GPHY284 Final Project
Theo Symonds

Mapping King Cobra Antivenom-treatment Accessibility Risk for Farmers in Kerala, India

INTRODUCTION

Research Question: Which areas of Kerala do farmers have less accessibility to reaching antivenom treatment when bitten by King Cobras?

The risk for farmers being bitten by snakes is considerably higher in agricultural fields, as farmers often work barefoot, and King Cobras are attracted to the rodents that feed on crops. Furthermore, agricultural fields tend to be in more rural settings with less road infrastructure to be able to reach hospitals in time to receive antivenom treatment.

Regional Focus

Due to the size of the country, covering the entirety of India would make it very difficult to see the risk areas in the final map products, so for this project we will focus on just one state in India, Kerala.

CRS Projection

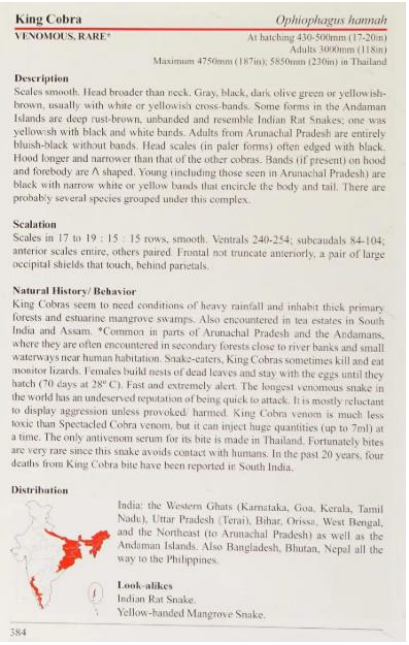
Since we will be assessing distances as a component of accessibility, it is important that we set our Coordinate Reference System (CRS) to a meters-based projection for India. The state of Kerala is taller than it is wide (covering more degrees of latitude than longitude), which means the Universal Transverse Mercator (UTM) projection set to Zone 43N (EPSG:32643) will be the ideal CRS to use for this project. This projection is common for GIS, surveying, and engineering projects due to Kerela's narrow longitudinal extent.

Data Sources

King Cobra distribution

The data source to map the distribution of where King Cobras are found will be from a book called "A Field Guide to Snakes of India", written by Romulus Whitaker and Ashok Captain. This book is revered as an extremely well curated guide for herpetologists in India, and it provides comprehensive biological details about each snake species found in India. Although there must exist a shapefile containing the distribution – as we can imagine that would have been required in order to print the maps in the book – but unfortunately this data is not publicly available online, and so a major aspect of this project is to create the first online dataset of this kind. Hopefully as the government of India continues to

implement its national snakebite mitigation strategy, geospatial data like this should hopefully be made more available online.
I have scanned the King Cobra page from the book (page 384) and saved it as a pdf for georeferencing in ArcGIS.



King Cobra — *Ophiophagus hannah*
VENOMOUS, RARE*
At hatching 430-500mm (17-20in)
Adults 3000mm (118in)
Maximum 4750mm (187in); 5850mm (230in) in Thailand

Description
Scales smooth. Head broader than neck. Gray, black, dark olive green or yellowish-brown, usually with white or yellowish cross-bands. Some forms in the Andaman Islands are deep rust-brown, unbanded and resemble Indian Rat Snakes; one was yellowish with black and white bands. Adults from Arunachal Pradesh are entirely bluish-black without bands. Head scales (in paler forms) often edged with black. Hood longer and narrower than that of the other cobras. Bands (if present) on hood and forebody are ^ shaped. Young (including those seen in Arunachal Pradesh) are black with narrow white or yellow bands that encircle the body and tail. There are probably several species grouped under this complex.

Scalation
Scales in 17 to 19 : 15 : 15 rows, smooth. Ventrals 240-254; subcaudals 84-104; anterior scales entire, others paired. Frontal not truncate anteriorly, a pair of large occipital shields that touch, behind parietals.

Natural History/ Behavior
King Cobras seem to need conditions of heavy rainfall and inhabit thick primary forests and estuarine mangrove swamps. Also encountered in tea estates in South India and Assam. *Common in parts of Arunachal Pradesh and the Andamans, where they are often encountered in secondary forests close to river banks and small waterways near human habitation. Snake-eaters, King Cobras sometimes kill and eat monitor lizards. Females build nests of dead leaves and stay with the eggs until they hatch (70 days at 28° C). Fast and extremely alert. The longest venomous snake in the world has an undeserved reputation of being quick to attack. It is mostly reluctant to display aggression unless provoked/ harmed. King Cobra venom is much less toxic than Spectacled Cobra venom, but it can inject huge quantities (up to 7ml) at a time. The only antivenom serum for its bite is made in Thailand. Fortunately bites are very rare since this snake avoids contact with humans. In the past 20 years, four deaths from King Cobra bite have been reported in South India.

Distribution
India: the Western Ghats (Karnataka, Goa, Kerala, Tamil Nadu), Uttar Pradesh (Terai), Bihar, Orissa, West Bengal, and the Northeast (to Arunachal Pradesh) as well as the Andaman Islands. Also Bangladesh, Bhutan, Nepal all the way to the Philippines.

Look-alikes
Indian Rat Snake.
Yellow-banded Mangrove Snake.

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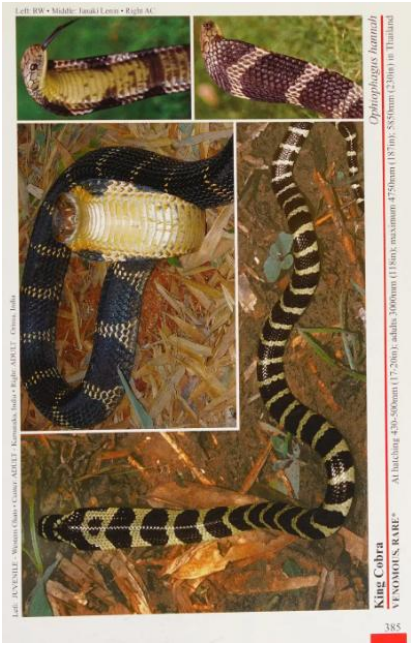


Agricultural Land

The Sentinel-2 satellite imagery data is a raster dataset that has Land Cover classified into 11 categories, at a resolution down to an astonishing 10m per cell. The purpose of this land cover dataset is to identify croplands where farmers will be working. This had to be downloaded from Esri's land Cover Explorer service instead of Living Atlas.

India: Sentinel-2 10m Land Use/Land Cover 2024

Type Map Service

Tags India, LULC, Sentinel2, Impact Observatory, landuse, landcover, 10m, 2024

Summary
This layer displays the Sentinel-2 10m Land Use/Land Cover product developed by Esri, Impact Observatory, and Microsoft.

Description
This layer displays the Sentinel-2 10m Land Use/Land Cover product developed by Esri, Impact Observatory, and Microsoft.

Data: Land cover in 2024
Data Projection: Universal Transverse Mercator (UTM)
Data Datum: WGS84
Extent: National
Source imagery: Sentinel-2
Cell Size: 10m
Type: Thematic
Source: Esri Inc.

Hospitals

The government of India provides a list of healthcare facilities across India, which has been made available in ArcGIS Living Atlas. Hospitals will serve as the points from which distance will be measured, with further distances from hospitals being deemed as higher risks for access to antivenom treatment. The availability of antivenom is not guaranteed at

every hospital, but state-funded public hospitals are more likely to carry antivenom which is why we will filter this dataset for public hospitals only.

India: Healthcare Facilities 2021

Type Feature Service

Tags India, Health, Healthcare, CHC, PHC, Hospital, UHC, UHP, Medical, Dispensary, Maternity, Nursing, Clinic

Summary

This layer shows healthcare facilities in India including hospitals, maternity centres, CHC, PHC, UHC, UHP, etc. for 2021.

Description

This layer provides complete list of primary health centres, sub centres, community health centres, district hospitals, and state hospitals with geo-location. State-wise list of hospitals and other required information like location, Category, Contact Details, Area PIN Code, landmark, etc. The Ministry of Health and Family Welfare, Government of India has set up the National Health Portal in pursuance to the decisions of the National Knowledge Commission, to provide healthcare related information to the citizens of India.

Data have been collected from two different sources and merged together. Following are original source of data collected:

1. Hospital Directory: https://data.gov.in/resources/nin-health-facilities-geo-code-and-additional-parameters-updated-till-last-month
2. Health Centres Directory: https://data.gov.in/catalog/all-india-health-centres-directory

Roads

OpenStreetMap contains many different road type classifications, from highways down to dirt roads. We will focus on Highway (Trunkway & Motorway), Primary, and Secondary roads for this project.

Administrative Boundaries

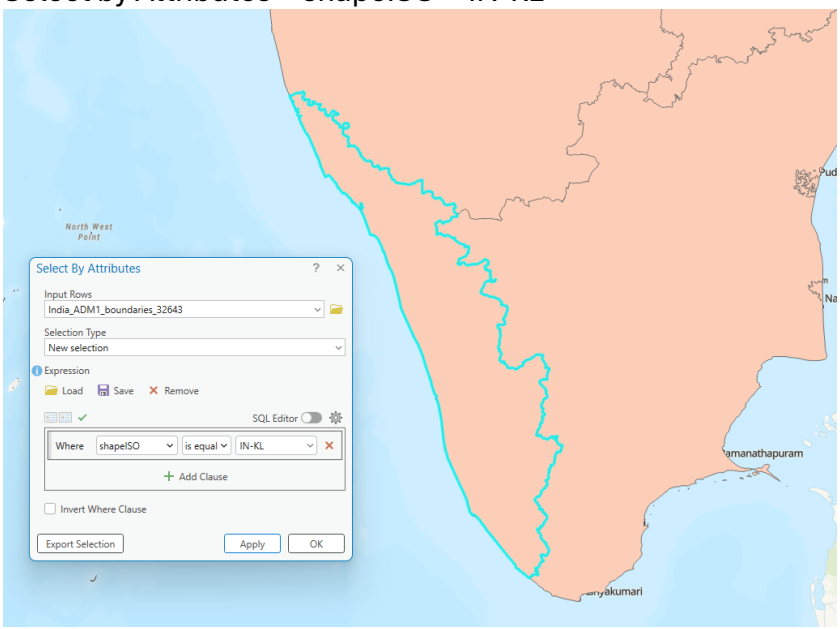
The Humanitarian Data Exchange provides ADM1 state boundaries for India as polygons. To isolate an outline of the Kerala state borders which will be used as a clip for our data, I saved only the Kerala feature (shapeiso: IN-KL).

METHODS

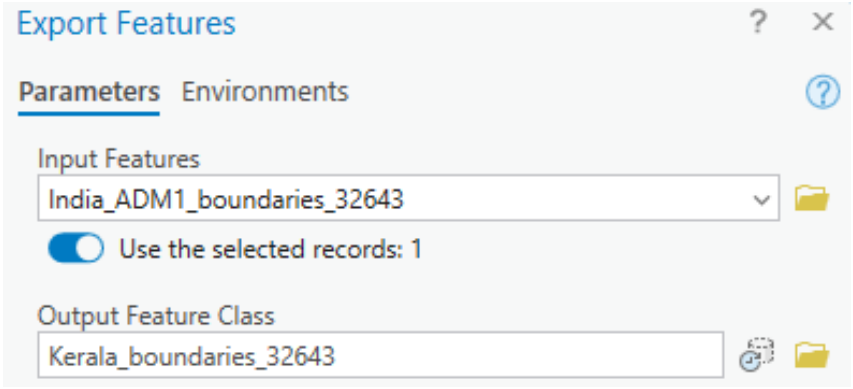
Creating Clip Data

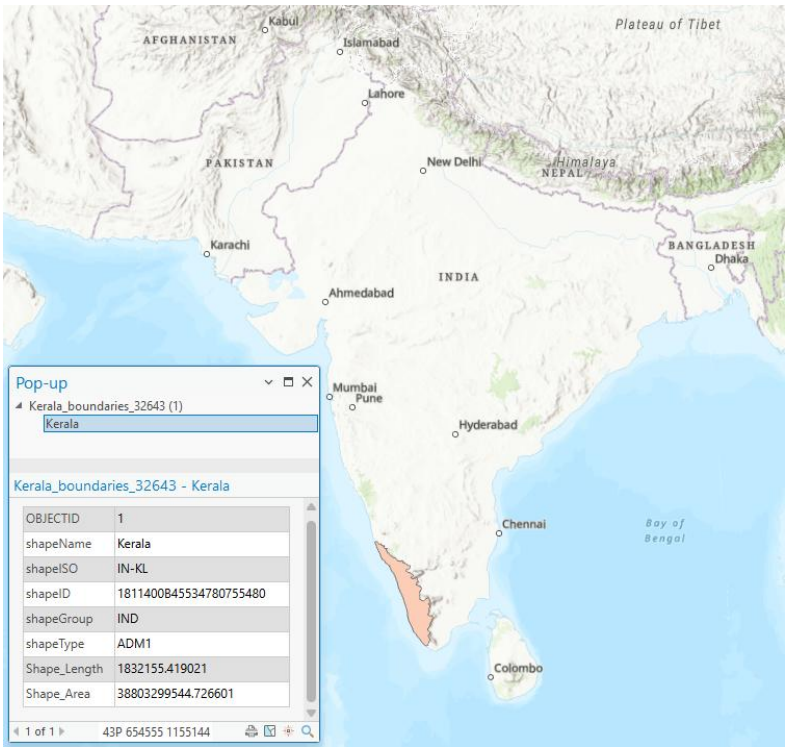
To help isolate our vector data and raster calculations to the state of Kerala, we will need a clip of the state boundaries which will come in handy for all our tools.

1. Reproject India ADM1 state boundaries from EPSG:4326 to EPSG:32643.
2. Select by Attributes > shapeISO=”IN-KL



3. Save selected feature as new feature layer.





Preparing Vectors & Raster Data (filtering, reprojecting and clipping)

To prepare our data for analysis, we need to filter out any unnecessary features we don't need, Clipping the vector data was straightforward, using the Pairwise Clip tool.

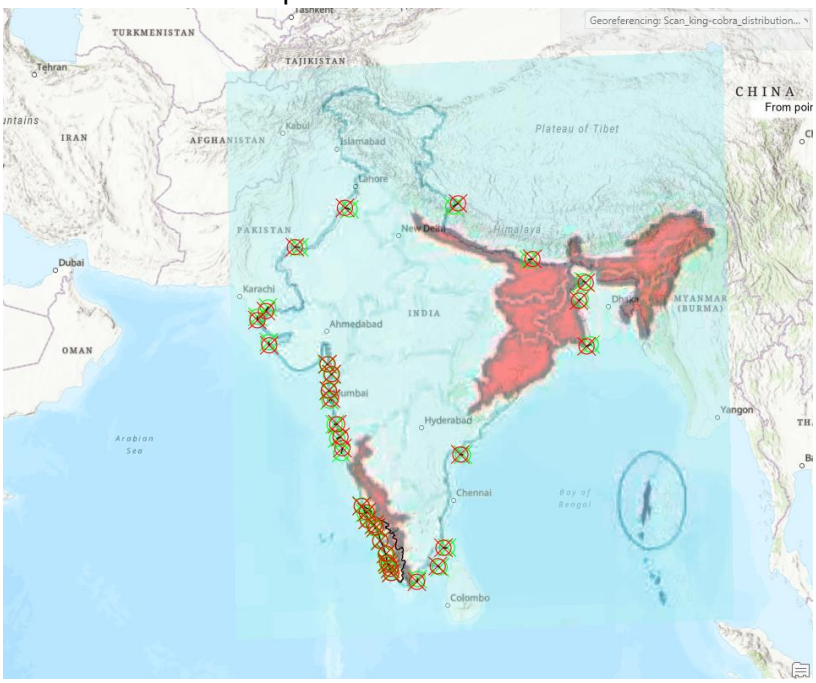
1. India Healthcare Facilities
    a. Select by Attribute (District Hospitals) > export selected features as new layer.
    b. Reproject to EPSG:32643.
    c. Pairwise Clip to Kerala boundaries.
2. OpenStreetMap Roads
    a. Select by Attribute (Motorway, Trunkway, Primary, Secondary) > export selected features as new layer.
    b. Reproject to EPSG:32643.
    c. Pairwise Clip to Kerala boundaries.
3. Land Cover
    a. Download from Sentinel already projected in EPSG:32643.
    b. Extract by Mask to clip raster to Kerala boundaries (preserving same cell resolution and projection).

Georeferencing & Drawing a King Cobra Distribution Polygon

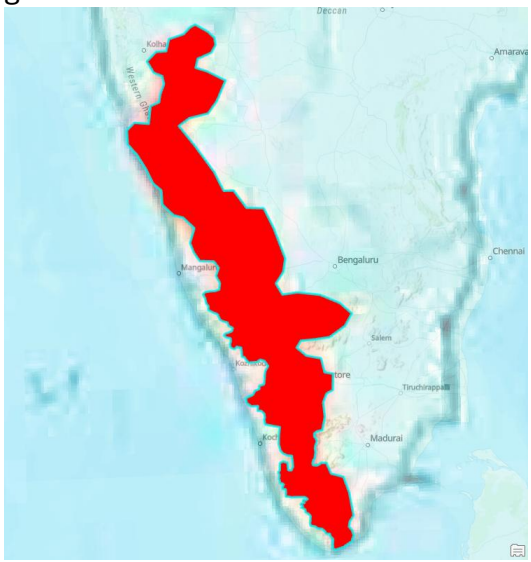
Since the King Cobra distribution extent map is coming from a pdf scan of my copy of Whitaker & Captain's book, we will need to georeference the distribution map to our India CRS first, before drawing a polygon for the distribution.

1. Scan map page of the book and save as pdf.

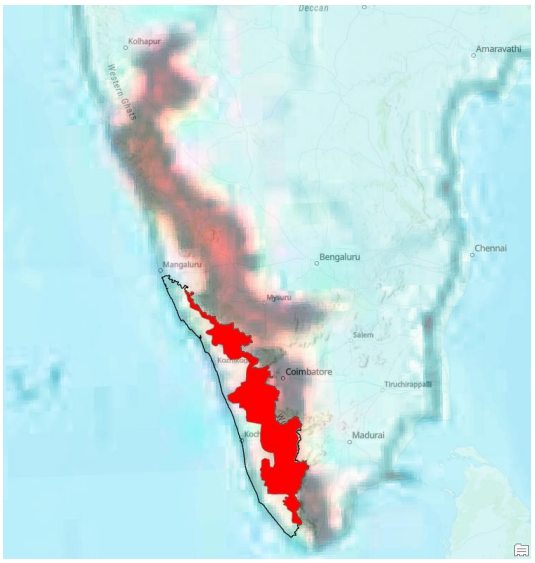
2. PDF to TIFF
3. Georeference tiff to outline of India. Imagery > Georeference
    a. Fit to display;
    b. Draw control points.



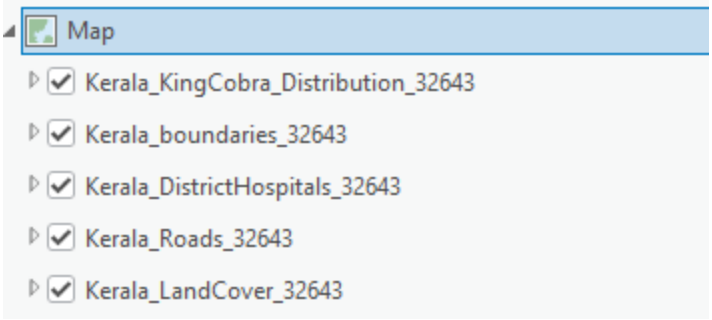
4. Use the distribution in the pdf scan to draw a new feature class polygon shape of the distribution.
    a. Create new polygon feature class (add to project geodatabase)
    b. Edit > Create Features > Draw polygons over King Cobra distribution seen in georeferenced tiff.



    c. Save and Pairwise Clip to Kerala boundaries.

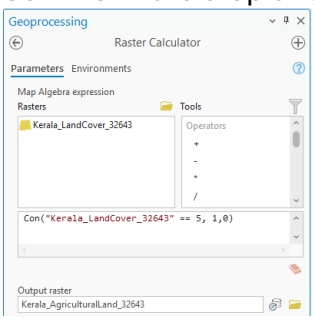


Now we have all the data we need to conduct spatial analysis.

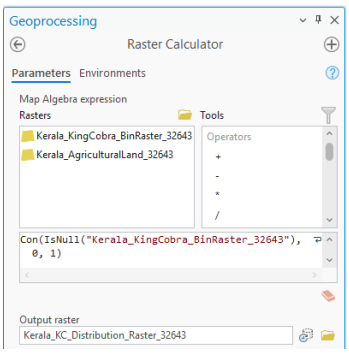


Building Accessibility Risk Index Raster

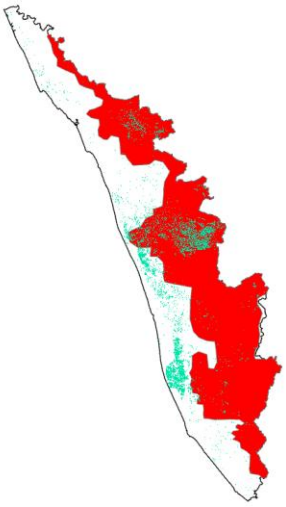
1. Raster calculator to create an agricultural-only layer (values classified as 5 in Sentinel-2 are croplands) with 0=non-agricultural and 1=agricultural area.

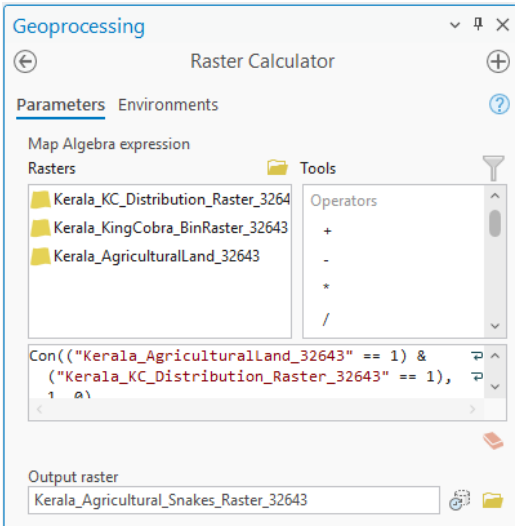


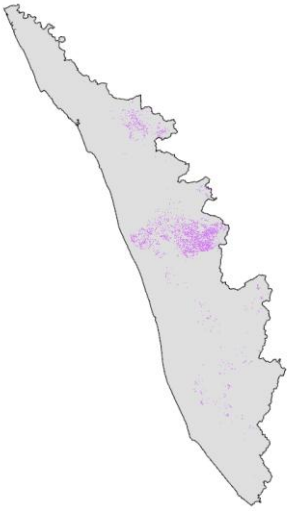
2. Polygon to Raster conversion to turn King Cobra distribution polygon into raster (1=snakes). Then run Raster calculator to add binary 0=no snakes and 1=snakes (snap to agricultural raster cells).



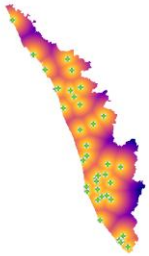
3. Raster calculator to find areas with both agricultural lands and King Cobras.



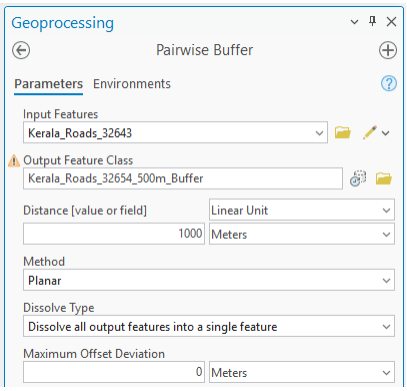


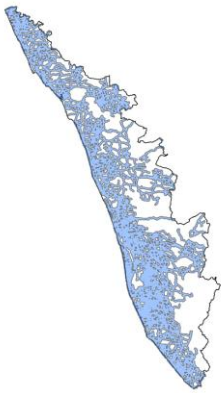


4. Measure distance to hospital using Euclidean Distance to get raster cells with distance in meters to the nearest hospital (snap to agricultural raster cells).

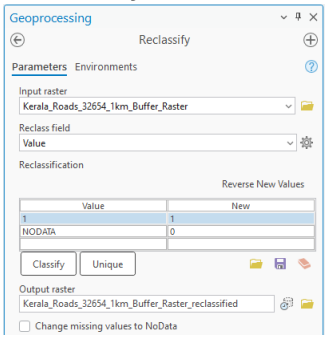


5. Create cost surface for distance near/far from major roads
    a. Pairwise Buffer roads (1km threshold from nearest road, dissolve all)

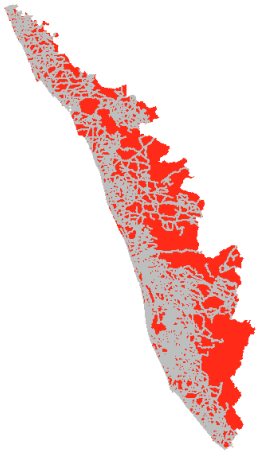




b. Polygon to Raster to create raster of cells that fall within roads buffer.
c. Reclassify to force Null values to be 0.

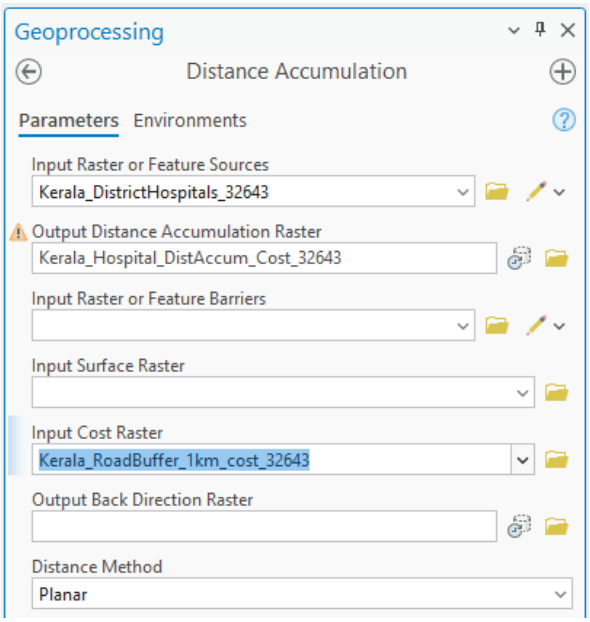


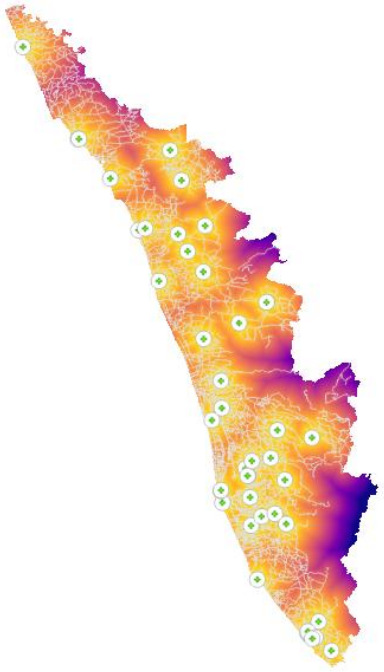
d. Raster calculator to create cost surface (low cost of 1 for cells within 1km of road, high cost of 2 for cells further than 1km from major road)



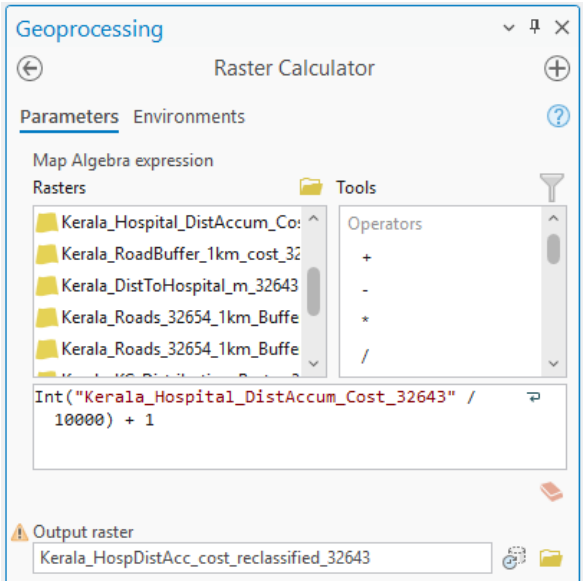
6. Create cost surface for distance from hospital using road coasts instead of Euclidean distance.
    a. Distance accumulation tool using road cost raster as cost input (instead of calculating straight-line Euclidean distance, this takes the road costs as parameter to calculate cost-weighted distance to hospital). The purpose of this calculation method is to assign increased cost to areas that are both far away from hospitals and also inaccessible by major roads. By using the 1 & 2 classification values from the road buffer, it is essentially doubling the

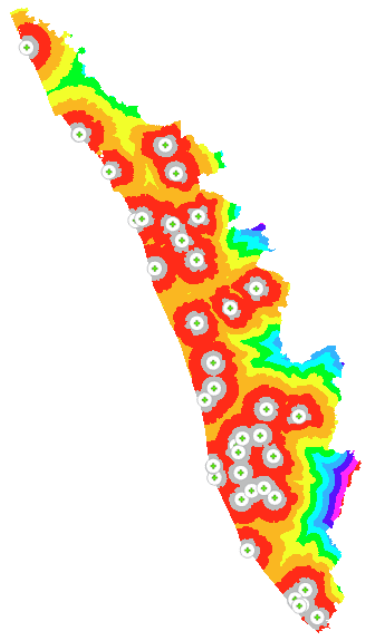
distance cost to a hospital when that area is also further than 1km from a major road (using the X2 value).



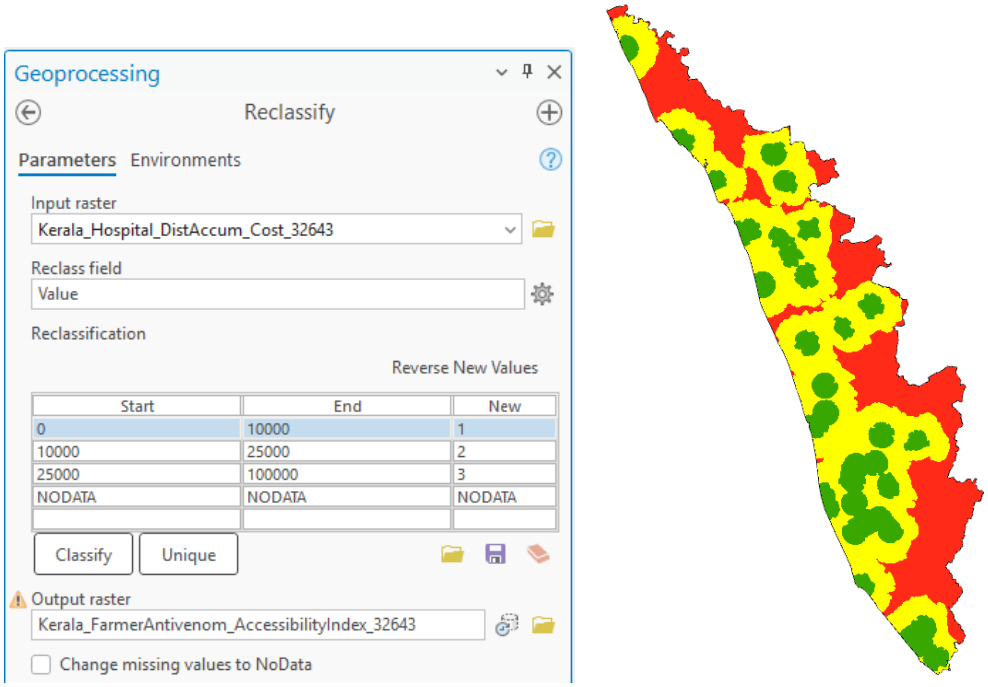


b. Calculate raster to get ordinal range using 10km intervals

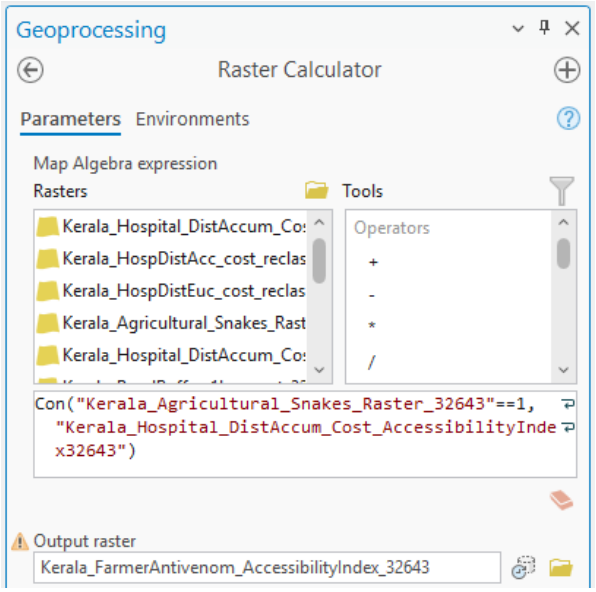


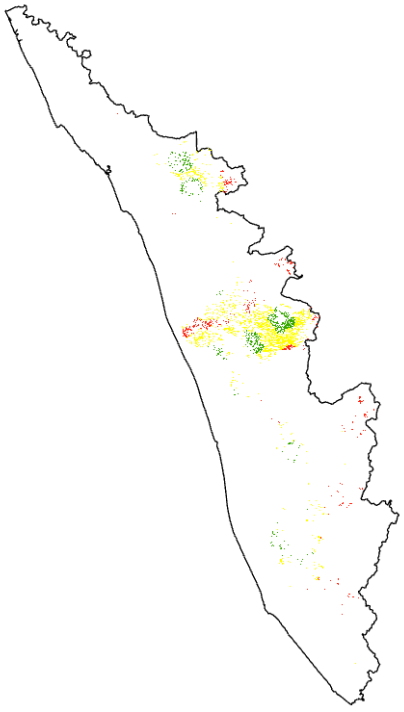


a. Reclassify with 1-3 ordinal classifications of road-based distance-weighted-cost to hospital. This will help our final map present areas of low-risk, medium risk, and high risk. Set low-risk to weighted distance cost below 10km, medium-risk to weighted distance cost between 10km-25km, and high-risk to weighted distance cost above 25km.



7. Create final risk index for only the agricultural areas with King Cobras present, using the road-accessibility weighted distance cost from hospitals index classification (1-better accessibility, 2-fair accessibility, 3-bad accessibility). Use raster calculator with raster algebra that assigns 1-3 index to areas where Agriculture & Snakes = 1 (areas with 0 return 0, and therefore are left out of accessibility index).





RESULTS

By identifying agricultural areas with King Cobra presence, and then calculating a road-based accessibility weighted-distance-cost to the nearest hospital for these areas, we were successfully able to map three levels of accessibility for farmers seeking antivenom treatments in Kerala, India.

Utility of the spatial analysis

This spatial analysis could support public health officials with planning new health infrastructure programs that serve the most vulnerable demographic to snakebites. With the knowledge of the areas where farmers bitten by King Cobras face lower-accessibility to antivenom treatment, we can target these areas with the construction of new hospitals and roads.

Considerations to improve the spatial analysis

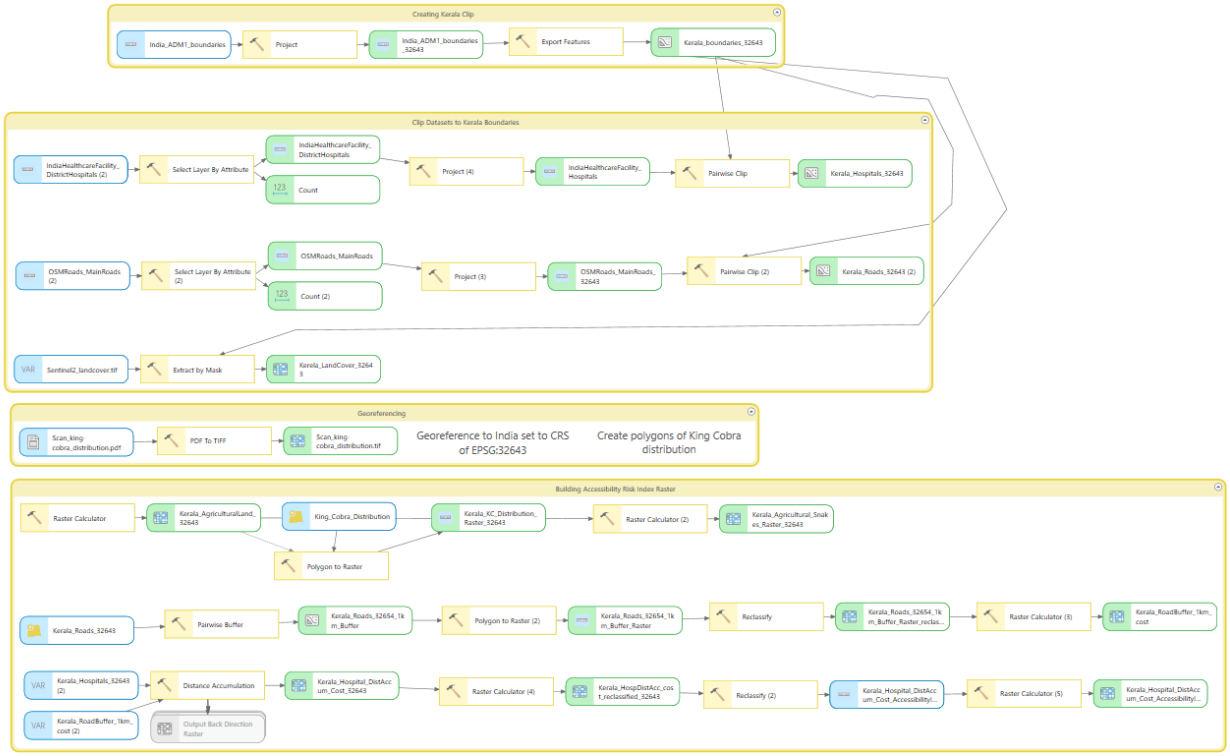
To strengthen the analysis, we can improve our weighted distance cost calculation by including impeding features such as rivers and vegetation as a parameter (called “Input Raster or Feature Barriers” in the Distance Accumulation tool). This can provide an even more significant weighted distance cost to hospitals as it will better reflect the reality of more serious travel impediments to hospitals.

Cartographic considerations

The final accessibility index does not cover a lot of the map, since the intersection of King Cobra distribution and agricultural areas is relegated to the inland portions of the state. To account for the sparse visuals of the risk areas, it would be best to provide zoomed-in views of the areas with a lot of low-accessibility classified cells (Red). It would also be best to include more reference information to contextualize where these low-accessibility areas are. For example, elevation data would show the mountains on the eastern portion of the state, and more city/road labels can help provide more details that public health officials in Kerala could find useful.

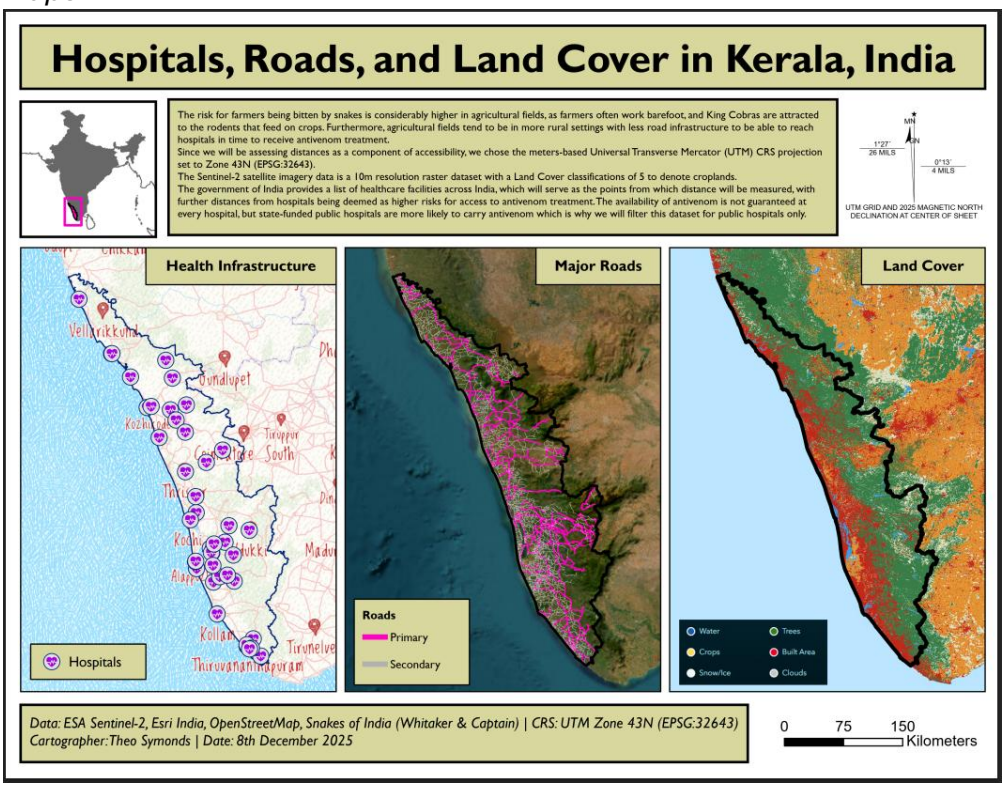
Appendix A

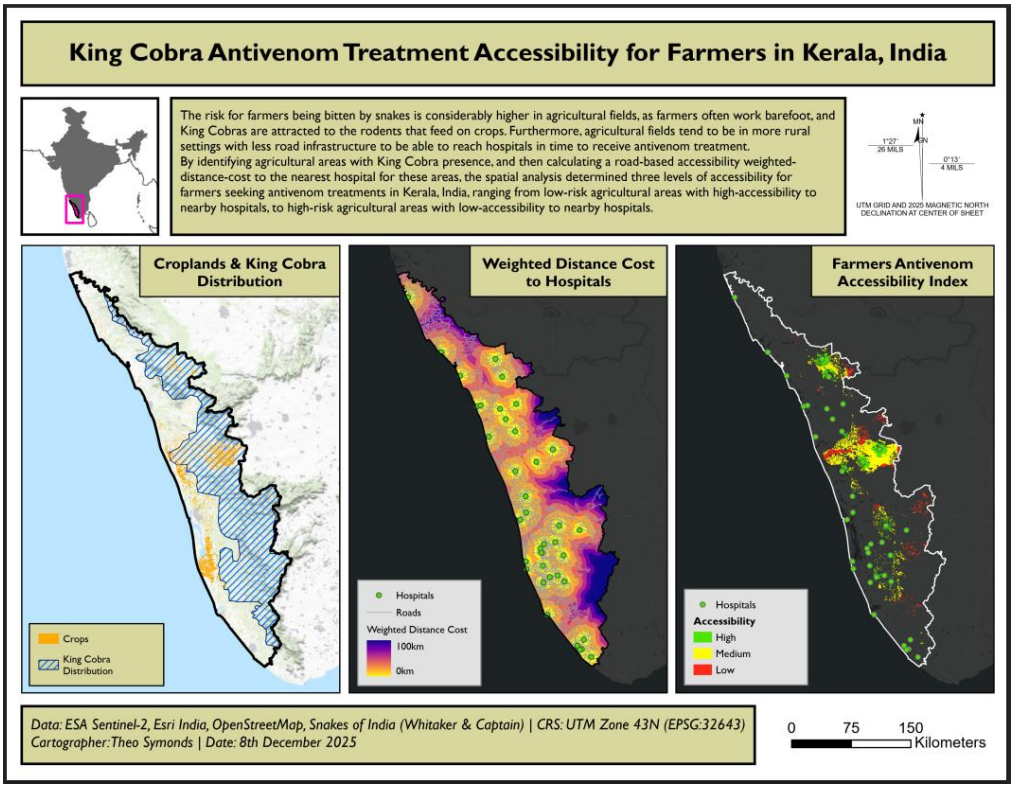
Workflow Diagram



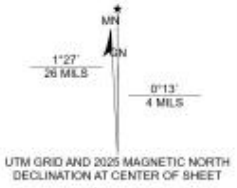
Appendix B

Maps





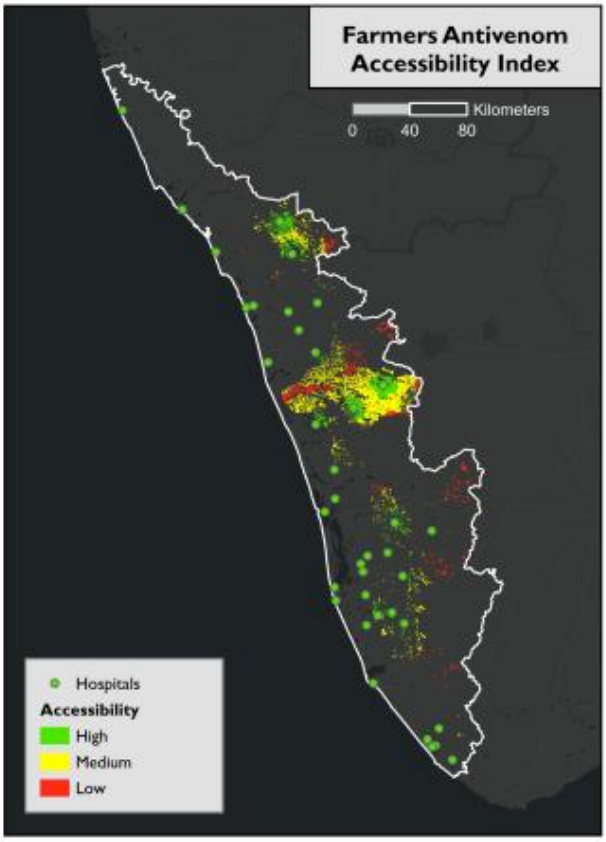
King Cobra Antivenom Treatment Accessibility for Farmers in Kerala, India

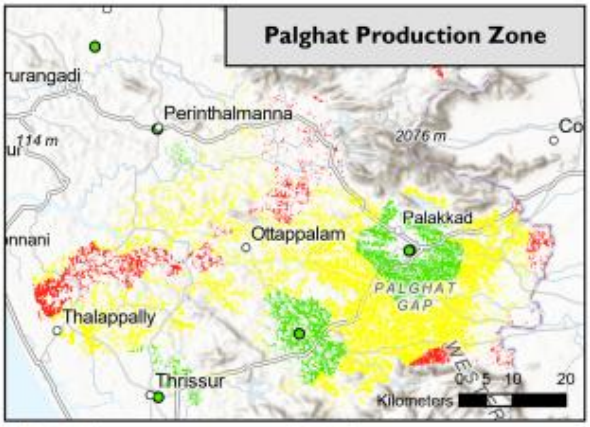


The risk for farmers being bitten by snakes is considerably higher in agricultural fields, as farmers often work barefoot, and King Cobras are attracted to the rodents that feed on crops. Furthermore, agricultural fields tend to be in more rural settings with less road infrastructure to be able to reach hospitals in time to receive antivenom treatment.

By identifying agricultural areas with King Cobra presence, and then calculating a road-based accessibility weighted-distance-cost to the nearest hospital for these areas, the spatial analysis determined three levels of accessibility for farmers seeking antivenom treatments in Kerala, India, ranging from low-risk agricultural areas with high-accessibility to nearby hospitals, to high-risk agricultural areas with low-accessibility to nearby hospitals.

This spatial analysis could support public health officials with planning new health infrastructure programs that serve the most vulnerable demographic to snakebites. With the knowledge of the areas where farmers bitten by King Cobras face lower-accessibility to antivenom treatment, we can target these areas with the construction of new hospitals and roads.





Data: ESA Sentinel-2, Esri India, OpenStreetMap, Snakes of India (Whitaker & Captain) | CRS: UTM Zone 43N (EPSG:32643)
Cartographer: Theo Symonds | Date: 8th December 2025