GeoSpatial Technology Landscape – R&D and its Linkages across Domains

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Evolving world of Geospatial Technology

Field Survey and Analog Mapping

- Field Measurements
- GPS - Total Stations
- Mobile platforms & IoT

Sensing Systems & Digital Image Processing

- Aerial Photogrammetry
- Remote Sensing
- Digital Data Models
- Change Studies
- …

Digital Maps – Desktop to Web

- CAD
- GIS
- Interactive Maps
- Web mashups

Geo Services

- Location as a Variable
- Consumerisation of Maps
- …

GeoAI

- Spatio-temporal Data Science
- Analytics for Science
- Analytics for Decision Making

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Geospatial Landscape in India

Major Players

- Cartography and Mapping
  - Survey of India (since 18th century)
- Aerial Photogrammetry and Satellite Technology
  - ISRO
  - National Remote Sensing Center
- Solution Providers
  - Multiple Agencies like GSI, FSI, and others
  - Academia, RnD
  - Industry

Technology Evolution

- Aerial and Satellite Image Processing
  - Map as a Product
- GIS as a System
  - Mapping to Spatial Analysis
- Information Technology
  - Static to Interactive Maps (WebGIS)
  - GeoSpatial Services
- Spatial Data Science and GeoAI
  - Geospatial as a Science

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RnD in GeoSpatial Technology

- Operational RnD
  - Adopting the technology to the Indian Conditions
  - Customisation of Processes
- Thematic or Domain driven RnD
  - Land Use Studies and Mapping
    - Land use products
  - Water Resources and Water Use
  - Agricultural Programs
  - Forestry – Fires, Field integration and so on
- Fundamental Technology Developments

Emerging field of Spatial Data Sciences

- Spatial Big Data Analytics
  - Mining the data for (cause-effect) relationships
  - Is it driven by the known or the Unknown (processes?)?
  - Discovering Knowledge from Data
- **GeoAI or Geo+AI?**
  - **Brings together GIS/Spatial Science, Data Mining, AI, HPC**
  - Extracting/Detecting/Identify Spatial Objects from Spatial and Temporal Data
  - Data Gap filling / Estimation / Prediction - Modelling
  - Locational Intelligence to Decision Support
  - **Can AI/ML/DL change the way we look at GeoSpatial Data and Processes??**

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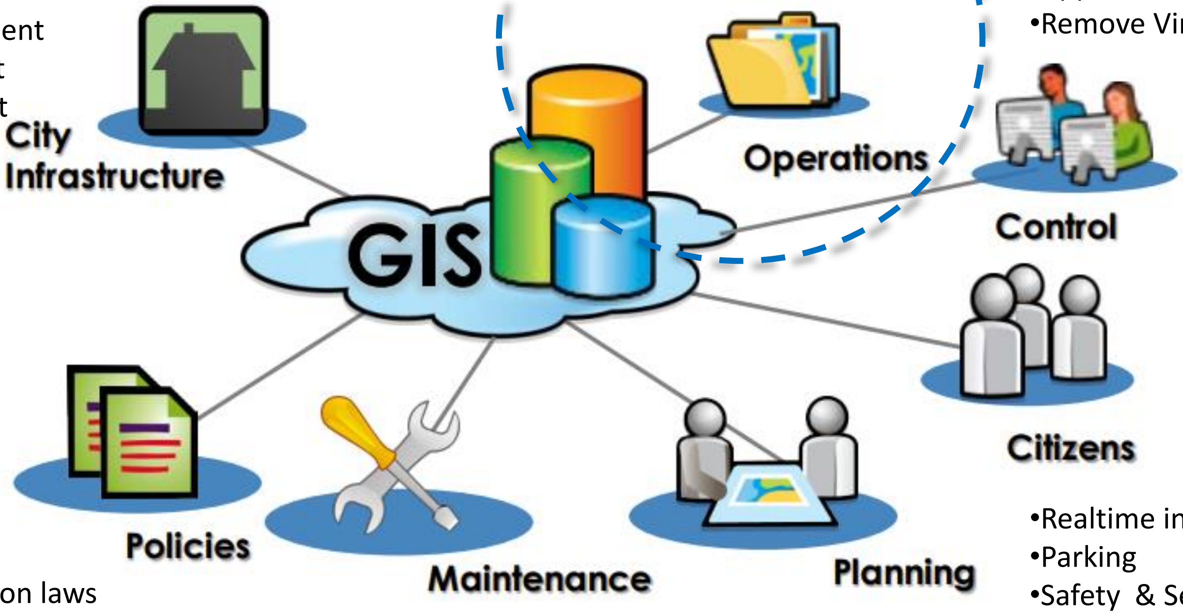
Lets, take Spatial Solutions in Aviation as an Example

- GIS Data uses in Airport environment (Understanding GIS requirements for Aviation)

•Landside operations
•Airside operations
•Safety & Security

•Air control
•Ground control
•Apron control
•Flight data clearance
•Approach and terminal control
•Remove Virtual Tower

•Property management
•Lease management
•Space management



•Realtime information on flights
•Parking
•Safety & Security

- Airspace regulations
- Compliance with civil aviation laws
- Compliance with military aviation laws

- Asset inspection
- Asset maintenance
- Asset monitoring
- Logistics
- Utilities
- Pavement management
- Repair and Constructions

- Land and airspace planning
- Landside access planning
- Airspace regulations
- Environmental regulations
- Noise regulations
- Cargo handling
- Obstruction surface Creation/Modification
- Obstruction Analysis/Evaluation

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Source: Report by Durga Prasad, Dhulipudi, KS Rajan

Accelerated Mapping

- We investigated the identification and classification of key Runway features automatically using **Machine Learning** and Computer Vision approaches.

- Durga & Rajan (2020,2021) studied the method of automatic airport feature extraction from satellite images.
    - Training Data Preparation
    - Transfer Learning Model
    - CNN

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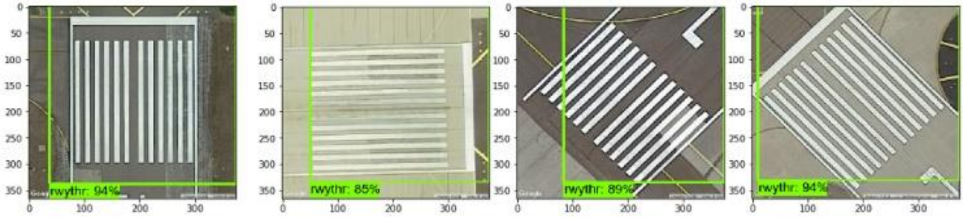
Outstanding Paper Award: Durga Prasad Dhulipudi., **& K S Rajan**. (2021). Geospatial Object Detection Using Machine Learning-Aviation Case Study. 2021 *Integrated Communications Navigation and Surveillance Conference (ICNS)*, 1-8.

ACCELERATED MAPPING

Geospatial Object Detection Using Machine Learning-Aviation Case Study

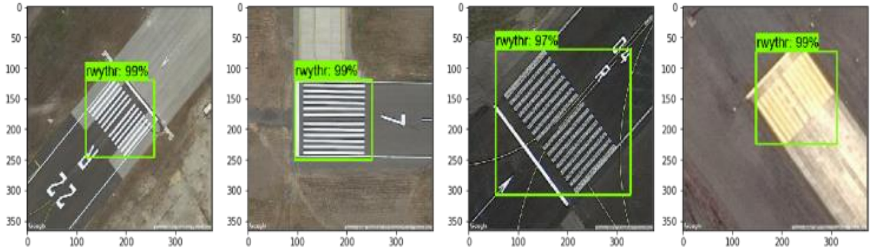
Phase I



	SUMMARY OF PHASE1 CONFIGURATION AND RESULTS
System Configuration	E5470 - Intel HD Graphics 520. Core i5 6300U - 8 GB RAM - 256 GB SSD RAM, 2.4ghz, Windows 10 Enterprise 64 Bit
Model used	Transfer learning with Faster R-CNN ResNet
Training time	2.5 hours
Dataset Size	200 images
Train Test ratio	80% & 20%
Iterations	200
Confidence	>85%
TP	>60%
Failure	Localization requires improvement

Phase II

Improved accuracies with more samples (GPU)



	SUMMARY OF PHASE2 CONFIGURATION AND RESULTS
System Configuration	Dell Intel64 Family 6 Model ~2200 Mhz, Windows 10 Enterprise 64 Bit, Precision Tower 5810, Microsoft Windows 10 Enterprise, 64GB RAM
Model used	Transfer learning with Faster R-CNN ResNet
Training time	~33 minutes
Dataset Size	1025 images
Train Test ratio	80% & 20%
Iterations	2000
Confidence	>94%
TP	>92%
Failure	Localization requires improvement

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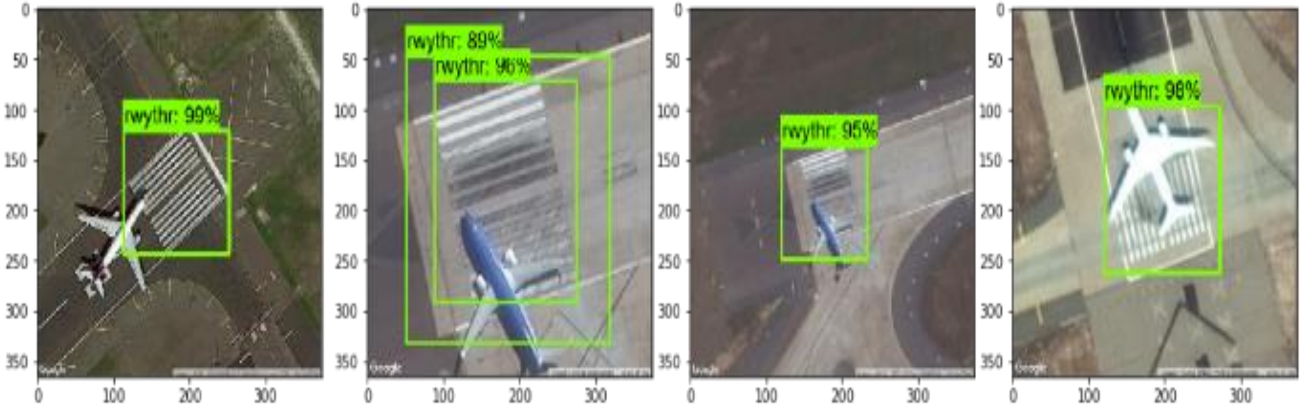
- Model Inference – Work In Progress

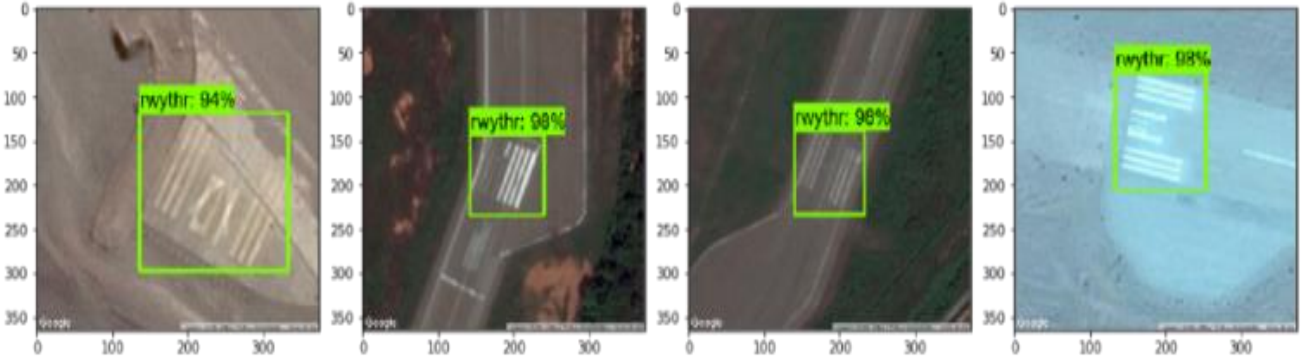
Geospatial Object Detection Using Machine Learning- Aviation Case Study

Phase II

With more samples and increasing the variety, we noticed accuracies **above 95%** even in the case of <u>**occlusions**</u> also.



Similar level of true positives detected in case of highly **unclear ambiguous** images .



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- Model inference in Occlusions and Ambiguity- Work In Progress

Agriculture: What is a Good Monitoring System ?

- A good baseline data
  - Coverage, periodic updates, record of causes of changes, if any
- Is Crop-calendar a good baseline?
  - esp. if it is one calendar for the whole district
- What about uncertainties in the crop calendar?
- Can Phenology be a good growth parameter ?

How Events like droughts affect Cropping patterns in a region?

- ➢ All are areas affected similarly/homogenously ?
- ➢ Can such analysis help us identify the **Causative and underlying factors**?

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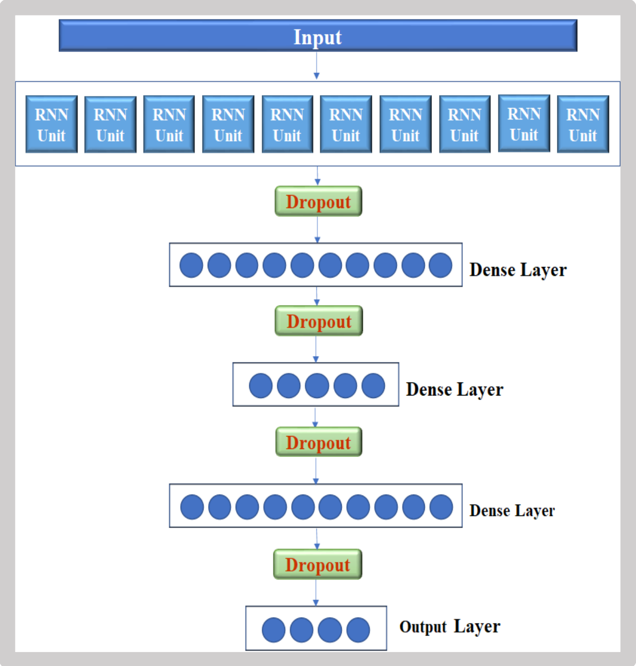
Deep Learning Approach for Cropping practices

Used 3 Deep Learning methods –

- 1-Dimensional Convolutional Neural
- Long Short Term Memory Networks (LSTM)
- Gated Recurrent Units (GRU)

Image Type	MODIS EVI
Ground truth	NRSC LULC
Resolution	500m
Time Period	12 years
No. of Images	276 (12 X 23)



Results Showed -

LSTM performs better (63% accuracy)

Trade-off between Image resolution, GT and Model appropriateness

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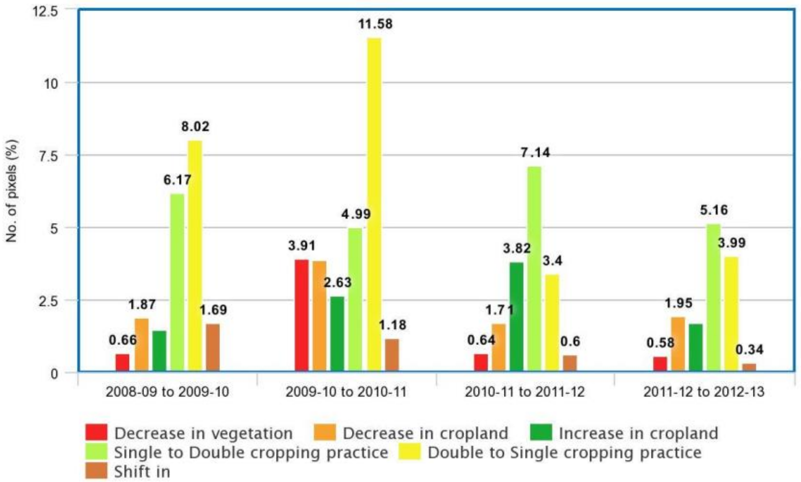
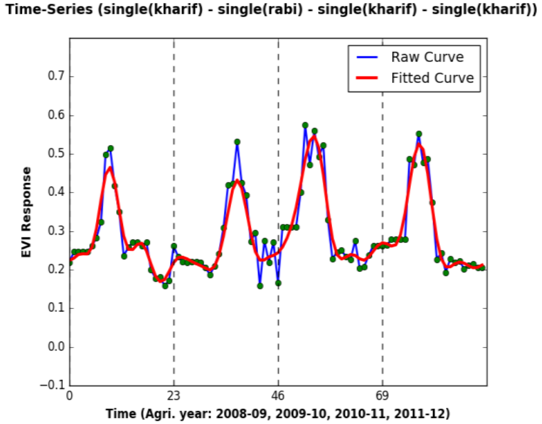
Events (Drought) and Cropping Practices

agricultural-year 2008-09 to 2011-12 (4 crop years)

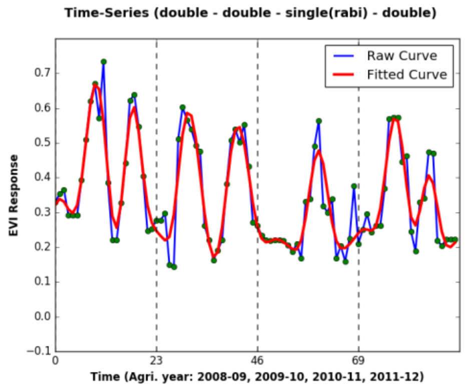
Table 2.a Change analysis for each transition (for agriculture years from 2008-09 to 2012-13).

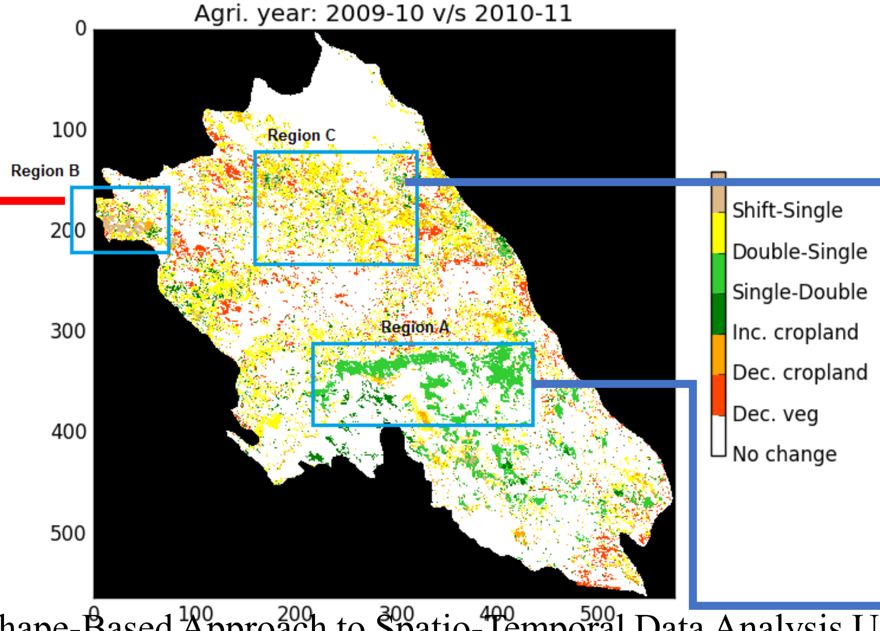


Region B: Away from River, Rainfed-Ground water irrigation

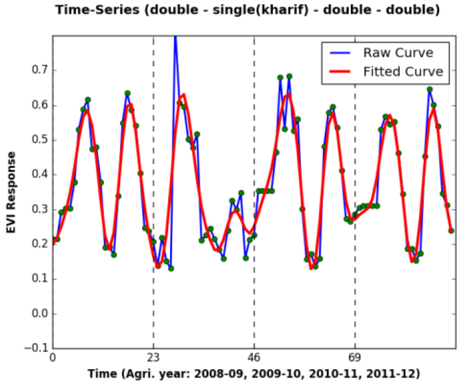


Region C: Upstream, Mostly Irrigation (canal/ground water) based





Region A: Downstream location, water surplus



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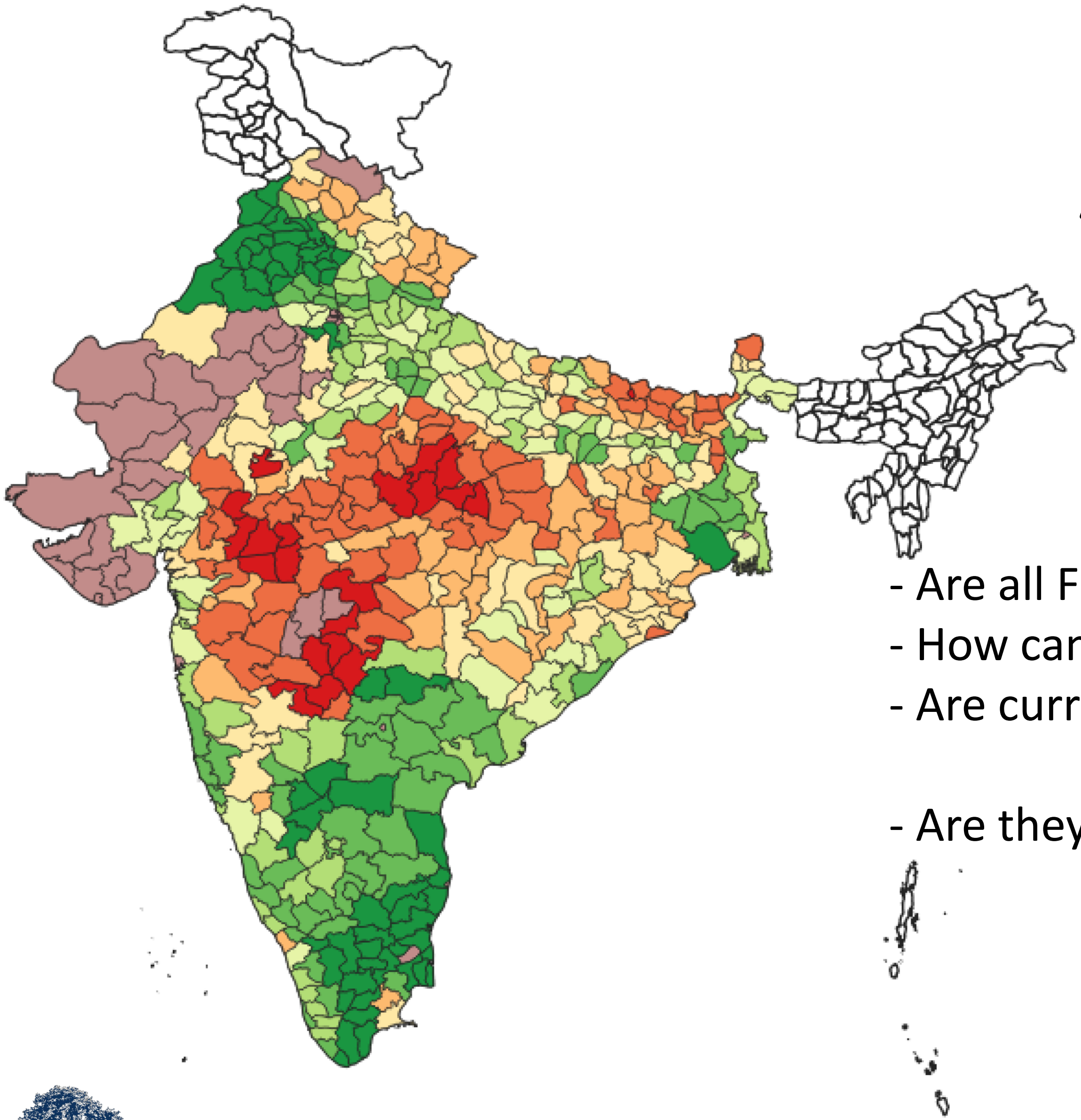
D Baheti, KS Rajan. 2017. A Shape-Based Approach to Spatio-Temporal Data Analysis Using Satellite Imagery. Proceedings of the 4th IEEE International Conference on Data Science and Advanced Analytics (DSAA), Tokyo, Japan. Oct 19-21, 2017.

Spatio-Temporal Data Analytics of Crop Yields



- Are all FOOD PRODUCING Regions/Districts in India **Sustainable**?
- How can we **Assess** Food Production / Crop Yields ?
- Are current methods/tools **useful** to do this?

- Are they **consistent Performers** or change over Space and time?

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FACTORS AFFECTING YIELD

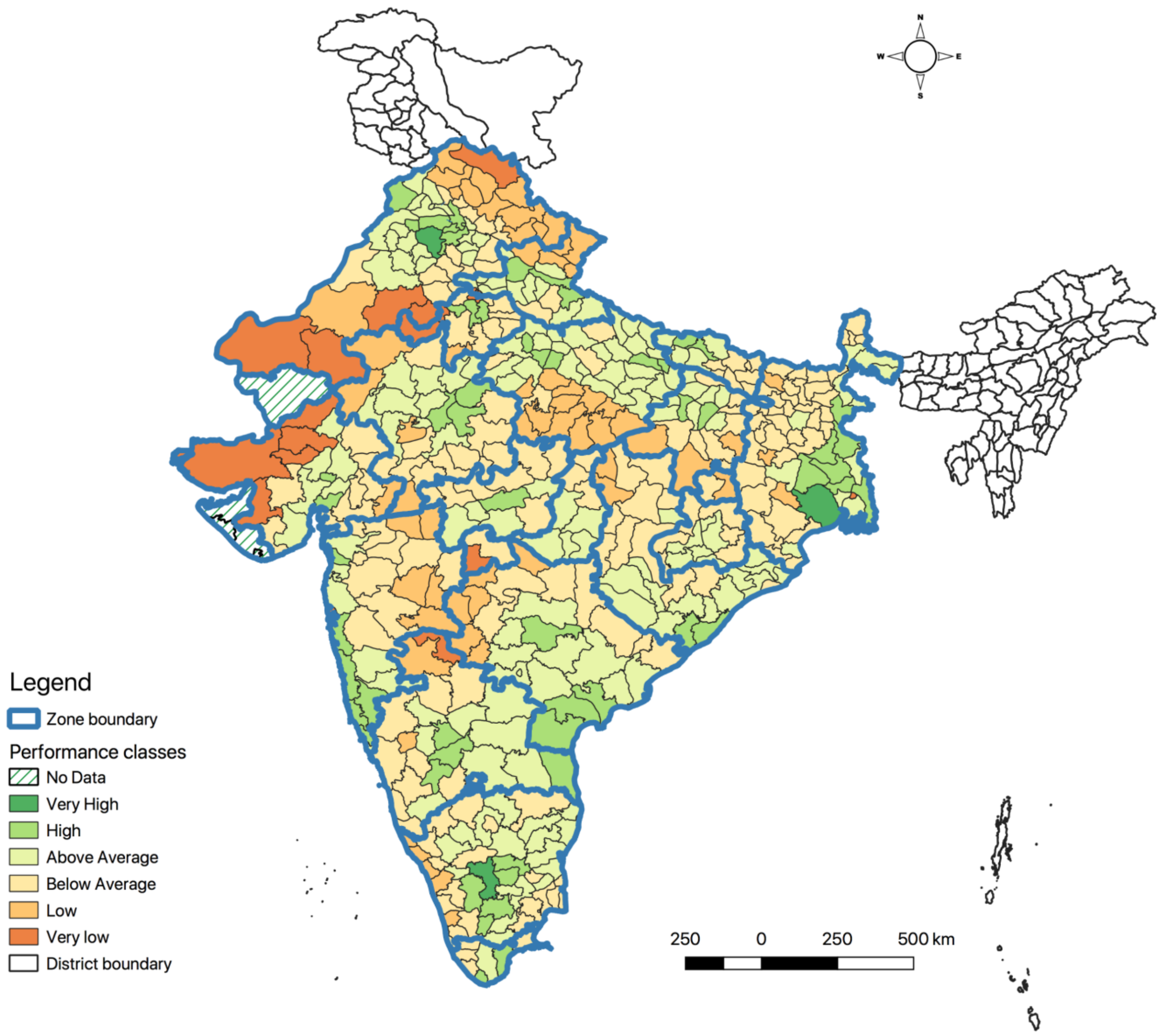
- Ecological factors
  - Availability of water resources (Rainfall, Irrigation mechanisms)
  - Type and quality of Soil
  - Temperature
  - Fertilizers, etc.

- Non-ecological factors – Management Practices
  - Cropping practices
  - Allocation of funds and resources
  - Training and education by government
  - Other socio-economic factors

Source: https://seepnetwork.org/Thematic-Areas-Agriculture-Food-Security

RESULTS

R2. PERFORMANCE CLASSES WITHIN ZONES



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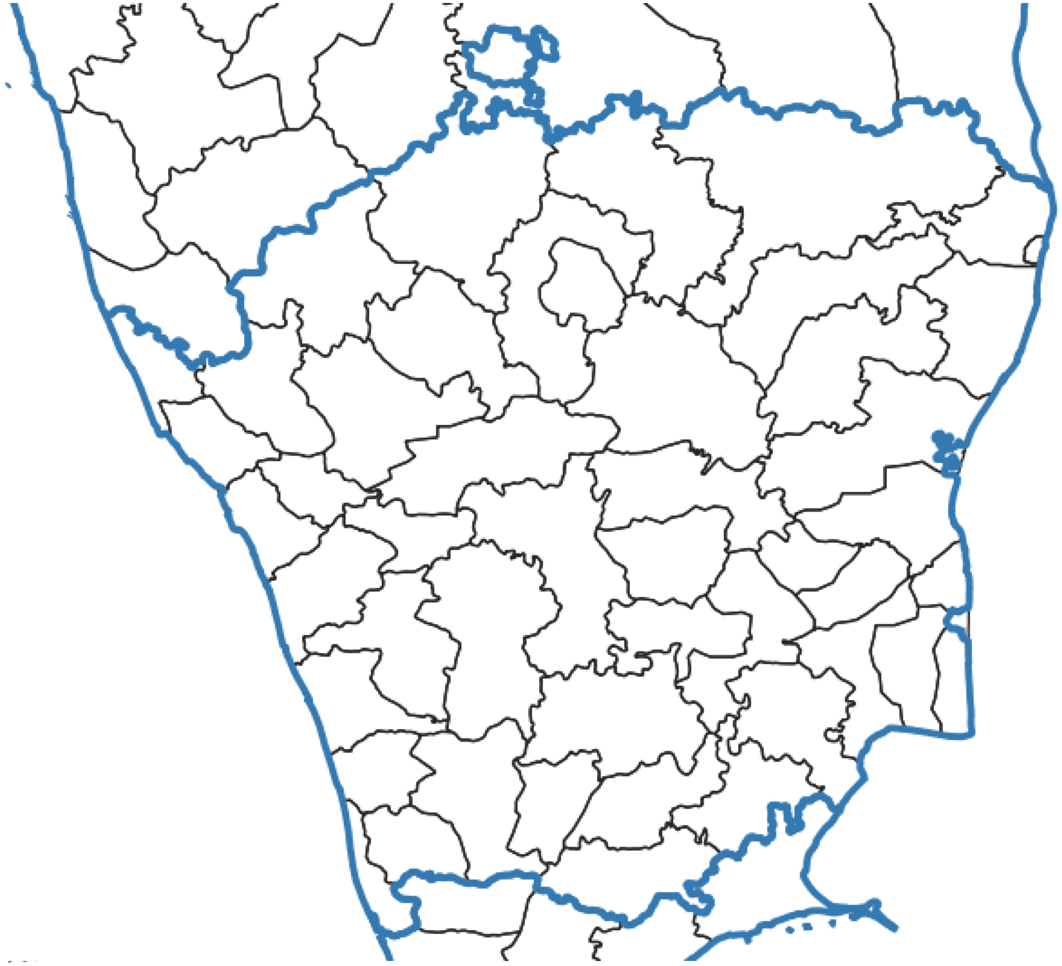
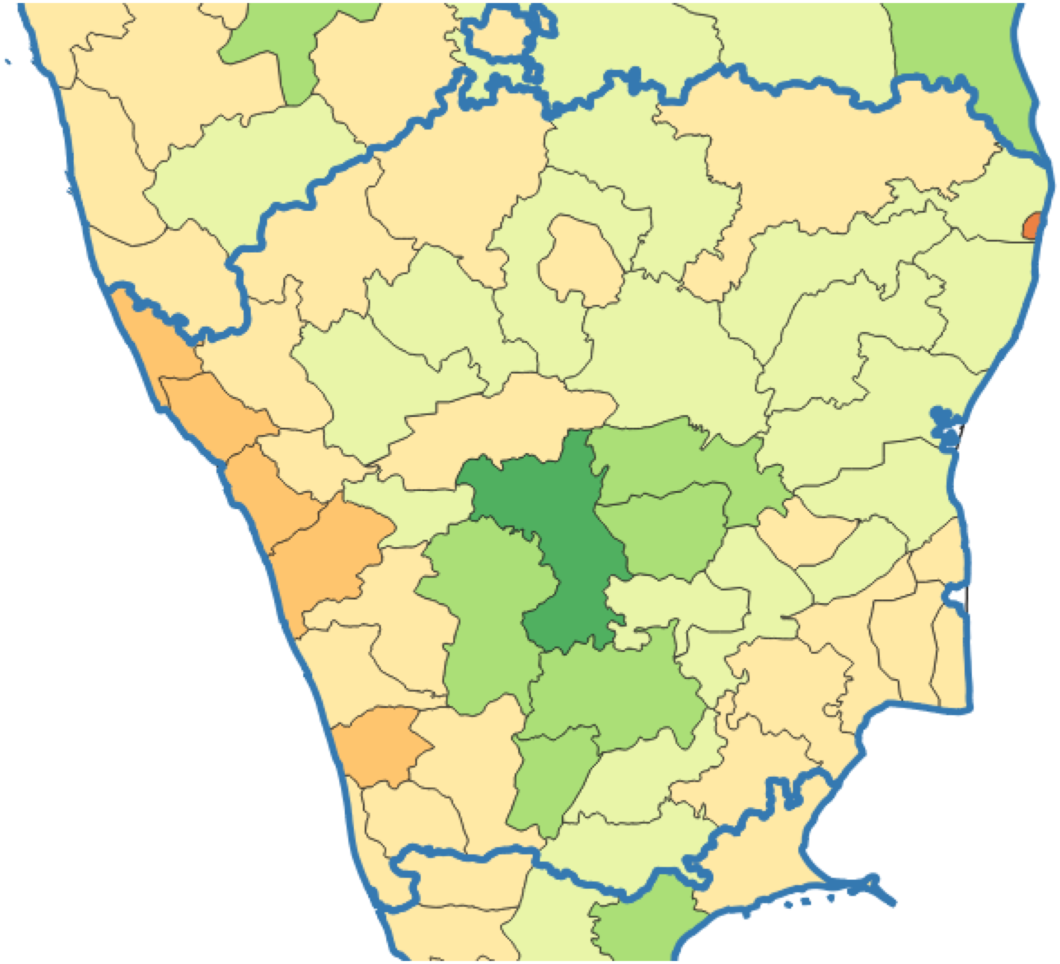
RESULTS

R2. Classification for a zone





Re-Analysis of TEMPORAL TRENDS

- For a specific zone,
  - We have performance classes
  - i.e., groups of homogeneous districts

- Performance may
  - remain consistent
  - Increase/decrease

- Observe effects on performance of each class
  - Drought/Flood years

- Within a zone
  - For the districts of a performance class
  - Plot their annual average with time

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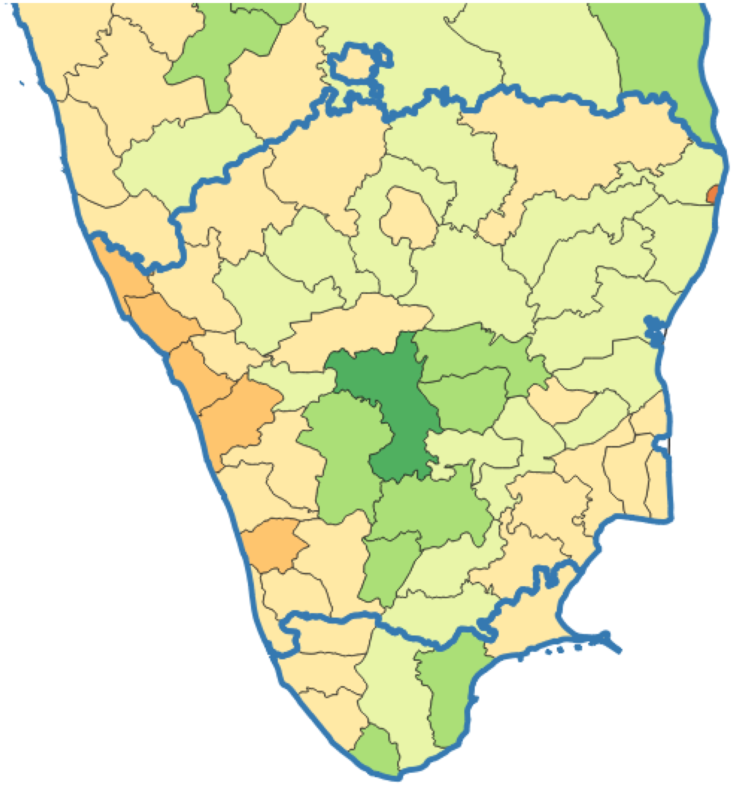
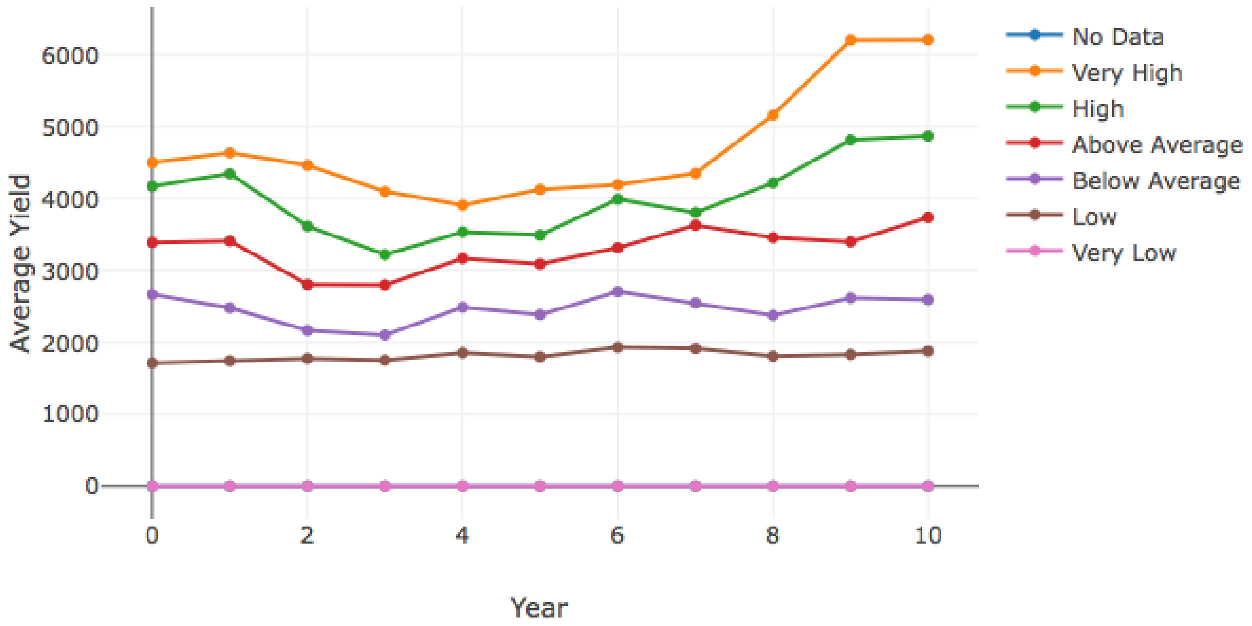
TEMPORAL TRENDS (1/2)





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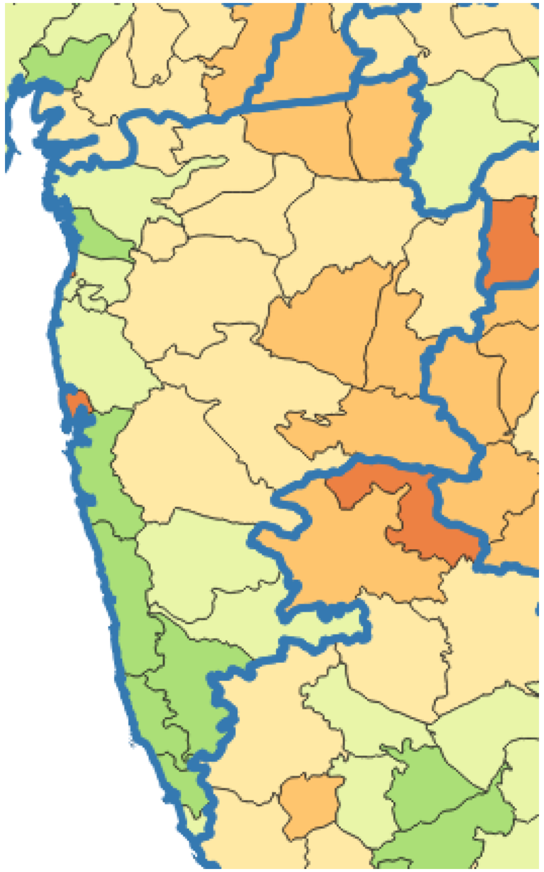
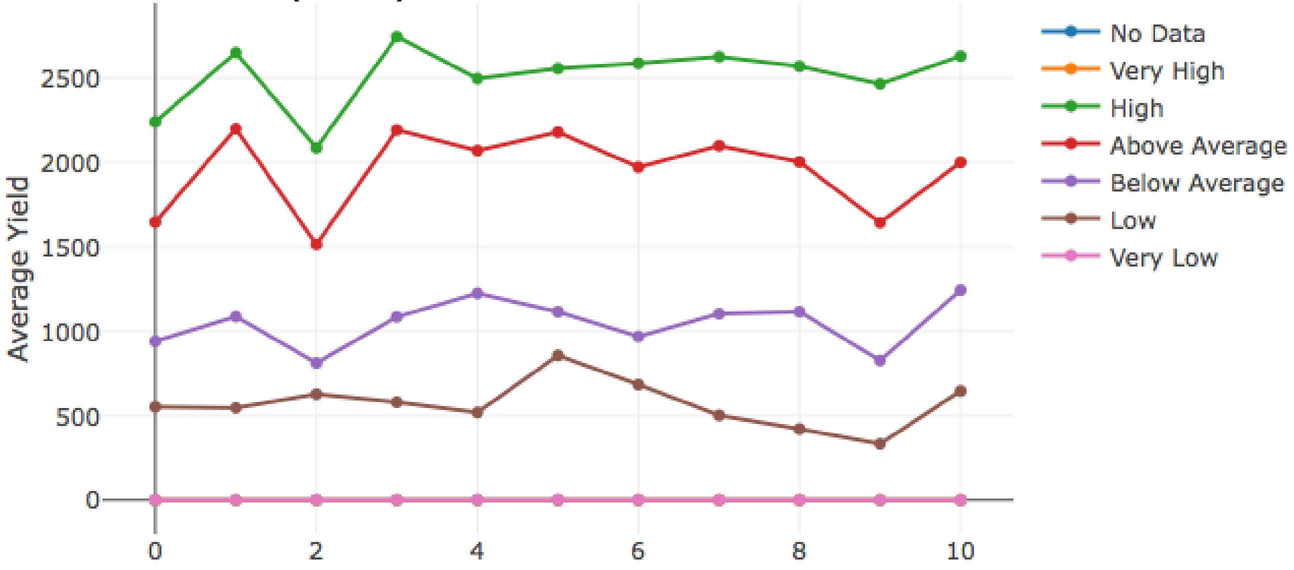
TEMPORAL TRENDS (2/2)





Class ID	No of districts	Min (in kg/ha)	Max (in kg/Ha)
1	0	-	-
2	6	1889.2	3171.4
3	7	1080	2827.4
4	9	489.8	2420.6
5	5	319.1	1014.4
6	0	-	-

Table 6.3: General statistics of performance classes of zone ID 379

Observations from Spatio-Temporal Analysis

- Spatio-Temporal output analysis
  - gives an understanding of yield patterns across the country

- Good and poor performing districts
  - In a given neighborhood
  - High performers close to the center of the zones
  - Performance deteriorates near the boundary

- **Performance Statistics**
  - Low – 87 (Combines 'Very Low' and 'Low')
  - Moderate – 344 (Combines 'Above average' and 'Below Average')
  - High – 61 (Combines 'High' and 'Very High')

- **High remains high; Low remains low**
  - Performance resilient with time; lines do not intersect
  - No drastic changes even in extreme events
  - External factors not predominant
  - Irrespective of the amount of inputs provided

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Geo←→AI : Where to go from here

- Early stages of Adoption of AI/ML/DL methods
  - Using more like a black box / model
    - Works well for general solutions
    - Supports Large data analysis and Computationally heavy processes
  - While results give good insights, throws-up more questions
    - When it fails to capture key Features and its context
- Geo←→AI – true Integration when Domain Adaptation of these Algorithms are possible
  - Spatial context
  - Temporal uncertainties
  - Processes capture or Indicative factors
  - From Data Analysis → Information generation → Knowledge discovery that supports/advances Science

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Lab for Spatial Informatics - Research Overview

IoT and Air Pollution Monitoring / Evaluation

Remote Sensing and IoT for Water Quality

GeoSpatial Science and Technology

- ❖ **Spatial Data Science/ Geo-AI**
  - ❖ **Spatio-temporal Analytics / Data Mining / Databases**
  - ❖ Health, Crop Yield analysis, Climate, Crime
  - ❖ Platforms developed
- ❖ **Geo-Visualization**
  - ❖ 4D Flood Visualization
  - ❖ Deep Learning on Terrain Super Resolution
  - ❖ 3D realistic terrains/topography
- ❖ **Geo-Governance - Web/Mobile GIS**
  - ❖ Air Pollution and Human Health
  - ❖ Water Quality and Quantity

FOSS4G

Environmental / Policy

Remote Sensing

- ❑ **Optical Imagery**
  - ❑ Feature Extraction – Roads, Buildings
  - ❑ Time-series Analysis – Crop phenology & Season Calendar
  - ❑ OBIA
- ❑ **HyperSpectral Sensing**
  - ❑ Key Parameter Characterisation – Vegetation
- ❑ **RS – Parameter Estimation**
  - ❑ Water Quality in Inland waterbodies

Spatial Modelling & Simulations

- ✓ **Spatial Modelling**
- ✓ **Strategic Environmental Assessments**
- ✓ **River Basin Hydrology**
- ✓ **Climate Extremes and Impacts**

Land Use Modelling – Urban, Agricultural

Forest Dynamics: Crop Modelling

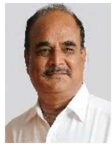
+ Collaborations with Other Institutions and Organisations

Faculty at LSI:


Prof. KS Rajan


Dr. RC Prasad


Dr. S Rehana


Dr. R Nagaraja

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Thank You!

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