DMCC, UND & Envtl Computing Workshop, 24-26/03/2021

Precision Agriculture & Regional Collaborations (CRADR)

Insights from *Collaborative Research and Engineering Digital Agriculture initiatives*
@ Agro-Informatics Lab, Centre of Studies in Resources Engineering (**CSRE**),
Indian Institute of Technology Bombay (**IITB**)

J Adinarayana

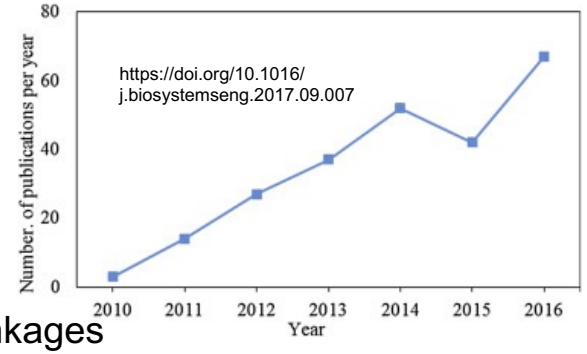
(President, APFITA & INSAIT)

National Collaborators

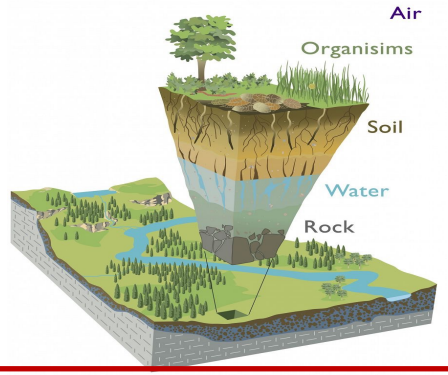
International Collaborators

(CRADR: Climate-Resilient Agriculture for Disaster Risk Reduction)
(APFITA: Asia-Pacific Federation for Information Technology in Agriculture
INSAIT: Indian Society for Agricultural Information Technology, Dharwad)

- Paradigm shift -
  Conventional to Precision Agriculture
  (maximization to optimization of agricultural inputs)



- It is a Systems-approach – need to identify linkages between contributing factors of a **Critical Zone**



Critical Zone - "a heterogeneous, near surface environment in which complex interactions involving rock, soil, water, air and living organisms that regulate the natural habitat and determine availability of life sustaining resources"

http://criticalzone.org/images/national/photos-and-images/1Na

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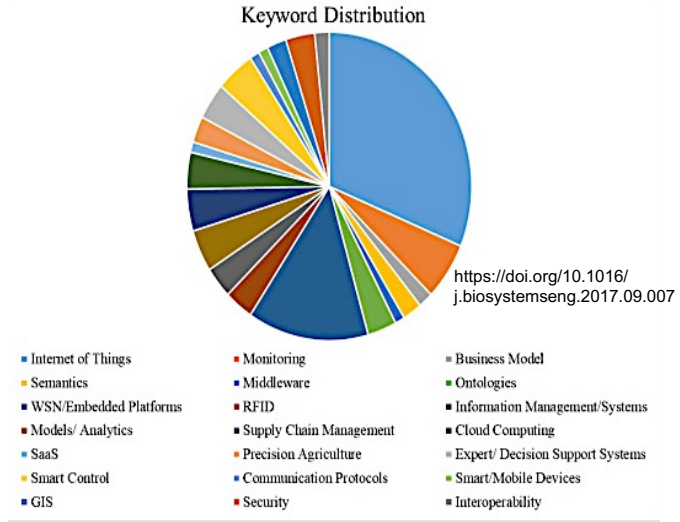
- Involves '**Rs**' in *Contemporary Farming*
  - Right Time
  - Right Place
  - Right Amount
  - Right Manner
  - Right Genetics
  - ***With right tools and techniques (Digital Agriculture)***



- Needs **multiple platforms, tools and techniques** to **Monitor, Manage and Adapt – MMA** - for generating state of the art ***GeoFarmatics***

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Need for Disruptive Innovations in Precision Agriculture - MMA

Data Generation

Proximal Sensing
- Field Sensing Platforms
- Scientific Instrumentation
- Crowd Sourcing
- Autonomous Ground Vehicles

Remote Sensing
- Multi-resolution Satellite Based
- Low-altitude flights and UAVs

Novel Sensing Platforms
- LiDAR
- Super resolution 3D cameras
- Hyperspectral and Thermal Imaging
- Genomics and Phenomics

(information assimilation through multi modal systems)

Data Processing

IoTs
- Precision Technologies
- Multi-model data aggregation
- IoT protocols
- Autonomous Operations

Processing
- Spatial and Temporal Analysis
- Statistical Exploratory Analysis
- Sensitivity and Correlation

Standards
- Open Data Standard
- Interoperability
- Data storage and retrieval
- Data security

(To understand the **underlying interrelation** between observations and **generate meaningful information.**

Computational techniques *and platforms* that can handle the data stream and are able to fulfil **Big-Data** requirements).

Relationship modelling between different factors that are involved in the process (cross-domain knowledge generation)

Reinforcement Learning

Some applications are too complex to model using established statistical methods

(means of **disseminating information and advisory** from ICDTs to end-users; provides **periodic updates to end-users for 'ahead-of-time' precautionary measures**)

Data Dissemination

Knowledge generation
- Ontology
- Domain Expertise
- Information Modelling

Knowledge transfer
- ServicesData
- Subscription services
- Domain Adaptation

Data Modelling

AppIn
- Crop Water Requirement
- Plant Stress Identification
- Genomics and Phenomics
- Regional Planning

Modelling
- Parameter Estimation
- Modelling Theory
- Novel Cross Domain

Machine Learning
- Empirical to Process
- Phenomenon modelling
- Predictive modelling
- Deep Learning

THE DISRUPTIVE LOOP: Helps to refine (1) sensing needs (infrastructure) *(fine or coarse & temporal or spatial or change in sensing systems)* for meaningful information; and (2) model development/ improvement

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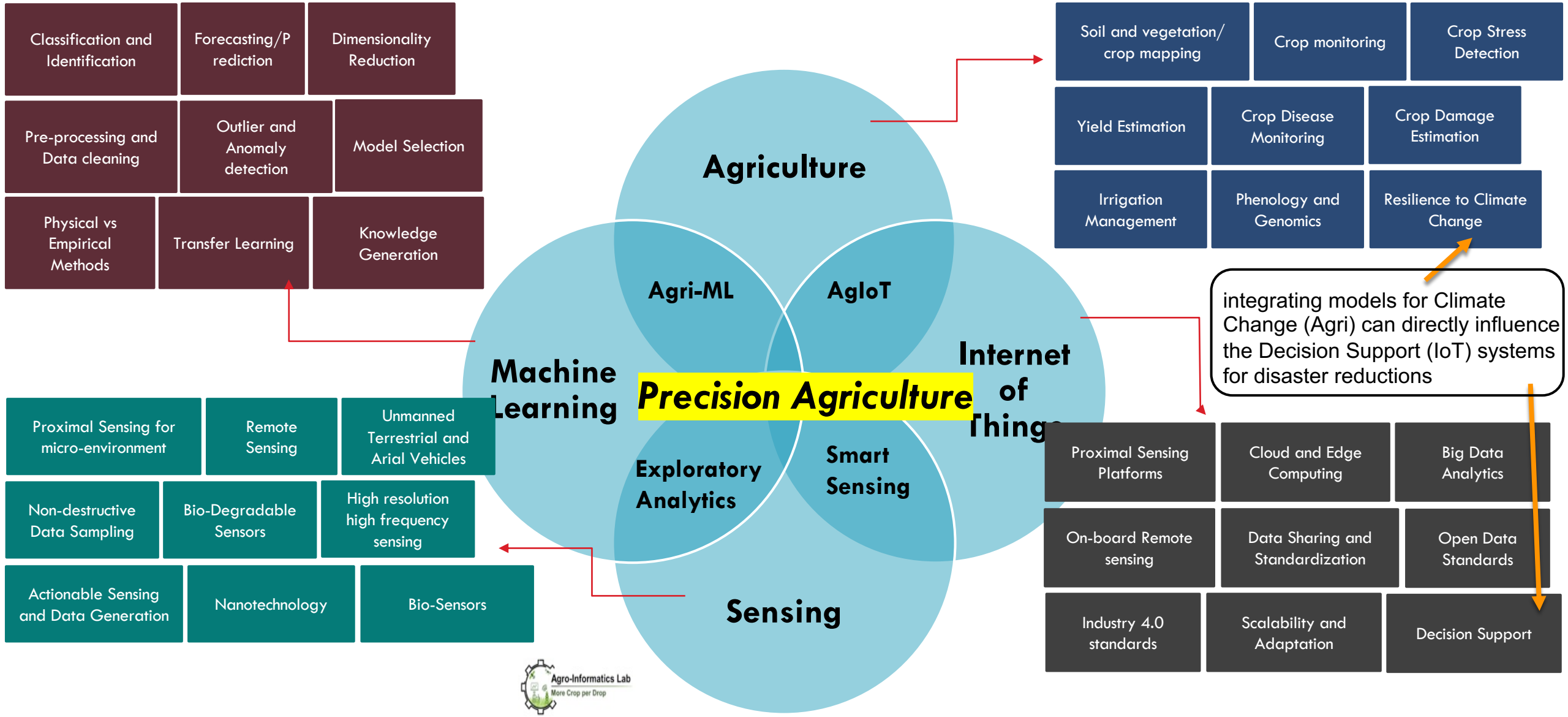
Digital Agriculture – Need of Infrastructure

Agriculture, IoT, Sensing and Machine Learning - individually present unique challenges and opportunities

Combining all the above modules and sub-modules, results in an integrated infrastructure



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Digital Agriculture is NOT ALL about machine learning!!

Conventional methods of sensing *are no more sufficient for generating deeper understanding of crop/plant behavior thereby* ***low innovations***

Sensing is not a stand-alone concept!!

understanding underlying interactions/processes/science, development of systems/ devices and data analytics and act accordingly are disruptive and finally **it requires a integrated infrastructure** that integrates all these components.

Disruptive Innovations – The Initiatives

Agro-Informatics Lab, CSRE, IIT Bombay work towards making systems SMART and adopt *MMA framework* to solve challenging problems in agriculture and its allied domains *in collaboration with multi-disciplinary groups from multi-institutions and nations:*

- ***GrIDSense*** [IIT Bombay, IIT Hyderabad, PDKV, Maharashtra Orange Growers Assoc.(MOGA)] (**Gr**oundwater-**I**rrigation-**D**isease **Sens**ing Syst**e**ms)
  (Information Technology Research Academy-Water of Min. of Elec. & IT, Govt. of India)

  ICT application for water, pest/disease management for yield improvement in horticulture (Citrus) *(Interoperable platform for remote monitoring and for near real-time decision making)*

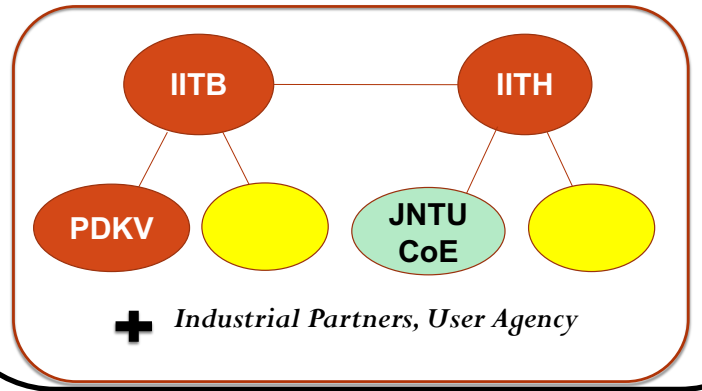
- ***DSFS*** (IIT Hyderabad, IIT Bombay, IIITH, PJTSAU, University of Tokyo) – (**D**ata **S**cience-based **F**arming **S**upport system for Sustainable Crop Production under Climatic change) **(Indo-Japan Joint Laboratory Project of DST/JST)**

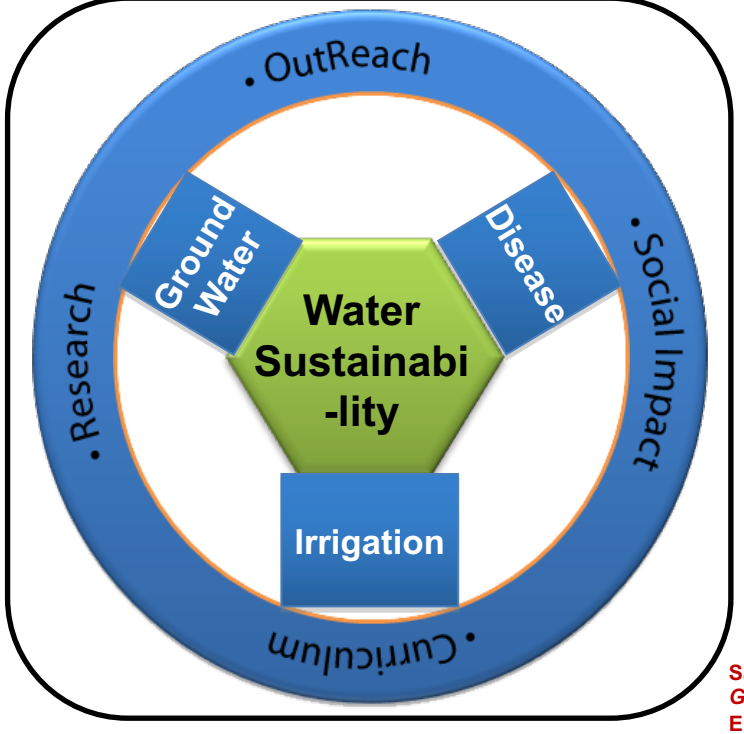
  Develop data science based approaches using *high-end integrated information and agricultural sciences* such as IoT, big data analytics, deep learning, crop modeling and *omics (Genomics/ Phenomics)* to support high performance and sustainable agri-systems in semi-arid tropics of India

ICT in Water and Pest/Disease Management for Yield Improvement in Horticulture (Citrus)

(Project Sponsor: ITRA-Water/MediaLabAsia (Digital India Corporation), DeitY, GoI)

Pyralets





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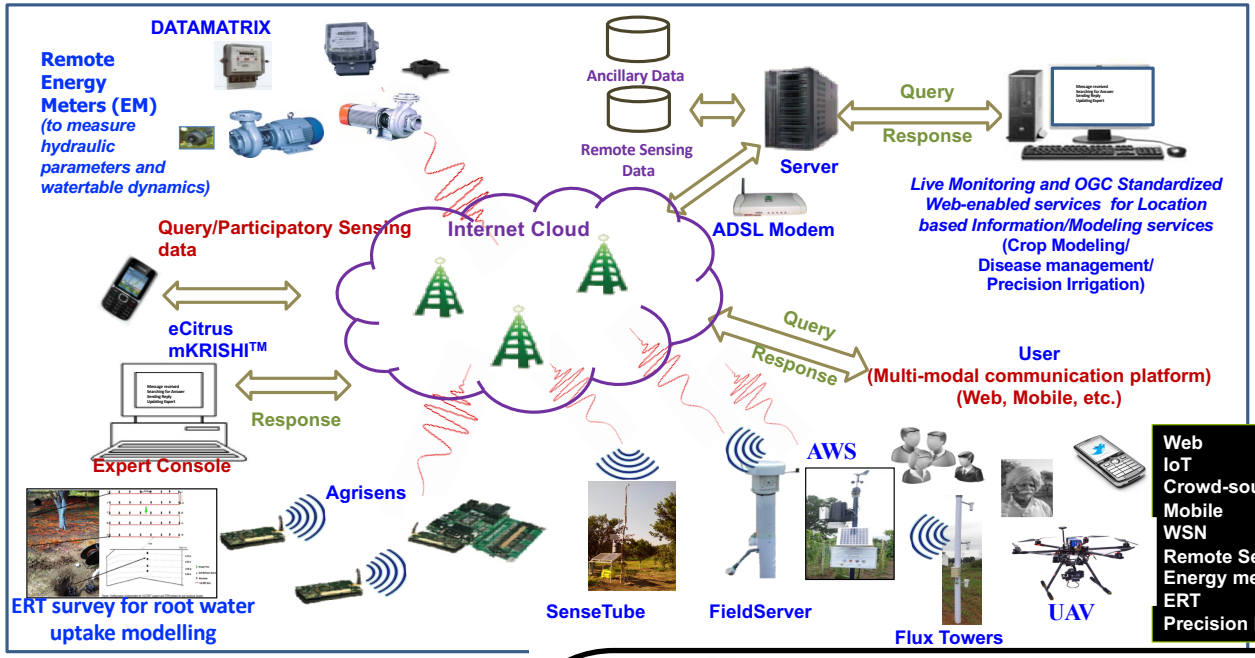
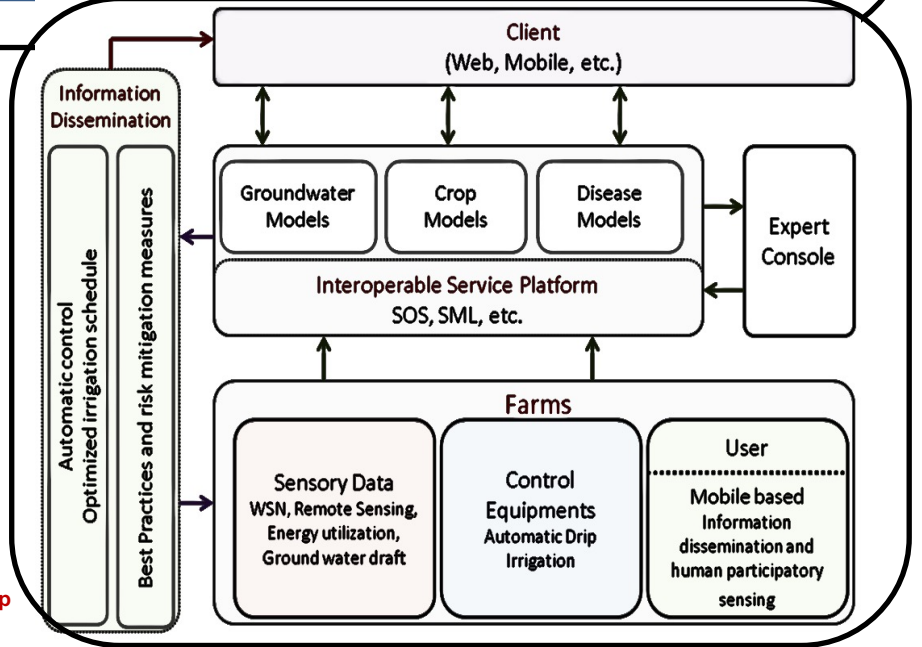
GrIDSense: Critical Zone Observatory through Multi-mode platforms/systems for Precision farming

(to understand the nexus between soil-plant-water-weather interactions)



(*GrIDSense*: Groundwater, Irrigation and Disease Sensing System)

integrated interoperable service platforms / systems (*GrIDSense*) for remote monitoring and decision support in precision horticulture



Sawant, et al. (2017, *Comp. and Elect in Ag);* Ranjan et al. (2018, *JI Applied Geophy);* Peddinti et al. (2018, Vadose Zone JI); Badnakhe et al. (2018, Comp Elect Ag); Peddinti et al. (2020, JI Hydr)

SENSE TUBE

Sense Analyse Act

It is now, known as *SenseQube*

An IoT Platform for Smart Agriculture

(Patent No. 2236/MUM/2015)

SENSE TUBE

An IoT Platform for Smart Agriculture

Specifications

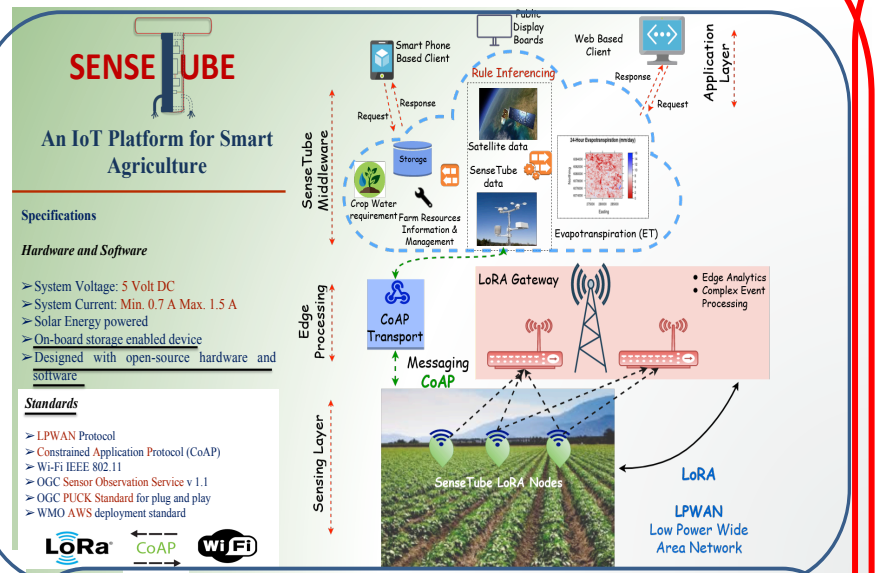
Hardware and Software

- System Voltage: 5 Volt DC
- System Current: Min. 0.7 A Max. 1.5 A
- Solar Energy powered
- On-board storage enabled device
- Designed with open-source hardware and software

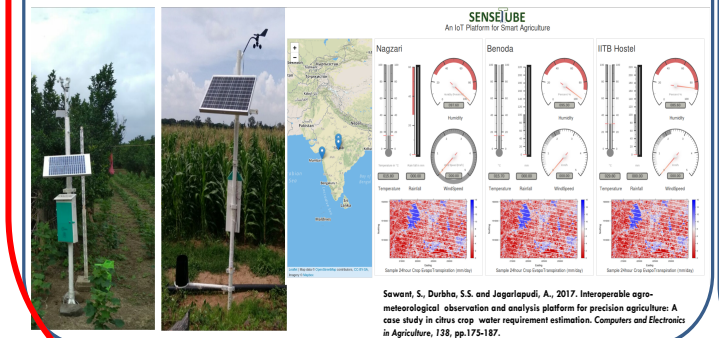
Standards

- LPWAN Protocol
- Constrained Application Protocol (CoAP)
- Wi-Fi IEEE 802.11
- OGC Sensor Observation Service v 1.1
- OGC PUCK Standard for plug and play
- WMO AWS deployment standard

LoRa CoAP Wi Fi



SenseQube – System and its dashboard



Sawant, S., Durbha, S.S. and Jagarlapudi, A., 2017. Interoperable agro-meteorological observation and analysis platform for precision agriculture: A case study in citrus crop water requirement estimation. *Computers and Electronics in Agriculture, 138*, pp.175-187.

Important Features

- Integrated telemetry of temperature, humidity, wind speed, wind direction, soil temperature and soil moisture over a range of 2-5 Km by every SenseTube Node
- Processing over the Edge: Real-time feedback to SenseTube LoRA Nodes by LoRA Gateways using LPWAN technology
- Secure connection to the SenseTube Middleware in a constrained resource environment using CoAP
- Analysis of incoming Streaming data along with Satellite imagery of the Area-of-Interest to estimate Crop-Water Requirement(CWR) at field scale.

Application Areas

- Weather Monitoring
- Precision crop water / nutrient management
- Precision crop pest / disease management

Acknowledgements

Part of this research and development work is supported by Information Technology Research Academy (ITRA), Media Lab Asia, Department of Electronics and Information Technology (DeitY), Ministry of Communications and Information Technology, Government of India [ITRA/15(66)/Water/PDMH/02/dated-21.09.2013]
Patent file no: 2236/MUM/2015

SENSE TUBE

An IoT Platform for Smart Agriculture

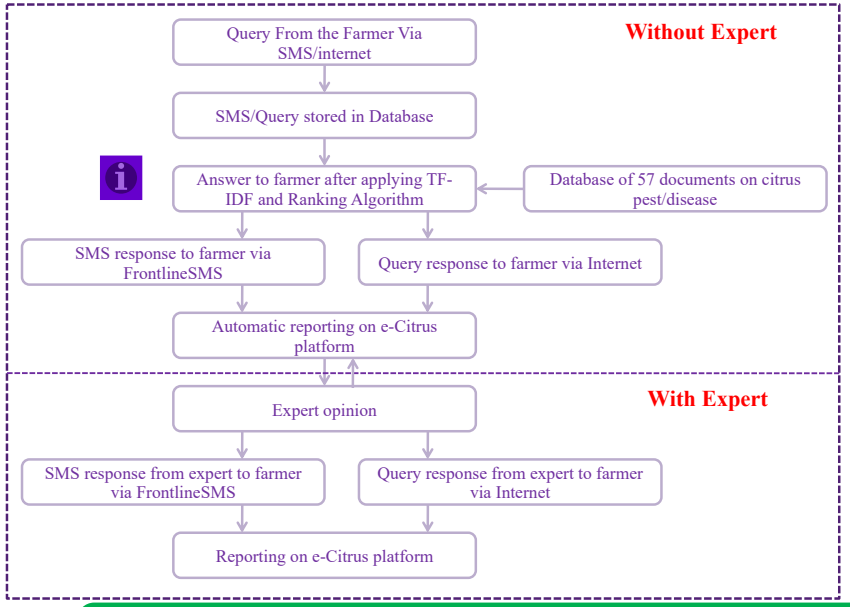
Geocomputational Systems and IoT Group
Email: connect@geosysiot.in
Website: www.geosysiot.in
Ph: 022-25767679

211, Centre of Studies in Resources Engineering (CSRE), IIT Bombay, Mumbai 400076

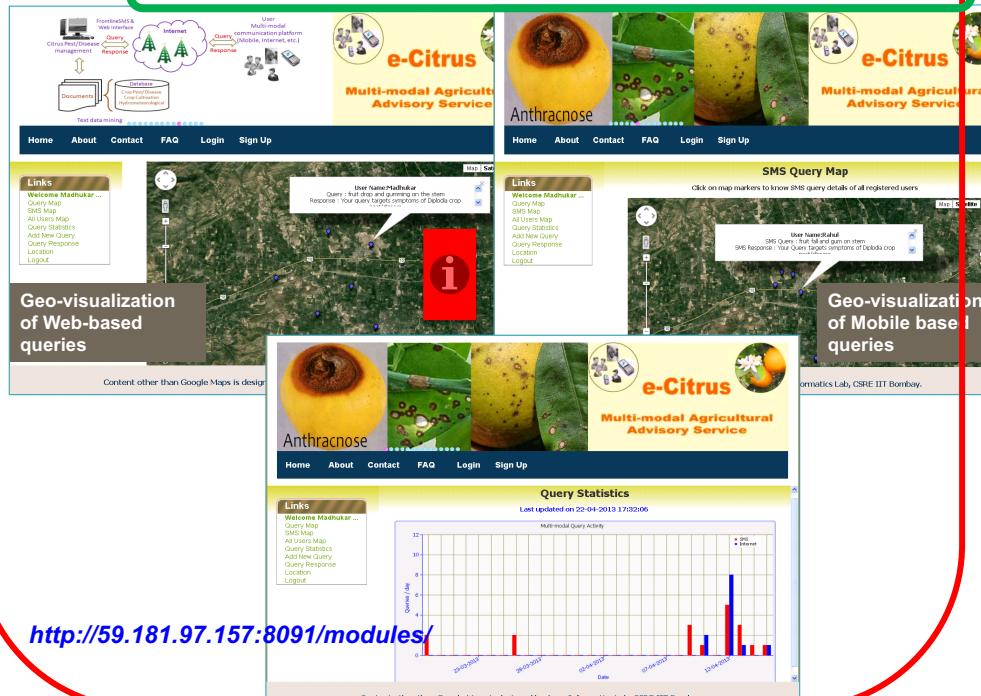
Video: https://youtu.be/yKlFULyEqc1
(Broadcasted in Marathi by ABP Majha)

Sawant, et al. (2017, *Comp. and Elect in Ag);* Ranjan et al. (2018, *JI Applied Geophy);*
Peddinti et al. (2018, Vadose Zone JI); Badnakhe et al. (2018, Comp Elect Ag);Peddinti et al. (2020, JI Hydr)

Information Flow in e-Citrus



e-Citrus: A multi-mode Crowd-sourcing platform for information gathering/ dissemination/agricultural advisory in pest/disease management



http://59.181.97.157:8091/modules/

DSFS Project

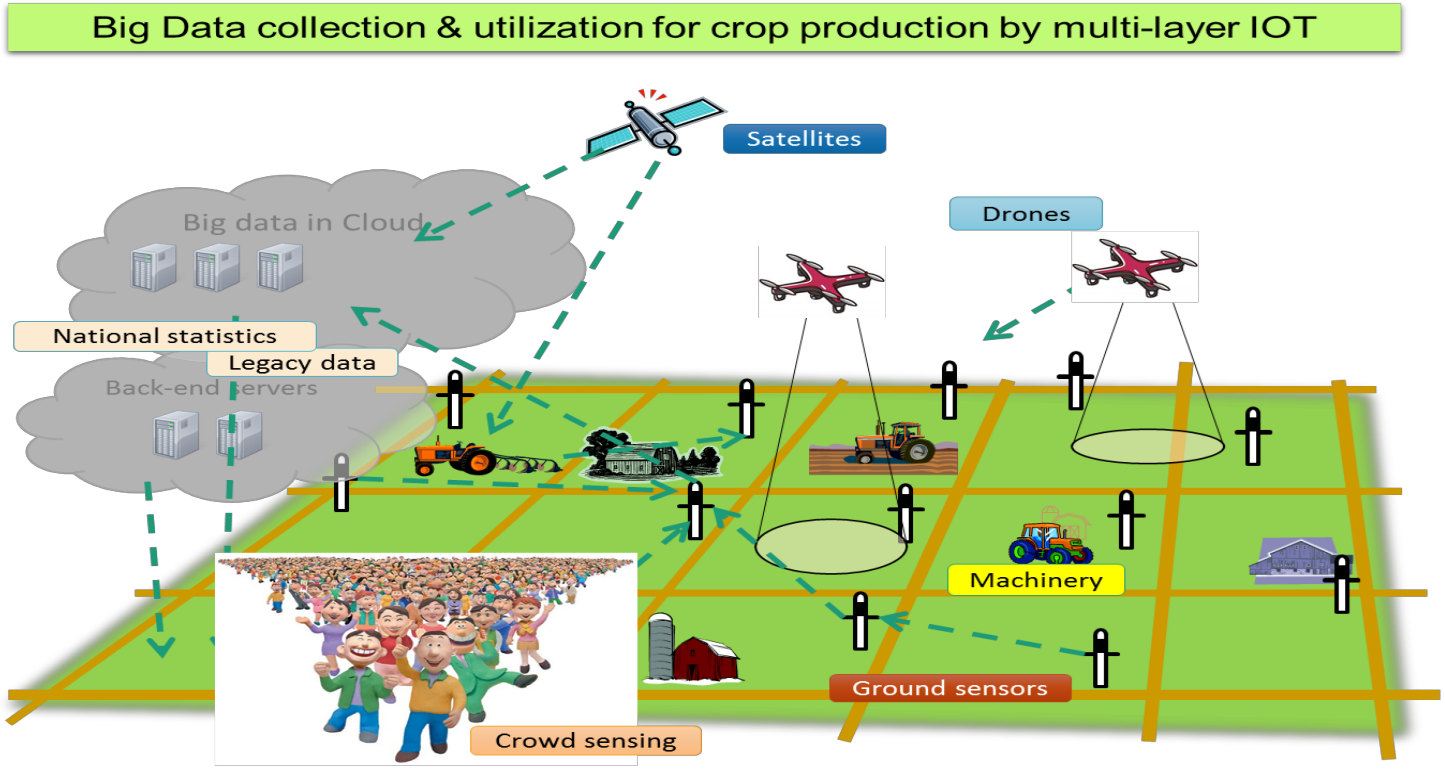
Data Science-based Farming Support system for Sustainable Crop Production under Climatic change

Project Goal: To develop data science based approaches using high-end integrated information and agricultural sciences such as ***IoT, big data analytics, deep learning, crop modeling*** and omics (***Genomics/Phenomics)*** to support high performance and sustainable agriculture – SMART FARMING

Focus on two major research topics:

A. *IT platform for Big Data based Smart Farming Support*

A. *Applications for Farmer & Agriculture Stakeholder and Breeders*



Critical zone observatory (framework)

DSFS (IIT Hyderabad, IIT Bombay, IIITH, PJTSAU, University of Tokyo and Chibu Univ.)

(Indo-Japan Joint Laboratory Project of DST/JST)

Data Science-based Farming Support System for Sustainable Crop Production

Establishment of bilateral Joint Laboratory for research to support sufficient and environmentally friendly production of safe and quality crops under climatic change

Farmers & agriculture stakeholders

Efficient Knowledge Transfer

- Mobile based systems JP,IN
- Personalized knowledge transfer IN
- Diagnostic knowledge-bases JP,IN
- Next generation farm KIOSK IN

Optimal Crop Management

- Water management IN,JP
- Pest & disease management IN
- Weather-based crop management IN

High Performance Breeding

- High-throughput phenotyping JP,IN
- Genomic selection model JP,IN
- G X E X M modelling JP

Agricultural Applications for Farmer & Agriculture Stakeholder

IT platform for Big Data based Smart Farming Supports

IoT/ Field Sensors

- IoT based field sensor node development IN,JP
- Crowd sensing IN
- Drone sensing using IoT JP,IN
- IoT Backhaul IN

Database for Big Data

- Data modeling JP
- Data integration platforms IN,JP
- Utilization of DIAS JP
- API design IN,JP

AI/Deep Learning

- Big data analytics IN,JP
- Deep Learning IN,JP
- Image/video analysis JP, IN
- Data fusion IN
- Decision support engines JP,IN

Focus

Development of *new* models/methods for crop intensification with intriguing influence of climate-related and farmer-centric abiotic stresses (H_2O and N)

Sub-Components

- New Method/Model to estimate On-Farm Crop stress dynamics & management through drone-based RGB and hyperspectral images (Rahul Raj, PhD student)
- Enhanced MLCan Model for Crop resource management under climate variability conditions on crop yield by optimizing use of water and nitrogen (Rohit Nandan, PhD student)
- Development of *On-farm DSS for optimal crop management*

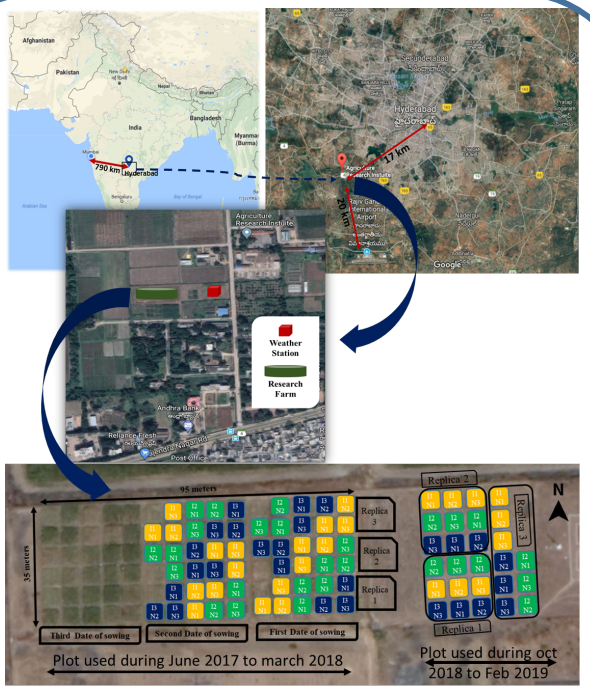
Focus

To accelerate plant breeding by enhancing precision of drought-tolerant crop selection using High Throughput Plant Phenotyping (HTPP)

(Soumyashree Kar, PhD Student)

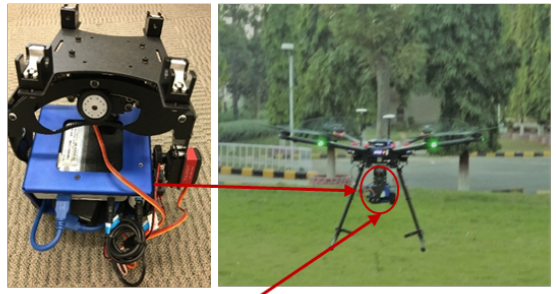
HTTP: An automated, non-invasive and comprehensive assessment of plant phenotypes in response to their genetic and environmental characteristics

1. Drone-based hyperspectral imaging for optimal crop management (PhD Student Rahul Raj and team)



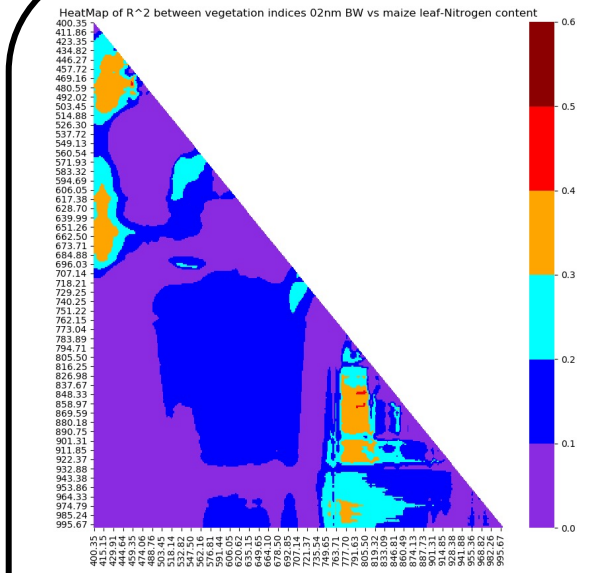
Study Area (SAT/Hyderabad)

Hyperspectral Imager

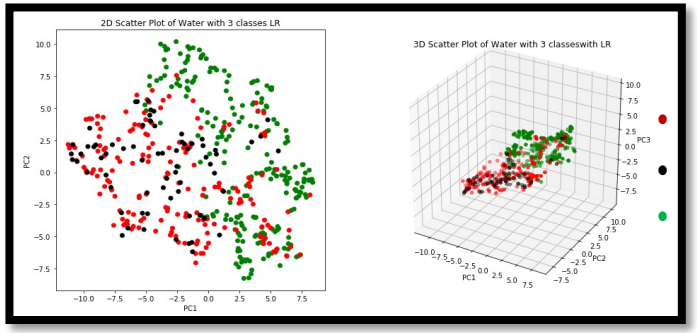


DJI Matrice 600 Hexacopter

RGB camera

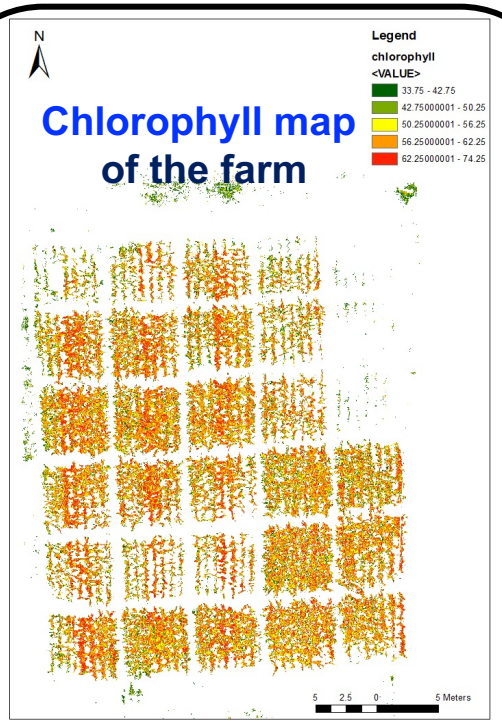


Nitrogen normalised difference indices correlation heatmap for selection of best indices

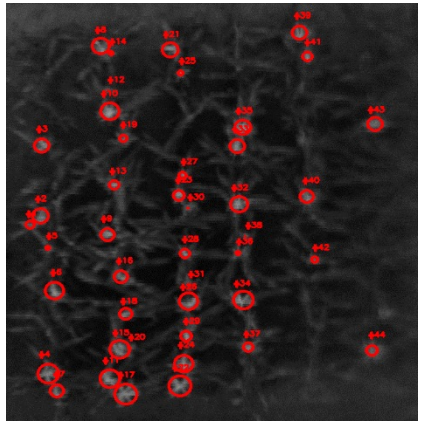


- LWC < 70 %
- 70 % - 80 %
- LWC > 80 %

Classification of high and low water content leaves using PCA



Chlorophyll map of the farm



Tassel count with 98 % accuracy from **hyperspectral image**

Roadmap

Integrate model with on-farm DSS

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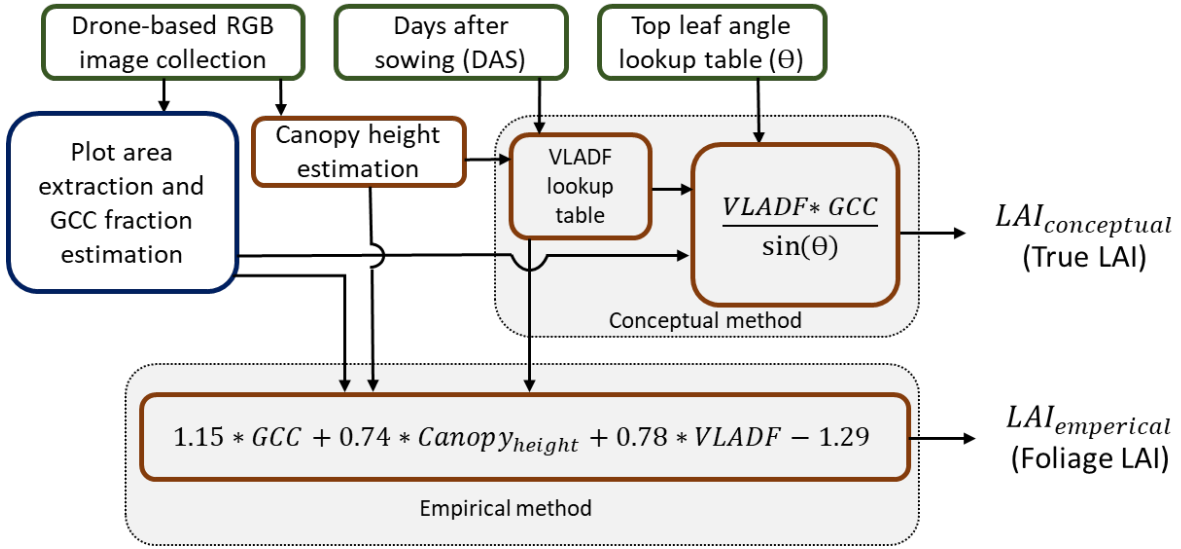
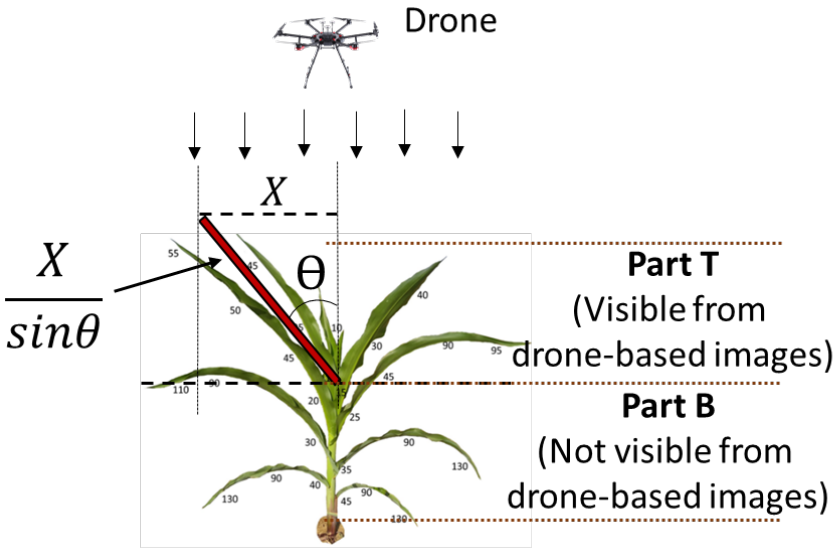
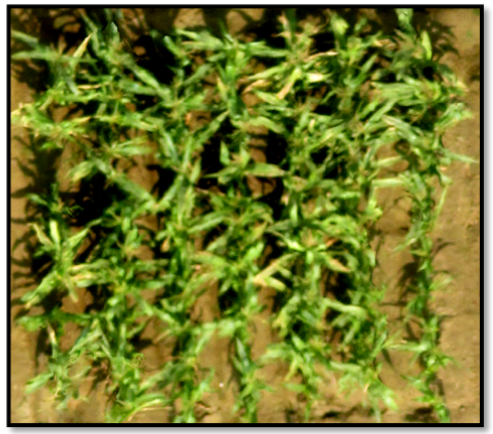
2. Drone-based RGB imaging for crop height and LAI estimation (PhD Student Rahul Raj and team)

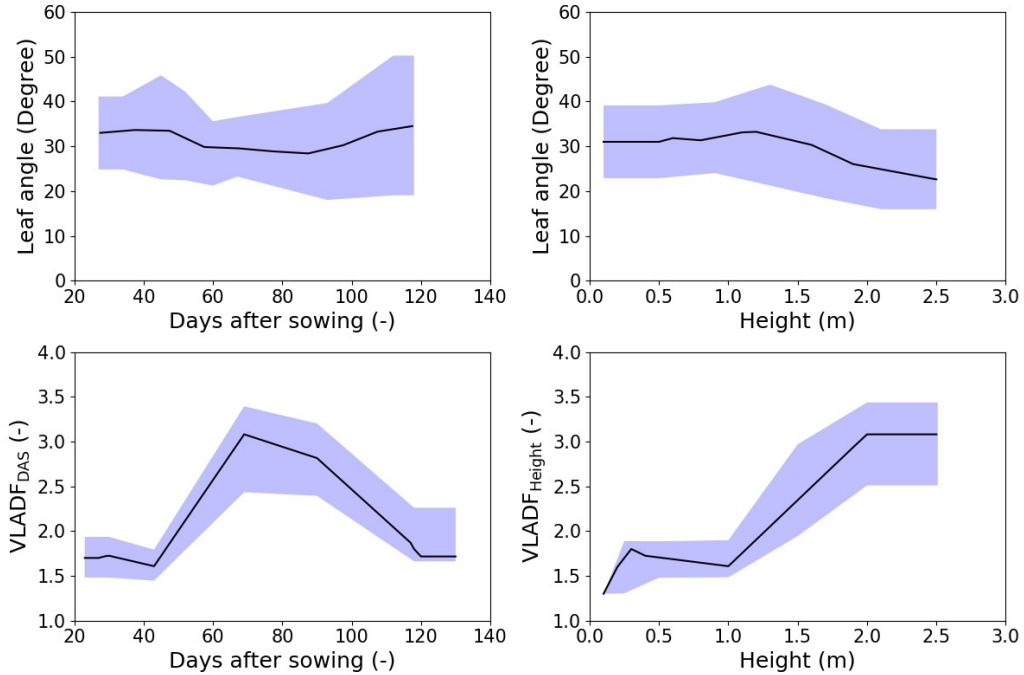


3D point cloud of the farm for canopy height calculation





Top view of plot 20
(25th Jan 2019)



$$VLADF_{height} = 1 + \frac{area_B}{area_T};\quad VLADF_{DAS} = 1 + \frac{area_B}{area_T};\quad VLADF = \frac{VLADF_{height} + VLADF_{DAS}}{2}$$

$$LAI_{VLADF} = VLADF * (Top\ of\ the\ canopy\ leaf\ area) = \frac{VLADF * GCC}{\sin(\Theta)}$$

More details available at
https://agroinformaticslab.github.io/

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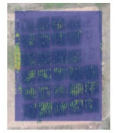
Data sciences based farming support system for sustainable crop production under climate change

- Collaborating institutes : **IIIT Hyderabad, IIT Bombay, IIT Hyderabad, PJTSAU, University of Tokyo (Japan)**
- Research Farm location: **ARI Hyderabad, PJTSAU** Location

The website shows the preliminary results of drone-based RGB and hyperspectral data analysis.
All the displayed results are for **maize crop** sown during **Rabi 2018-19 season**

Plot Information

Leaf Water

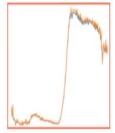


Leaf Area Index- 1

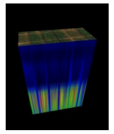
Leaf Area Index- 2

Tassel Counting

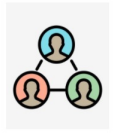
BRDF



Spectral Cube



Team



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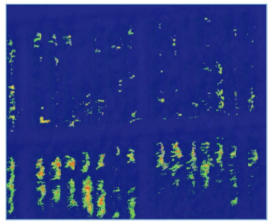
Home Tassel Count Plot Info LWC BRDF
HyperSpectral Cube LAI 1 LAI 2 Team

Leaf Water Content Visualisation

LWC at 6-leaf stage (11th Nov 2018)



Click the mouse on a point on the field to view the area around it.The sliders can be moved to adjust the opacity of the zoomed windows.

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Home Tassel Count Plot Info LWC BRDF
HyperSpectral Cube LAI 1 LAI 2 Team

Leaf Area Visualisation

Reset | LAI map | Field

Move the smaller slider for changing opacity of the current stage.
Reset will reset opacity changes for all stages.

Date : 12 December 2018

Stage : Late Vegetative

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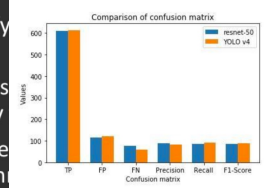
Tassel Counting

Home Tassel C
HyperSpectral C

Maize tassel detection using deep learning

- Object Detection deals with identify of certain classes in the image
- Deep learning uses neural networks representations of features directly
- In deep learning, a convolutional ne of deep neural networks, most com analysing visual imagery
- For this work Faster R-CNN and YOLO v4 algorithms are used to detect tassels in the images

Comparison between YOLO v4 and Faster R-CNN



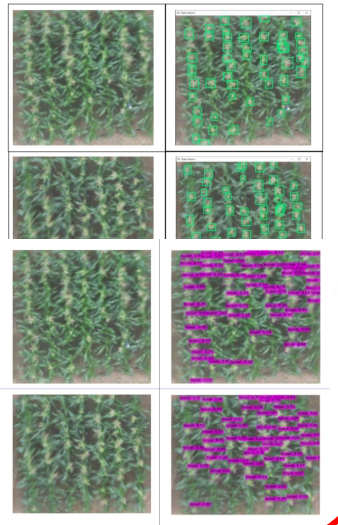
- Here we can see both the models are performing in similar way.
- But if we consider execution time, YOLO v4 is faster.
- For detecting tassels in 27 plots YOLO v4 took 1 second and Faster R-CNN took 56 seconds

Faster R-CNN results

Total Tassels	801
True Positive	610
False Positive	115
False Negative	76
Precision	0.88
Recall	0.84
F1-score	0.859

YOLO v4 results

Total Tassels	801
True Positive	610
False Positive	115
False Negative	76
Precision	0.88
Recall	0.84
F1-score	0.859



2. Weather-based crop resource management [Rohit Nandan, PhD Student and team]

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How does corn respond to climate change conditions?

⬇

To what extent water and N management can offset the negative effects of climate change?

Steps

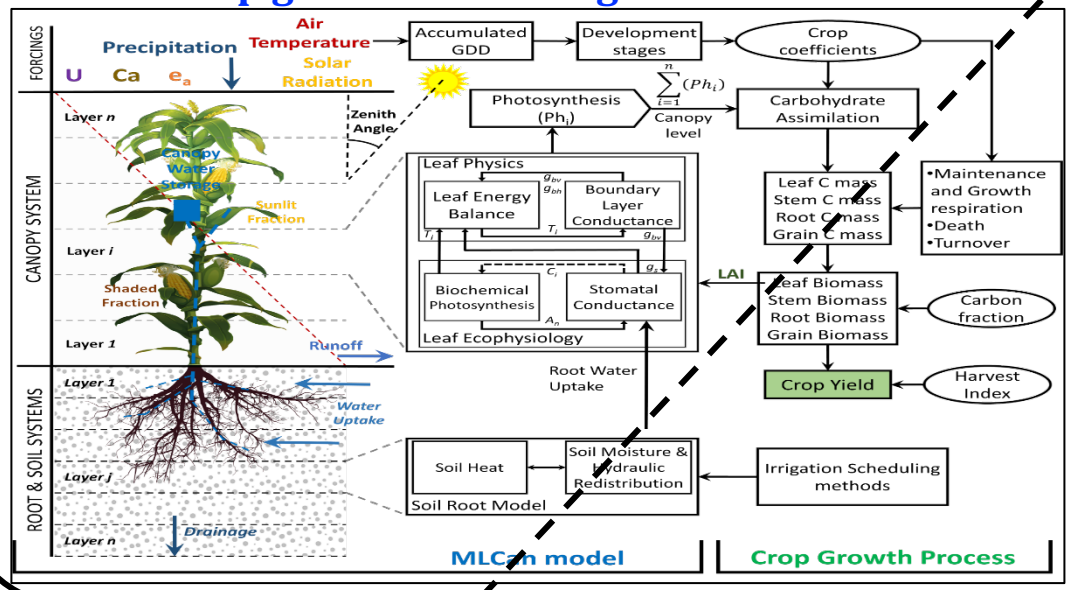
- Generated the Climate Change (CC) Scenarios
- Simulated the impact of Climate Change on Crop Yield (CY)
- Identified Dry Years and applied irrigation scheduling methods on the dry years
- Examined the role of the irrigation scheduling methods on CY under CC
- Studied the impact of nitrogen management on CY under CC

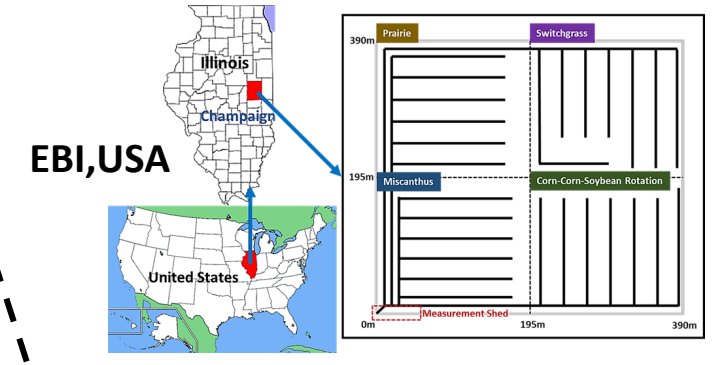
Multi Layer Canopy Model

MLCan can *capture acclimation (adaptation) aspects of vegetation under future climate.*

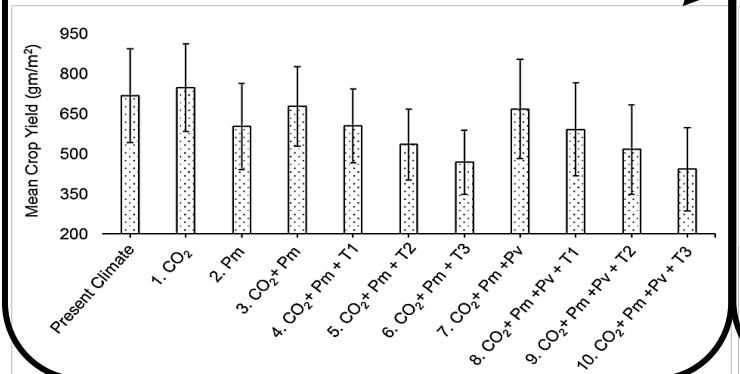
-MLCan also *simulates multiple canopy and soil related parameters* that is helpful *to understand the behaviour of different condition on different parameters*

MLCan-crop growth modelling framework

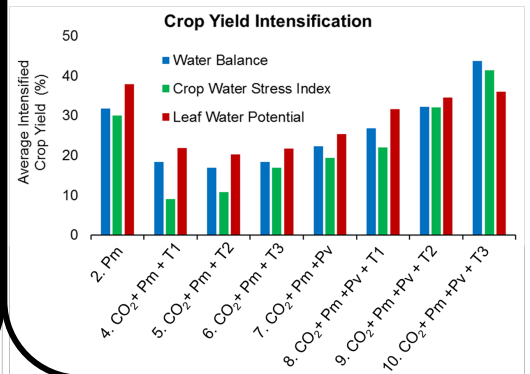


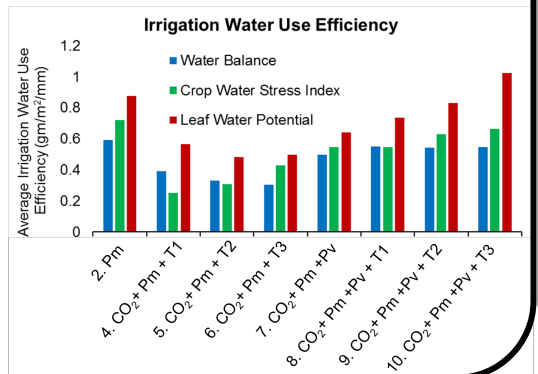


Impact of Climate Change

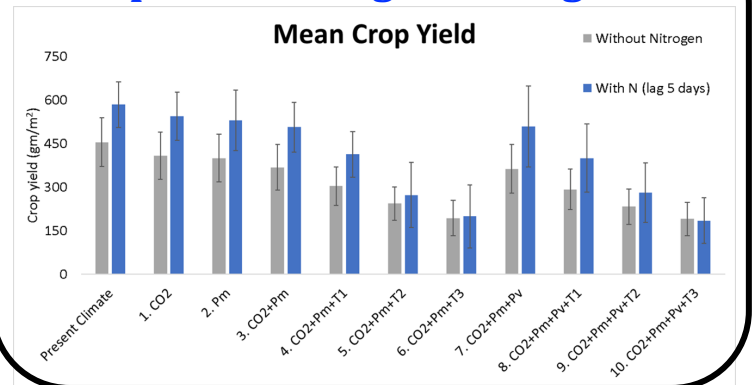


Impact of Irrigation scheduling methods





Impact of Nitrogen management



Data Science-based Farming Support System for Sustainable Crop Production under Climatic Change

WP6: High Performance Plant Breeding (Soumyashree Kar, PhD Student and Team)

Focus: To accelerate plant breeding by enhancing precision of drought-tolerant crop selection using High Throughput Plant Phenotyping (HTPP)

Background

1. Defining a phenotype

P = G + E (+ GEI)

(Phenotype (P) is a function of genotype (G), environment (E), and the interaction between G and E i.e. GEI)

2. Defining a drought-tolerant plant based on trait phenotypic values

What is a **drought-tolerant** plant?

- **A plant that has enough water to complete its life cycle (low early-vigour and better water-use)**
  - **Stage-I: Early-Vigour (Canopy- Growth Traits)**
    - Morphological features:
      - Low early vigour
      - Soil coverage
    - Important Traits:
      - Biomass / 3D Leaf Area (LA3D)
      - Plant Height (PH)
      - Canopy / Projected Leaf Area (PrjA)
  - **Stage-II: Water-Use Efficiency (Canopy Conductance Traits)**
    - Physiological features:
      - Increased Water Use Efficiency (WUE)
      - Save water for later crop stages (grain filling)
    - Important Traits:
      - Low ET (E_p)
      - Low Transpiration (E_{tp}) under high VPD
      - Low Transpiration Rate (E_r) under high VPD
- A plant that has used all the water in the soil profile (involves root dynamics, etc.) (**NOT** included in this study)

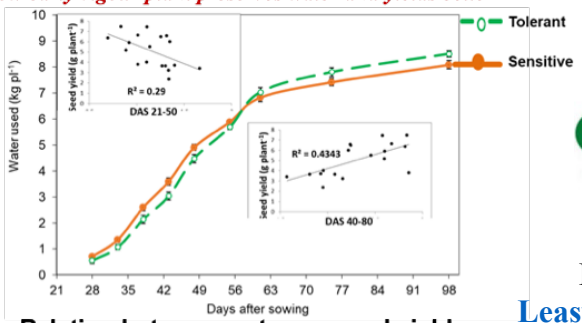
Plant phenomics *are largely carried out under controlled conditions; and is* ***difficult to do it under field***/ non-controlled **experimental set-ups which requires simultaneous scan of 100s of genotypes**

HTTP: An automated, non-invasive and comprehensive assessment of plant phenotypes in response to their genetic and environmental characteristics

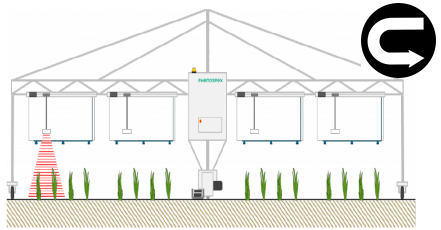
- The effect of spatial variation on phenotypic observations mask the genotypic diversity and affect the identification of desired genotypes.
- Main Objective - Development of a Spatio-Temporal Analytic Pipeline' to process *multiple replications of 100s of genotypes simultaneously and cluster them into discrete groups based on High, Medium and Low early vigor characteristics using temporal HTTP Data.*

Why low early-vigour?

Low early vigour plant preserves water and yields better



Relation between water-use and yield (Source: Zaman et al., 2011)



High Throughput Plant Phenotyping Platform – *LeasyScan*

The LeasyScan HTPP platform is equipped with Phenospex's **3D laser scanners** *(mounted with automated sprinkle irrigation)* which provide 3-D images of the plants to extract **leaf area, leaf angle, plant height, and average canopy leaf area**. The platform has a total of 8 trenches (each having 2 columns) comprising 288 sectors (**associated with individual load-cells** - gravimetric sensors/balances - that **records the change in mass every 15 min that helps in changes in ET**) in each column of a trench (**total number of plants monitored simultaneously = 8x2x288 = 4608**). FieldScan also includes a **sensor network** to measure the **ambient weather parameters** throughout the day, locally for **mimicking plant behavior in field conditions**

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HTPP experiments with LeasyScan platform and analysis

東京大学
THE UNIVERSITY OF TOKYO

Statistical Modeling of HTPP data for spatial variation and GxE interaction analysis

CIAT
International Center for Tropical Agriculture
Since 1967 Science to cultivate change

Conducting field experiments and validation

Big Data Analytics in Precision/Smart Agriculture

(both a Top down and Bottom up approach)

Top-down
Goal is to identify and focus on technologies that can function together and can provide integrated infrastructure for better decision making

Services and DSS

Advisory
- Crop water requirement
- Pest/Disease control
- Ground water utilization

Information Dissemination
- Agro-meteorological conditions
- Periodic crop quality estimation
- Crowd sourcing platform

Automated modelling
- Predictive crop pest/ disease model
- Water stress detection
- Phenology identification and plant health

Decision Support
- Resource management
- Yield estimation
- Crop planning
- Disaster management

Standards and Processing

Standards
- OGC standards
- Data collection and sampling standards
- Data dissemination
- QA & QC standards

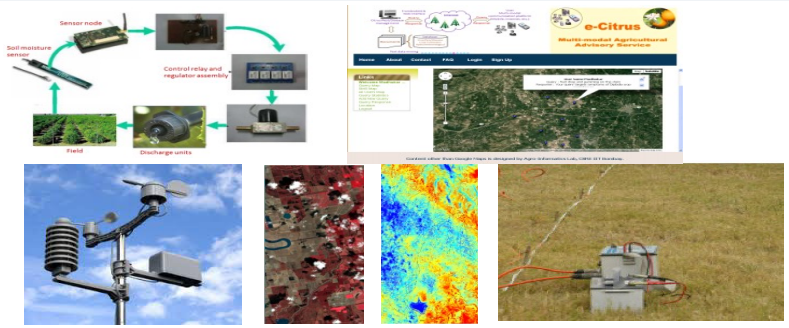
Process Models
- Plant biochemistry
- Radiative transfer models

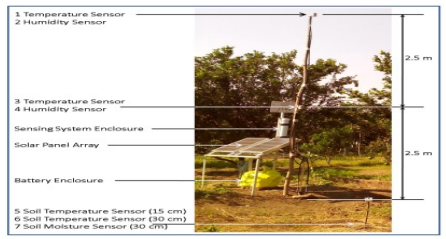
Empirical Models
- Hyperspectral processing
- Cyclic disease/pest impact

Computational Models
- Parallel processing
- Data mining
- Correlation estimation
- Machine learning
- Regression analysis

Methods
- Knowledge generation
- Model agro-climatic conditions, plant health and phenology
- Provide integrated services

Sensing Platforms





Bottom-up
Goal is to generate knowledge base from a diverse, heterogeneous and multi-mode system that identifies and explores complex interrelations between agricultural systems

Climate-Resilient Agriculture for Disaster Risk Reduction

European Union | Asi@Connect | TEIN COOPERATION CENTER

BACKGROUND

APAN Asi@Connect

- Agriculture Working Group (AgWG)

- Disaster Mitigation Working Group (DMWG)

LIST OF PROJECT PARTNERS

IT for Agriculture

- National Agriculture and Food Research Organization (NARO), Japan
- Centre of Studies in Resources Engineering, Indian Institute of Technology Bombay, India
- The University of Tokyo, Japan

Disaster Mitigation

- Academia Sinica Grid Computing Center (ASGC), Taiwan
- Hydro – Informatics Institute (HII), Thailand

Supporting Agencies

- Hydro – Informatics Institute (HII), Thailand
- National Electronics and Computer Technology Center (NECTEC), Thailand
- Thailand Research and Education Network (ThaiREN), Thailand
- ASEAN Hydroinformatics Data Centre

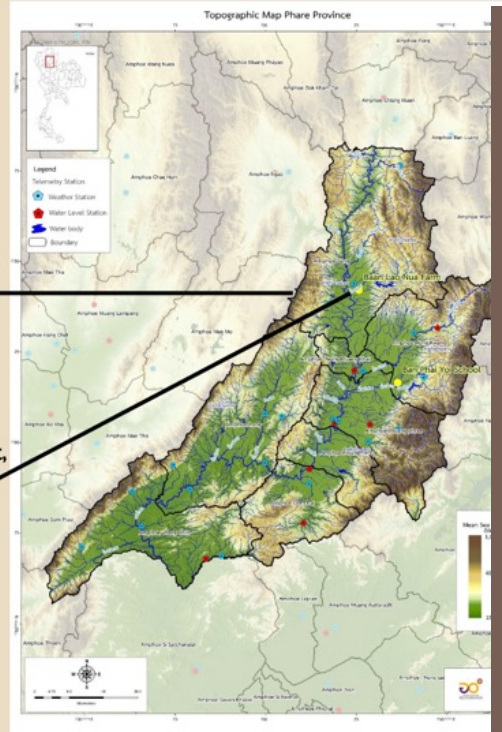
CASE STUDY AREA

MACRO Level

Provincial Level: Phrae Province Water Resources Management Operation Center

MICRO Level

Community Level: Ban Lau Nua (Happy Farm), Ban Klang sub-district, Song district, Phrae province



OBJECTIVES OF PROJECT

- To exchange the evaluation of meteorological parameters impact on agricultural production for climate-resilience agriculture
- To expand the use of STI for climate-smart agriculture by transferring technologies
- To create resilience and build the capacity of participating countries in relation to meteorological impacts on agricultural production
- To improve food security, livelihood and disaster resilience at local level

ACTIVITIES PLAN

1

22-24 FEB 2021
Workshop 1 (Virtual Meeting):

- Kick-off & Background information of Case-study area (Phrae province and Happy Farm)
- Understanding the key technologies and innovations for Climate – Smart Agriculture
- Disruptive innovations in precision agriculture

2

15 – 16 MAR 2021
Workshop 2 (Virtual Meeting):

- Key technologies and innovations for Climate – Smart Agriculture

3

MAY 2021
Workshop 3 (Virtual Meeting):

- Mitigation of short-term impacts, analysis of mitigation workflow and development of implementation plan
- Summary of the project and plan for the next step

Take Away

- Precision Agriculture – huge opportunities for innovations in farming through disruptive tools and techniques for developing state of the art GeoFarmatics
- Scientific/Community/Commercial-benefits
- Green to Digital Revolution (to achieve efficiency - more crop per drop)
- Need for inter-disciplinary collaborations to improve/scale-up infrastructure, informatics culture in Agriculture/Rural communities and for Climate-resilient Agriculture/Food Security/Sustainability

Leverage SMART Technologies in Precision Agriculture

(**S**cientific, **M**arketable, **A**ffordable, **R**eliable & **T**ime-saving)

Thank you

adi@iitb.ac.in

Agro-Informatics Lab
More Crop per Drop