html

Other Textbooks

- Burrough, P. A. and McDonnel, R. A. (1998) Principles of Geographical Information Systems. Oxford.
- Longley P. A., Goodchild M. F., Maguire D. J., Rhind D.W., (2005). Geographic information system: Principles, techniques, management and applications. Abridged edition, J Wiley, Hoboken.
- Longley, P. and Batty, M. (1996) Spatial Analysis: Modelling in a GIS Environment. John Wiley and Sons
- Parker, R. N. and Asencio, E. K. (2008) GIS and Spatial Analysis for the social sciences: coding, mapping and modeling. Taylor and Francis.



Course outline

- Introduction:
  - Overview of functionalities of GIS,
  - application of GIS; utility, engineering, mapping, suitability site selection.
- Analysis: Attribute data queries:
  - Arithmetic and
  - logical operation based analysis.
- Spatial Queries:
  - Proximity operators,
  - set queries,
  - Boolean operation.
- Buffers: Around point, line and polygon features.
- Feature merging: Elimination/dissolution of polygons.
- Network analysis.
  - Network tracing, network routing, optimal patterns application in service industry; transportation planning, traffic, routing.
- Digital Terrain in engineering works.
- Cost distance: least cost pathway determination
- applications, pipeline design, power line location, route location.

Course outline

I

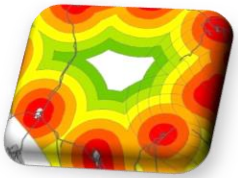
- Overview of geospatial analysis
- Building Blocks of Spatial Analysis
  - Spatial data models and methods
  - Geometric and Related Operations
  - Queries, Computations and Density
  - Distance Operations
  - Directional Operations
  - Grid Operations and Map Algebra
- Data Exploration and Spatial Statistics
  - Statistical Methods and Spatial Data
  - Exploratory Spatial Data Analysis
  - Point Sets and Distance Statistics

II

- Surface and Field Analysis
  - Modeling Surfaces
  - Surface Geometry
  - Visibility
  - Watersheds and Drainage
  - Gridding, Interpolation and Contouring
  - Deterministic Interpolation Methods
  - Geostatistical interpolation

III

- Network and Location Analysis
  - Introduction
  - Key Problems in Network and Location Analysis
  - Network Construction, Optimal Routes and Optimal Tours
  - Location and Service Area Problems
  - Arc Routing
- Spatial modelling
  - Types of spatial models
  - Other models

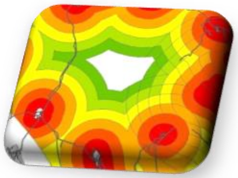


Lecture Plan

Week	Topic		Week	Topic	
1	Introduction to SDA		8	Network Analysis - II	
2	Geometric-Based SDA techniques		9	Districting and normalization	
3	Queries, Computations and density		10	Spatial Autocorrelation	
4	Overlay Analysis		11	Spatial Regression	
5	Surface Field Analysis		12	Spatial Modelling	
6	CAT I		13	CAT II	
7	Network Analysis - I		14		

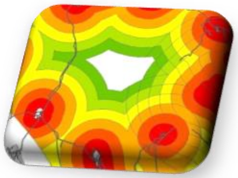
Spatial Concepts

Spatial concepts (a category of basic concepts) define the relationship between us and objects, as well as the relationships of objects to each other.



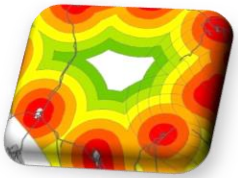
Spatial and Analysis

- **Spatial:** of or relating to space.
- **Analysis :** detailed examination of the elements or structure of something, typically as a basis for discussion or interpretation.



So what is spatial analysis?

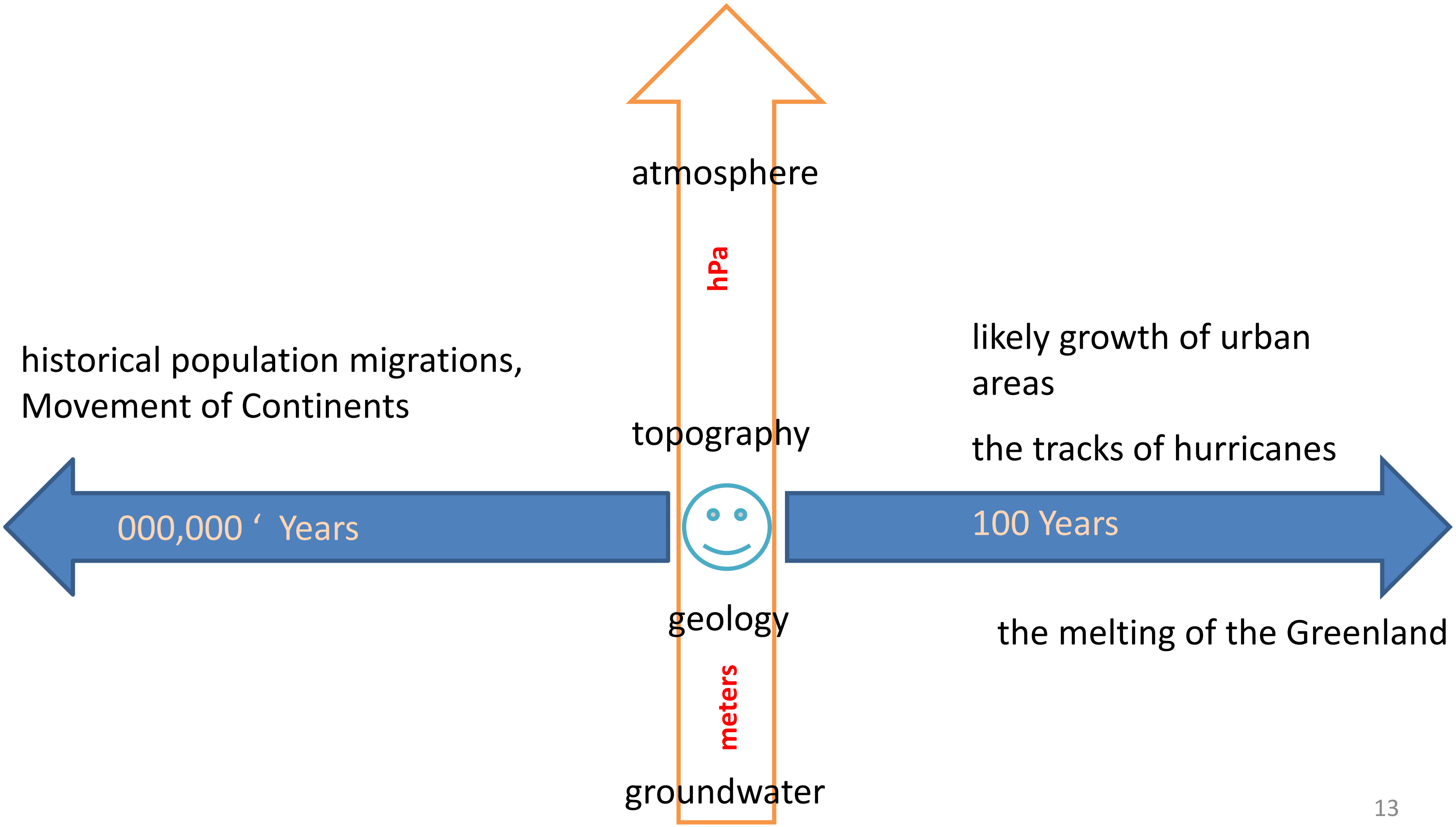
- Spatial analysis or spatial statistics includes any of the formal techniques which study entities using their **topological**, **geometric**, or **geographic** properties.
- The phrase is often used in a more restricted sense to describe techniques applied to **structures at the human scale**, most notably in the **analysis of geographic data**.

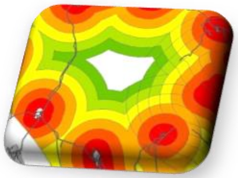


So what is spatial analysis? (2)

- Geo(spatial) analysis provides a distinct perspective on the world, a unique lens through which to **examine events, patterns**, and **processes** that operate **on** or **near** the **surface** of **our planet**.

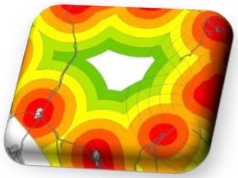
Dimensions of spatial analysis





Definitions

- Haining (1994): [SDA] is a body of methods and techniques for analyzing events at a variety of spatial scales, the results of which depend upon the spatial **arrangement** of the events.
- Goodchild et al. (1989) : (SDA) is a set of techniques devised to support a spatial perspective on data. To distinguish it from other forms of analysis, it might be defined **as a set of techniques whose results are dependent on the locations of the objects or events being analyzed**, requiring access to both the locations and the attributes of objects
- Fischer (1999) : Spatial analysis is a technology which typically requires two types of information about spatial objects: **attribute** and **locational** information.

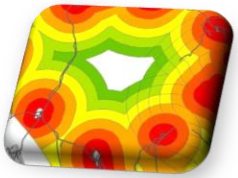


Quiz : which is SDA?

- Calculating the average income for a group of people ?
  - *is **not** spatial analysis because the result doesn't depend on the locations of the people.*
- Calculating the center of the Kenyan population?
  - *is spatial analysis because the result depends directly on the locations of residents.*

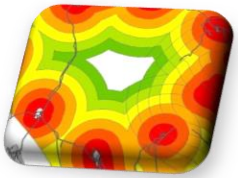
Basic Primitives

- The building blocks for any form of spatial analysis are **a set of basic primitives that refer to**
  - the place or places of interest,
  - their attributes and their arrangement.
- These basic primitives are discussed in the following subsections



1. Place

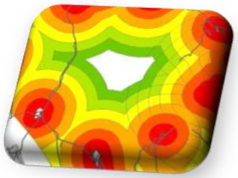
- At the center of all spatial analysis is the concept of place.
- People identify with places of various **sizes** and **shapes**, from the room to the parcel of land, to the neighborhood, the city, the county, the state or province, or the nation-state.
- Places may overlap, as when a watershed spans the boundary of two counties, and places may be nested hierarchically, as when counties combine to form a state or province.



2. Attributes

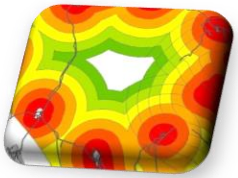
Name
Elevation
Country
Temperature
Rainfall
Population
County
Land use
Street
Soil type
Rock Type
Geology
Family Name
Age
Gender
Expensive
Dangerous
……………..

- the preferred term for any **recorded characteristic** or property of a place.
- A places **name** is an obvious example of an attribute, but a vast array of other options has proven useful for various purposes.
- Some are **measured**, including **elevation**, **temperature**, or rainfall. Others are the result of classification, including soil type, land-use or land cover type, or rock type.
- Government agencies provide a host of attributes in the form of statistics, for places ranging in size from **countries** all the way down to **neighborhoods** and **streets**.



3. Objects

- The places discussed above, vary enormously in size and shape
- In spatial analysis it is customary to refer to places as objects.
- In studies of roads or rivers the objects of interest are long and thin, and will often be represented as **lines** of zero width
- In studies of climate the objects of interest may be weather stations → **points**
- two-dimensional extent of places, which is represented as **areas,**
- elevations or depths are important and may be appropriate to represent places as **volumes**



3. Objects (2)

(a) Points as pairs of coordinates, in latitude/longitude or some other standard systems

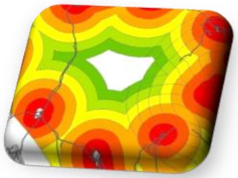
(b) Lines as ordered sequences of points connected by straight lines

(c) Areas as ordered rings of points, also connected by straight lines to form polygons

4. Maps

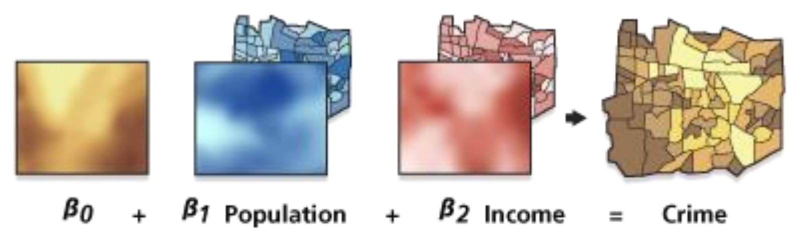
WORLD MAP 1799

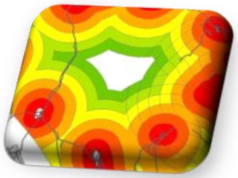
- Historically, maps have been the primary means to **store** and **communicate spatial data**.
- Objects and their attributes can be readily depicted, and the human eye can quickly discern patterns and anomalies in a well-designed map.
- Maps have traditionally existed on paper, as individual sheets or bound into atlases but now with advent of computers they can be interactive



5. Multiple properties of places

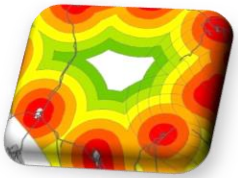
- Spatial analysts think of multiple classes of objects as forming **layers of information** superimposed on each other.
- A study might be conducted on **just one layer**, analyzing the patterns formed by the objects in that layer and looking for clues as to the processes that created the pattern.
- In other cases the patterns of one **layer might be analyzed in relation to other layers.**
- For example, the pattern of crime in an area might be studied to see if it bears any relationship to the pattern of income and population.





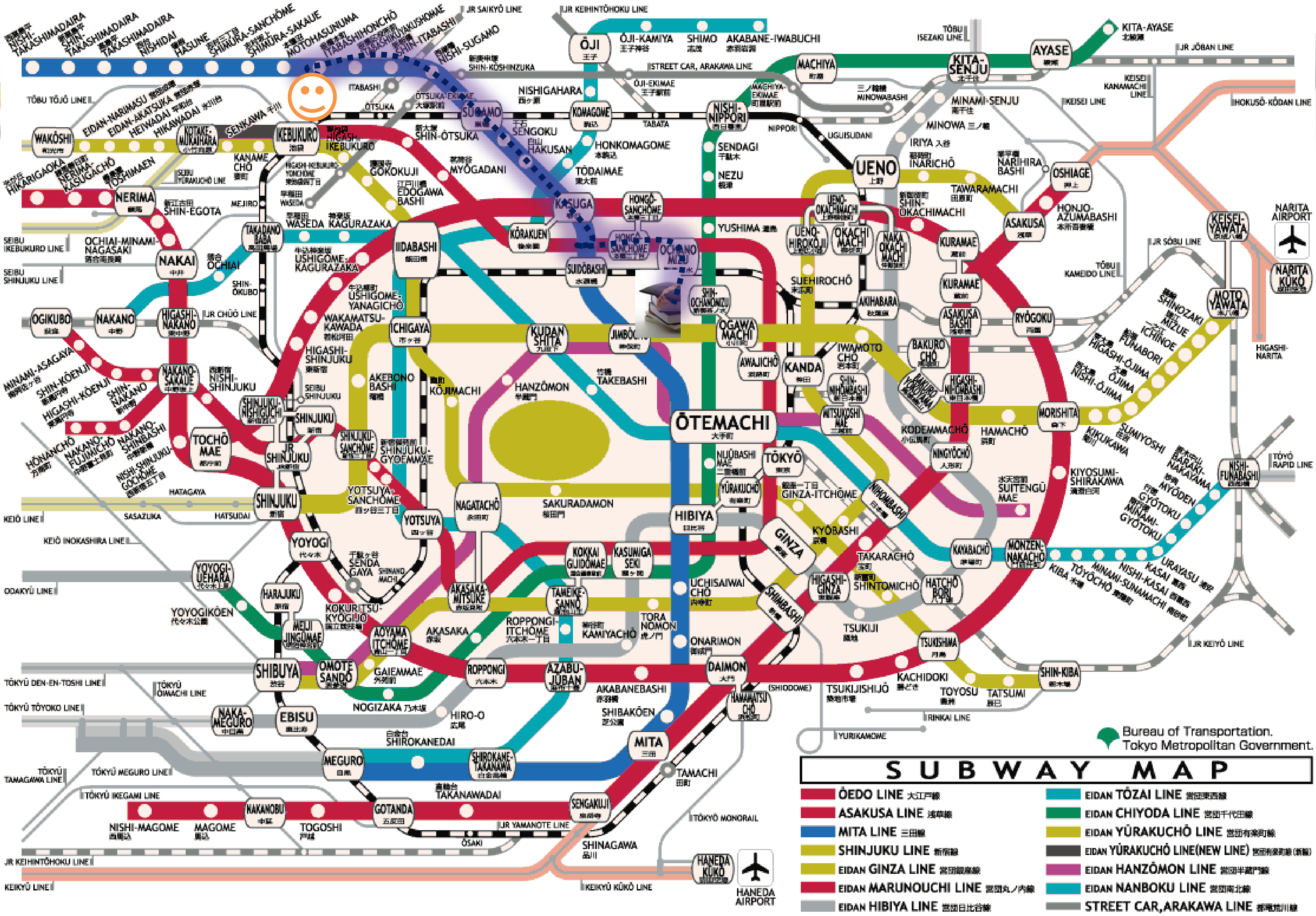
6. Fields

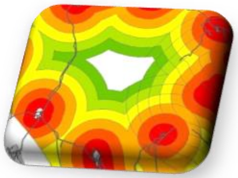
- There are two ways of thinking about phenomena on the Earths surface.
  - The **discrete-object view**, reality is like an empty table-top littered with discrete, countable objects that can be assigned to different classes.
  - In the second, the **continuous-field view**, reality is a collection of continuous surfaces, each representing the variation of one property, such as **elevation**, over the Earths surface.



7. Networks

- Networks constitute one-dimensional structures embedded in two or three dimensions.
- Discrete point objects may be distributed on the network, representing such phenomena as landmarks or bridges on road networks, or observation points on rivers.
- Discrete line objects may also be found, in the form of tunnels, stretches of highway with a constant number of lanes, or river reaches.
- Continuous fields may also be distributed over the one-dimensional network, defining such variables as travel speed, railroad gradient, traffic density, or stream velocity

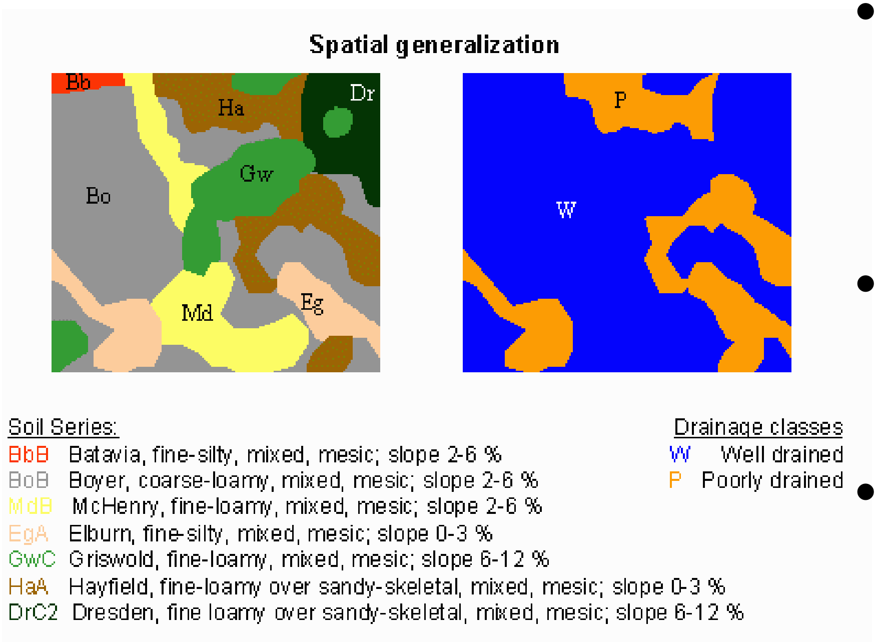

SUBWAY MAP
Bureau of Transportation. Tokyo Metropolitan Government.
ŌEDO LINE 大江戸線
ASAKUSA LINE 浅草線
MITA LINE 三田線
SHINJUKU LINE 新宿線
EIDAN GINZA LINE 営団銀座線
EIDAN MARUNOUCHI LINE 営団丸ノ内線
EIDAN HIBIYA LINE 営団日比谷線
EIDAN TŌZAI LINE 営団東西線
EIDAN CHIYODA LINE 営団千代田線
EIDAN YŪRAKUCHŌ LINE 営団有楽町線
EIDAN YŪRAKUCHŌ LINE(NEW LINE)
EIDAN HANZŌMON LINE 営団半蔵門線
EIDAN NANBOKU LINE 営団南北線
STREET CAR, ARAKAWA LINE
ŌTEMACHI
UENO
IKEBUKURO
SHINJUKU
SHIBUYA
TŌKYŌ
HIBIYA
GINZA
SUGAMO
KASUGA
SUIDŌBASHI
ŌJI
AYASE
KITA-SENJU
NARITA AIRPORT
NARITA KŪKŌ
HANEDA AIRPORT
HANEDA KŪKŌ
JR YAMANOTE LINE
JR CHŪŌ LINE
JR SŌBU LINE
JR KEIHINTŌHOKU LINE
JR SAIKYŌ LINE
JR JŌBAN LINE
JR KEIYŌ LINE
TŌKYŪ TŌYOKO LINE
TŌKYŪ DEN-EN-TOSHI LINE
KEIŌ LINE
ODAKYŪ LINE
SEIBU SHINJUKU LINE
SEIBU IKEBUKURO LINE
TŌBU TŌJŌ LINE
KEISEI LINE
TŌKYŌ MONORAIL
YURIKAMOME
RINKAI LINE



8. Density estimation

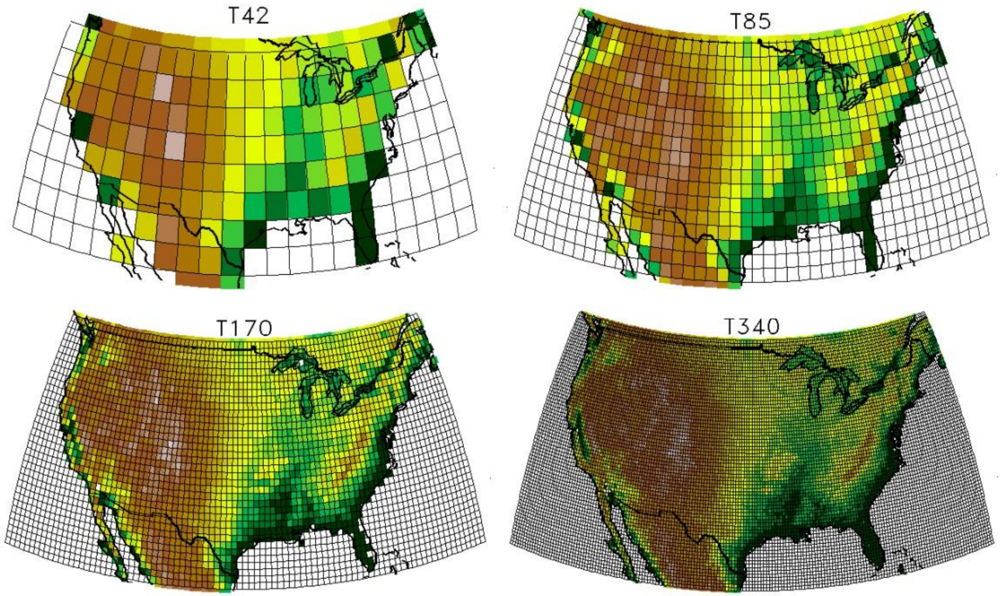
- One of the more useful concepts in spatial analysis is **density**
  - the density of humans in a crowded city,
  - or the density of tracks across a stretch of desert, or the density of retail stores in a shopping center.
- Density provides an effective link between the discrete-object and continuous-field conceptualizations, since density expresses the number of discrete objects per unit of area, and is itself a continuous field.

9. Detail, resolution, and scale (1)

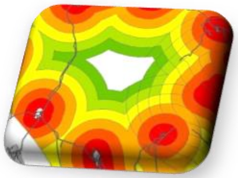


- The surface of the planet is almost infinitely complex, revealing more and more detail the closer one looks.
- An apparently simple concept such as a coastline turns out to be problematic in practice.
- should its representation as a polyline include every indentation, every protruding rock, even every grain of sand?
- in reality decisions must be made about the amount of detail to include

9. Detail, resolution, and scale (2)

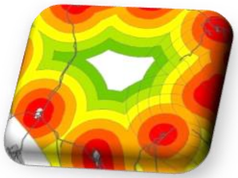


- Spatial resolution is the term given to a threshold distance below which the analyst has decided that detail is unnecessary or irrelevant.



10. Topology (1)

- In mathematics, a property is said to be topological if it survives stretching and distorting of space.
  - *Draw a circle on a rubber sheet, and no amount of stretching or distorting of the sheet will make it into a line or a point.*
  - *Draw two touching circles, and no amount of stretching or distorting will pull them apart or make them overlap.*
- It turns out that many properties of importance to spatial analysis are topological, including:



10. Topology (2)

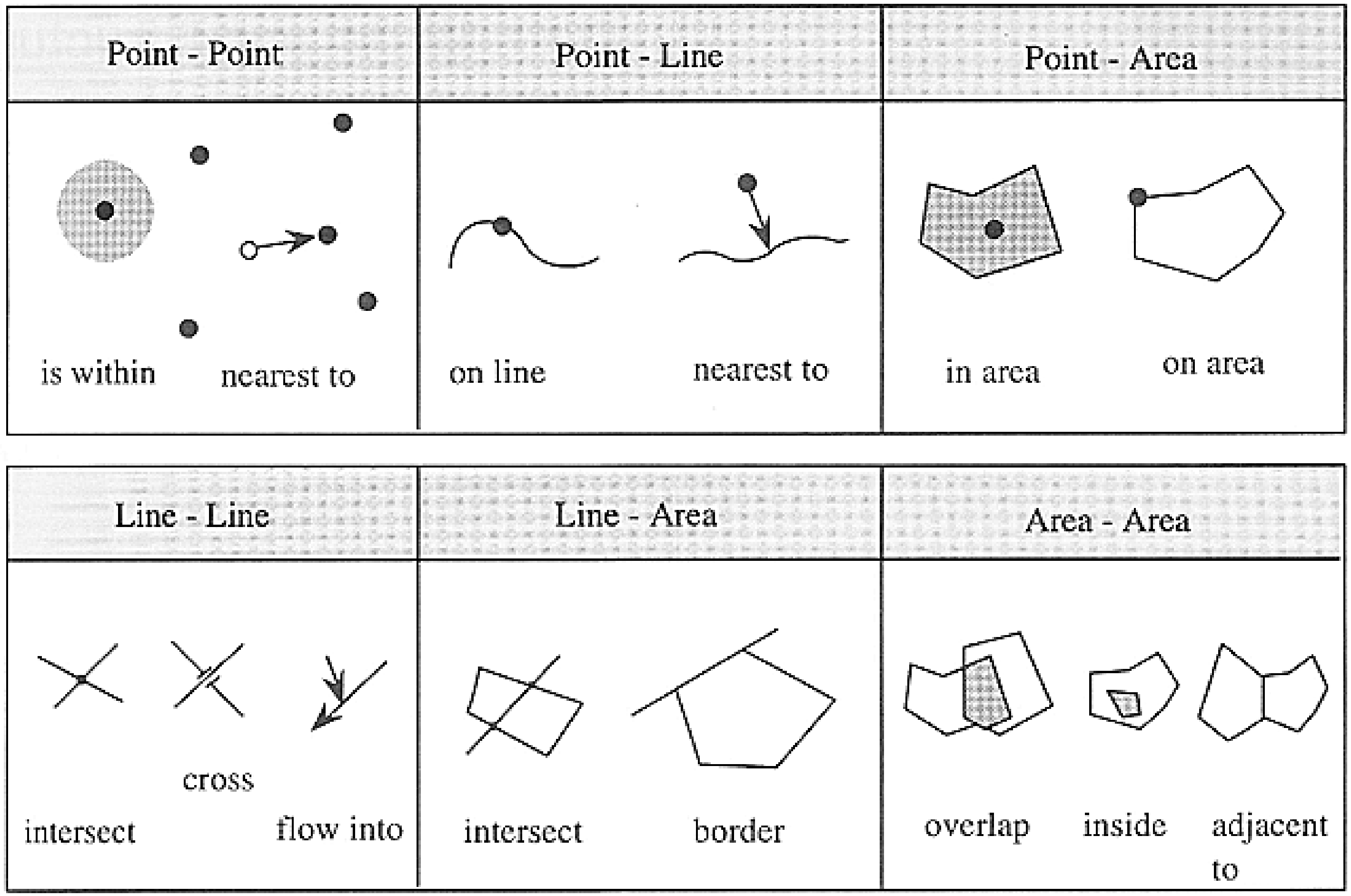
(a) **Dimensionality**: the distinction between point, line, area, and volume, which are said to have topological dimensions of 0, 1, 2, and 3 respectively

(b) **Adjacency**: including the touching of land parcels, counties, and nation-states

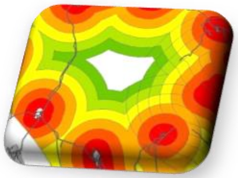
(c) **Connectivity**: including junctions between streets, roads, railroads, and rivers

(d) **Containment**: when a point lies inside rather than outside an area

10. Topology (3)

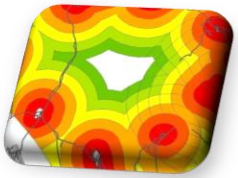


SPATIAL RELATIONSHIPS



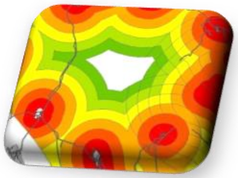
Spatial relationships

- Despite the emphasis placed on it in, Basic Primitives, and in spatial analysis generally, location is **not in itself very interesting.**
- The power of location comes not from location itself, but from the linkages or relationships that it establishes from relative positions rather than absolute ones



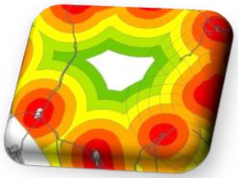
1. Co-location

- Many useful insights can come from comparing the attributes of co-located places. For example, ***a cluster of cases of lung cancer in a port city might be explained by knowing that asbestos was widely used in the construction of ships in that city in the Second World War***
- Analysts often use the term **overlay** to refer to the superimposition and analysis of layers of geographic data about the same place.
- Overlay may require the superimposition of area on area, or line on area, or point on area, or line on line, or point on line, depending on the nature of the objects in the database



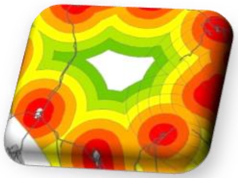
2. Distance, direction and spatial weights matrices

- Knowledge of location also allows the analyst to determine the distance and direction between objects.
- Distance between points is easily calculated using formulas for straight-line distance on the plane or on the curved surface of the Earth, and with a little more effort it is possible to determine the actual distance that would be traveled through the road or street network.



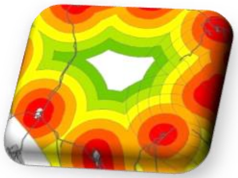
2. Distance, direction and spatial weights matrices

- Many types of spatial analysis require the calculation of a table or matrix expressing the **relative proximity** of pairs of places, often denoted by W (a spatial weights matrix).
- Proximity can be a powerful explanatory factor in **accounting for variation in a host of phenomena**, including flows of migrants, intensity of social interaction, or the speed of diffusion of an epidemic



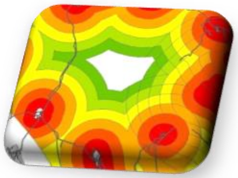
3. Multidimensional scaling

- Multidimensional scaling (MDS) is the general term given to the problem of reconstructing locations from knowledge of proximities.
- Tobler and Wineburg (1971) provided an excellent example in which the unknown locations of 33 ancient pre-Hittite settlements in Cappadocia were inferred from knowledge of their interactions with other settlements whose locations were known, based on the assumption that interaction declined systematically with distance
- **Scaling techniques** have been used to create a wide range of specialized maps, including maps on which distances reflect travel times rather than actual distances, or the similarity of the species found in each place, or the perceptions of relative proximities in the minds of local residents



4. Spatial Context

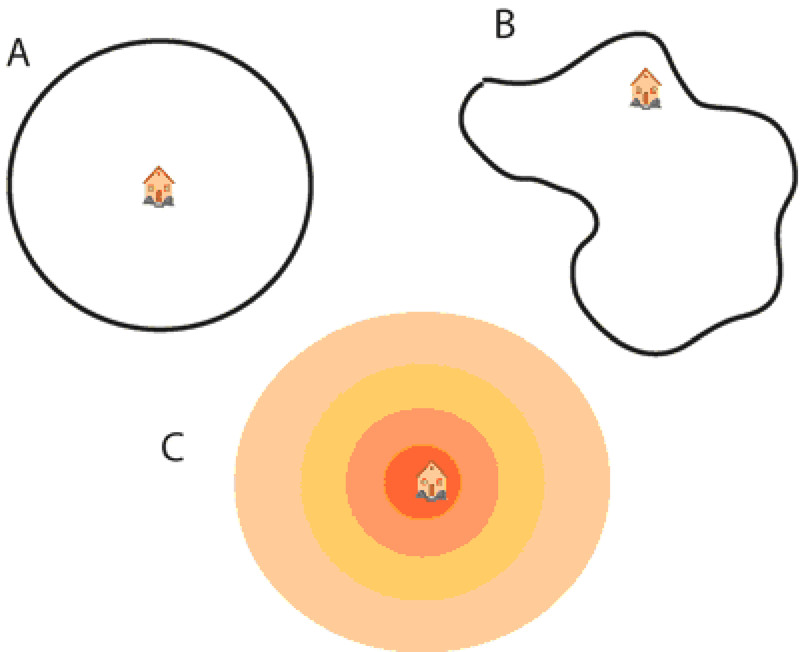
- Much useful insight can often be gained by comparing the attributes of objects with those of other objects in close proximity.
- The behavior of a person on a crowded street might be explained in terms of the proximity of other people;
- the price of a house might be due in part to the existence of expensive homes in the immediate vicinity; and an area might find its homes losing value because of proximity to a polluting industrial plant.
- Location establishes context, by allowing distances between objects to be determined, and by providing information on their relevant attributes.



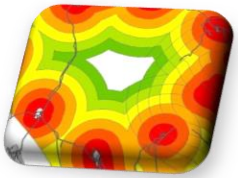
5. Neighborhood

- Very often neighborhood is the basis of spatial context, characterizing the nature of a persons surroundings.
- Neighborhoods are often conceived as partitioning an urban space, such that every point lies in exactly one neighborhood, but this may conflict with individual perceptions of neighborhood, and by the expectation that neighborhood extends in all directions around every individuals location

5. Neighborhood

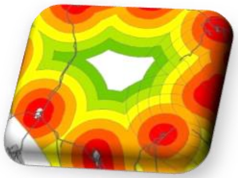


- In Figure A **the neighborhood is defined as a circle** centered on the house, extending equally in all directions.
- In Figure B **neighborhood is equated with an existing zone**, such as a census tract or precinct, reflecting the common strategy of using existing aggregated data to characterize a household’s surroundings. In
- In Figure C weights are applied to surroundings based on distance, allowing **neighborhood to be defined as a *convolution***



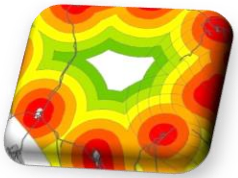
6. Spatial heterogeneity

- The Earths surface displays almost incredible variety, from the escarpments of the Great riftvalley, landscapes of the Tibetan plateau to the deserts of Australia and the urban complexity of London or Tokyo.
- Nowhere can be reasonably described as an average place and it is difficult to imagine any subset of the Earths surface being a representative sample of the whole.



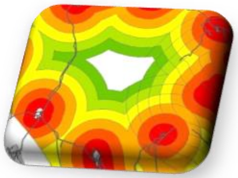
6. Spatial heterogeneity

- The results of any analysis over a limited area can be expected to change as that limited area is relocated, and to be different from the results that would be obtained for the surface of the Earth as a whole.
- These concepts are collectively **described as spatial heterogeneity, and they tend to affect almost any kind of spatial analysis conducted on geographic data**.
- Many techniques such as Geographically Weighted Regression take spatial heterogeneity as given as a universally observed property of the Earths surface and focus on providing results that are specific to each area, and can be used as evidence in support of local policies.
- Such techniques are often termed place-based or local.



7. Spatial dependence

- anyone examining the Earths surface in detail would be struck by how **conditions tend to persist locally**, and how it is possible to divide the surface into regions that exhibit substantial internal similarity
- For example, the **desert regions are characterized by lack of rainfall, the tropical rainforests by abundant rainfall and dense vegetation, and the Polar Regions by extreme cold**.
- Conditions at nearby points are not sampled independently and randomly from global distributions, but instead show remarkable levels of interdependence.



7. Spatial dependence

- The general term for this phenomenon is **spatial dependence**.
- Its pervasiveness was aptly captured by Tobler in what has become known as his First Law of Geography: "**All things are related, but nearby things are more related than distant things**". The magnitude of the effect can be measured using a number of statistics of spatial autocorrelation.
- It also underlies the discipline known as geostatistics,

8. Other relationships

Homework – Research on:

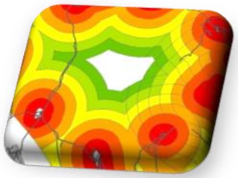
(a) Spatial sampling

(b) Spatial interpolation

(c) Smoothing and sharpening

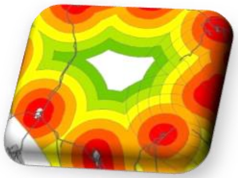
(d) First- and second-order processes

SPATIAL STATISTICS



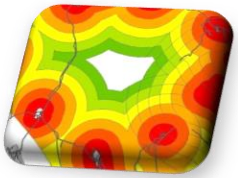
Spatial statistics

- The term spatial statistics refers to the application of statistical concepts and methods to data that has an explicit spatial structure that is important to understanding those data.
- Spatial statistics is a discipline in its own right, closely associated with traditional statistical methods and more modern computational statistics, but with the added complexity of spatial dependence



Spatial statistics

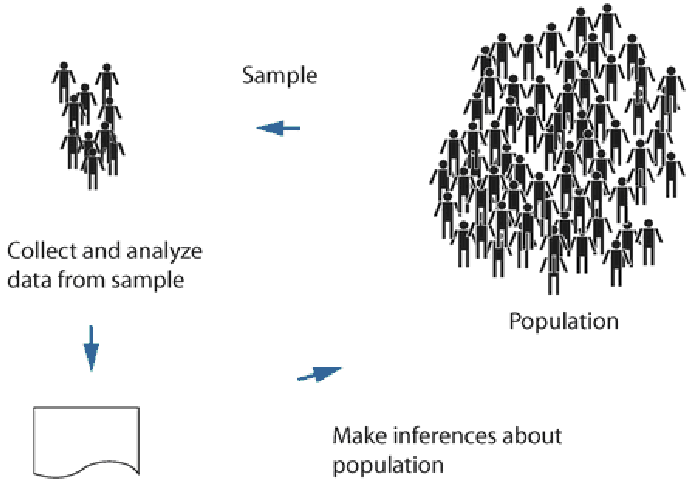
- **Spatial probability**
  - spatial analysts may avoid the virtual impossibility of predicting exactly where landslides will occur by assigning them probabilities based on patterns of known causes, such as clay soils, rainfall, and earthquakes.
  - A map of probabilities assigns each location a value between 0 and 1, forming a probability field.



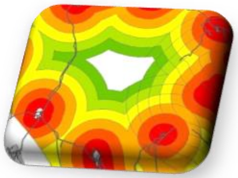
Spatial statistics

- **Probability density**
  - One of the most useful applications of probability to the Earth’s surface concerns uncertainty about location..
  - It is easy to confuse probability density with spatial probability, since both are fields. But they have very different purposes and contexts.
  - Probability density is most often encountered in analyses of positional uncertainty, including uncertainty over the locations of points and lines.

Spatial statistics



- **Statistical inference**
  - One of the most important tools of science is statistical inference, the practice of reasoning from the analysis of samples to conclusions about the larger populations from which the samples were drawn.



Assignment 01– 10 marks

Each student to choose a ward(Nairobi/Kiambu) whose road sections are not topologically correct –e.t they have overshoots, undershoots and overlaps. **Class rep to coordinate and ensure no overlaps**

Required :

1. Extract the data for your ward from OSM and store the data in a ArcGIS Personal geodatabase
2. Create a **raw feature dataset** and upload the raw data
3. Build topology for the ward
4. Save the topologically-correct road feature under **a new feature dataset**
5. Zip and upload the database (yourRegNo.zip) on the link https://forms.gle/eHUXSwBTGFznkvSz7

Deadline: Next Week Monday -0800hrs

THANK YOU.