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**
- IIT Bombay
- DMCC, UND & Env'tl Computing Workshop, 24-26/03/2021
- CRADR: Climate-Resilient Agriculture for Disaster Risk Reduction

**International Collaborators**
- MONASH University
- ILLINOIS
- 東京大学
- HOKKAIDO UNIVERSITY
- ICRI construed as "Institute for the Crop Research"
- ECUMENICAL UNIVERSITY OF DRESDEN
- TECHNISCHE UNIVERSITÄT MÜNCHEN
- NARO

(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”

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
### 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

#### Data Processing
- **IoTs**
  - Precision Technologies
  - Multi-model data aggregation
  - IoT protocols
- **Processing**
  - Spatial and Temporal Analysis
  - Statistical Exploratory Analysis
  - Sensitivity and Correlation
- **Standards**
  - Open Data Standard
  - Interoperability
  - Data storage and retrieval
  - Data security

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

#### 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.

---

### Knowledge generation
- **Ontology**
- Domain Expertise
- Information Modelling

### Knowledge transfer
- Services Data
- Subscription services
- Domain Adaptation

### Appln
- 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

---

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

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

- Data Dissemination
  - Some applications are too complex to model using established statistical methods

- Data Modelling
  - Domain Adaptation
  - Information Modelling

- Data Generation
  - Field Sensing Platforms
  - Scientific Instrumentation
  - Crowd Sourcing
  - Autonomous Ground Vehicles

- Data Processing
  - Precision Technologies
  - Multi-model data aggregation
  - IoT protocols

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

---

(info assimilation through multi modal systems)

(means of disseminating information and advisory from ICDTs to end-users; provides periodic updates to end-users for ‘ahead-of-time’ precautionary measures)
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.
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 \textit{MMA framework} to solve challenging problems in agriculture and its allied domains \textit{in collaboration with multi-disciplinary groups from multi-institutions and nations:}

\begin{itemize}
  \item \textbf{GrIDSense} [IIT Bombay, IIT Hyderabad, PDKV, Maharashtra Orange Growers Assoc.(MOGA)] (\textit{Groundwater-Irrigation-Disease Sensing Systems})  
  (\textit{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)  
  (\textit{Interoperable platform for remote monitoring and for near real-time decision making})

  \item \textbf{DSFS} (IIT Hyderabad, IIT Bombay, IIITH, PJTSAU, University of Tokyo) – (\textit{Data Science-based Farming Support system for Sustainable Crop Production under Climatic change}) (\textit{Indo-Japan Joint Laboratory Project of DST/JST})

Develop data science based approaches using \textit{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

IITB

IITH

PDKV

JNTU CoE

Industrial Partners, User Agency

---

**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, J Applied Geophy); Peddinti et al. (2018, Vadose Zone Jl); Badnakhe et al. (2018, Comp Elect Ag); Peddinti et al. (2020, JI Hydr)
Query From the Farmer Via SMS/internet

SMS/Query stored in Database

Answer to farmer after applying TF-IDF and Ranking Algorithm

Database of 57 documents on citrus pest/disease

Answer to farmer after applying TF-IDF and Ranking Algorithm

SMS response to farmer via FrontlineSMS

Query response to farmer via Internet

Automatic reporting on e-Citrus platform

Query response from expert to farmer via Internet

Expert opinion SMS response from expert to farmer via FrontlineSMS

Reporting on e-Citrus platform

Information Flow in e-Citrus

An IoT Platform for Smart Agriculture

SenseQube – System and its dashboard

Specifications

Standards

➢ LPWAN Protocol
➢ CoAP (Constrained Application Protocol)
➢ Wi-Fi IEEE 802.11
➢ OGC Sensor Observation Service v1.1
➢ OGC PUCK Standard for plug and play
➢ WMO AWS deployment standard

Standards

➢ LPWAN Protocol
➢ CoAP (Constrained Application Protocol)
➢ Wi-Fi IEEE 802.11
➢ OGC Sensor Observation Service v1.1
➢ OGC PUCK Standard for plug and play
➢ WMO AWS deployment standard

SenseQube

– System and its dashboard

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

Critical zone observatory (framework)
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

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

- Development of new models/methods for crop intensification with intriguing influence of climate-related and farmer-centric abiotic stresses (H₂O and N)
- 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)

**Chlorophyll map of the farm**

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

**Classification of high and low water content leaves using PCA**

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

**Nitrogen normalised difference indices correlation heatmap for selection of best indices**

**Roadmap**
- Integrate model with on-farm DSS

**Hyperspectral Imager**
- DJI Matrice 600 Hexacopter
- RGB camera

**Integrate model with on-farm DSS**
2. Drone-based RGB imaging for crop height and LAI estimation (PhD Student Rahul Raj and team)

\[ \text{VLADF}_{\text{height}} = 1 + \frac{\text{area}_B}{\text{area}_T}; \quad \text{VLADF}_{\text{DAS}} = 1 + \frac{\text{area}_B}{\text{area}_T}; \quad \text{VLADF} = \frac{\text{VLADF}_{\text{height}} + \text{VLADF}_{\text{DAS}}}{2} \]

\[ \text{LAI}_{\text{VLADF}} = \frac{\text{VLADF} \times \text{GCC}}{\sin(\theta)} \]

3D point cloud of the farm for canopy height calculation

More details available at https://agroinformaticslab.github.io/
Data sciences based farming support system for sustainable crop production under climate change

- Collaborating institutes: IIT Hyderabad, IIT Bombay, IIT Hyderabad, PJTSAU, University of Tokyo (Japan)
- Research Farm location: ABHI 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.

Leaf Water Content Visualisation

Leaf Area Visualisation

Tassel Counting

Maize tassel detection using deep learning

Comparison between YOLO v4 and Faster R-CNN results

- Faster R-CNN

- YOLO v4
2. Weather-based crop resource management [Rohit Nandan, PhD Student and team]

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

MLCan-crop growth modelling framework
- Multi Layer Canopy Model
  - Can capture acclimation (adaptation) aspects of vegetation under future climate
  - Simulates multiple canopy and soil related parameters

Impact of Climate Change
- EBI, USA

Impact of Irrigation scheduling methods
- MLCan model

Impact of Nitrogen management
- Crop Growth Process

Impact of Nitrogen management
- Crop Yield
- Water Balance
- Crop Water Stress Index
- Leaf Water Potential

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

Impact of Nitrogen management
- Mean Crop Yield
- With N (9 kg/ha)
- Without N
**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**

**Physiological features:**

- Increased Water Use Efficiency (WUE)
- Save water for later crop stages (grain filling)

**Important Traits:**

- Low ET ($\text{ET}_{\text{L}}$)
- Low Transpiration ($\text{Tr}_{\text{L}}$) under high VPD
- Low Transpiration Rate ($\text{Tr}_{\text{L}}$) under high VPD

**Morphological features:**

- Low early vigour
- Soil coverage

**Important Traits:**

- Biomass / 3D Leaf Area (LA3D)
- Plant Height (PH)
- Canopy / Projected Leaf Area (PrjA)

**Stage-I: Early-Vigour (Canopy-Growth Traits)**

**Stage-II: Water-Use Efficiency (Canopy Conductance Traits)**

**High Throughput Plant Phenotyping Platform – LeasyScan**

The LeasyScan HTPP platform is equipped with Phenospex’s 3D laser scanners (mounted with automated portable 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 record 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 = 8 x 2 x 288 = 4608). FieldScan also includes a sensor network to measure the ambient weather parameters throughout the day, locally for mimicking plant behavior in field conditions.

**Conducting field experiments and validation**

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

**HTPP experiments with LeasyScan platform and analysis**

**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.

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

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.

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
  - Hyperspectral processing
  - Cyclic disease/pest impact
- Empirical Models
- 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

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

Process Models
- Plant biochemistry
- Radiative transfer models
- Hyperspectral processing
- Cyclic disease/pest impact

Empirical Models

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

Services and DSS

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

Sensing Platforms

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

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

BACKGROUND

- 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
Provincial Level: Phrae Province Water Resources Management Operation Center
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
(Scientific, Marketable, Affordable, Reliable & Time-saving)

Thank you
adi@iitb.ac.in