It’s Time for Precision Farming in Cassava

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6 October 2023

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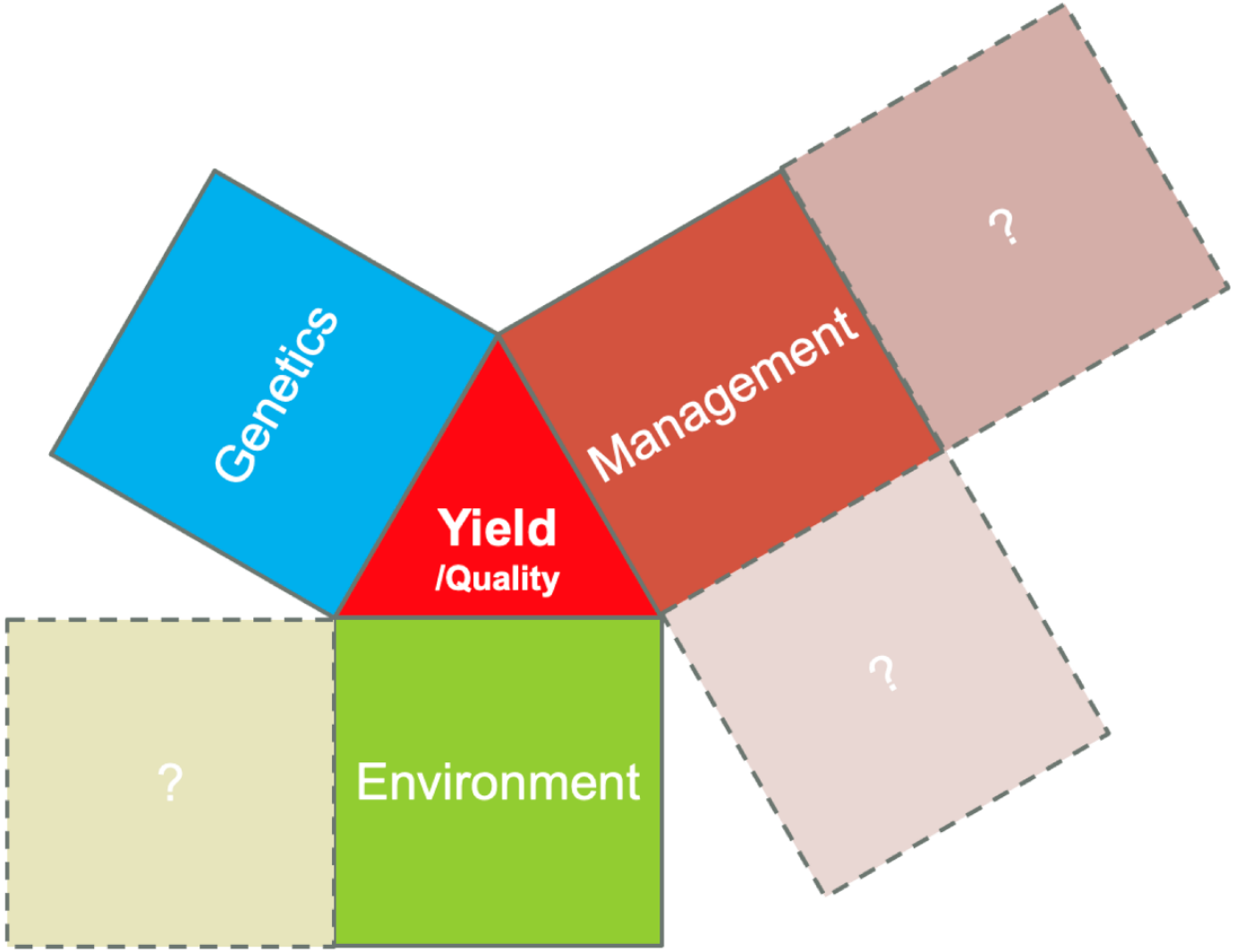
- Assistant Professor, Department of Agronomy, Kasetsart University
- Former Head of Department of Agronomy, Faculty of Agriculture
- University of Wisconsin-Madison, USA
- Ph.D. (Plant Breeding and Plant Genetics Program)
- **Cassava Breeder** & Plant Breeder
- **Smart / Precision Agriculture**

Fundamental Factors to Gain in Crop Yields / Quality

- Genetic
- Management

  (Cultivation practices)
- Environment
- Other?



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Approaches for Climate Resilience Agriculture

(The main drivers of crop production response: **temperature, carbon dioxide**, **rainfall pattern**)

- **Breeding Approaches**
  - Change Physiological Traits
  - Develop New Crops Tolerant to Biotic and Abiotic Stress
- **Physiological Approaches**
  - Mitigation Strategies
    - soil conservation using cover crops, crop rotations, and intercropping systems
  - Adaptation Strategies
    - Increasing Crop Diversity
    - Use of Crop Models in Making Decisions and Predictions
    - Adoption of **Remote Sensing** and **Precision Agriculture**

integrating precision agriculture involving modeling and remote sensing could play an important role in achieving global food security

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Thailand Tapioca / Cassava

- #2 in root production
- #1 in exporter of tapioca products
- the key economic crops for Thailand

Thai average = 21 T/ha (3.4 T/rai)

World = 11 T/ha (1.8 T/rai)

Skillful growers: 31-37 T/ha (5-6 T/rai)

Irrigation system: 67.5 T/ha (10.8 T/rai)

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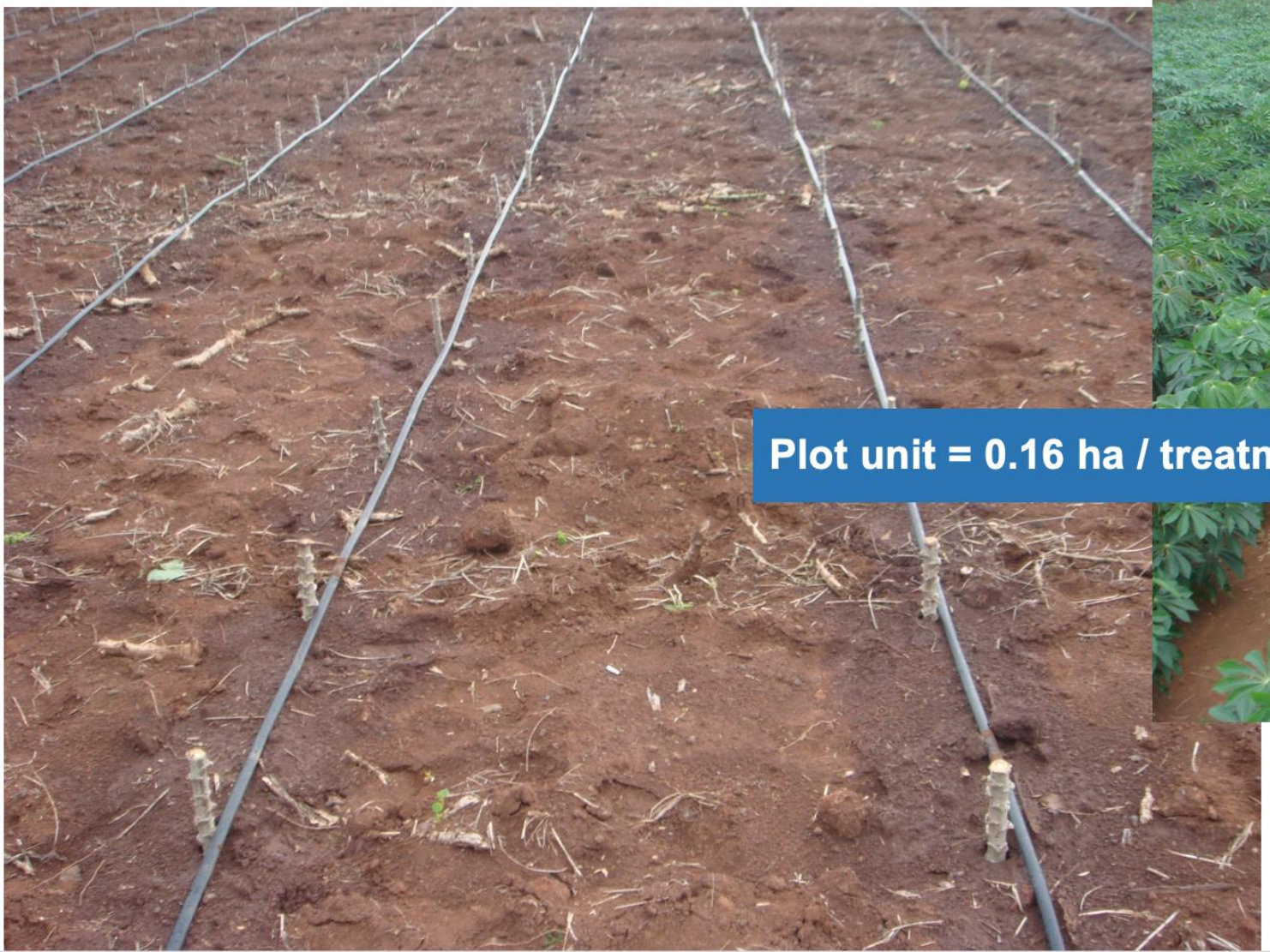
Cassava Field with Drip Irrigation System



Plot unit = 0.16 ha / treatment

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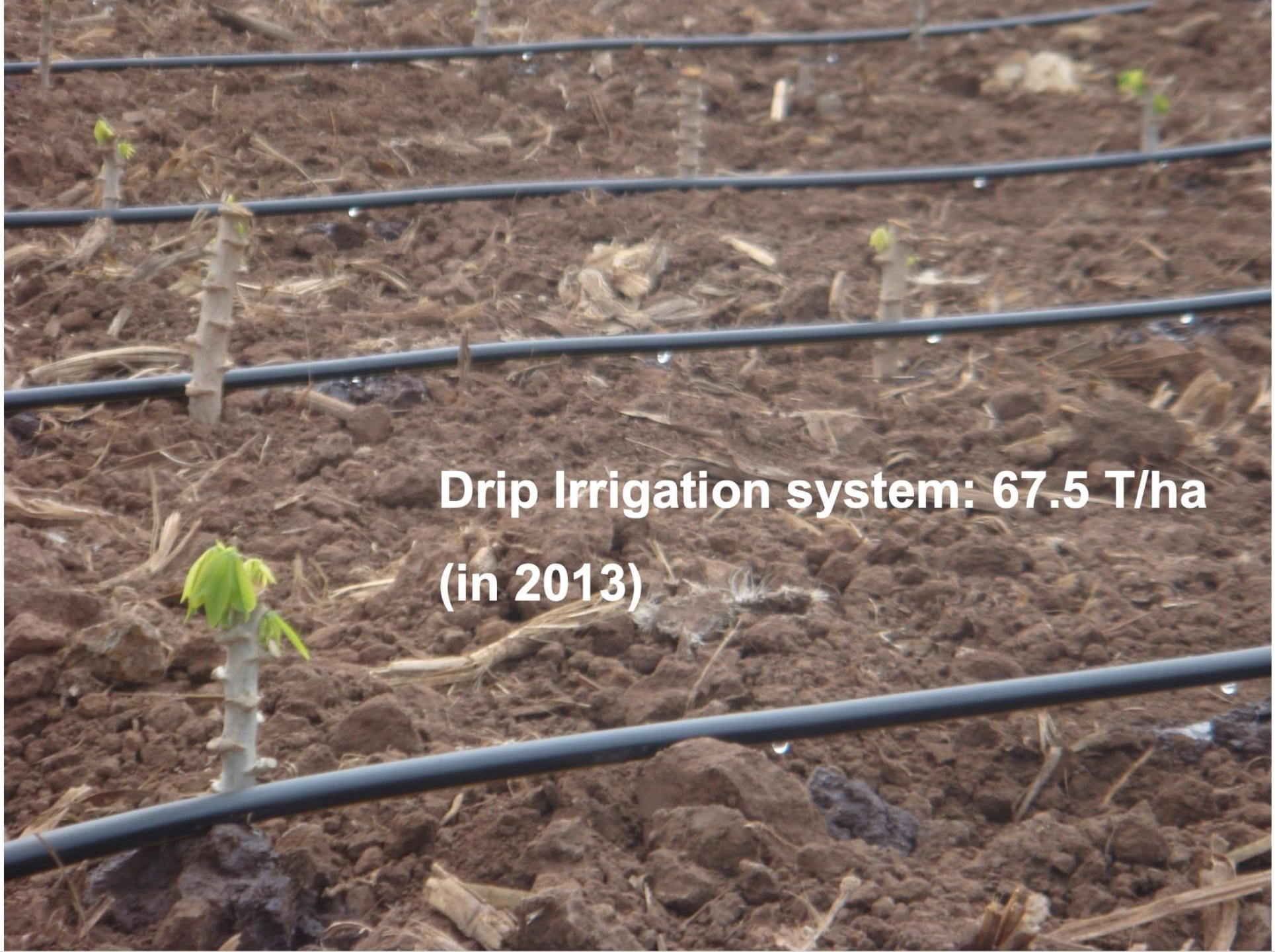

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Fundamental Factors to gain in crop yields / quality

- **Genetic**
- **Management**

  (Cultivation practices)
- **Environment**
- **Other?**

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Proactive Breeding Approach

The Agronomy Department,

Kasetsart University (KU)

- Initiative germplasm introduction discussion with CIAT, Colombia since **March 2011**
- 1st introduction: CMD resistant clones (C33 & TME3) from CIAT, Colombia in **May 2013**

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Proactive Breeding Approach

TTDI

- **2nd introduction from IITA, Nigeria in 2018** :

  IITA-TMS-IBA980505, 972205, 980581, 920057 & TMEB419

- **3rh introduction from CIAT, Hawaii in 2020:** 3,765 F_1 Seeds
- **4th introduction from CIAT, Colombia in 2021:** 32 CMD resistant clones
- **5th introduction from CIAT, Colombia in 2023:** 655 F_1 seeds

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A breeding line with Potential CMD Tolerant

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KUD55-7-9 (R5 x R90)

KUD55-7-9

KU50

Cassava inbred develpoment since 2011

S_1 (inbred progeny) of KU50

HNT, a landrace has CMD resistant gene

Good Cultivation Practices => Good Yield

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Crop Management

- Choosing a planting location and season
- Land preparation
- Choosing varieties
- Choosing good quality stem cuttings
- Suitable planting (ridging, spacing)
- Applying fertilizer
- Controlling weed
- Controlling pests
- Harvesting
- Applying irrigation system

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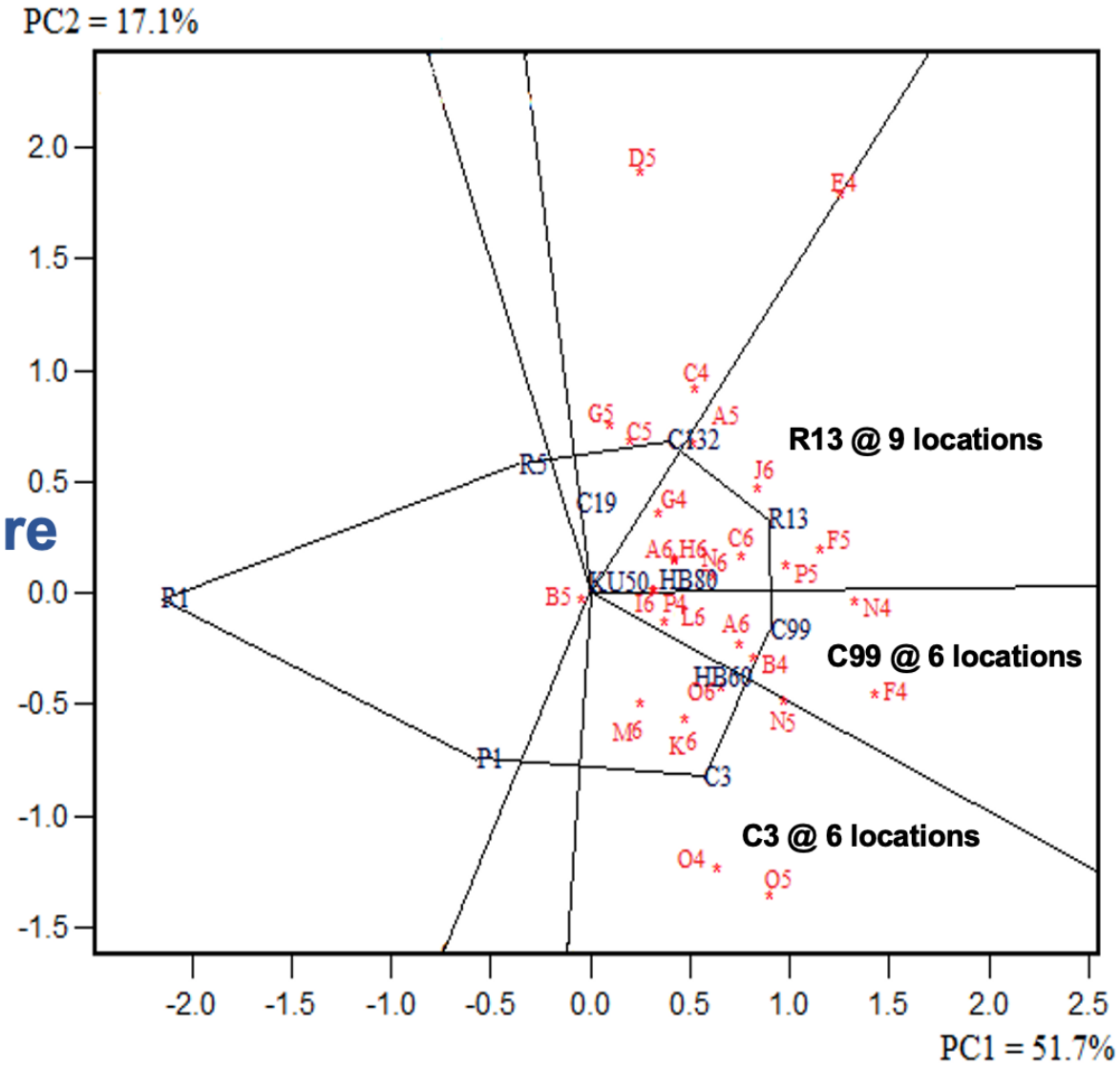
G x E Effect = Production

- 11 Lines/Varieties
- 28 Selection trials (Environments)

- Missing parts for Precision Agriculture
  - **Climate:** Rainfall, Temparation
  - **NDVI**
  - **LAI (Leaf area Index)**
  - **Ground truth (Farmer field data)**

GGE biplot



Potential of Thai Cassava

- **Genetics ➔ Good varieties**
- **Management ➔ Good cultivation practices**

- **Environment ? ➔ Remote Sensing**

GISTDA

Geo-Informatics and Space Technology Development Agency

(Public Organization)

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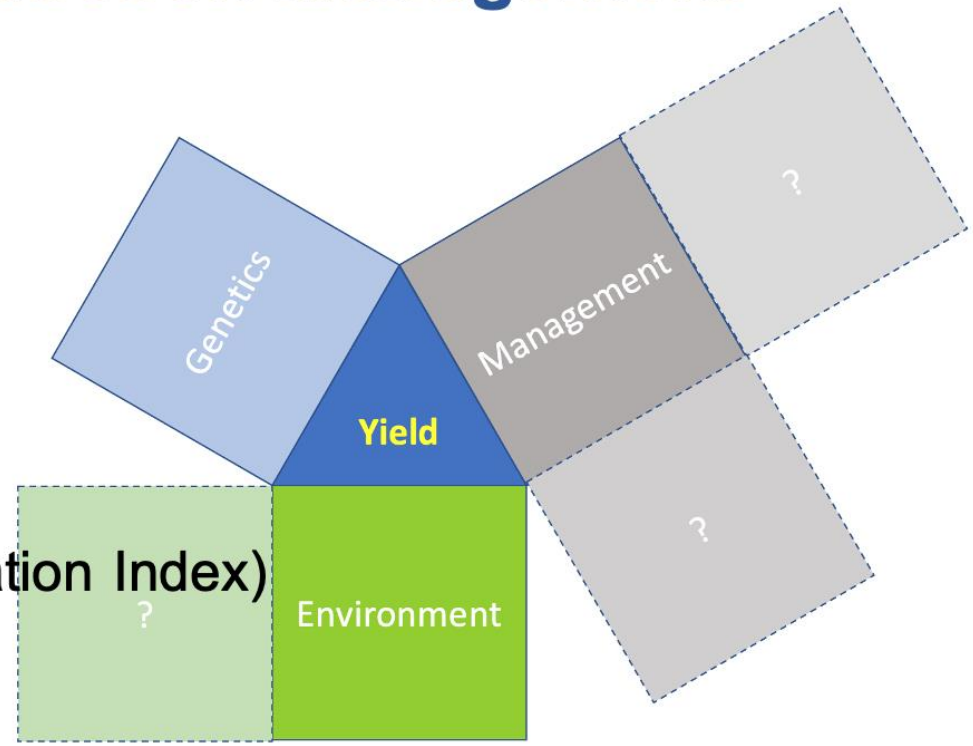
Critical Information for Cassava Production Management

Climate data

- Rainfall
- Temparation
- Moisture
- Multispectral (NDVI: Normalize Difference Vegetation Index)



Big data tank (field data)

- Phenotype
- Cultivation practices

+ **Private Sectors**

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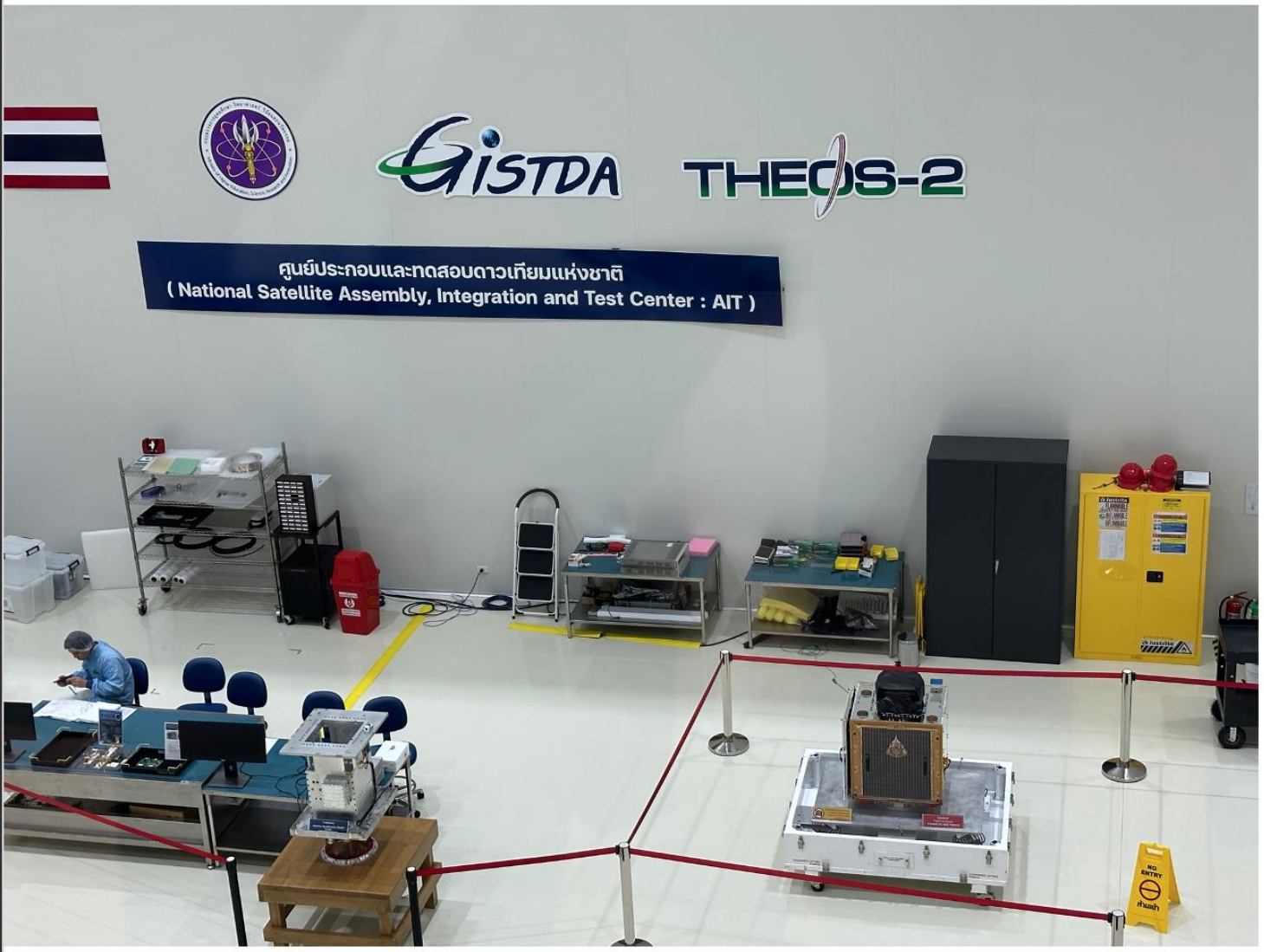
Thailand New Satellite



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A Solution for Smart Cassava Farming

- Varieties + Cultivation practices
- Good management = Precision management

  = Use **precise data** & **analyses** for **crop management**

Precision Farming = ✓ **Remote Sensing data +**

✗ **Field data +**

✓ **Data analytic**

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ENVIRONMENTAL RESEARCH
LETTERS

PERSPECTIVE

Boosting Thailand's palm oil yield with advanced seasonal predictions

Parichart Promchote[1], Binod Pokharel[2,*], Liping Deng[3,*], Shih-Yu Simon Wang[4], Jin-Ho Yoon[5] and Piya Kittipadakul[1]

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Supplementary material for this article is available online

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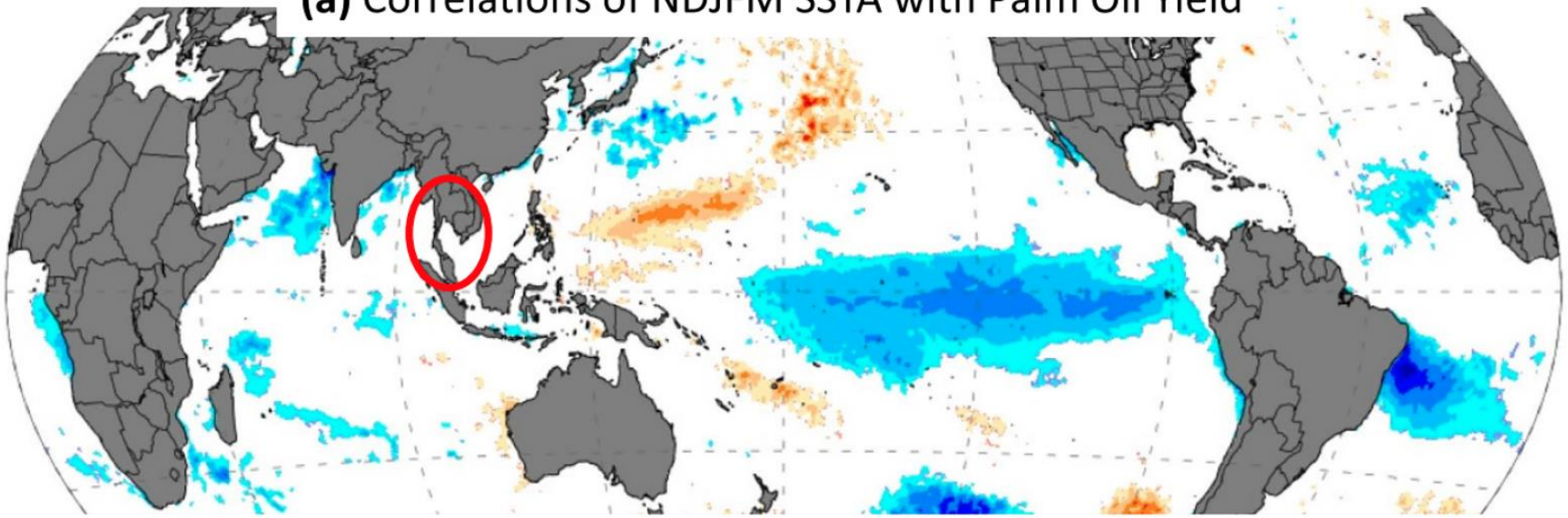
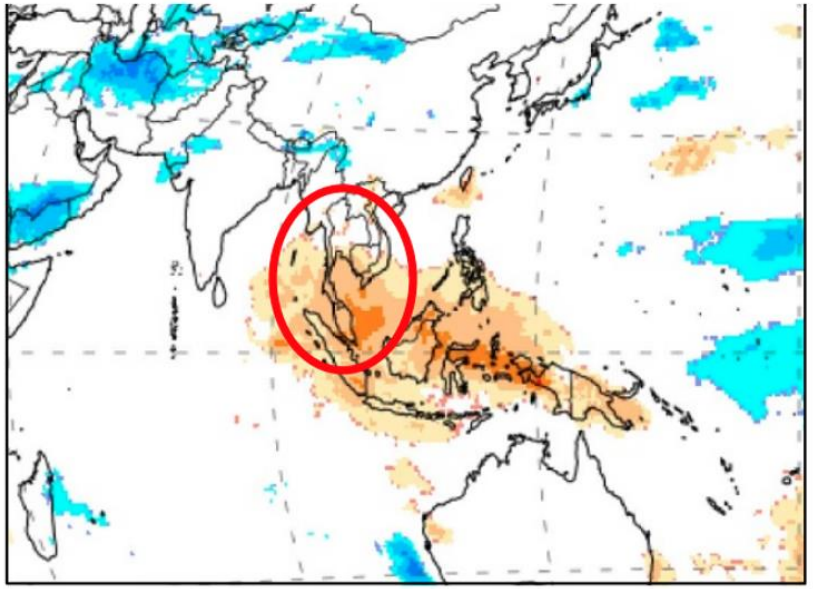
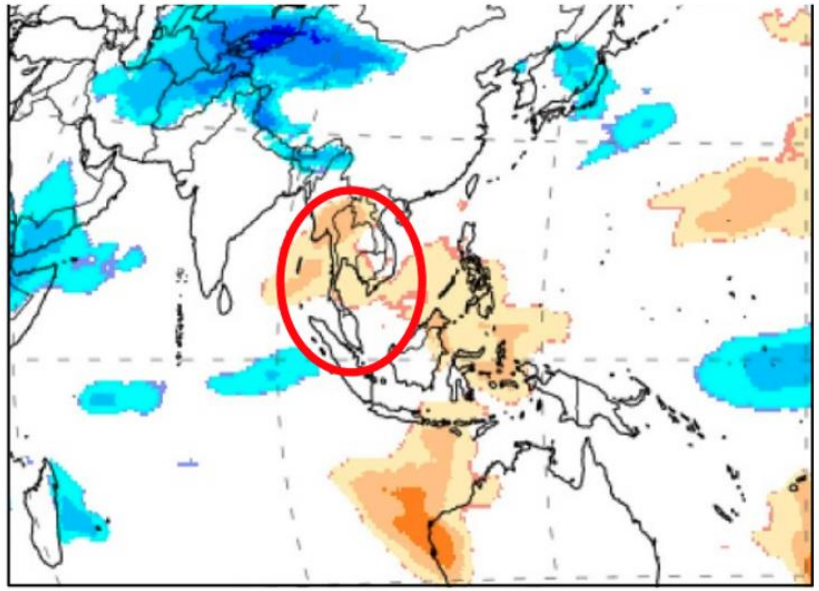
(a) Correlations of NDJFM SSTA with Palm Oil Yield



(b) Correlations of NDJFM Cloud Cover



(c) Correlations of NDJFM Precipitable Water



- In Thailand, palm oil production is closely tied to the seasonal monsoon period from May to October, which provides the necessary water for fruit bunch development.

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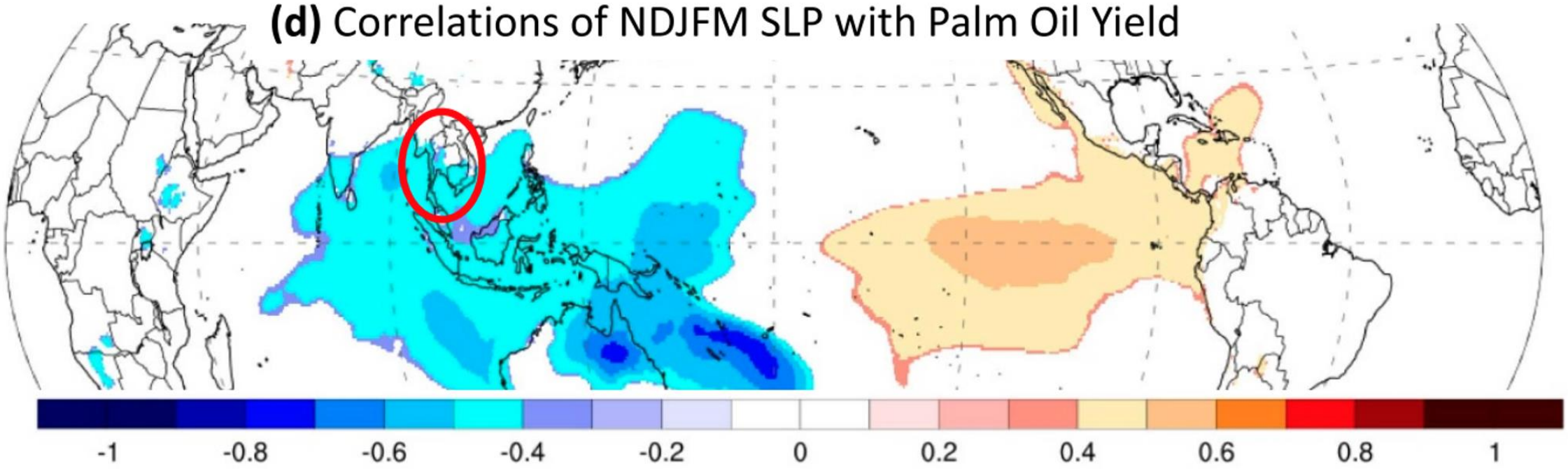

Figure 2. One-point correlation maps of the annual CPO production time series with (a) SST anomaly, (b) ERA5 cloud cover, (c) ERA5 precipitable water content, and (d) ERA5 mean SLP during the NDJFM season from November of the previous year. Only values with the correlation coefficient that is significant at $p < 0.1$ are plotted. The area of Thailand locates in red circles and its southern region is a major oil palm plantation.

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Ground truth = Field data

- Precise data of yield (per area)
- Cultivation practices
- Climate data
- Soil data
- Pest and Disease Data

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Ground truth: GPS with GARMIN eTex10

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Ground truth: LAI with Sunscan Canopy Analysis

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Ground truth: 75 days after planting in different fields

Phirun 2 @ Sriracha District

Kasetsart 50 @ Ban Bueng District

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Ground truth: Cassava Roots at 75 DAP

@ Sriracha District

Rayong 9 variety

Phirun 2 variety

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Ground truth: Cassava roots at 120 days after planting

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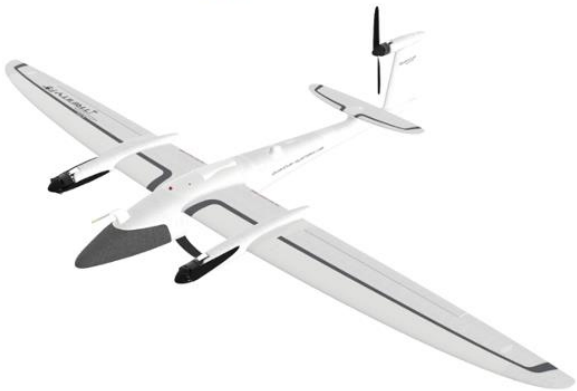
Drone: Trinity F90+ of Quantum-Systems (Germany)

Ground truth



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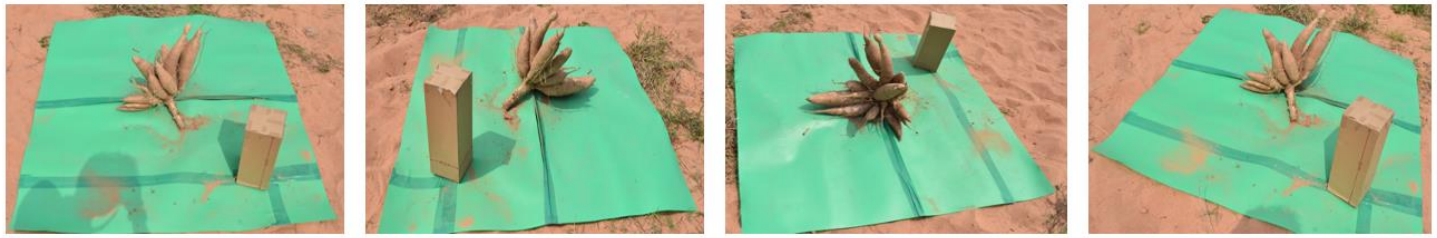
Cassava Root Crown Phenotyping

- Using three-dimension (3D) multi-view stereo reconstruction

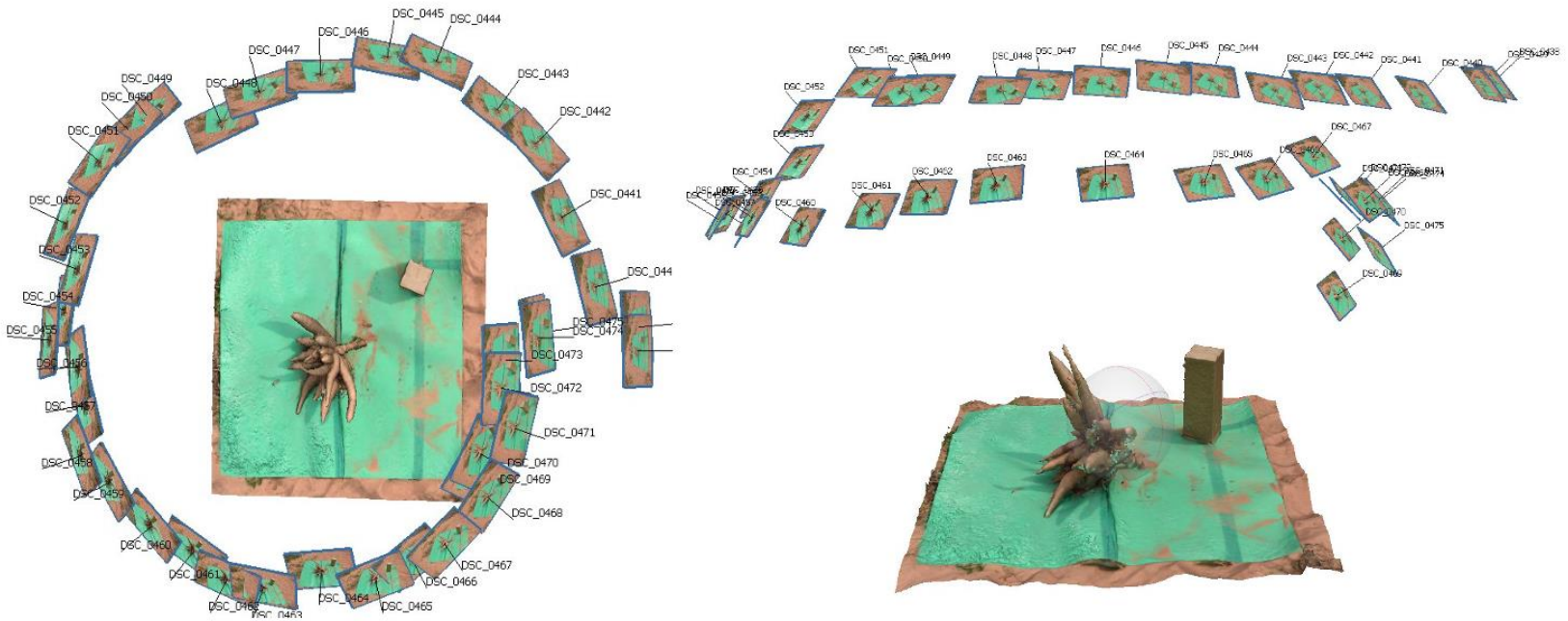
a



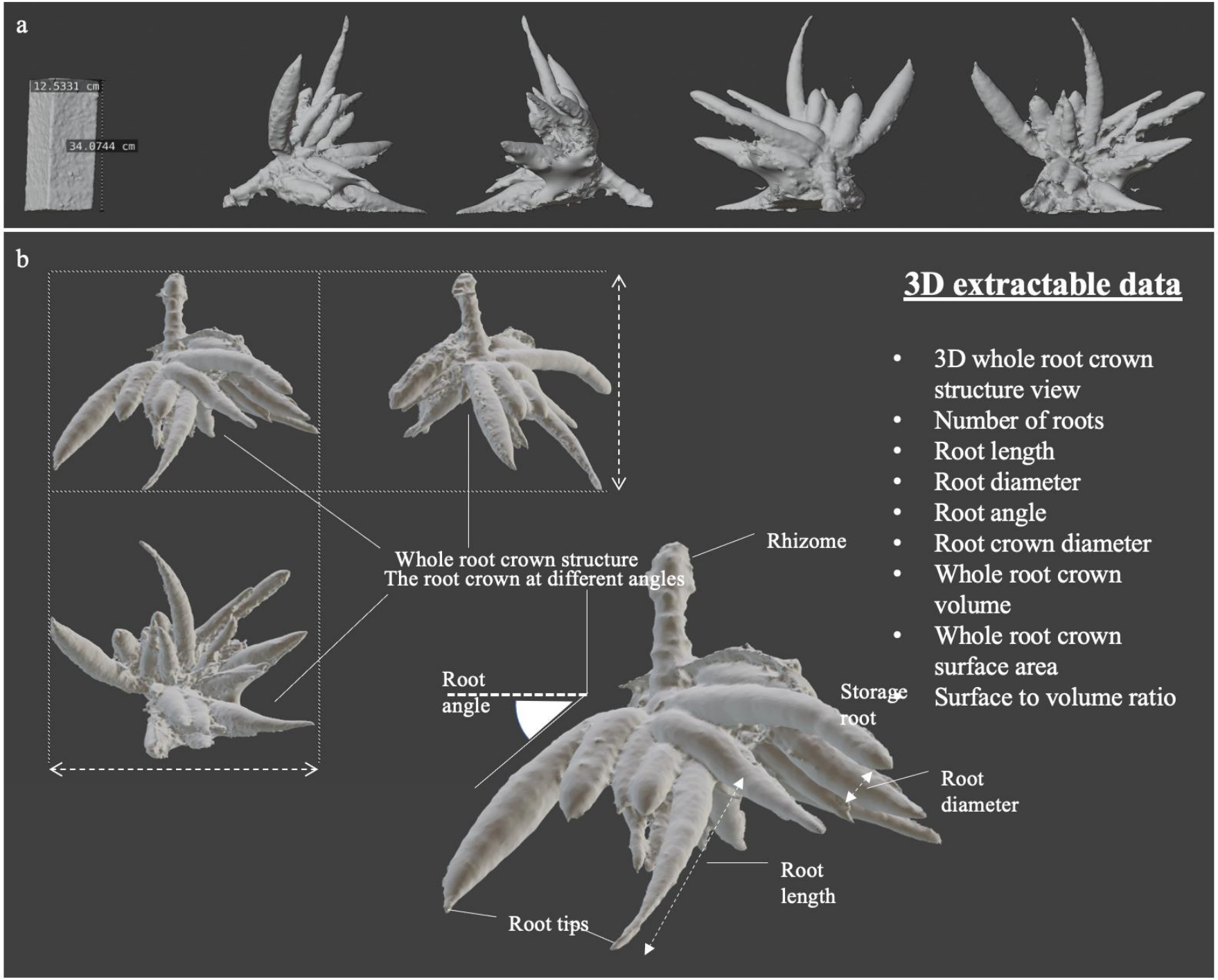
b

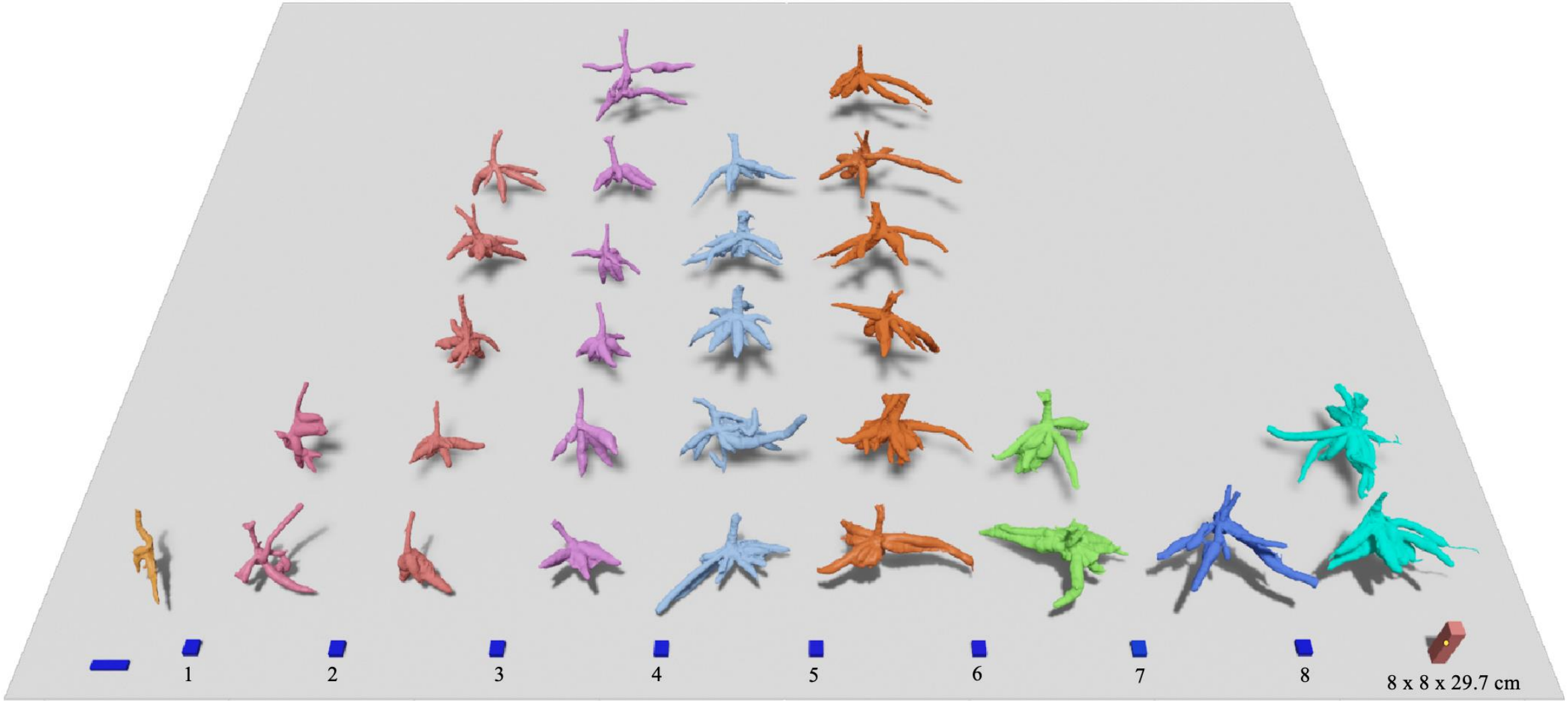
Cassava Root Crown Phenotyping

a



b


a
12.5331 cm
34.0744 cm
b
3D extractable data
3D whole root crown structure view
Number of roots
Root length
Root diameter
Root angle
Root crown diameter
Whole root crown volume
Whole root crown surface area
Surface to volume ratio
Whole root crown structure
The root crown at different angles
Rhizome
Root angle
Storage root
Root diameter
Root length
Root tips



Volume (x1000, cm^3)

scientific reports

Check for updates

OPEN

Cassava root crown phenotyping using three-dimension (3D) multi-view stereo reconstruction

Pongsakorn Sunvittayakul[1], Piya Kittipadakul[2,3], Passorn Wonnapinij[1,4,5], Pornchanan Chanchay[1], Pitchaporn Wannitikul[1], Sukhita Sathitnaitham[1], Phongnapha Phanthanong[2], Kanokphu Changwitchukarn[2], Anongpat Suttangkakul[1,4,5], Hernan Ceballos[1,2,3,4,6] & Supachai Vuttipongchaikij[1,3,4,5]✉

Phenotypic analysis of cassava root crowns (CRCs) so far has been limited to visual inspection and very few measurements due to its laborious process in the field. Here, we developed a platform for acquiring 3D CRC models using close-range photogrammetry for phenotypic analysis. The state of the art is a low cost and easy to set up 3D acquisition requiring only a background sheet, a reference object and a camera, compatible with field experiments in remote areas. We tested different software with CRC samples, and Agisoft and Blender were the most suitable software for generating high-quality 3D models and data analysis, respectively. We optimized the workflow by testing different numbers of images for 3D reconstruction and found that a minimum of 25 images per CRC can provide high quality 3D models. Up to ten traits, including 3D crown volumes, 3D crown surface, root density, surface-to-volume ratio, root numbers, root angle, crown diameter, cylinder soil volume, CRC compactness and root length can be extracted providing novel parameters for studying cassava storage roots. We applied this platform to partial-inbred cassava populations and demonstrated that our platform provides reliable 3D CRC modelling for phenotypic analysis, analysis of genetic variances and supporting breeding selection.

Precision Farming

- **Know the crops:** cultural practice
- **Genotypes:** Hybrids (Inbred x Inbred)
- **Environments:** Physical and biological data in term of environments (seasons, practices, soils)
  - Satellite - Drone
  - Smart sensor (IoT)
  - Genotyping and phenotyping
  - -Omics data (transcriptomics, metagenomics, metabolomics)
- **Long term crowdsourcing data:** five years, 1 - 10 K sites
- **Analyses:** Machine Learning, Data Mining, Meta-analysis
- **Team:** expertise from different fields

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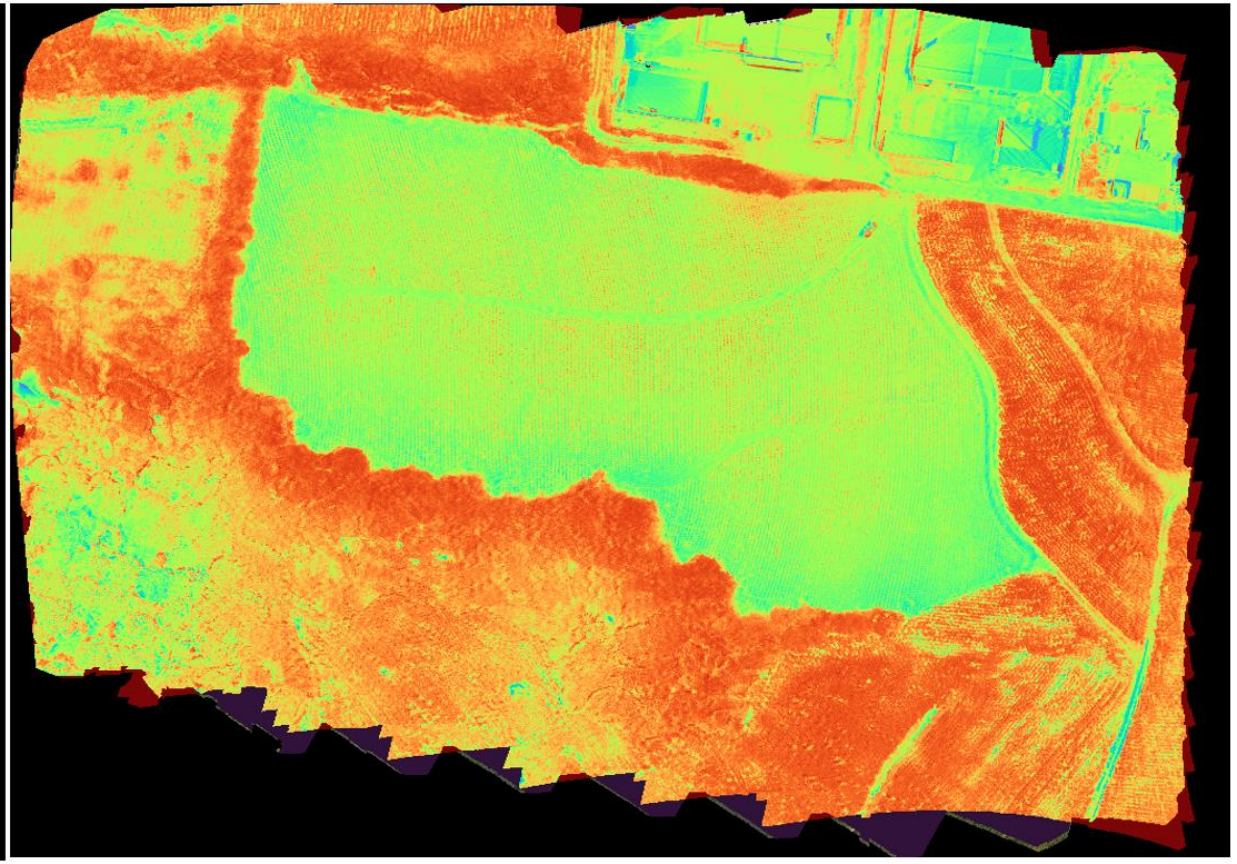

RGB

NDVI

NDVI = (NIR-RED)/(NIR+RED)

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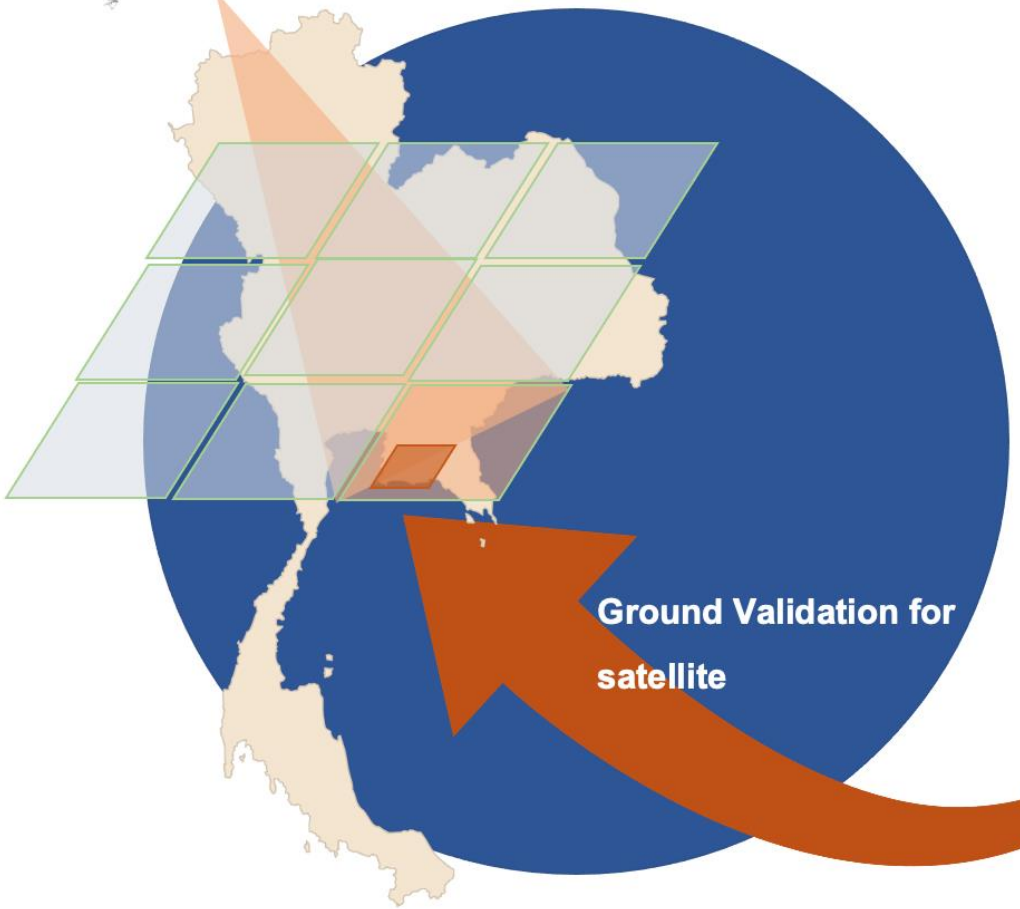
Smart Cassava Farming

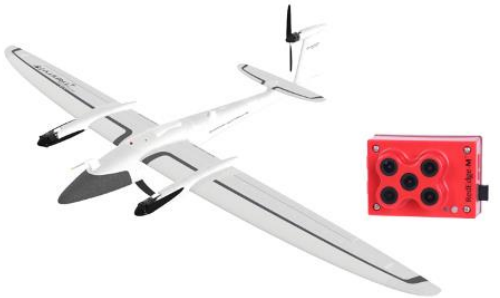
Satellite data for amplifying

Nationwide data



Ground Validation for satellite

Multispectral Sensor

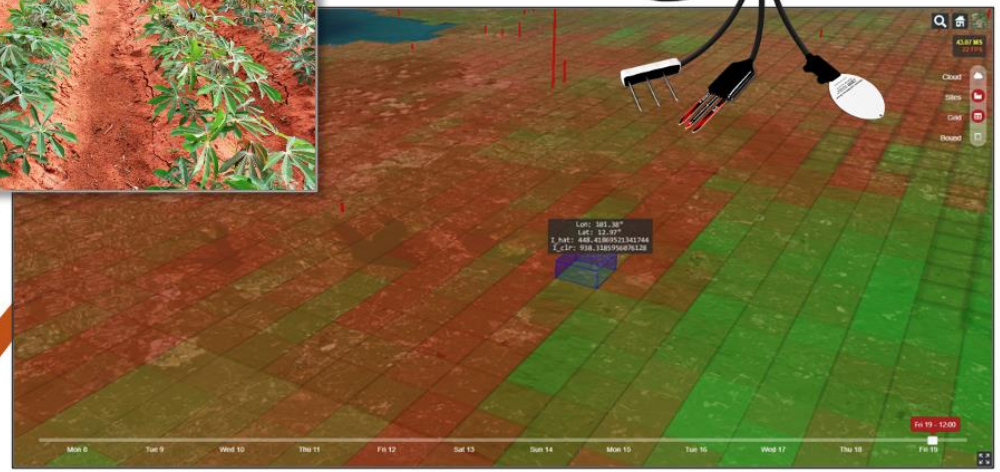


IoT

Rainfall, Temperature,

Soil moisture, Soil condition,

Light



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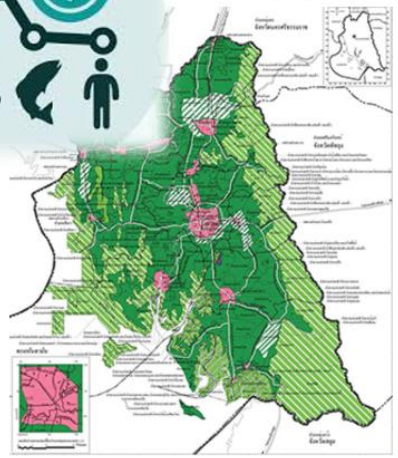
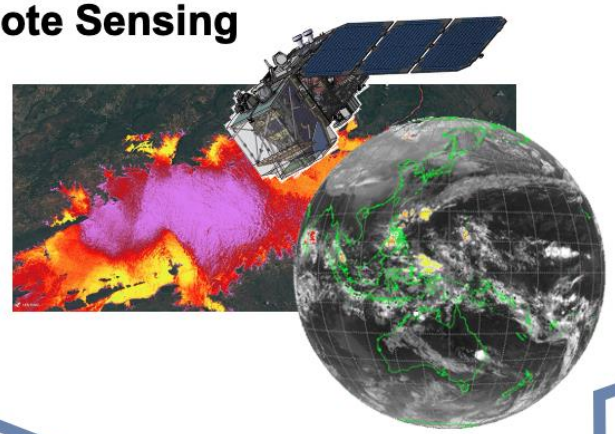
Land use data



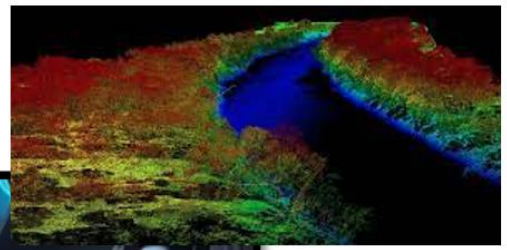
Remote Sensing



Crowdsourcing

Survey data

Ground truth



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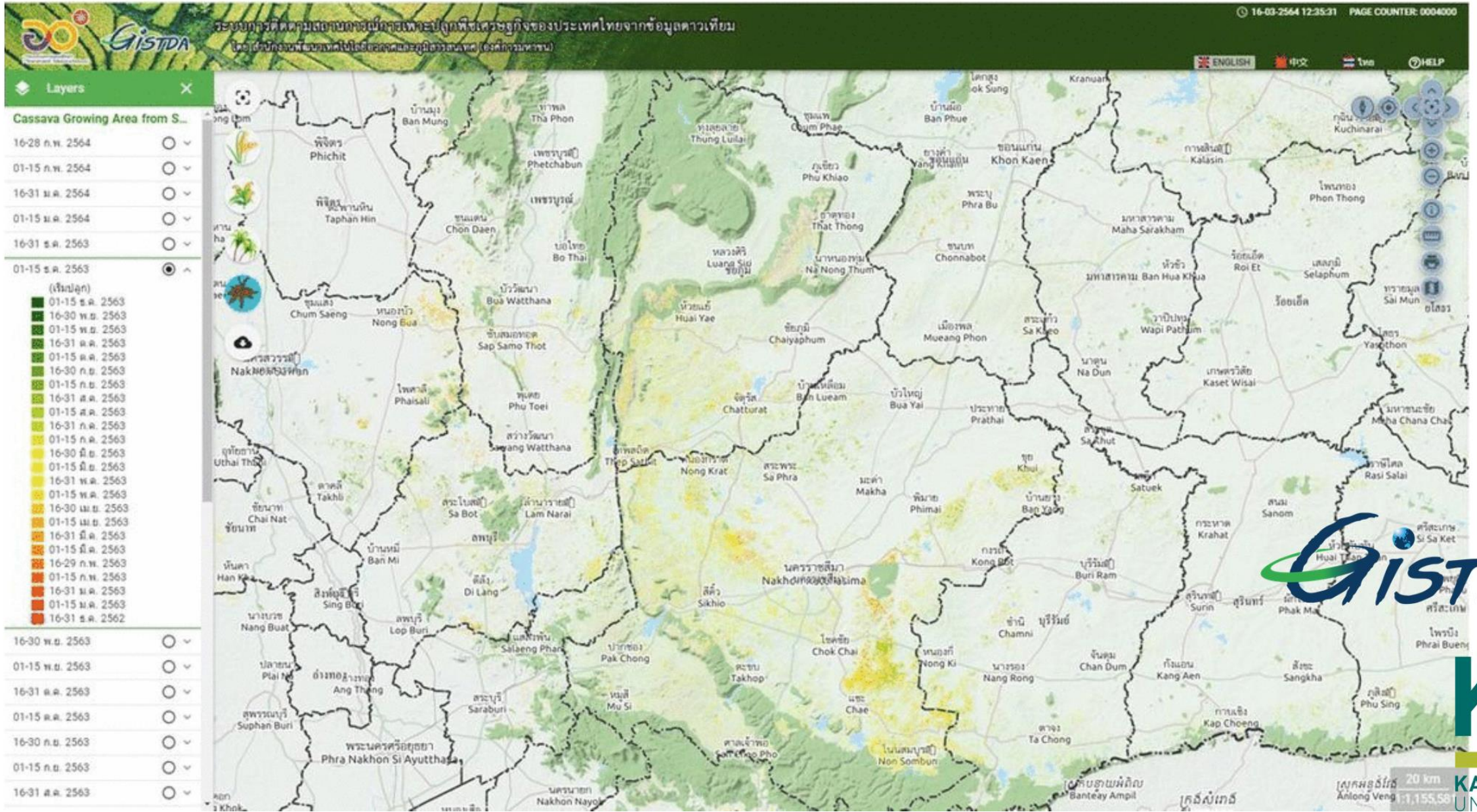
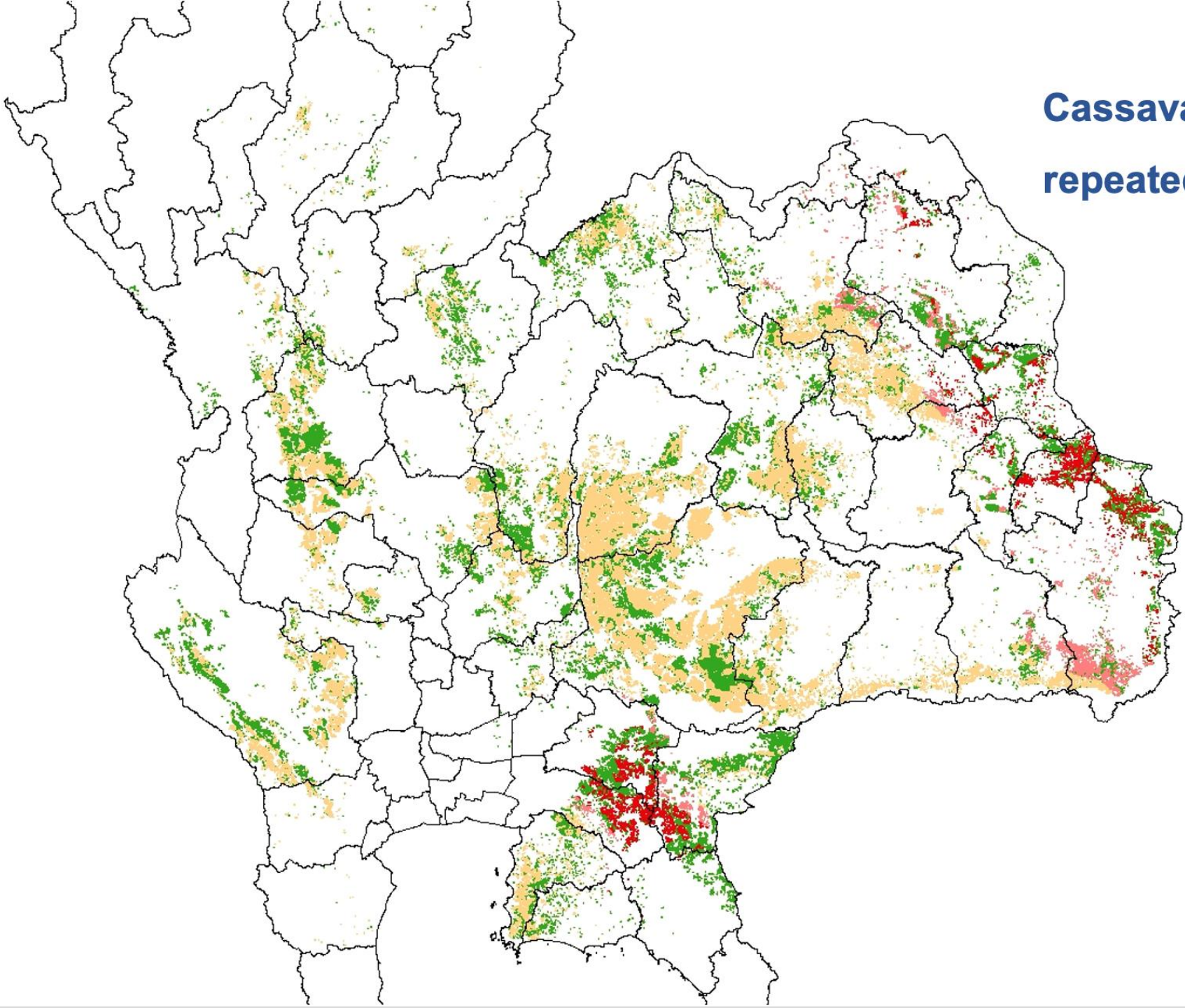
Thailand Cassava Plantation Area Monitoring from Satellite





Cassava plantation in repeated drought areas over 10 years

- **Drought 1-3 times a year of 638,131 ha**
- **Drought 4-5 times a year of 35,855 ha**
- **Drought 6-10 times a year of 46,862 ha**

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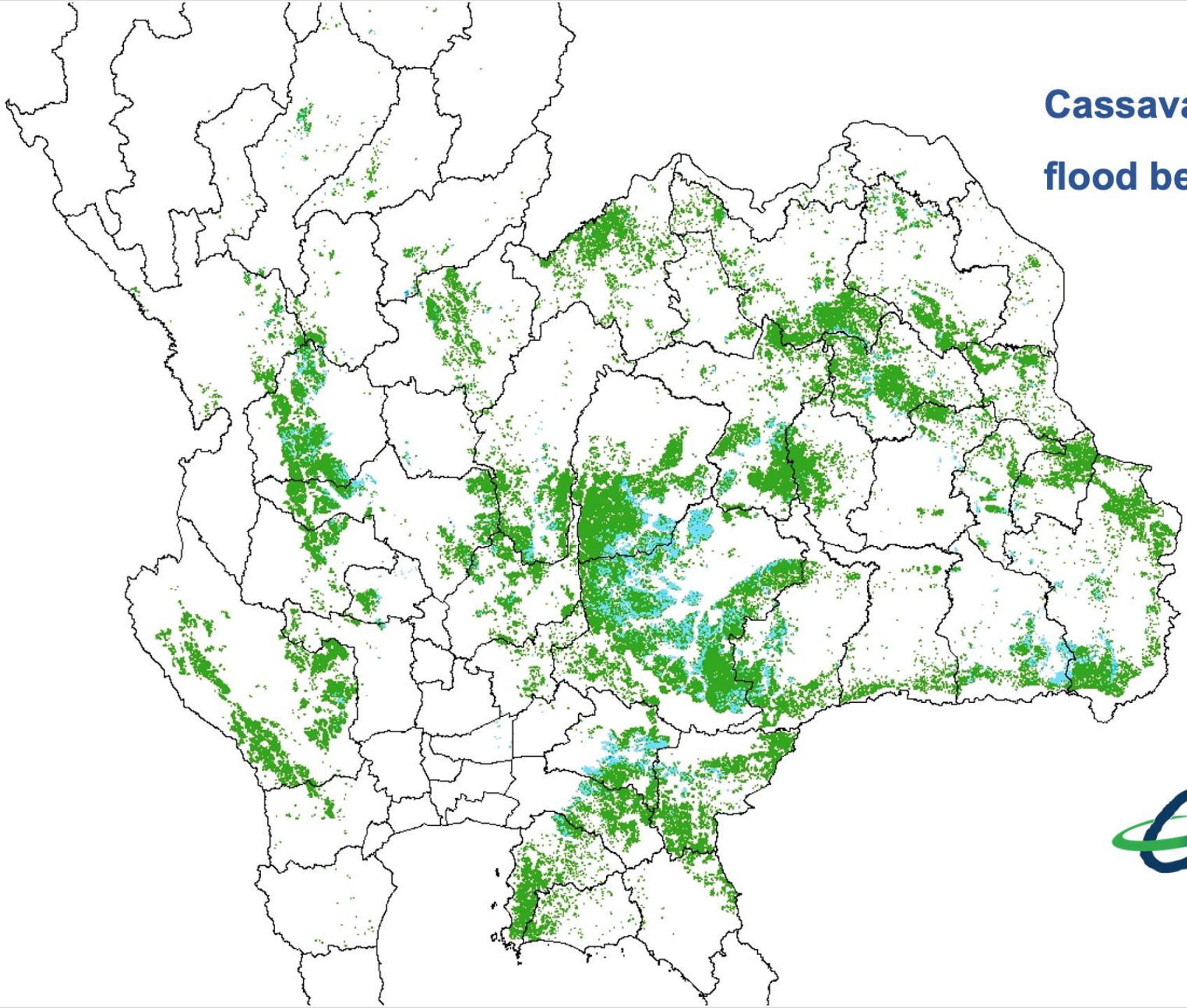

Cassava plantation in flood bed areas over 13 years

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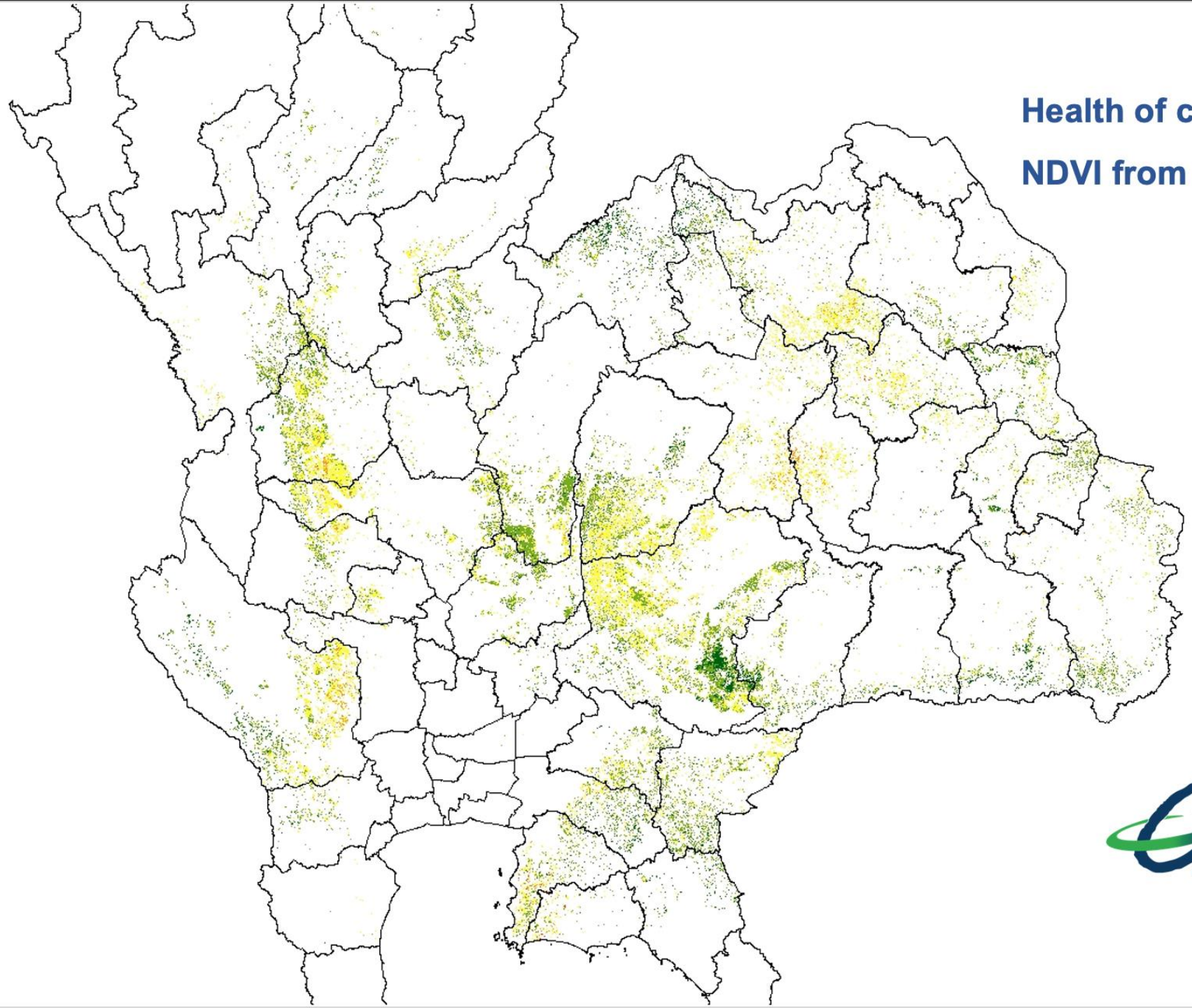

Health of cassava growth reflexed by NDVI from satellite over 10 years

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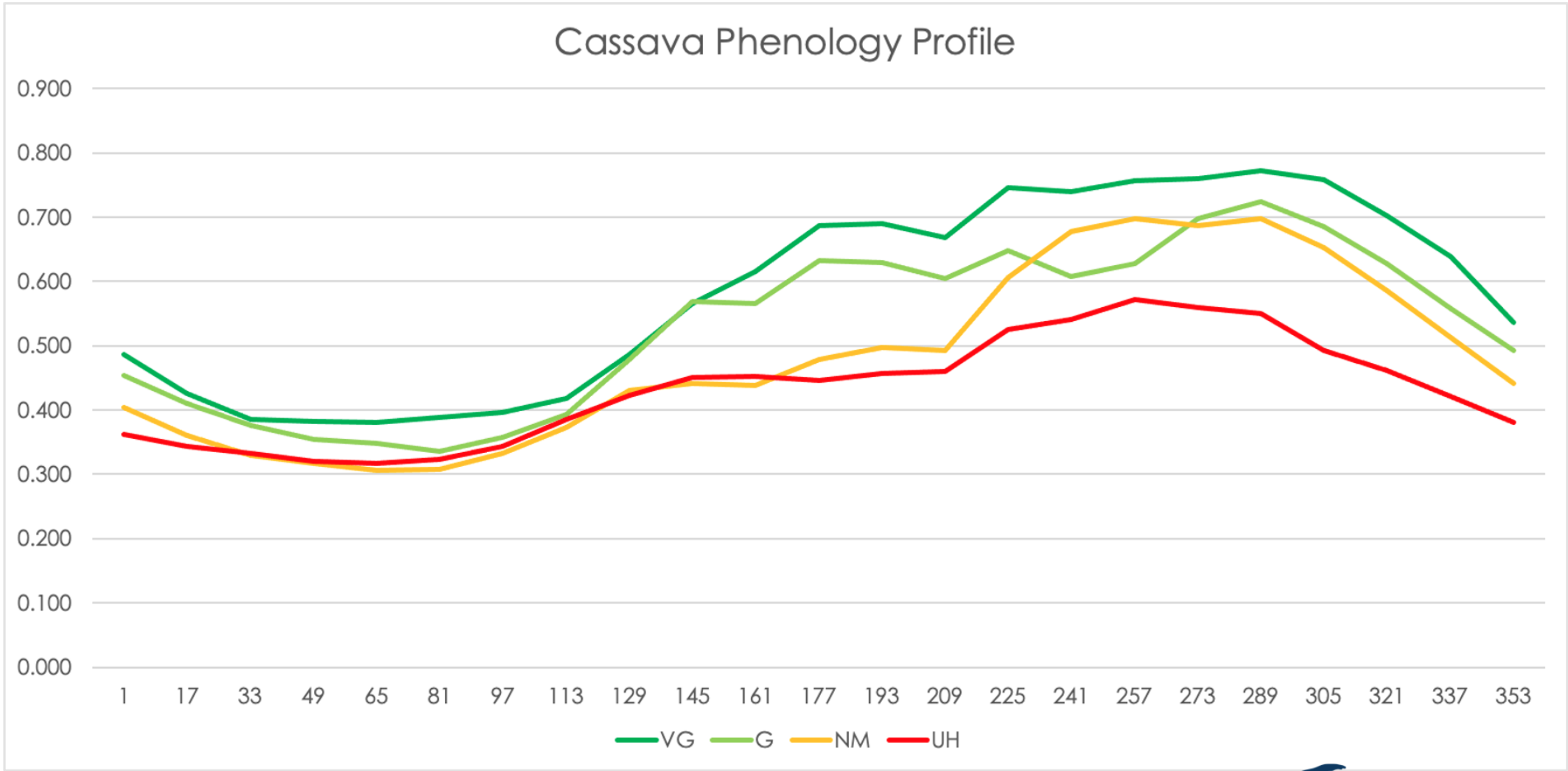
NDVI reflex cassava health in growth period



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The Index for Plant Health and Yield Assessment

- Normalize Difference Vegetation Index: NDVI
- Ratio Vegetation Index: RVI
- Green Normalized Difference Vegetation Index: GNDVI
- Leaf area Index: LAI
- Soil Adjusted Vegetation Index: SAVI

GISTDA

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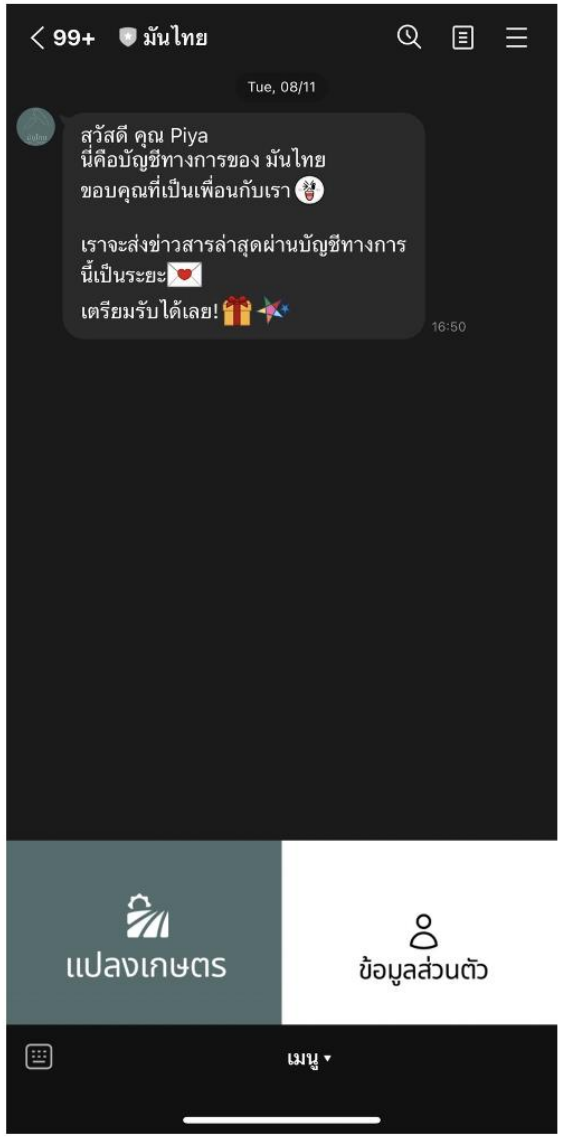
Crowdsourcing

Mobile Application “Mun Thai” : Production plot database



Mobile Application “Mun Thai” via Line application

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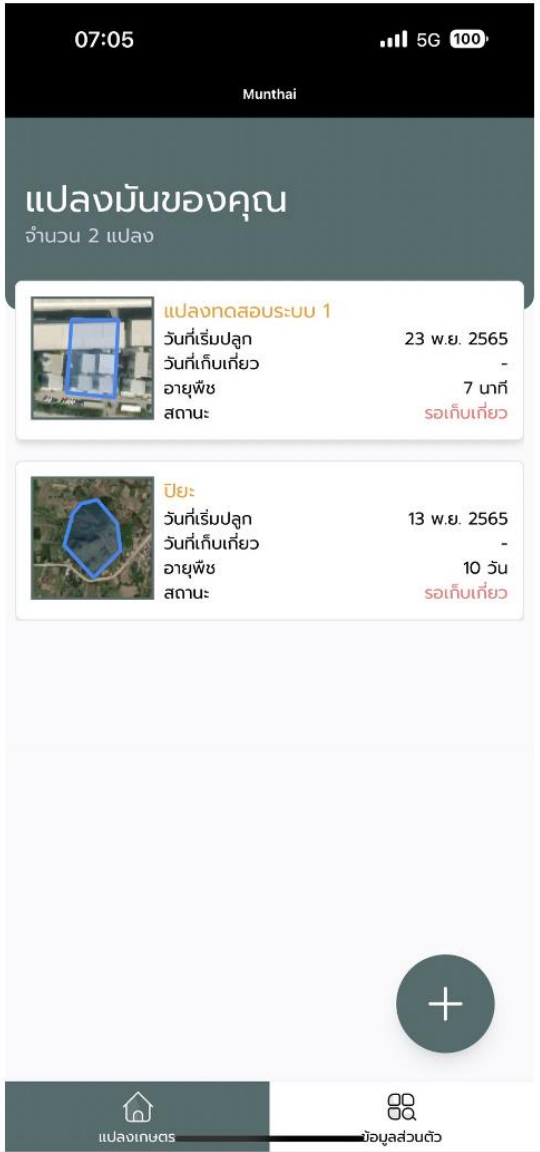
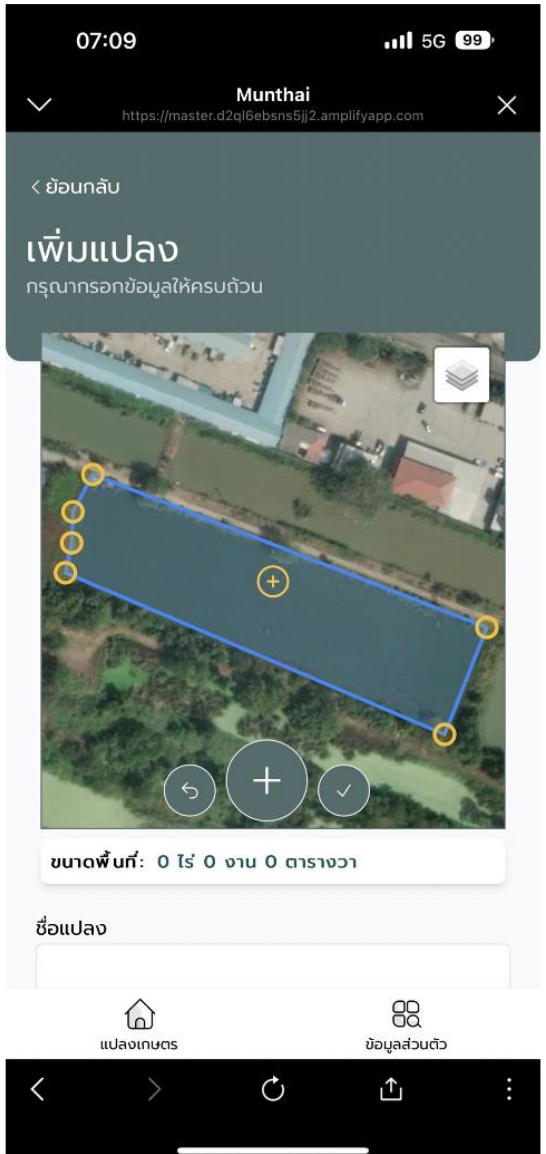
Crowdsourcing





- Crating Shape File
- Field ID & detail
- Farm management detail
- Harvesting

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Sustainable Smart Framing

take-home message

- **Enough trial sites** => enough field data
- **Expert team** => right tools for smart farming
- **Good data scientists** => right direction/result from data
- **Long-term database** => increase accuracy
- **Continuously developing platform** => user friendly for users
- **Enough budget** => guarantee to improve a practical system

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Future Collaborations

- **Development and technology transfer of smart agriculture and hands-on breeding programs for sustainable cassava production in Lancang-Mekong region (Lao PDR, Cambodia, Vietnam and Thailand)**
- **Participating LMC Countries:** Thailand, Lao PDR, Cambodia Vietnam and China

BURLEIGH DODDS SERIES IN AGRICULTURAL SCIENCE

Achieving sustainable cultivation of cassava

Volume 2: Genetics, breeding, pests and diseases

Edited by Dr Clair Hershey, formerly International Center for Tropical Agriculture (CIAT), Colombia

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Breeding cassava for higher yield

Piya Kittipadakul, Pasajee Kongsil and Chalermpol Phumichai, Kasetsart University, Thailand; and Shelley H. Jansky, USDA-ARS Vegetable Crops Research Unit and University of Wisconsin-Madison, USA

1 Introduction

This chapter reviews the strategies and factors for success in cassava breeding for higher yield, including the importance of genetic diversity and breeding schemes. There is a particular focus on Thailand, which has some of the most successful breeding programmes toward improving cassava varieties over a period of more than 40 years. The programmes have increased root yield and starch content, which have provided great benefits to many stakeholders through raising farmers' income and increasing starch production efficiency in the industry.

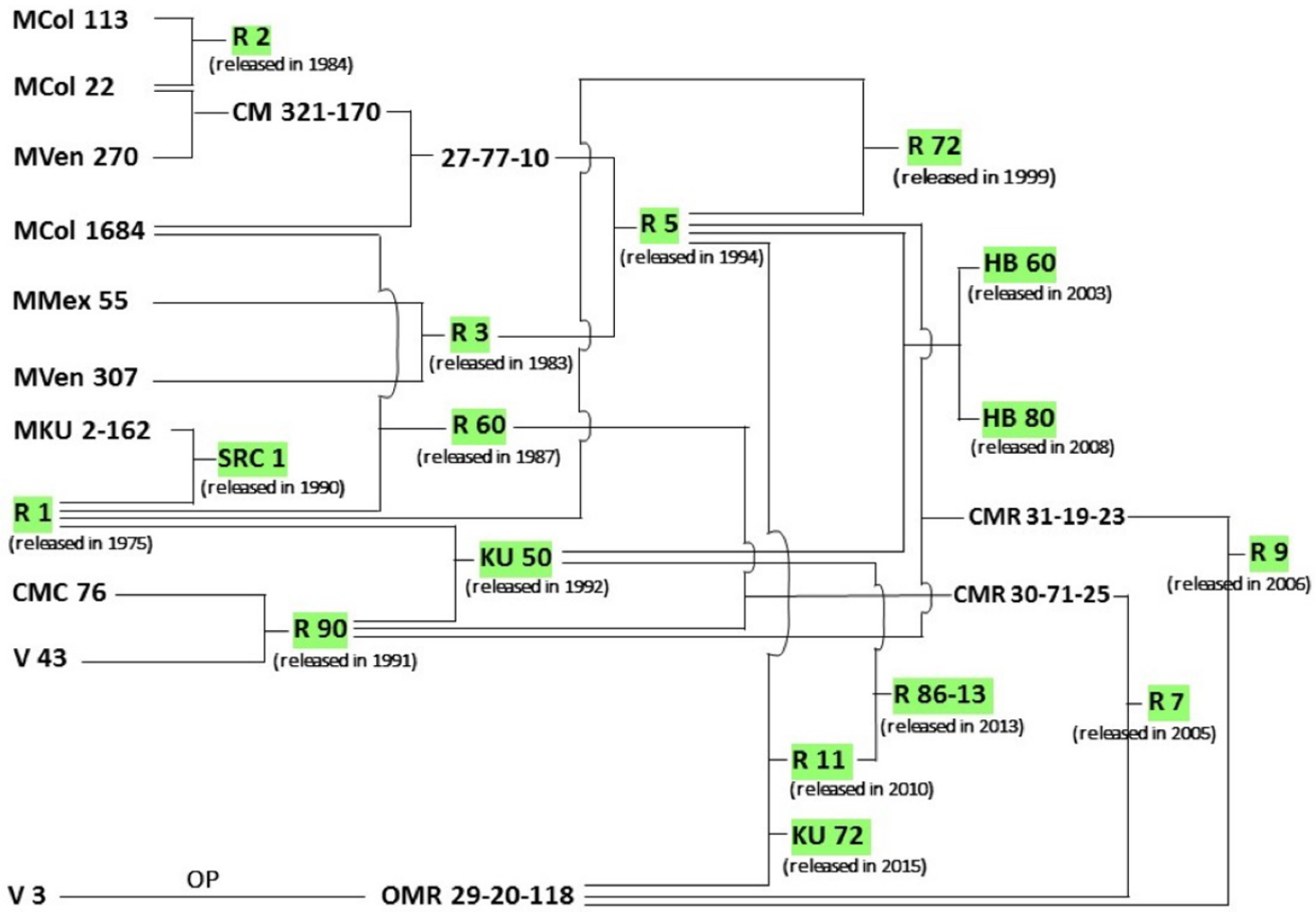
Cassava is a root crop that adapts well to a wide range of both high productivity and stressful environments (Ceballos et al., 2012). Farmers mostly grow cassava in poor soil and drought-stressed areas, where the crop typically has comparative adaptive advantages

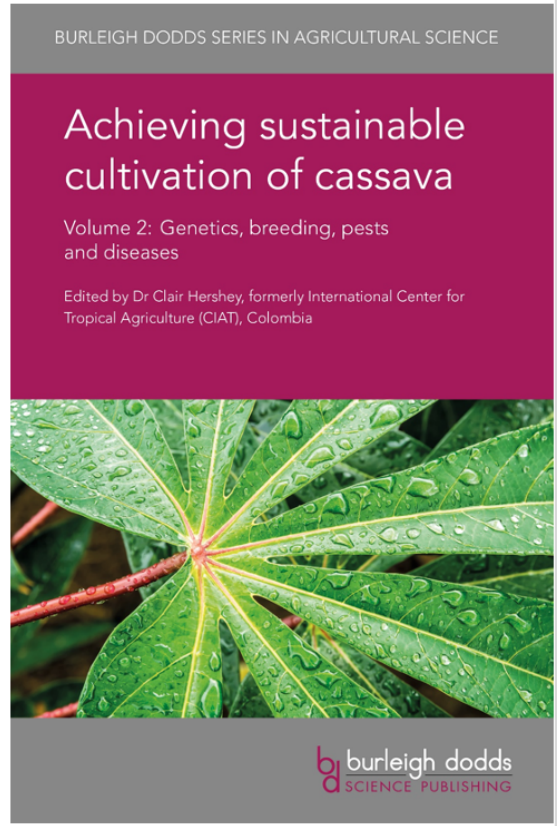
http://dx.doi.org/10.19103/AS.2016.0014.18

p 139 - 170

Kittipadakul, P., P. Kongsil, C. Phumichai, and S.H. Jansky. 2017. Chapter 7 **Breeding cassava for higher yield**, pp. 139-170. *In* C. Hershey, C., eds. Achieving sustainable cultivation of cassava Volume 2: Genetics, breeding, pests and diseases. Burleigh Dodds Science Publishing, Cambridge, UK (ISBN: 9781786760043).

Pedigrees of Thai Cassava Varieties





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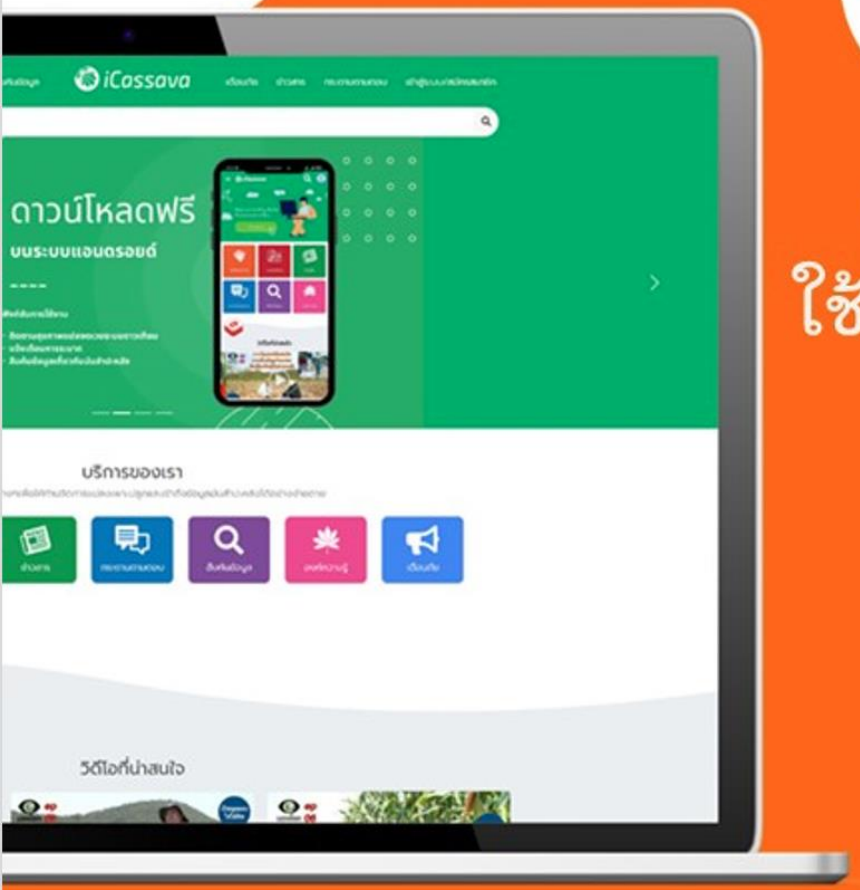

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President of Plant Breeding and Multiplication Association of Thailand

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Evaluation of *manihot glaziovii* scion-cassava understock grafting for cassava growth and root yield during rainy and dry seasons

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ABSTRACT

Grafting of cassava (*Manihot esculenta* Crantz) understocks with scions from *Manihot glaziovii* was proposed to improve the cassava root yield and as a temporal approach to overcoming the problem of cassava mosaic disease (CMD). This work compared performance of nongrafted KU50 with *M. esculenta* grafted as understock with *M. glaziovii*, KU50 or HB80 scions. KU50 and HB80 are released *M. esculenta* varieties. Work was conducted in the field using a randomized complete block design (RCBD) with four replicates in two seasons (rainy and dry seasons) in Thailand. The *M. glaziovii* grafted plants were larger than nongrafted controls. Grafting also increased fresh root yield by 25% (dry season) and 37% (rainy season) and dry matter content by 19% (dry season) and 42% (rainy season) over the nongrafted controls. Net photosynthesis (P_n), stomatal conductance (g_s) and growth parameters indicated that the grafted plants had a higher photosynthetic capacity and more vigorous growth than nongrafted controls during the dry season. Correlation coefficients of P_n and g_s with growth and productivity parameters at different ages of the plant were highly significant during the dry season but not in the rainy season. This study demonstrated that *M. glaziovii*–cassava grafting improved cassava growth and root yield.

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cassava; grafting; *Manihot glaziovii*; Mukibat System; starch; yield trial