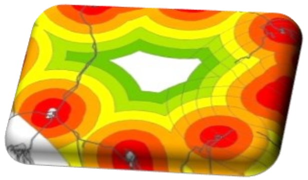
GIS in Agriculture



GIS Applications

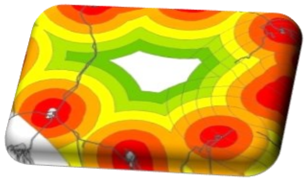
EGE 2421 /EGS 2401

GIS in Agriculture

Lecture No. 03

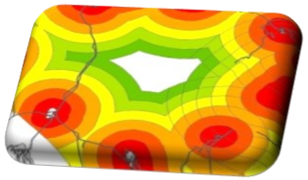
Felix Mutua, Ph. D

Wednesday, September 27, 2023



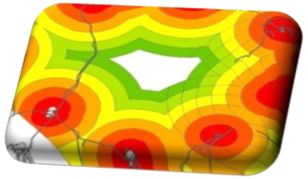
Lecture Plan

Week	Topic		Week	Topic	
1	Overview		8	Networks – I *(concepts, network problems)*	
2	Review of GIS analysis Techniques		9	Networks – II *(building networks, optimization)*	
3	GIS in Agriculture *(concepts, application areas, Crop Suitability Analysis)*		10	Networks – III *(routing, tracking)*	
4	Natural resource Management – I *(concepts, application areas)*		11	Utility Management *(concepts, viewsheds,lineof sight)*	
5	Natural resource Management – II *(Groundwater, forestry)*		12	Health and Disease control *(concepts in epidemiology)*	
6	GIS in Business *(store location, consumer profiling)*		13	Governance *(crime, districting, LIS, census)*	
7	CAT I		14	CAT II	



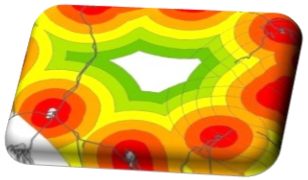
Introduction

- Droughts, floods, swarms of insects and poor farming techniques have plagued the agricultural community for centuries. Improvements have been made to insure the safety and gain of crops worldwide and yet these factors and many more continue to make or break individuals and communities affected by them.
- Geographic Information Systems are incredibly helpful in being able to map and project current and future fluctuations in precipitation, temperature, crop output, and more.



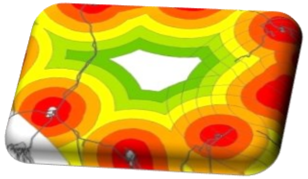
GIS Can Help Increase Food Production

- By mapping geographic and geologic features of current (and potential) farmland scientists and farmers can work together to create more effective and efficient farming techniques.
- Doing this could increase food production in parts of the world that are struggling to produce enough for the people around them.
- GIS can analyze soil data combined with historical farming practices to determine what are the best crops to plant, where they should go, and how to maintain soil nutrition levels to best benefit the plants.



GIS for Precise Farm Management

- GIS for Precise Farm Management Monitoring market trends, improving yields, and predicting weather are among the many responsibilities required to reduce the risk of loss and increase profitability.
- The Farmers Almanac has been replaced with geospatial analysis and predictive modeling. With these tools at their disposal, farmers now have the ability to visualize their land, crops, and management practices in unprecedented ways for precise management of their businesses.
- Today, accessing spatial data has become an essential farm practice. Government agencies such as the U.S. Department of Agriculture (USDA) and the European Union host Web sites that deliver valuable information to help farmers better understand their land and make more informed decisions.
- This data can be accessed on the Internet and used to create intelligent maps for better farm business practices

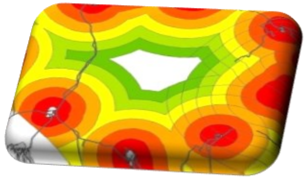


GIS in Agriculture

Application of GIS can be categorized in tow broad classes

- **Precision Agriculture** - use of current, automated sensors and systems to optimize Agricultural production
- **Classical application** - such as groundwater exploration, suitability analysis and yield estimation

Precision Agriculture



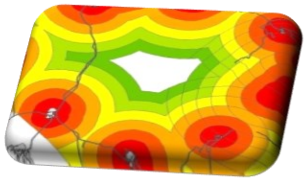
GIS-Enabled Precision Agriculture Tools

- ***Yield monitors***
  - serve as information gathering tools and decision support systems for the precision agriculture practitioner.
  - The information gathered by yield monitors serves as the basis for many production and management decisions. Examples of these are determining management zones, selecting crop varieties, and applying inputs such as fertilizer or nitrogen.
  - Creating zones within fields of different yield productivity levels is one of the primary techniques for managing fields on a site-specific basis. The delineation of yield zones based on yield variances would not be possible without GIS analytical tools.

GIS-Enabled Precision Agriculture Tools

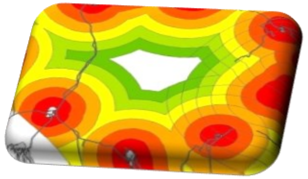
Yield monitors

- Yield monitors are one of the first precision agriculture tools that were introduced.
- They allow the combine harvester to collect real-time data on the amount of yield harvested and other related parameters, such as grain moisture.
- The yield monitor also includes a GPS receiver, which records the physical location, along with the yield data.
- The information can be displayed on a map, referred to as "yield map".
- This helps the farmer in many ways, as he can relate yield variations in the field to other factors that can affect the yield, such as variation in soil, application of inputs, irrigation etc.



GIS-Enabled Precision Agriculture Tools

- **In-field sensors**
  - Most precision agriculture technologies use sensors. This includes the yield monitor, GPS data, satellite data, sensors mounted on drones etc.
  - Some sensors are placed in the field at different monitoring stations, to measure the immediate surroundings of the plant, while growing. For example:
    - Soil moisture sensors measure the moisture content of the soil, enabling farmers to make smart irrigation management decisions.

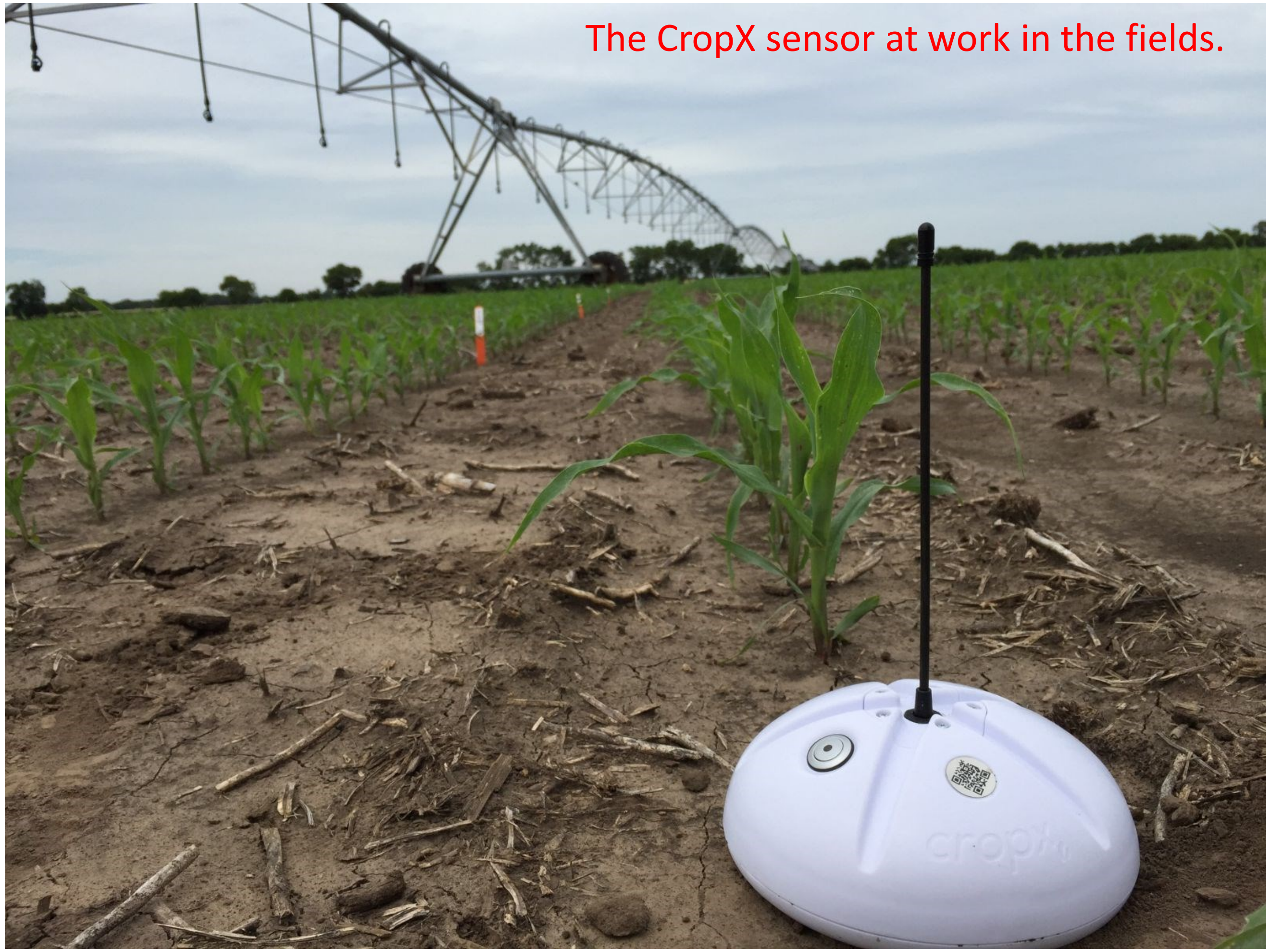


GIS-Enabled Precision Agriculture Tools

- **In-field sensors**
  - Soil moisture sensors measure the moisture content of the soil, enabling farmers to make smart irrigation management decisions.
  - Another type of soil sensor is soil electrical conductivity sensor. The readings of the soil electrical conductivity can be used for salinity estimation, and therefore help farmers with fertilization and irrigation management.
  - Some new sensors are mounted on the leaves and stem of the plant, providing valuable data on the plant’s status, such as water uptake and water stress. New technology, using very thin graphene-based sensor will allow to “tattoo” the sensors on the plant’s leaves.
  - Other sensors include soil temperature sensors, soil pH, air temperature and humidity.

GIS-Enabled Precision Agriculture Tools

- The CropX software system for advanced adaptive irrigation is gaining traction on large American farms.
- Sensor stations placed strategically in the fields according to a GPS-enabled smartphone app sync to the phone to transmit data updates on soil conditions.
- CropX not only informs farmers about the amount of water, fertilizer and pesticide needed by each patch at specific times, but can control the irrigation system accordingly, automatically handling daily decisions for farmers.


The CropX sensor at work in the fields.

GIS-Enabled Precision Agriculture Tools

- The Tevatronic system fully automates irrigation and fertilization customized to achieve desired root system depth, as well as the decision-making behind them.
- Tevatronic's wireless sensors collect precise data from soil in each zone of the farm.
- A smart controller converts this cloud-stored data in real time into a precise irrigation-fertilization cycle without human intervention.
- The system increases productivity from 15-31% and saves up to 27-75% on water and fertilizer, depending on the crop.

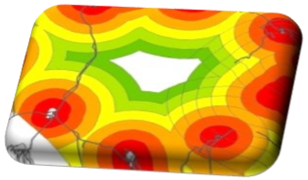
Tevatronic wireless sensors

GIS-Enabled Precision Agriculture Tools

The Yara N-Sensor is **a real-time variable-rate nitrogen sensor** that allows farmers to measure crop nitrogen requirement as the fertilizer spreader passes across the field and variably adjusts the fertilizer application rate accordingly.

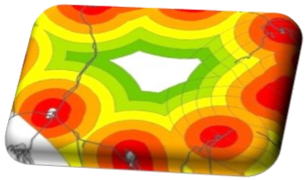
The N-Sensor has been developed to determine the crop nitrogen status by measuring the light reflectance properties of crop canopies and to enable variable-rate fertilization "on-the-go".

N-Sensor of Yara, mounted on the roof of a tractor cab, for measuring the canopy reflectance and, indirectly, the N fertilizer rate required by the crop.



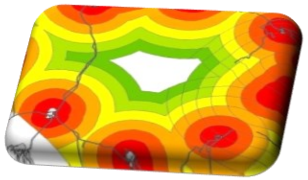
GIS-Enabled Precision Agriculture Tools

- **Targeted Soil Sampling**
  - The ability of farmers to produce high yielding crops is heavily dependent upon the soil in which the crops are grown. The soil type and its physical and chemical characteristics must be in proper balance in order to maximize production potential, and ultimately, return on investment
  - Targeted soil sampling consists of two primary methods, grid and zone sampling. In each method GIS software is used in conjunction with GPS to create a boundary of a field and break down the areas within the boundary into individual segments for study.



GIS-Enabled Precision Agriculture Tools

- **Variable Rate Applications**
  - The high costs of pesticides, herbicides, fertilizer, and labor make it important to utilize such inputs as accurately and efficiently as possible
  - Before inputs can be applied at a variable rate, farmers must determine what the application will be based upon. For example, nitrogen application decisions are generally based on the average yield from previous years..
  - Fertilizer and lime application decisions are based on the information gathered from targeted soil sampling.
  - Additionally, farmers may use aerial imagery or soil maps to break the field into management zones and treat the areas individually.

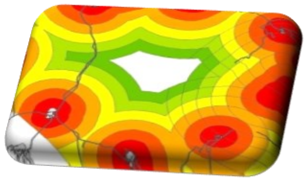


GIS-Enabled Precision Agriculture Tools

- **Equipment Guidance**
  - Whether farmers are planting, applying inputs, or harvesting, it is important to operate the machinery in the most efficient manner possible.
  - Labor, fuel and input costs, and potential for breakdown increase if the machinery is operating more than necessary.
  - Overlapping areas of the field or skipping areas will result in over-application or underapplication of inputs such as herbicides and pesticides.
  - Over-application can result in damage to the crop and environment, and under-application will result in the input not achieving the desired crop effect.
  - Equipment guidance and VRA are similar in that they both serve to maximize the return on investment of equipment, inputs, and labor.
  - Equipment guidance systems can be placed on any type of agricultural machinery that would benefit farmers to drive in a more concise pattern.
  - Equipment operators have traditionally relied on visual cues such as a point on the horizon, a marking system consisting of foam emitters that mark the applied areas, tire tracks, or by counting over a certain number of rows to begin the next application pass.

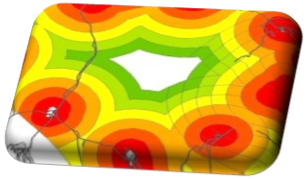
GIS-Enabled Precision Agriculture Tools

- **Automated Steering System**
  - Auto steering has been practiced before in farming, but it was not very successful.
  - The introduction of advanced real-time kinematic global positioning system (RTK-GPS) made the process more efficient.
  - RTK-GPS was integrated with auto-steering software and the results were much better.
  - In precision farming, the tractor needs to move uniformly throughout the farm.
  - Achieving such a task with human-driven tractors is not possible. Farmers often skip patches of land and overlap on rows, but with auto-steering it will be uniform from point A to Z.
  - The auto-steering software reduces human error since it has an accuracy of + or –30mm.



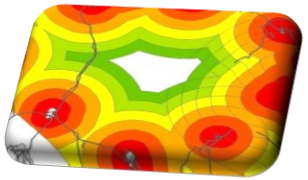
GIS-Enabled Precision Agriculture Tools

- Data from satellites and drones provide an additional dimension of the field, that was rarely considered before – a view from above.
- This is a unique and important aspect of precision agriculture. It enables farmers to detect problems, which were very difficult to detect before this technology became available.
- Drones and satellites can provide information on pests and diseases, the nutritional status of the crop, help in yield prediction and more.



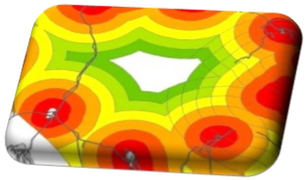
GIS-Enabled Precision Agriculture Tools

- AI-driven bots are assisting in the process of harvesting crops faster and with greater care. Overall providing better productivity outputs.
- A combination of more efficient robot weeders and drones allows farmers to:
  - Apply chemicals with greater precision
  - Collect data analysis which provides early alerts about the appearance of invasive weeds
  - Helps farmers keep weeds under control while using 20x fewer herbicides.



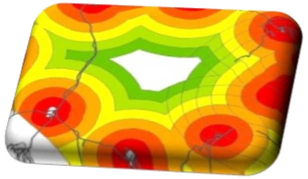
GIS-Enabled Precision Agriculture Tools

- **Data management system**
  - To record, process, store and disseminate all the data collected in precision farming, you require an efficient data management system.
  - Data collected by remote sensors and GPS is raw which makes it very complicated. It needs to be processed by an expert before it can be consumed by famers.
  - With a proper data management system, you can monitor your farm, take high resolution images and process them using advanced software. Ensure the system has a high accuracy to avoid distorting the data.
  - A proper data management system also prevents loss of data.



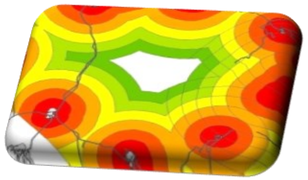
What´s next in precision agriculture

- Precision agriculture technologies can be categorized into three groups:
  - Technologies that measure and collect data.
    - More and more sensors
  - Decision support software platforms and apps.
    - Based on AI, mobile, big data
  - Precision application of inputs.



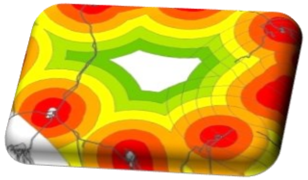
Precision Agriculture – Emerging trends

- Precision agriculture software packages have moved from general GIS applications to systems tailored to meet the needs of farmers with a minimum of training.
- improved reliability and user-friendliness in both hardware and GIS software will continue into the future.
- the development of decision support systems, which will help farmers to interpret the massive amounts of data and will help them to make better farm production decisions
- Farmers who successfully collect data about their farm through yield monitoring, soil sampling, or remote sensing are often left with the problem of data analysis. The question arises, "I have the data — now how do I capitalize on it?" Recommendations will need to be tailored to the specific region of the country, crop, and soil conditions, among other variables, but a company could develop standard analyses and recommendations that incorporate these certain parameters.
- the move to Internet-based data access. Whether the data is collected by the farmer, a third party service provider, or government agencies, the Internet can serve as a clearinghouse

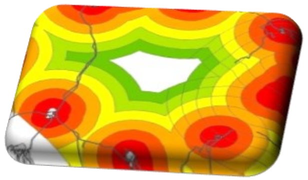


Precision Agriculture – Emerging trends

- use of GIS-enabled farming tools to assist in adhering to strict environmental standards.
- A niche market may develop for analysis and recommendations to farmers who do not have the ability to conduct such analysis, or to determine how to use the results to improve management decision-making.
- Farmers of the future will have more Internet-based data available, and GIS will be an important tool not only for data analysis, but also for environmental compliance.

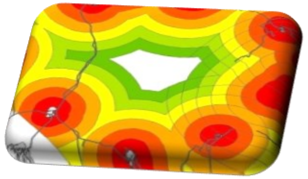


Classical Applications of GIS in Agriculture



Suitability Analysis

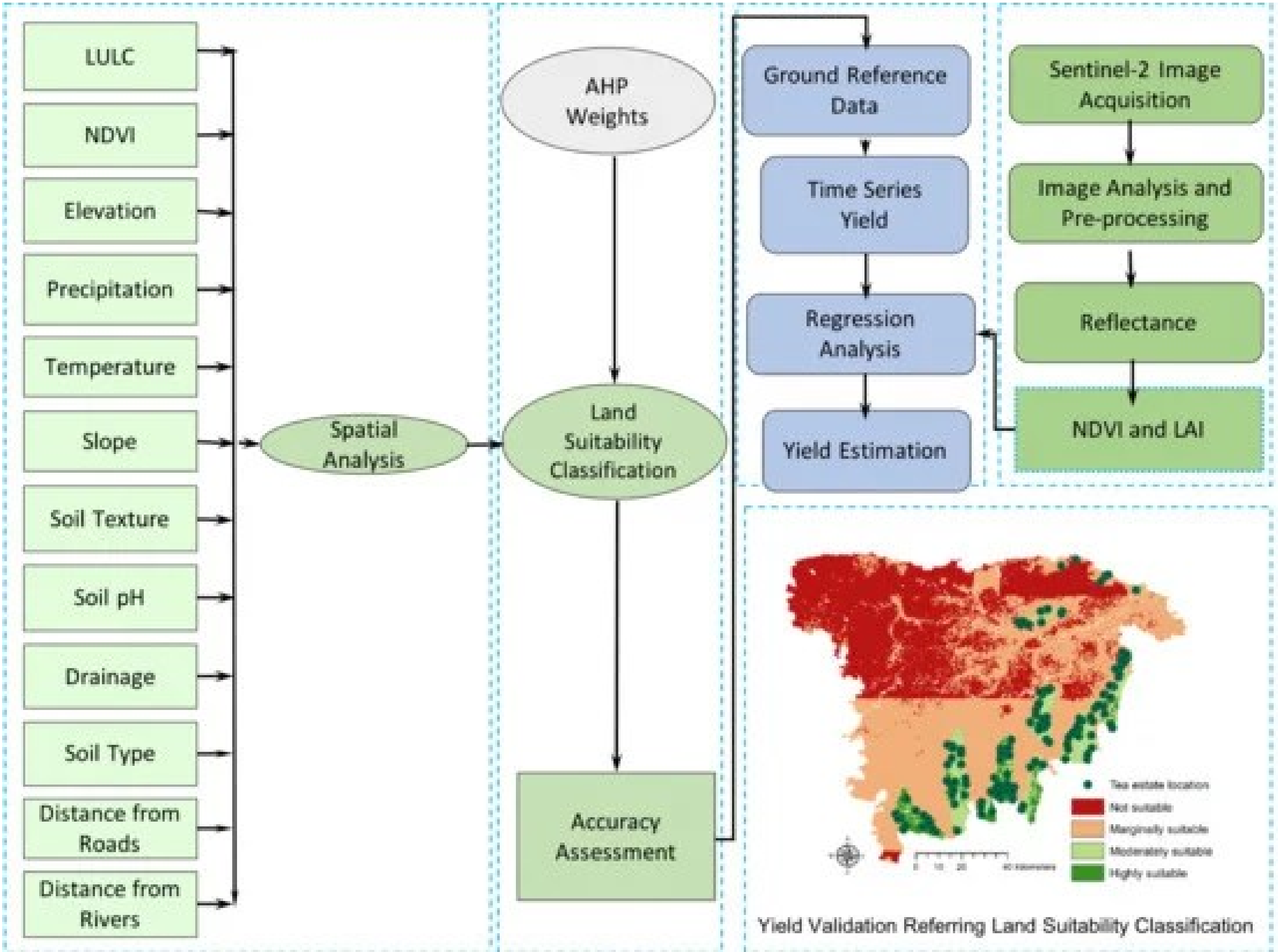
- Suitability Analysis allows you to qualify, compare, and rank candidate sites based on how closely they adhere to criteria that you select and define.
- This scalable workflow can answer questions such as the following:
  - Which region of the country is most suitable for expansion?
  - Within the selected region, which area is most conducive to sales growth?
  - Within the market selected for expansion, which candidate site is best?
  - How does weighting the existence of competitors as two times more important than the number of people in your trade area change the suitability score?



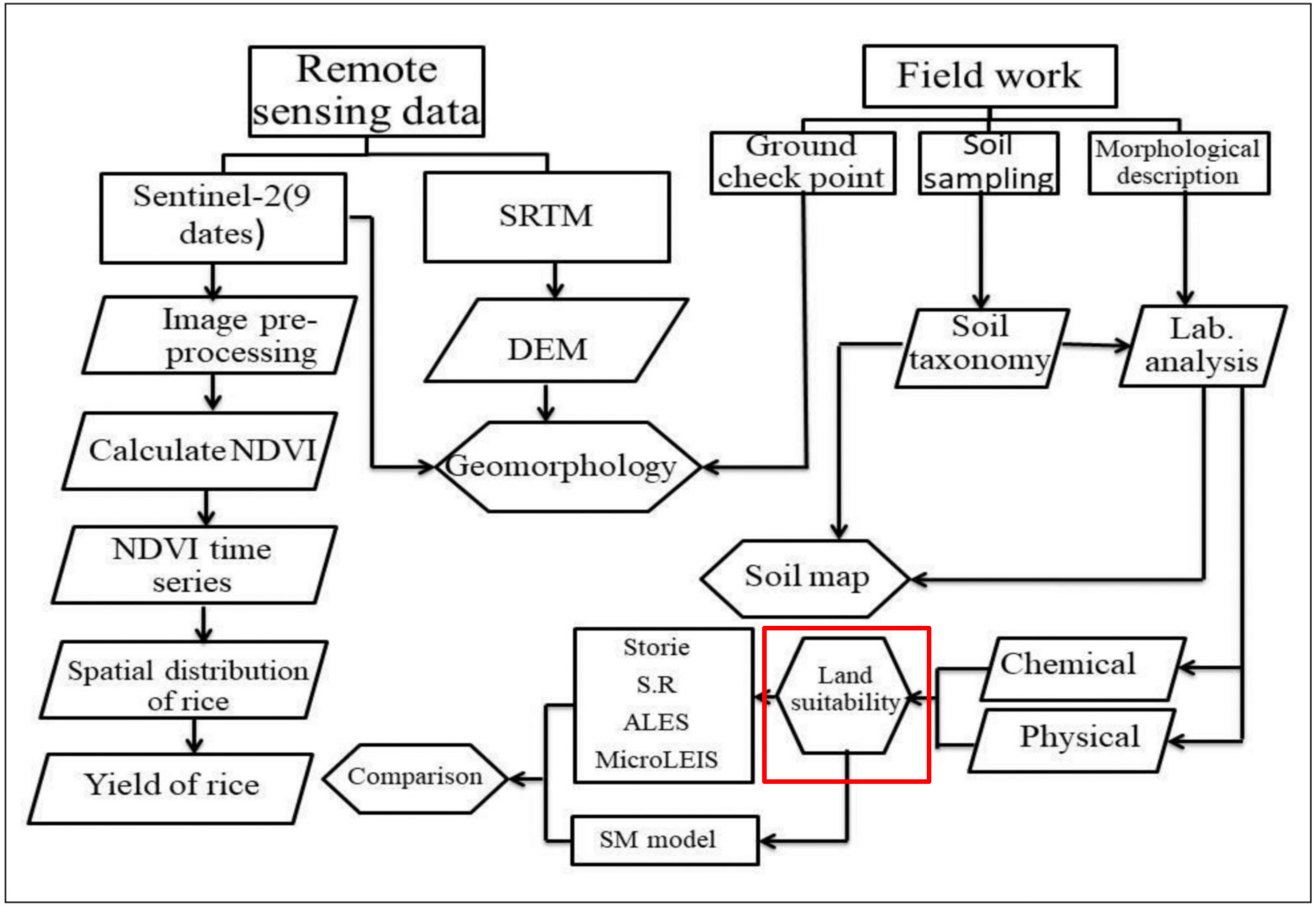
Crop Suitability Analysis

- Crop/land Suitability Analysis allows one compare, and rank candidate sites(land) based on how appropriate it is for certain crop(s)
- This is based on a multi-criteria, primarily derived from the ecological requirements of the crop
- One of the most popular applications of Classical GIS in Agriculture
- Involves the use multiple layers of soil, rainfall, pH, temperature and other parameters that are overlaid, giving least-most suitable areas for consideration

Examples

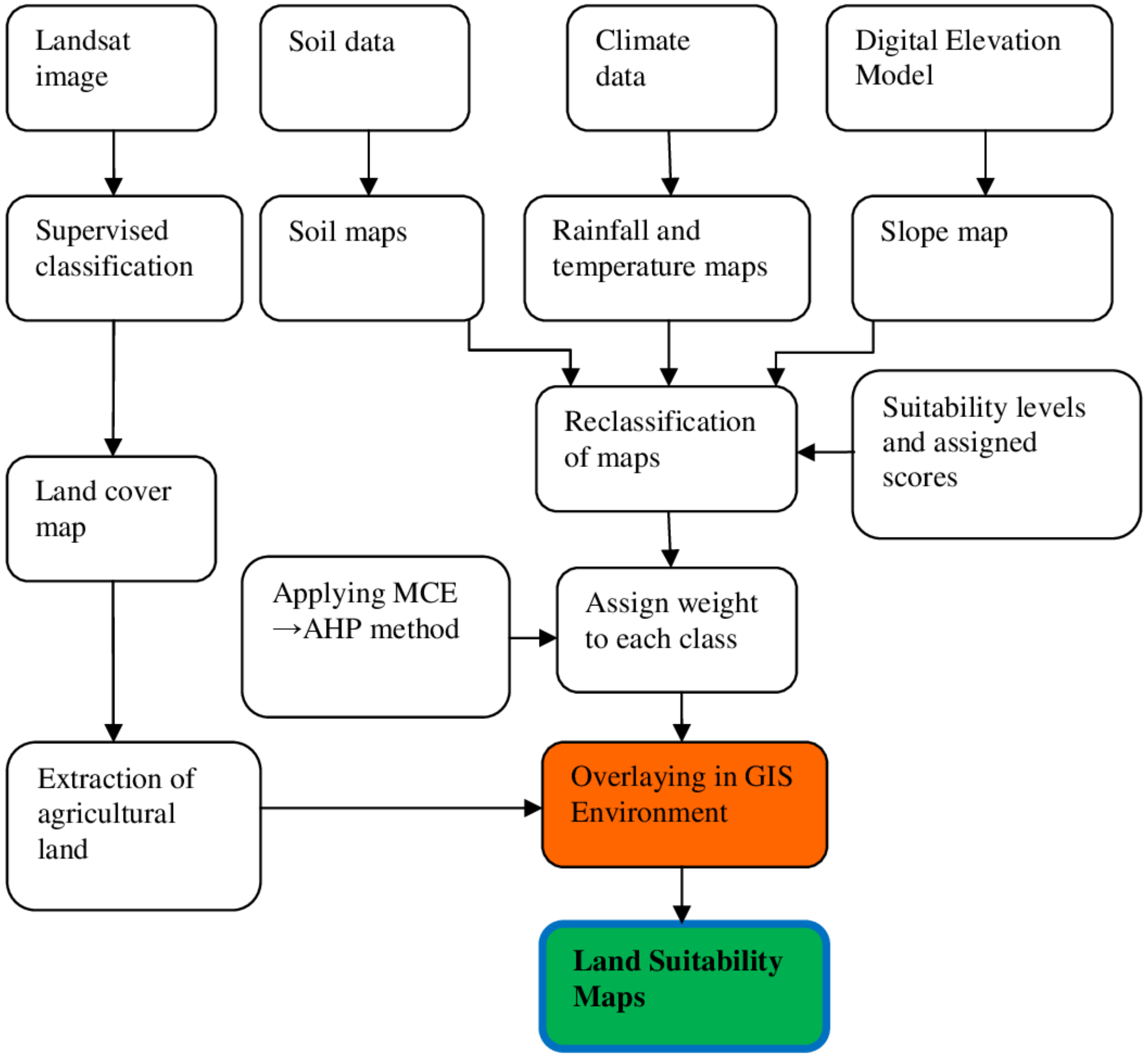

LULC
NDVI
Elevation
Precipitation
Temperature
Slope
Soil Texture
Soil pH
Drainage
Soil Type
Distance from Roads
Distance from Rivers
Spatial Analysis
AHP Weights
Land Suitability Classification
Accuracy Assessment
Ground Reference Data
Time Series Yield
Regression Analysis
Yield Estimation
Sentinel-2 Image Acquisition
Image Analysis and Pre-processing
Reflectance
NDVI and LAI
Yield Validation Referring Land Suitability Classification

Examples

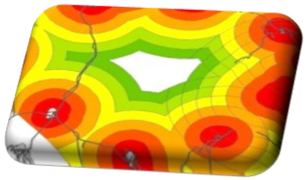


Remote sensing data
Field work
Sentinel-2(9 dates)
SRTM
Ground check point
Soil sampling
Morphological description
Image pre-processing
DEM
Soil taxonomy
Lab. analysis
Calculate NDVI
Geomorphology
NDVI time series
Soil map
Spatial distribution of rice
Storie
S.R
ALES
MicroLEIS
Land suitability
Chemical
Physical
Yield of rice
Comparison
SM model

Examples



Landsat image
Soil data
Climate data
Digital Elevation Model
Supervised classification
Soil maps
Rainfall and temperature maps
Slope map
Reclassification of maps
Suitability levels and assigned scores
Land cover map
Applying MCE →AHP method
Assign weight to each class
Extraction of agricultural land
Overlaying in GIS Environment
Land Suitability Maps

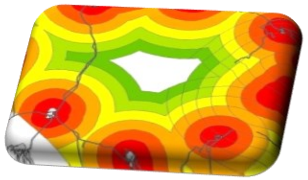


But how does is it done?

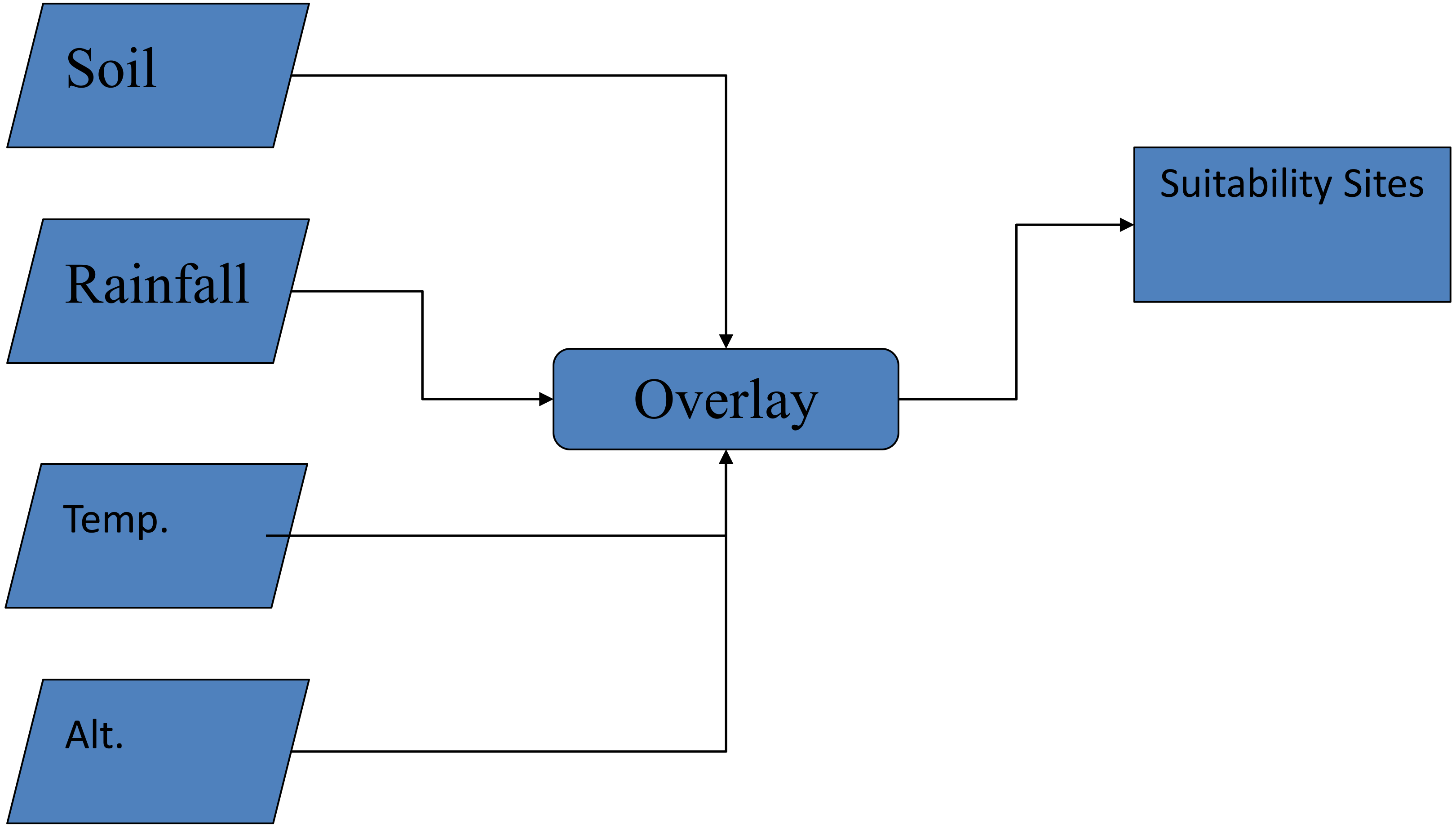
Where Can I grow high grade Maize in Kenya?

Maize requires the following

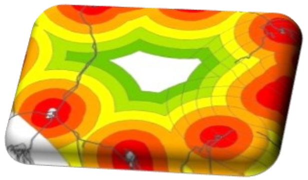
- Good well drained loam soil
- Altitude range :1000-2900M Asl (depends on variety)
- Rainfall : annual 600-100 mm
- Temperature : 18-27˚C.
- Soil : temperate podzols to the leached red, well-drained light loam or alluvial soil with a pH of between 5.5-7.0.



Model



Best Implemented through raster Overlay

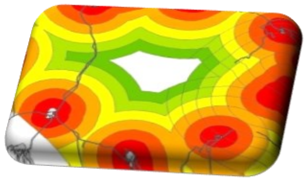


Classification

- Need to convert all the layers to the same base (0 – 5; 0 is the worst, 5 is the best)

Layer	Value	Class
Soil	Sand	0
	Clay	3
	Loam	5
Rainfall	0-200	0
	200-400	1
	400-800	2
	800-1200	3
	1200-1500	4
	>15000	5

Layer	Value	Class
Temp.	<15	0
	15-18	2
	18-20	3
	20-25	4
	25-30	5
	>30	0
Alt.	0-1000	1
	1000-1200	5
	1200-1500	4
	1500-3000	3



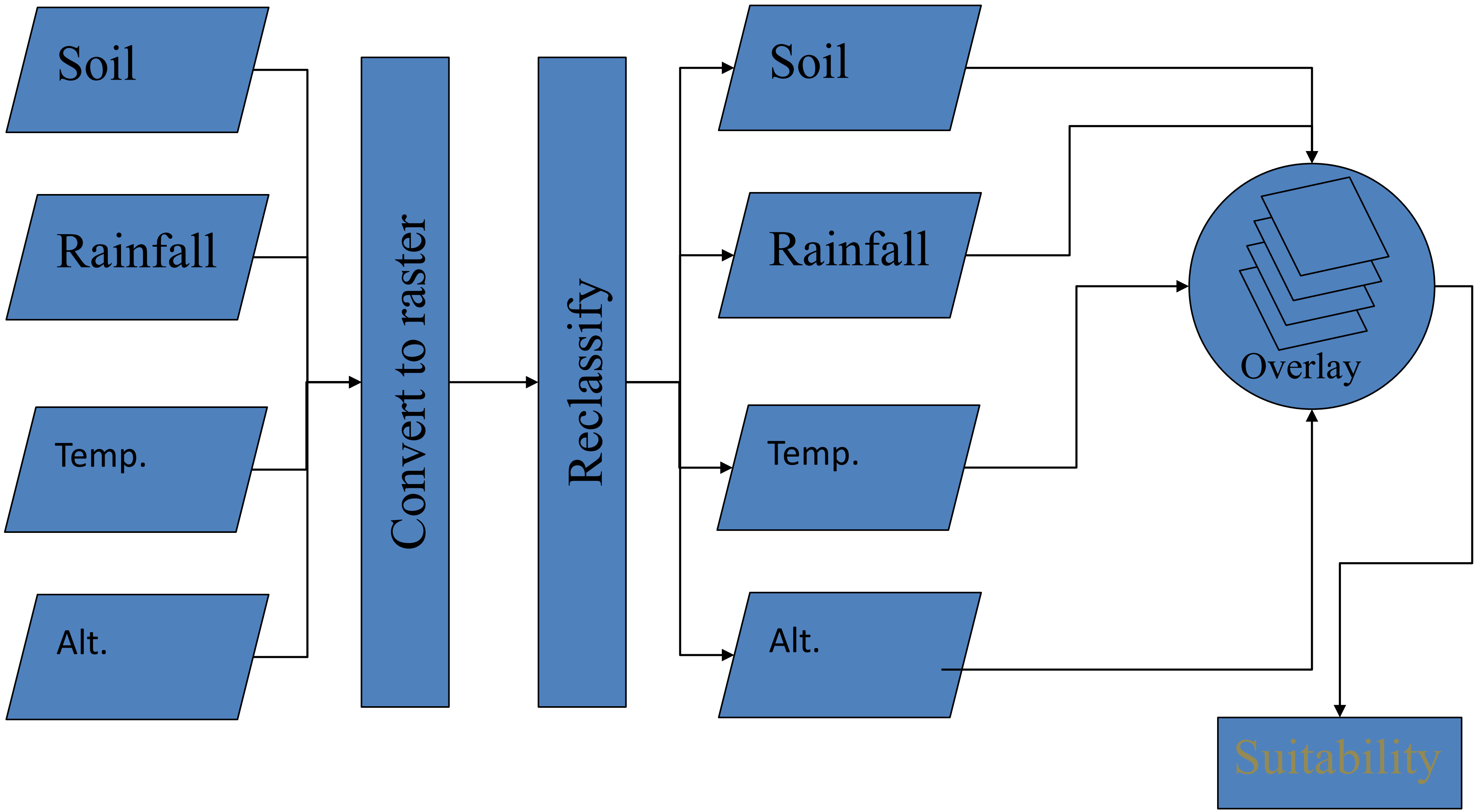
Logical Flow

Prepare :
Collection
Projection
Clipping

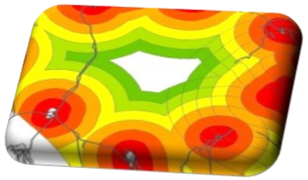
Convert :
Vector > Raster
Resampling

Reclassify :
0 – worst
5 – best

Model



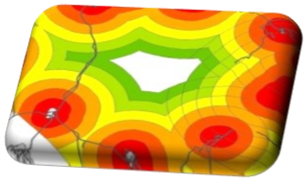
Soil
Rainfall
Temp.
Alt.
Convert to raster
Reclassify
Soil
Rainfall
Temp.
Alt.
Overlay
Suitability



Model Output

- Output will depend on input parameter classes with :
  - 0 : Not suitable
  - 1 : Least suitable
  - 2 : Moderate Suitable
  - 3 : Suitable
  - 4 : Highly suitable
  - 5 : Best suitable

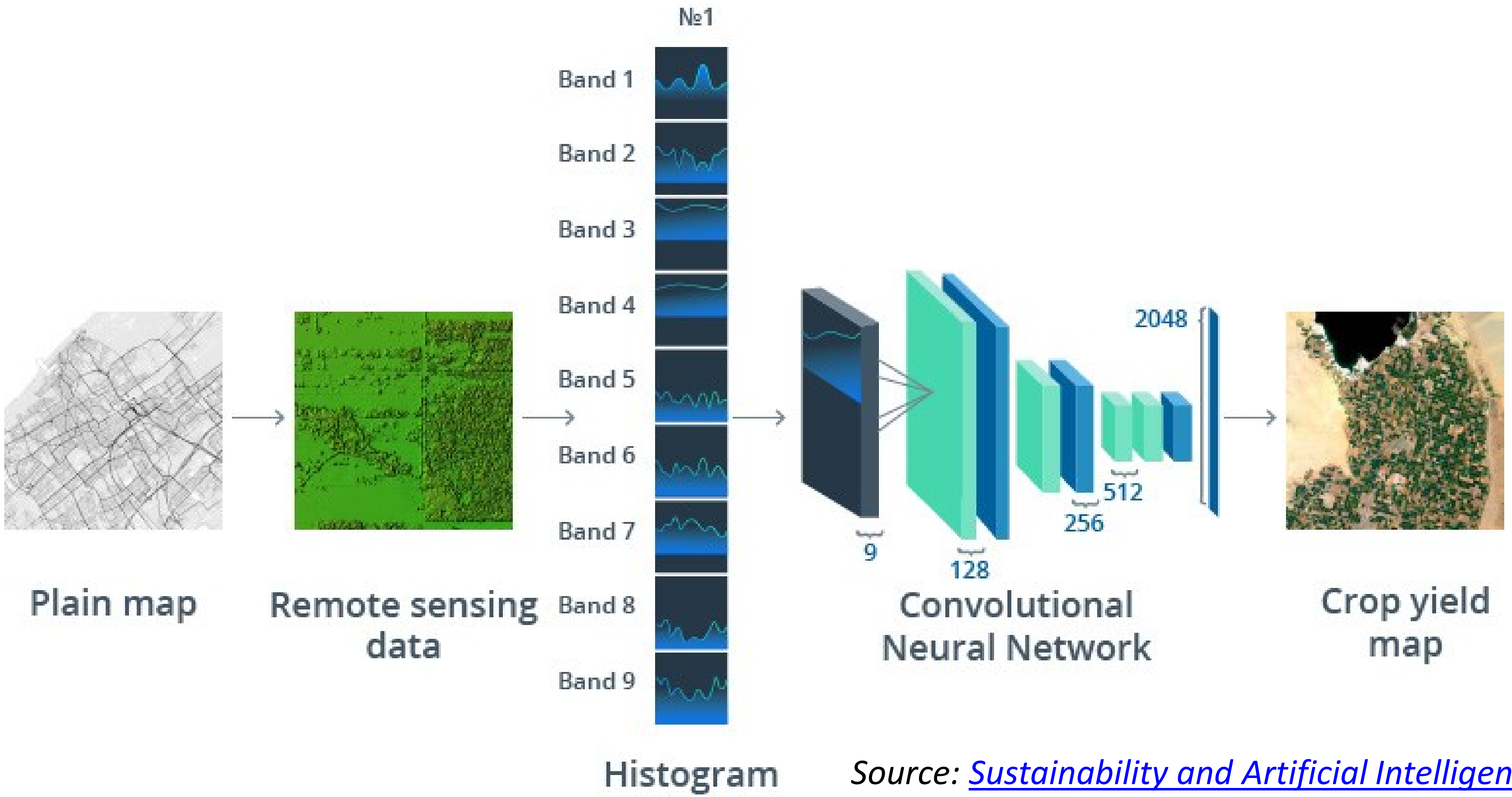
The classes 0-5 are arbitrary and you can choose any range provided it makes sense and suits the application



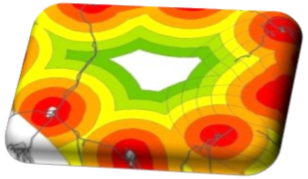
Crop yield prediction

- Accurate yield prediction can help governments ensure food security and businesses forecast profits and plan budgets. The recent development of technology connecting satellites, sensing, big data, and AI can enable those predictions.
- One of the most profound techniques in this field is Convolutional Neural Networks (ConvNets or CNNs). A ConvNet is a deep learning algorithm that is taught to identify the productivity of a crop.
- Developers train this algorithm by feeding it images of crops whose yield is already known to find productivity patterns. CNN has an accuracy of about 82%.

Crop yield prediction

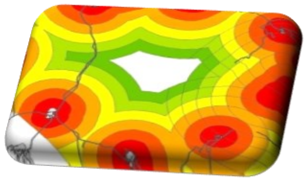


Source: [Sustainability and Artificial Intelligence Lab, Stanford University]()



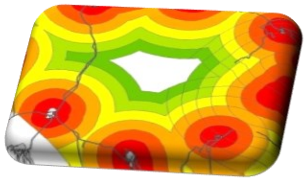
Livestock monitoring

- The simplest application of farm GIS software in animal husbandry is the tracking of movement of specific animals.
- This helps farmers find them on a farm and monitor their health, fertility, and nutrition. GIS services that allow you to do that comprise trackers installed on animals and a mobile device that receives and visualizes information from those trackers.
- *Here's one example.* You want to monitor the weight of your beef cattle. Each animal has a tracker on its ear or neck. Every time it steps on the digital scales, the scales read the ID of that animal and assign a new value to that ID in the system.
- You don't need to manually enter that data. Meanwhile, if there's an alarming change in the animal's weight, you can quickly find that animal and check its health.



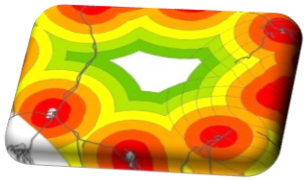
Insect and pest control

- The invasion of harmful insects and pests, or infestation, does heavy damage to agriculture. A look from above can enable accurate, timely alarms to prevent that. Yet even high-resolution images might not provide visible early signs of infestation.
- The alternative would be using AI.
- You develop a neural network and train it using deep learning algorithms. Through this training, you feed the neural network images of infested land, and the network learns to find samples that indicate infestation.
- After that, you feed it satellite images of the land you want analyzed.



Flooding, erosion, and drought control

- Marrying GIS and agriculture can help prevent, assess, and mitigate the negative impact of destructive natural phenomena.
- To identify flood-susceptible areas, you can use flood inventory mapping techniques. You need to collect data such as past floods, field surveys, and satellite images. Use those data to create a dataset to train a neural network to spot and map flood risks, and you will create an ultimate disaster management tool.
- If you need to check land for susceptibility for soil erosion, you could pair Universal Soil Loss Equation (USLE) with GIS and remote sensing. Run satellite images through spectral analysis to check USLE factors and verify those images with field observations.
- As a result, you can create a map featuring the level of deterioration of the soil across the field.



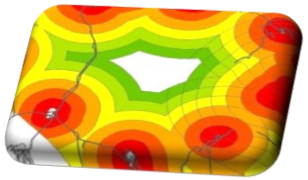
Assignment 02

Using your home constituency, you are required to choose a crop of your liking and conduct a suitability analysis. Specifically

- Research on the crop requirements (*read at least 5 peer reviewed papers*)
- Collect and process the data to your area
- Conduct a weighted overlay using ArcGIS modelling tool
- Package the model and the data in to one Geodatabase
- Prepare a PowerPoint presentation (*max 10 slides –presenting the work*) – must include a flowchart of the whole process

Submit a zipped folder of the above and submit to
https://forms.gle/RGGdcS6EoSaS5rtH7 - EGS 2401

https://forms.gle/b5nRcqJXfWzcLjFX8 - EGE 2421



Homework

Conduct research on the use of Big data, Artificial intelligence and IoT on Precision agriculture. Identify potential applications that you can consider developing/customizing for local use. This could potentially form basis for your final project