

# Open Source GeoSpatial tools and methods for natural resource mapping in drylands of Africa

Francis Oloo, PhD  
Sospeter Wekesa  
Godwin Murithi

# Team



**Francis Oloo, PhD**

**Position:** Postdoctoral Researcher/GIS Analyst

**Organization:** GeoPsy Multidisciplinary Research

**Country:** Kenya

Email: [oloofrank@gmail.com](mailto:oloofrank@gmail.com)



**Sospeter Wekesa**

**Position:** Hydrologist and Water Resource Engineer

**Organization:** Technical University of Kenya

**Country:** Kenya

Email: [soswek@yahoo.com](mailto:soswek@yahoo.com)



**Godwin Murithi**

**Position:** Student Assistant

**Organization:** Technical University of Kenya

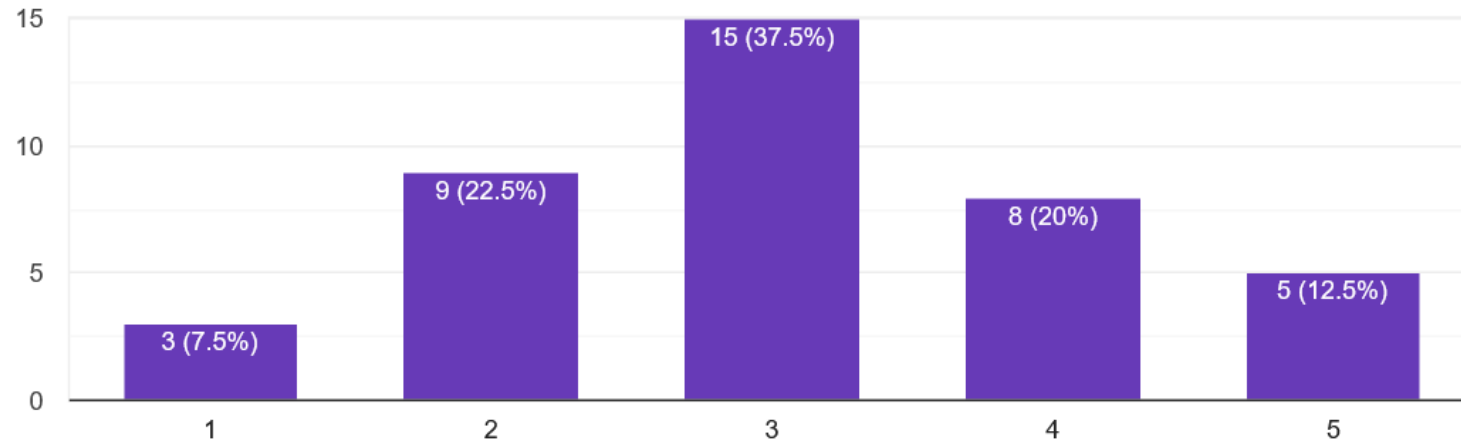
**Country:** Kenya

Email: [godiewyn54@gmail.com](mailto:godiewyn54@gmail.com)

# Audience

How would you rate your knowledge/expertise in GIS?

40 responses







# Motivation for the course

- Natural resources such as land, vegetation, water, minerals and wildlife are critical for the livelihoods of any community
- Knowing the locations, users and status of these resources is vital for their sustainable management, exploration and use
- There is need to affordable tools, methods and skills for assessing, mapping and monitoring natural resources

# Lesson objectives

- i. To introduce the learners to basic geospatial concepts
- ii. To introduce the learners to concepts of spatial data handling particularly with regards to natural resources
- iii. To promote the understanding and the use of geospatial methods and tools in natural resource assessment, planning and management
- iv. To equip the learners with skills for spatial modelling of water and natural resource management



# What is spatial about natural resources

- Natural resources, be it land, water, forests, wildlife or minerals are found in specific locations on the surface of the earth
- Their unique “geospatial” locations play a role, determining their patterns of use, exploration, management
- Location also influences the processes that are linked to the sustainability of these resources
- Understanding the location and the spatial context of natural resources is therefore key for their management



# Basic geoSpatial Concepts

## Location

- The position or site occupied by or where a feature or something interest is found
- “geo-location” is a location on the surface of the earth
- Location is key to any information
- On a map, a location can be represented in terms of longitudes and latitudes





# Basic geoSpatial Concepts

## Global Positioning System (GPS)

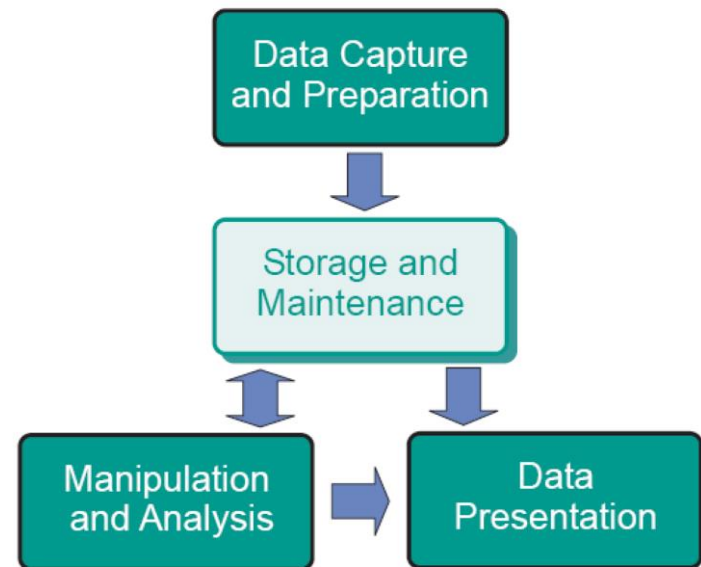
- A GPS is a means of measuring and recording location
- It is a worldwide navigation system
- Uses satellites as reference points to calculate locations
- A GPS measures longitudes (X), latitudes (Y), and heights (Z)



# Basic geoSpatial Concepts

## Geographic Information System (GIS)

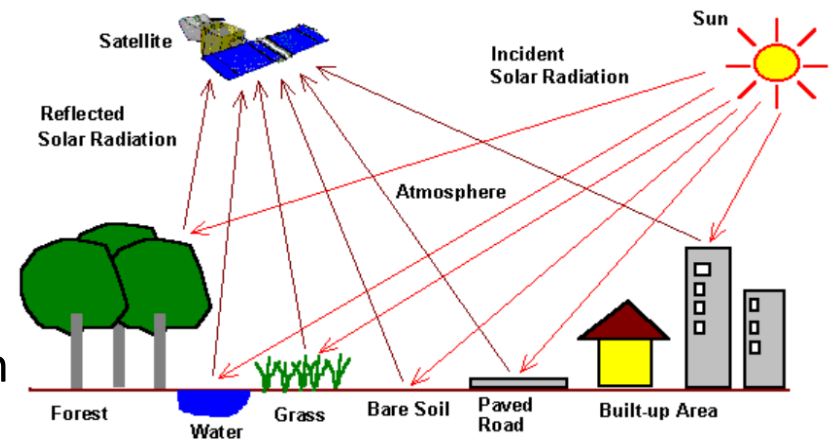
- Is a computer-based system for handling, analysing and presenting geographic or spatial data.
- Consists of hardware, software and methods to support capture, manipulation, analysis and output of spatially referenced data.
- Analysis of spatial data is vital for solving, visualising, explaining natural resource processes and patterns



# Basic geoSpatial Concepts

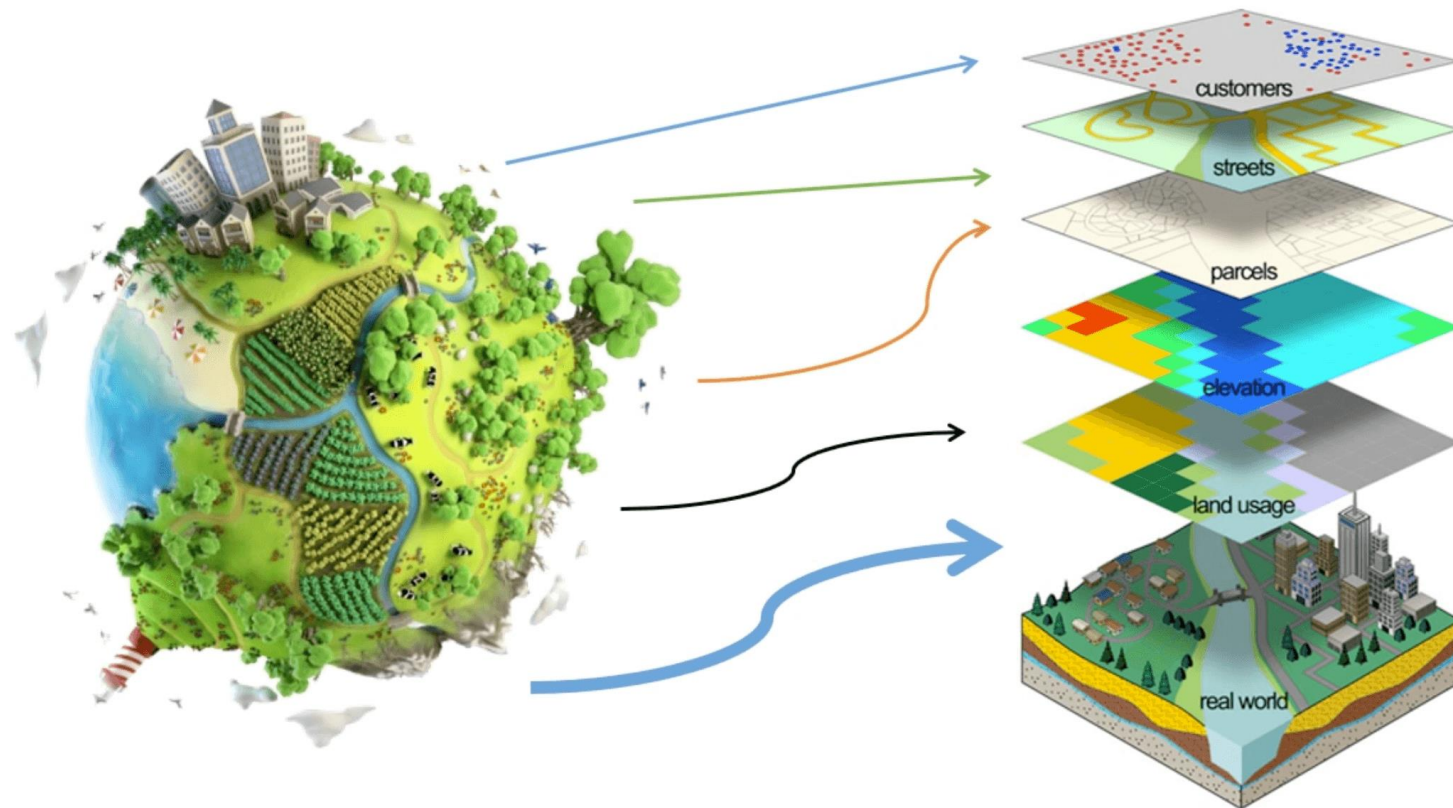
## Remote sensing

- Is the science and technology of acquiring information about earth's surface using airborne or space borne sensors
- The sensors are carried in aircrafts, air balloons, drones, satellites or space crafts
- Remote sensors record information on land, water or within the atmosphere
- Active sensors that can record information beneath the earth surface of under water



Source: <https://earthdata.nasa.gov/learn/remote-sensing>

# Spatial data models



Source: <https://www.geo.university/courses/environmental-modelling-and-analysis-in-gis>



# Spatial data models

- To store and manipulate data about the real world in a GIS system, the real world has to be modelled into data formats that the computer can understand
- A [model](#) is representation of the key elements of a reality
- A model [selects](#) only the aspects of the real world that are important for addressing the question at hand
- There are two main models for storing spatial data:
  - Vector data models
  - Raster data models

# Spatial data models

## Vector data

- Stores geographic information as geometric objects:

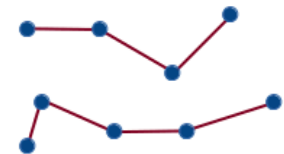
### a. Points:

- Represented as single coordinate pairs (longitude, latitude)
- Useful for representing water points, settlements



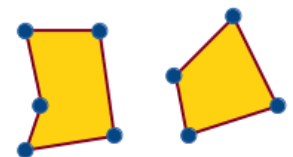
### b. Lines

- Represented as a sequence of coordinate pairs
- Useful for representing streams, rivers, paths



### c. Polygons

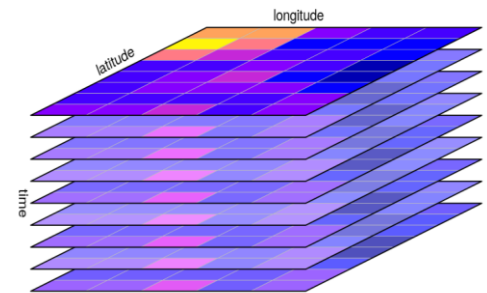
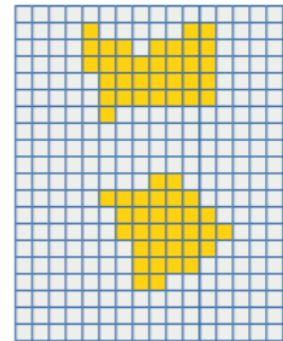
- Represented as a collection of coordinate pairs that represent the outer boundaries of a feature
- Useful for representing forests, lakes, oceans, expansive cities



# Spatial data models

## Raster data

- Stores geographic information in grids of regular cells or pixels
- Best suited for representing geographic data with unclear boundaries such as elevation, temperature, vegetation
- The size of each cell, is referred to as the spatial resolution and determines the level of detail that is captured by the raster data
- A single raster data can contain multiple bands of different variables but at the same resolution
- Multi-band raster data are useful in spatio-temporal data analysis



# Spatial data models

## Attributes

- Are the text or numbers that describe what is represented by the vector and raster data
- For instance, the temperature stored in a raster cell or the town name in a vector point
- Spatial data models commonly use a georelational model to connect the geographic representation and the attribute



Attribute Names		
Name	Year Built	GEOMETRY
Empire State Building	1931	POINT(40.748, -73.986)
Times Square	1904	POINT(40.758, -73.986)
Rockefeller Center	1939	POINT(40.759 -73.979)

Attributes (what)

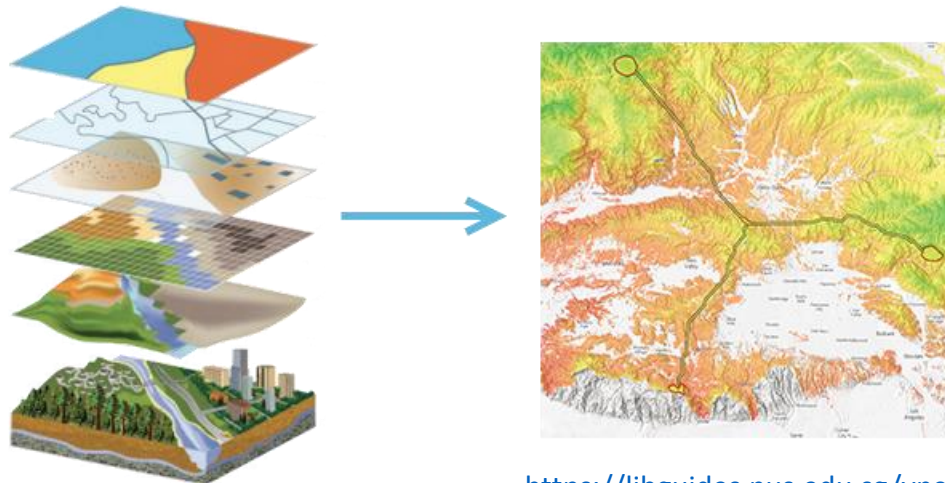
Hidden Spatial Column (where)

Source:  
<http://michaelminn.net/tutorials/gis-data/>



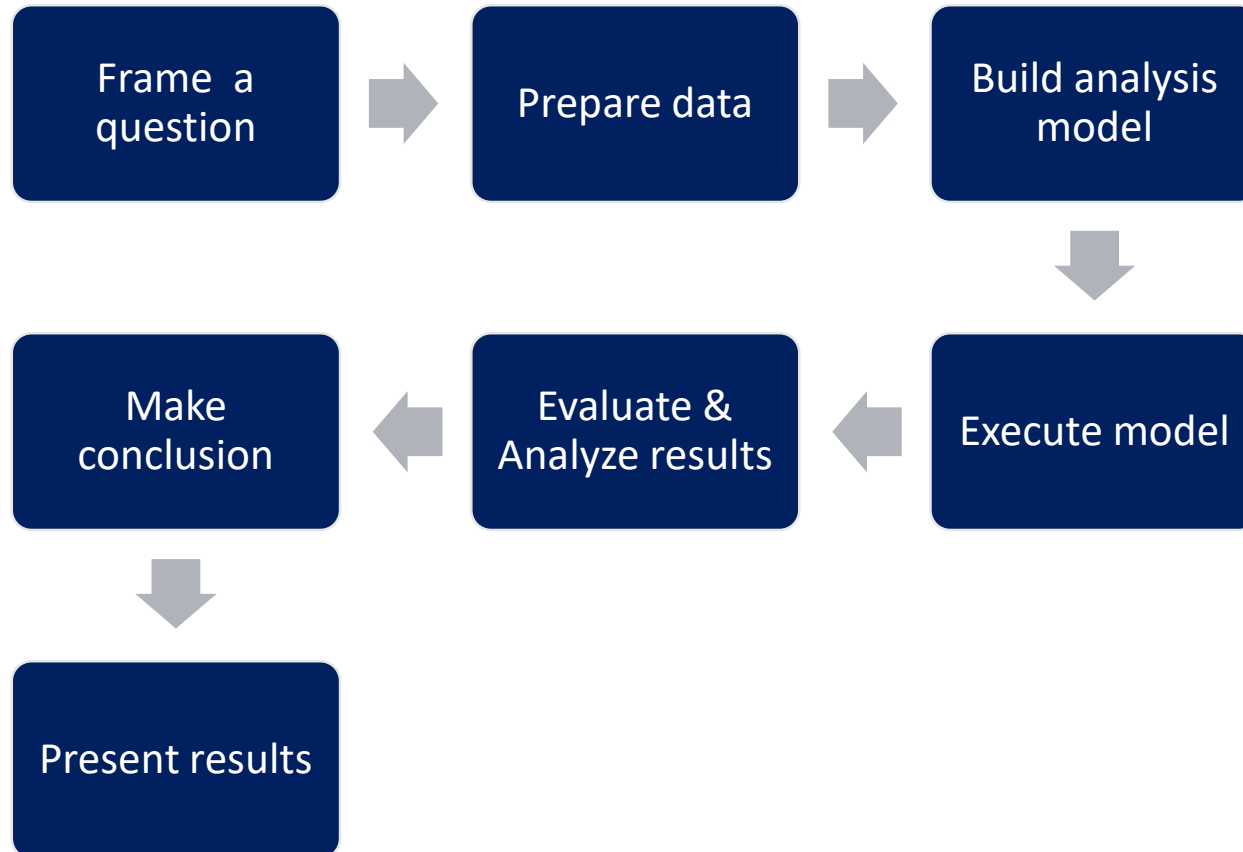
# Spatial Analysis

- Is the process of applying analytic techniques to geographically referenced datasets to extract or generate new geographic information to address a particular question or objective
- The ultimate goal of spatial analysis is to solve a problem spatial
- It involves combining spatial data with methods from geographic information science to solve geographic problems



<https://libguides.nus.edu.sg/yncgis>

# Spatial Analysis steps



# Spatial Analysis Methods

- Spatial analysis entails characterising spatial geometries and topological relations of a phenomena in order to identify properties and patterns
- Spatial analysis is guided by **spatial concepts**
- Methods from mathematics, statistics and other analytical field are used to characterize the spatial concepts
- Spatial analysis can be achieved by math-like expressions containing operations and functions with raster data
  - a. Operations:** Fundamental mathematical and logical operations on raster data
  - b. Functions:** Complex combinations of operations

# Spatial Concepts

Concept	Description	Representation	Relevance
<b>Root concepts</b>			
<b>Location</b>	Understanding where	Coordinate system	Place; distribution; pattern
<b>Distance</b>	Relative position	Planimetric; surface; 3D	Spatial constraint, proximity, accessibility
<b>Anisotropy</b>	Directional dependence	Property dependent	Flows, movements
<b>Boundary</b>	Edge of spatial entity	Discrete; fuzzy; object	Landform; process regime; structure
<b>Heterogeneity</b>	Spatial variability	Univariate; scale-dependent	Roughness; complexity
<b>Spatial geometry</b>			
Complexity	Spatial complexity	Spatial autocorrelation	Lability; dynamics
Size	Geographic area	Planimetric; surface	Process-form; landforms
Shape	Geometric form	Geometric; irregular	Deposition; deformation; tectonics; surface processes
Symmetry	Geometric form	Symmetric; asymmetric	Deformation; tectonics
<b>Spatial topology</b>			
Adjacency	Spatial variability	Neighborhood; context	Boundaries; system couplings; topographic position
Association	Spatial dependence	Spatial coincidence; spatial intersection; connectivity;	Matter-process-form; genetics
Connectivity	Spatial continuity	Network	Mass-flow cascade; structure
Containment	Spatial organization	Hierarchies; spatial constraints	Landform evolution; topographic structure

Source: Bishop et al, 2020 <https://doi.org/10.1016/B978-0-12-409548-9.12429-7>

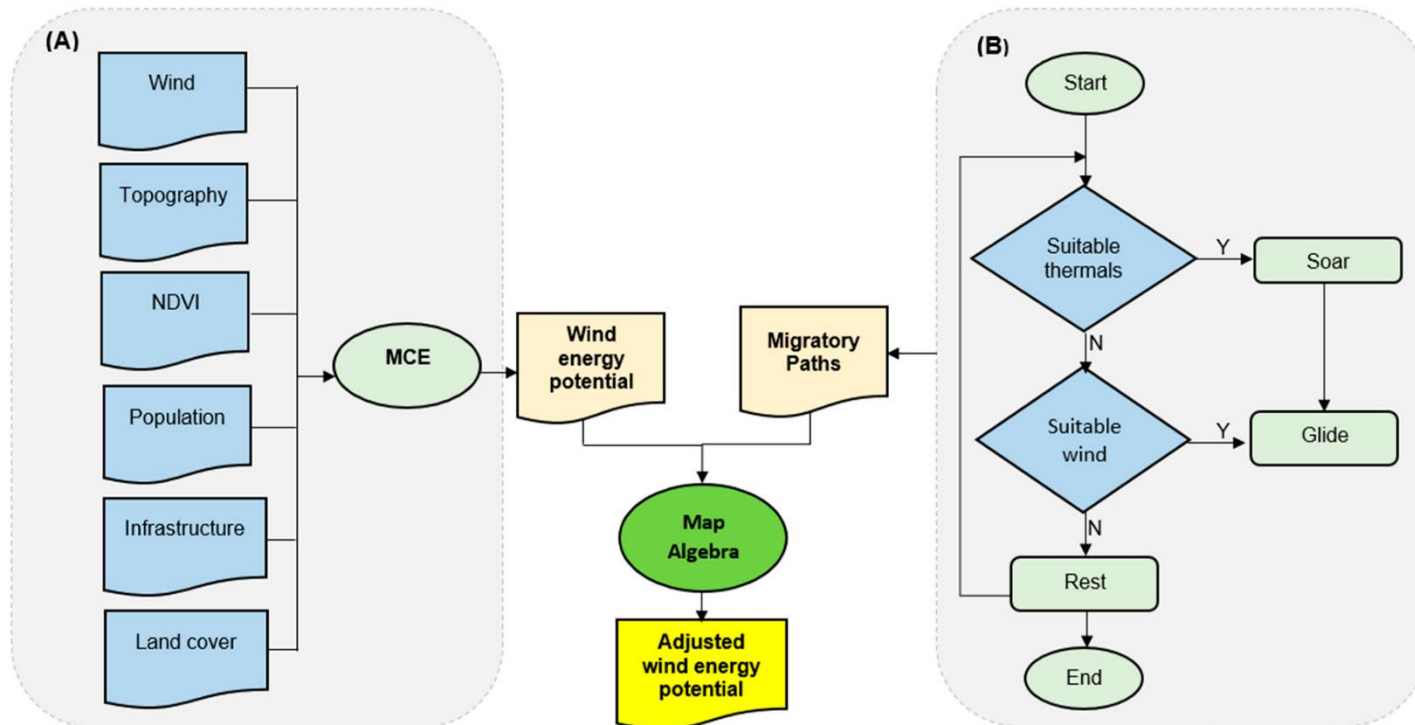


# Spatial Analysis: Operations

- **Relational:** use quantitative relationship to evaluate a condition as true or false.
- **Boolean:** Use Boolean logic (and, or not) to evaluate condition as true or false
- **Combinatorial:** assign specific values to an output grid based on the combinations of values in two input grids
- **Logical:** compares two different sets of numbers (e.g. two raster grids) and uses this comparison to assign a new value.
- **Accumulative:** calculates a single value from a cumulative operation on a single grid
- **Assignment:** store the results of an expression – can be assignment or a mathematical expression

# Spatial Analysis: Functions

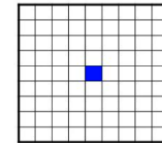
- Functions are higher order data manipulations on spatial data, built from the more basic operators



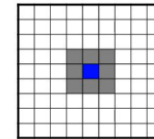
Source: Oloo et al, 2018 <https://www.mdpi.com/2071-1050/10/5/1470/htm>

# Spatial Analysis: Functions

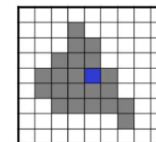
- Types of spatial analysis functions include:
  - Local:** computation is carried out on a single cell, one after another, the results depend on this cell only e.g. NDVI.
  - Focal:** computation is carried out on a predefined focus/neighbourhood of the point/cell of interest. Uses a moving window algorithm
  - Zonal:** Requires a zone and value data. The value data is summarised for each zone
  - Global:** Operations implemented across the entire data, resulting in one global value



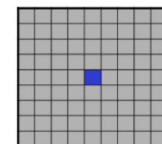
Local



Focal



Zonal

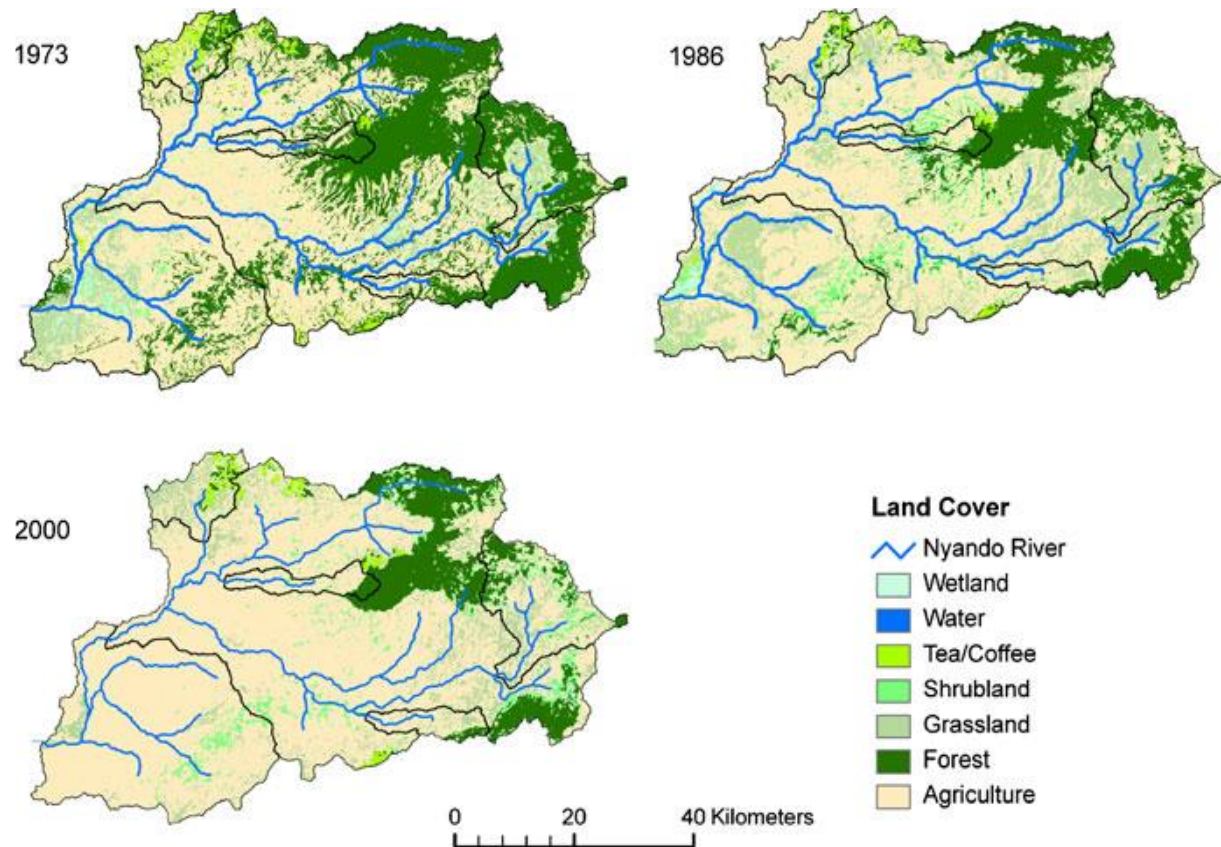


Global

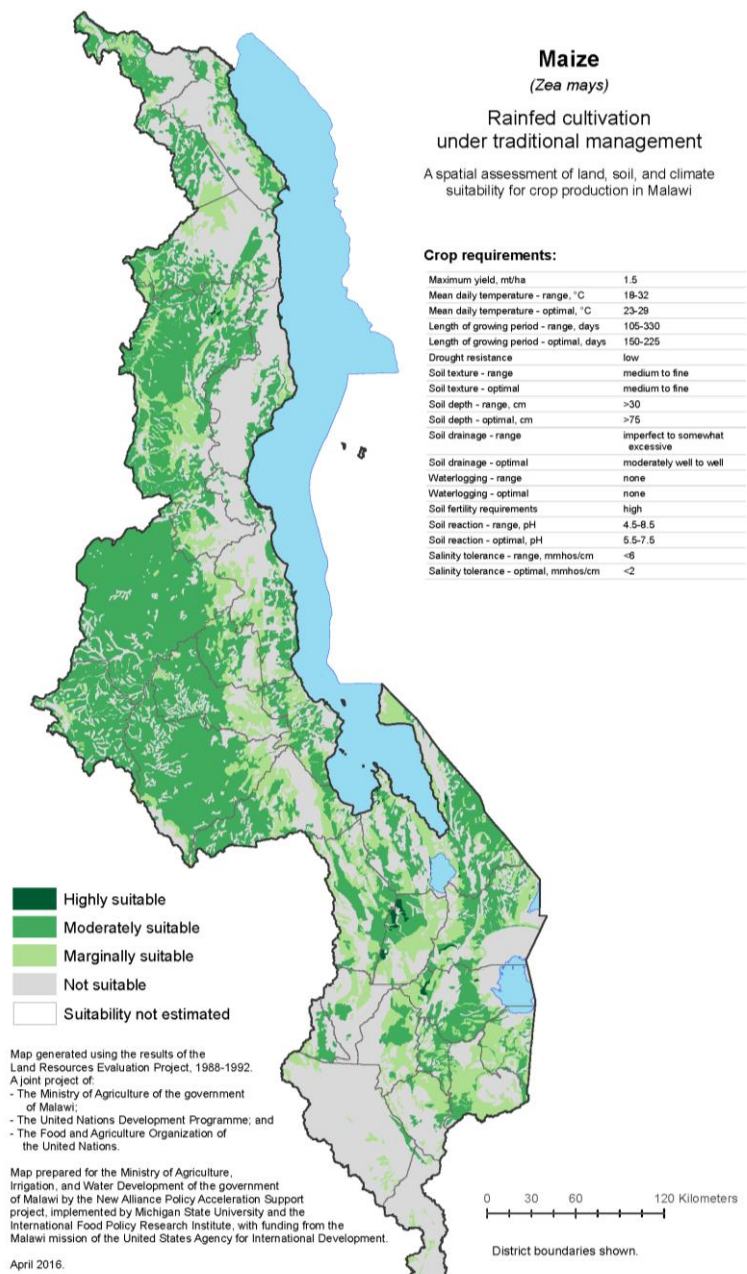
# Spatial Analysis of natural resources

- Due to their inherent spatial nature, spatial analysis methods have been applied to understand properties and patterns of natural resources
- Common examples include
  - Land use/ land cover mapping
  - Crop suitability assessment
  - Invasive species mapping and modelling
  - Water resource assessment
  - Forest fire mapping
  - Mineral resource mapping
  - Resource planning
  - Disease mapping
  - Flood and Drought risk mapping
  - Wetland mapping
  - etc

# Land use/land cover mapping

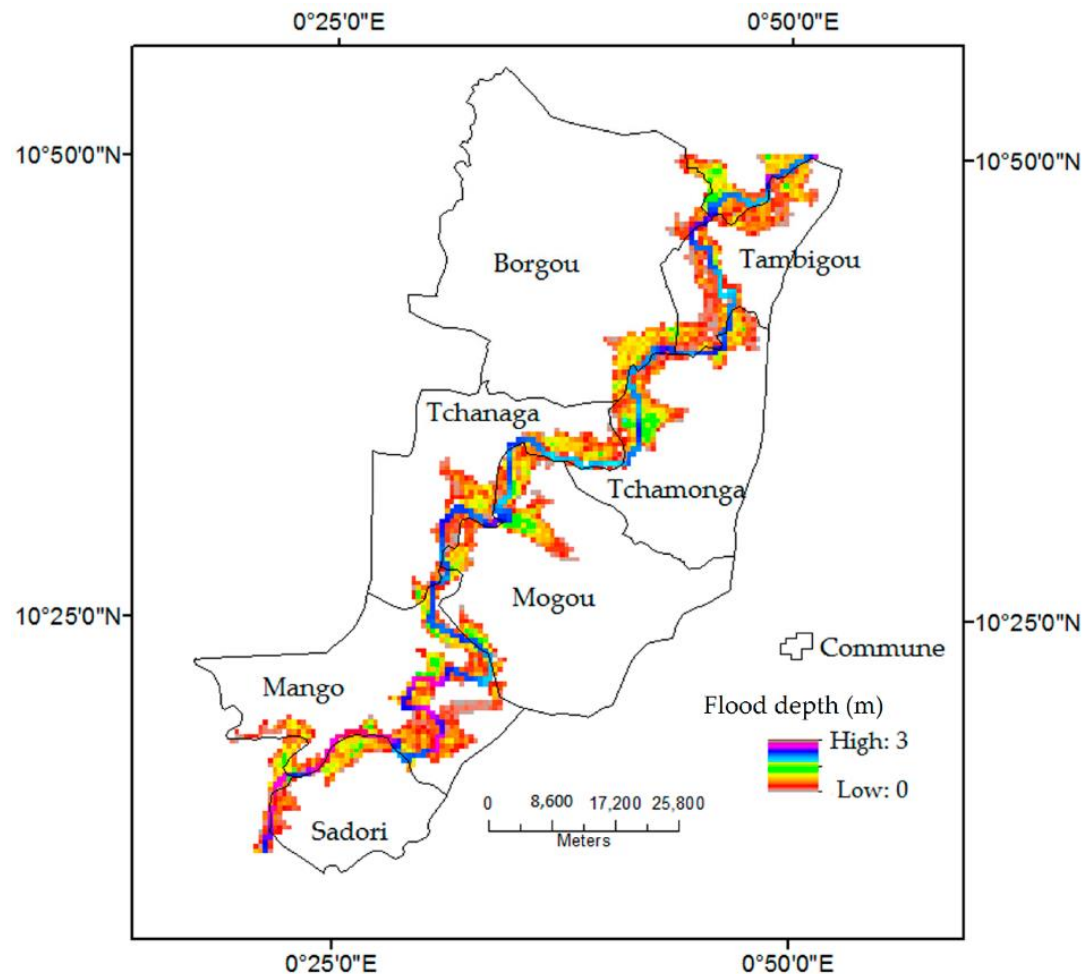






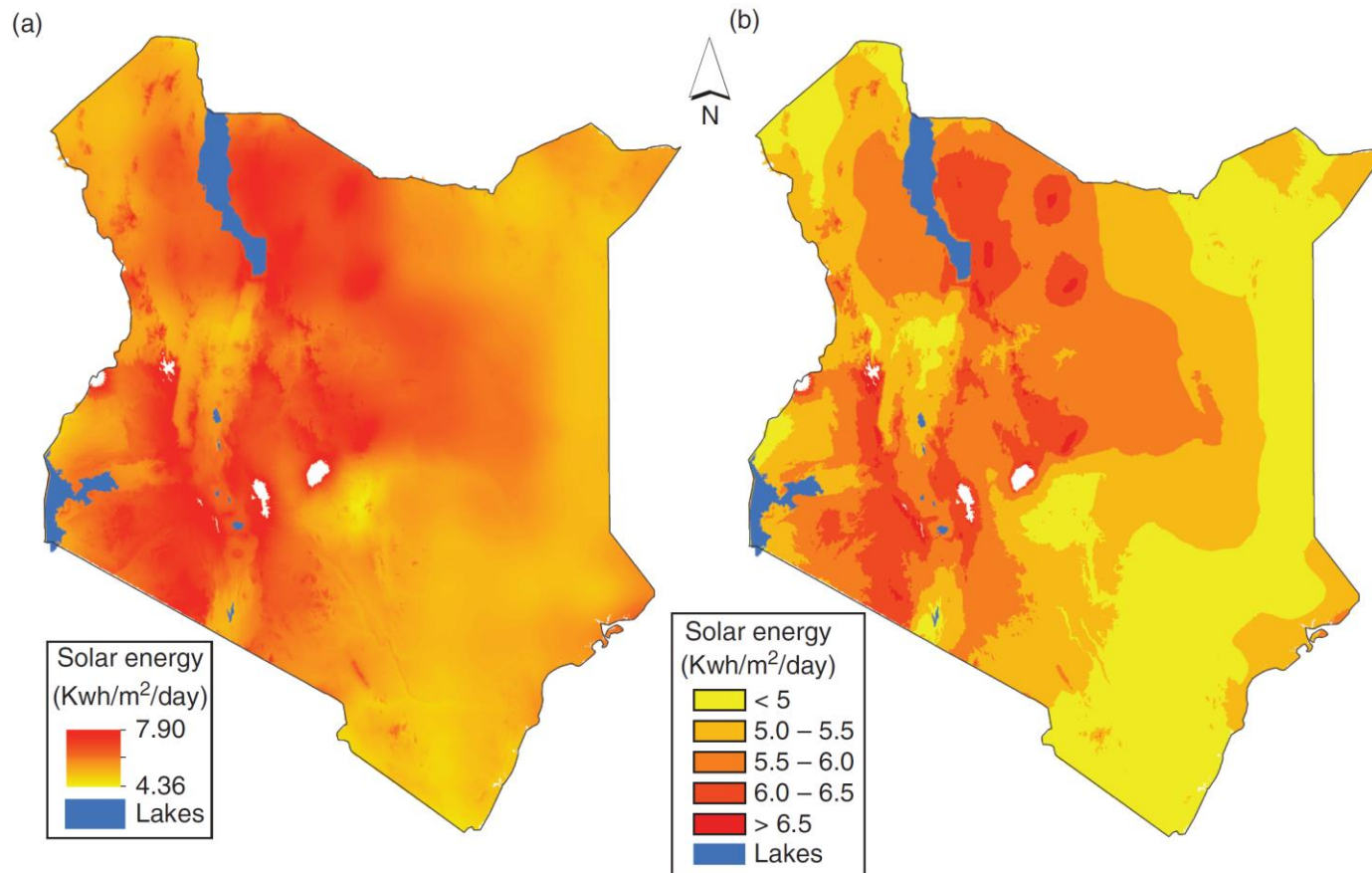
# Crop suitability mapping

# Flood risk mapping



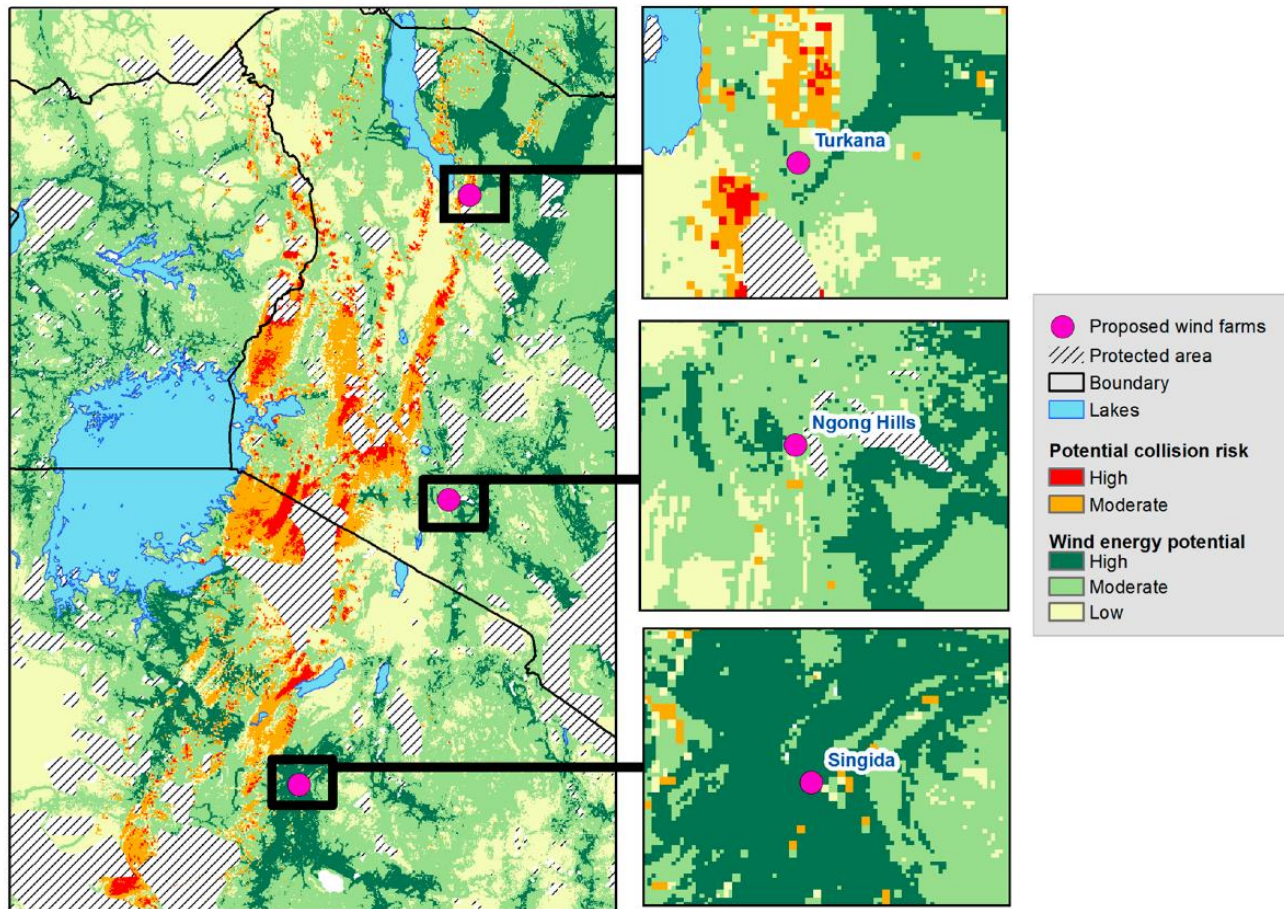
Source: Komi et al, 2016 <https://www.mdpi.com/2306-5338/3/4/42/html>

# Solar energy assessment



Source: Oloo et al, 2015 <https://130.225.53.24/index.php/sepm/article/download/1042/1006>

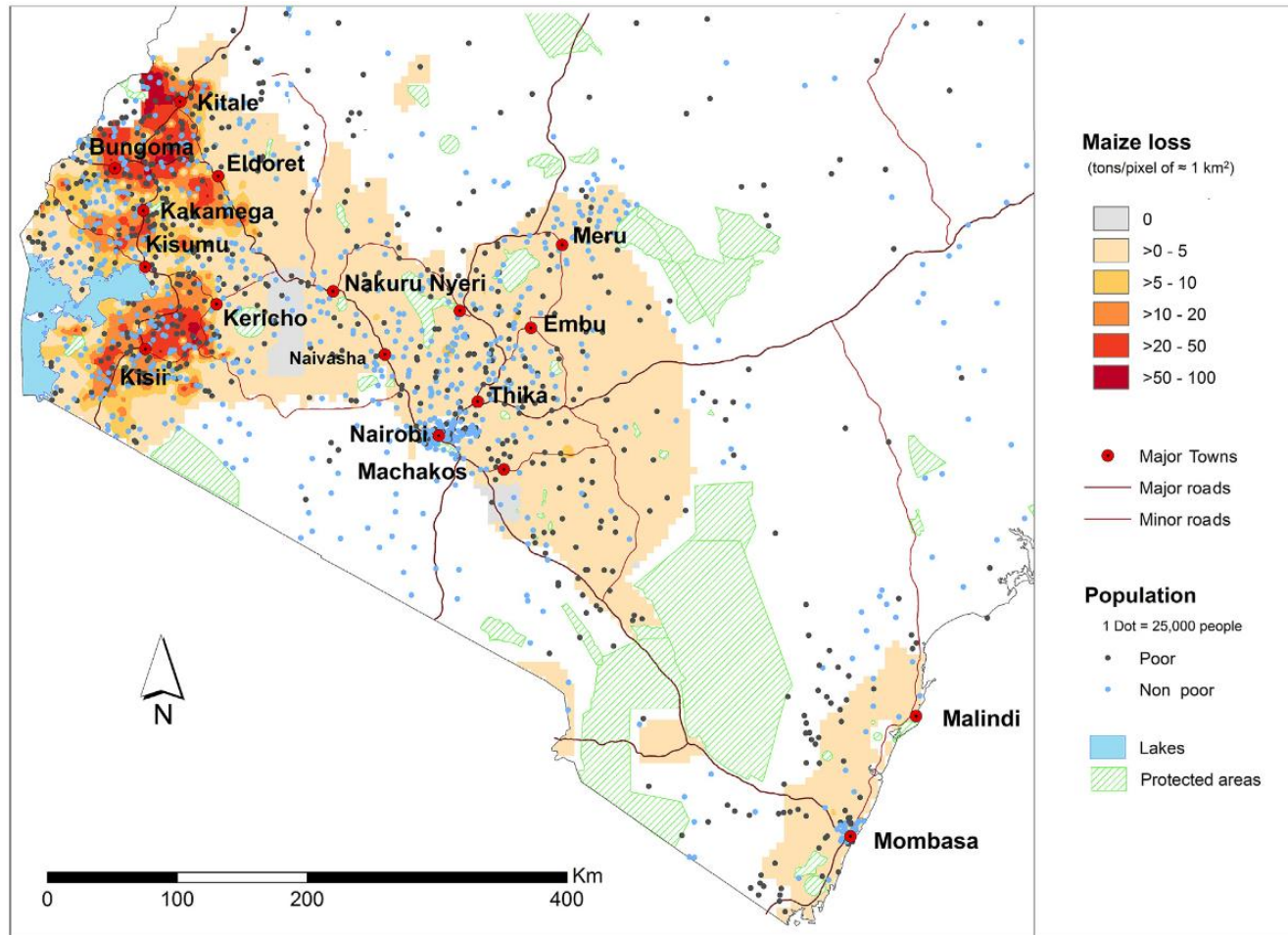
# Wind energy assessment



Source: Oloo et al, 2018 <https://www.mdpi.com/2071-1050/10/5/1470/htm>



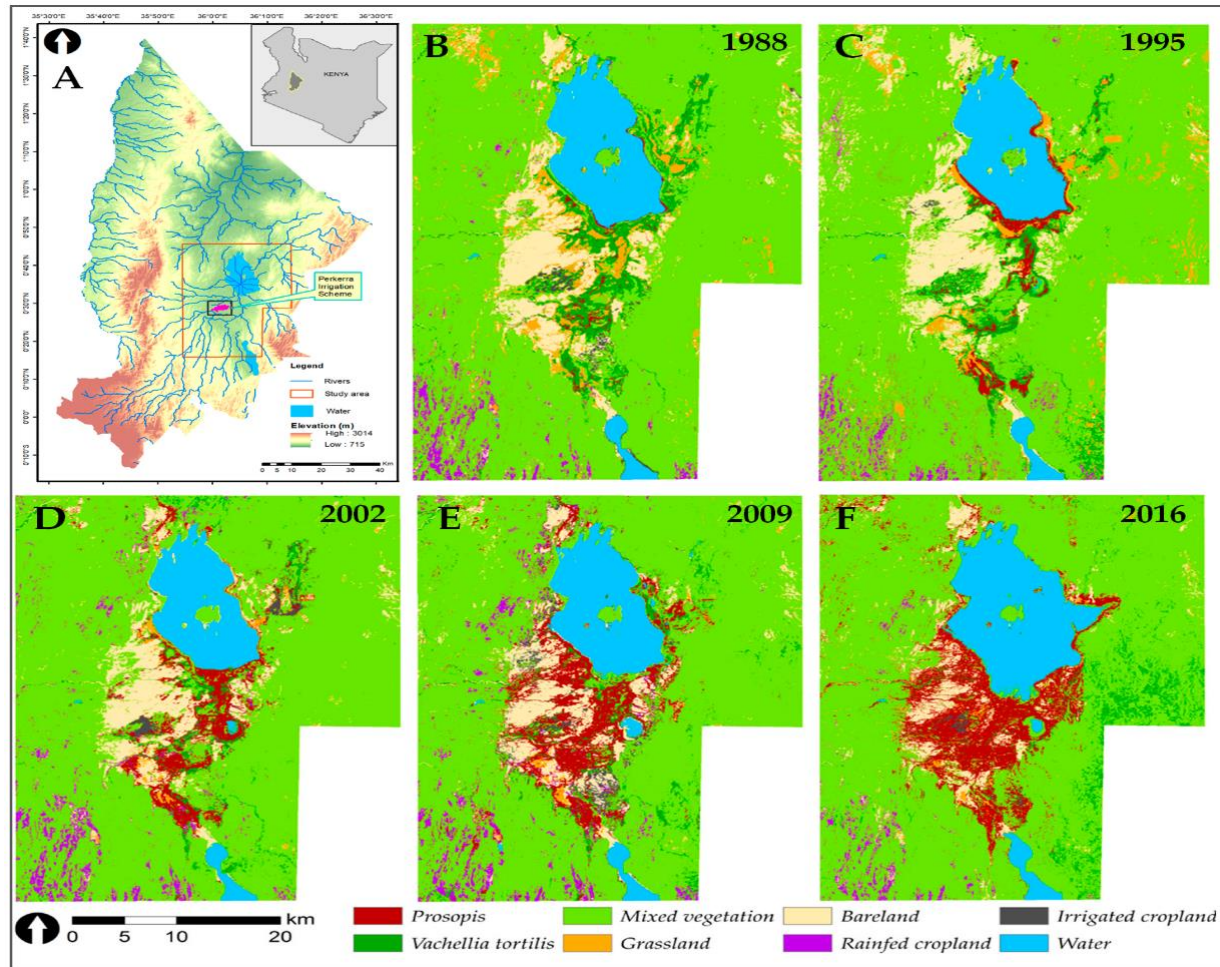
# Crop disease modelling



Source: De Groote, Oloo et al, 2016

<https://www.sciencedirect.com/science/article/abs/pii/S026121941530171X>

# Invasive species mapping



Source: Mbaabu et al, 2019 <https://doi.org/10.3390/rs11101217>



# Open geospatial Tools



# Demonstration

QGIS + Python + R

# Questions & Comments

[oloo@geopsy-research.org](mailto:oloo@geopsy-research.org)

The preparation of these material was supported by European Geoscience Union (EGU)  
Higher Education (HE) Teaching Award

