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Agronomy and management options for cassava production systems under variable climate scenario

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Outline…..

- Background
- Current status of agronomy
- Effect of climate change on Cassava
- On going research

Cassava in Asia

- More than 8 million farmers grow cassava in Asia covering approximately 4.2 million ha, and it is increasing………
- A direct food crop to an industrial crop ……….. export oriented

	Cambodia	China	India	Indonesia	Laos PDR	Philippines	Thailand	Vietnam
Production ('000 t)	10,207	4,794	4,554	20,775	3,096	2,815	31,161	11,045
Harvest area ('000 ha)	388	291	204	867	94	225	1,462	580
Yield (t ha^{-1})	25.9	16.2	21.9	23.5	32.2	12.3	21.0	18.7
Fertilizer:								
Inorganic	6–38%	Low–high	Med–high	50–95%	<1%	Very little	Up to 75%	74–85%
Organic	1.3%	N/A	N/A	22–32%	<1%	Some		1–6%

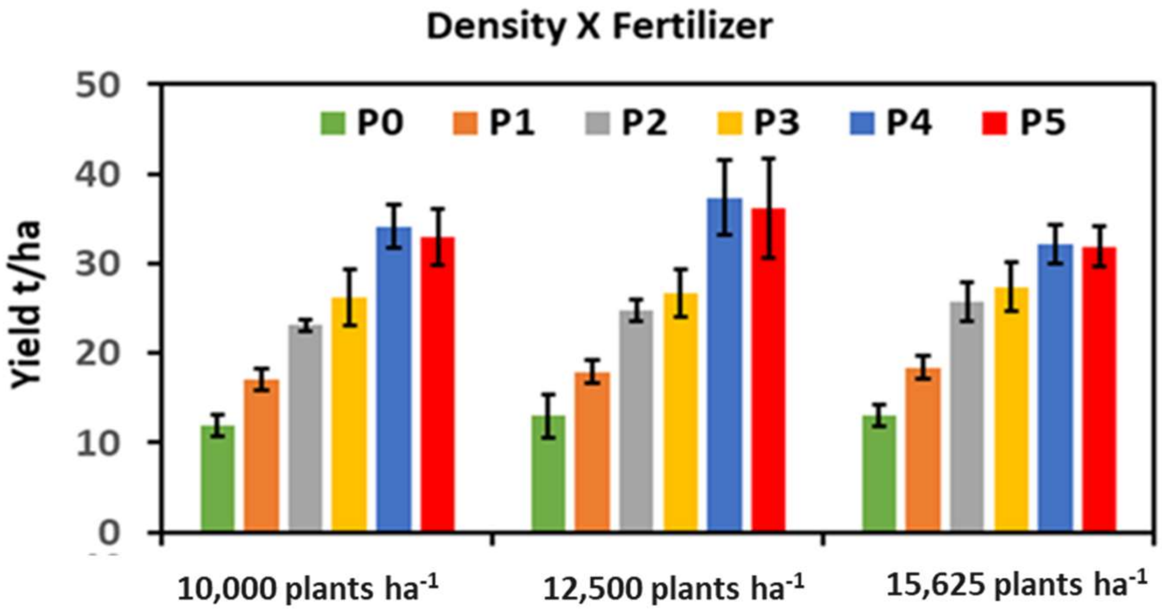
Malik *et al*. 2020

Region	Sikka	North Sumatra	Laos	Cambodia	Son La	Dak Lak
Do you understand what the NPK values mean on the fertiliser you apply?	27.03%	36.23%	0.8%	1.29%	11.3%	11.5%

Smith et al. http://cassavavaluechains.net/wp-content/uploads/2018/09/Discussion-paper-number-8.pdf

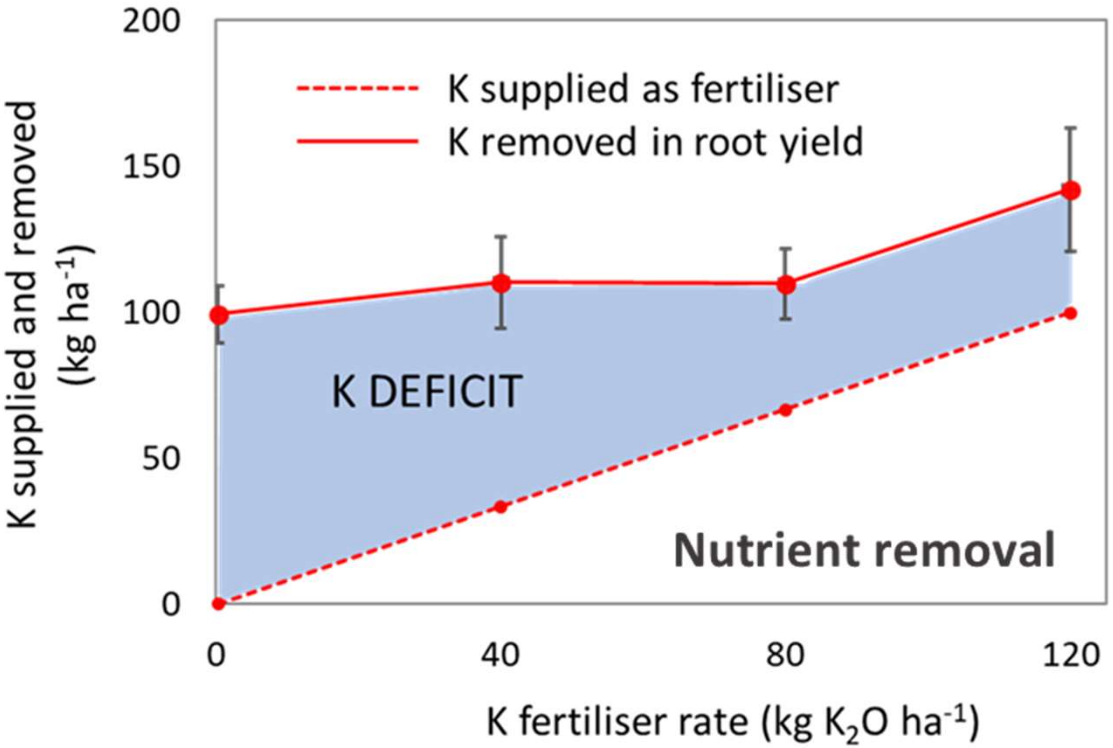
Fertility management:

Fertiliser – What and how much: new mix or market available mix?



Participatory research

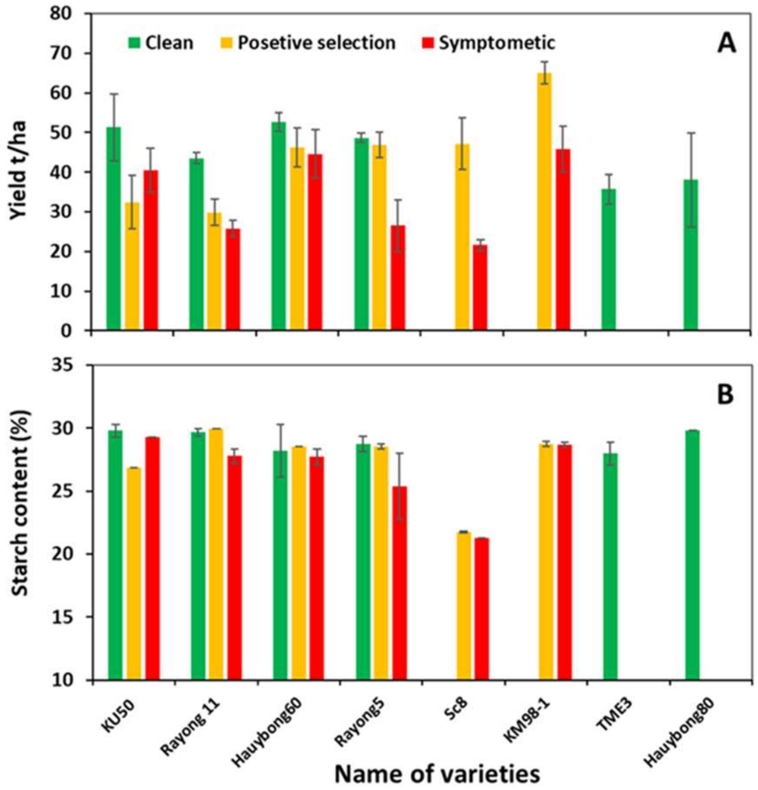
Nutrient balance of the cassava crop



Amounts of K supplied as fertiliser and removed in tuber yield at harvest for treatments (0,40,80,120 kg ha^{-1} K_2O).

Ming et al. (2020) Agronomy, 10, 1103; doi:10.3390/agronomy10081103

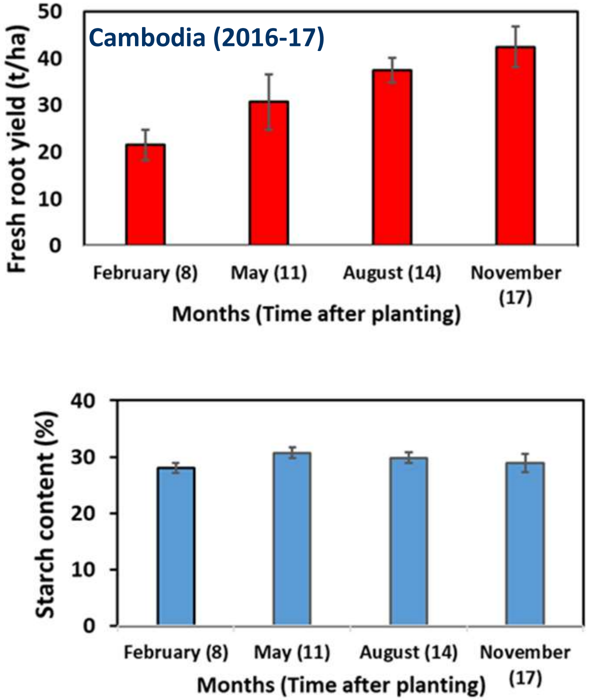
Disease free planting material

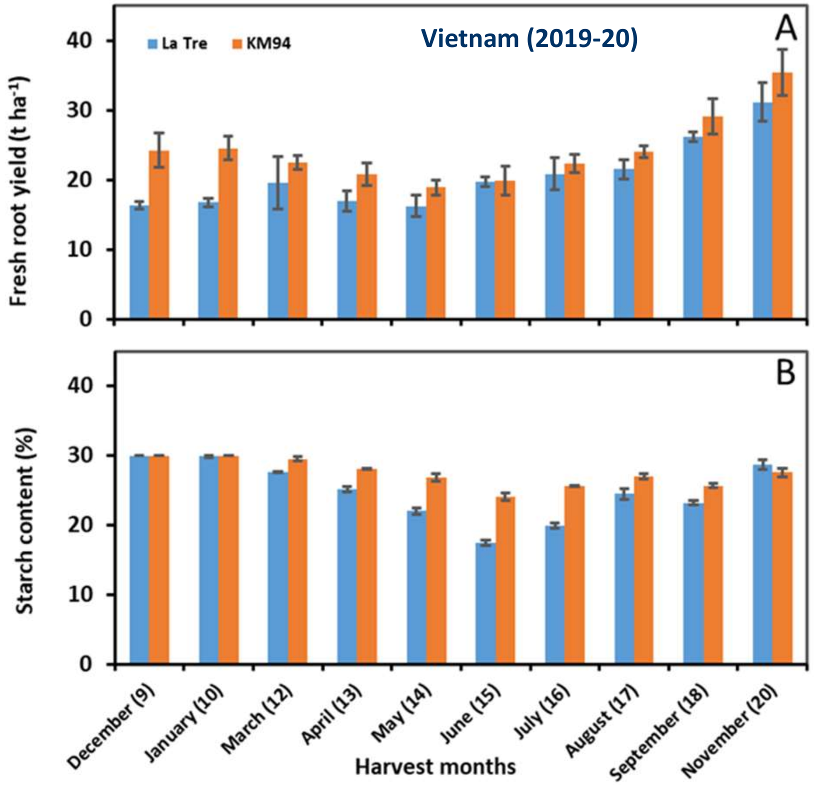


Plot yield was 1.2- to 2.2-fold higher in plants from clean and/or positive selection planting material than those from symptomatic planting material

Clean management practice (i.e. clean [disease free] stakes, timely weeding and fertilization

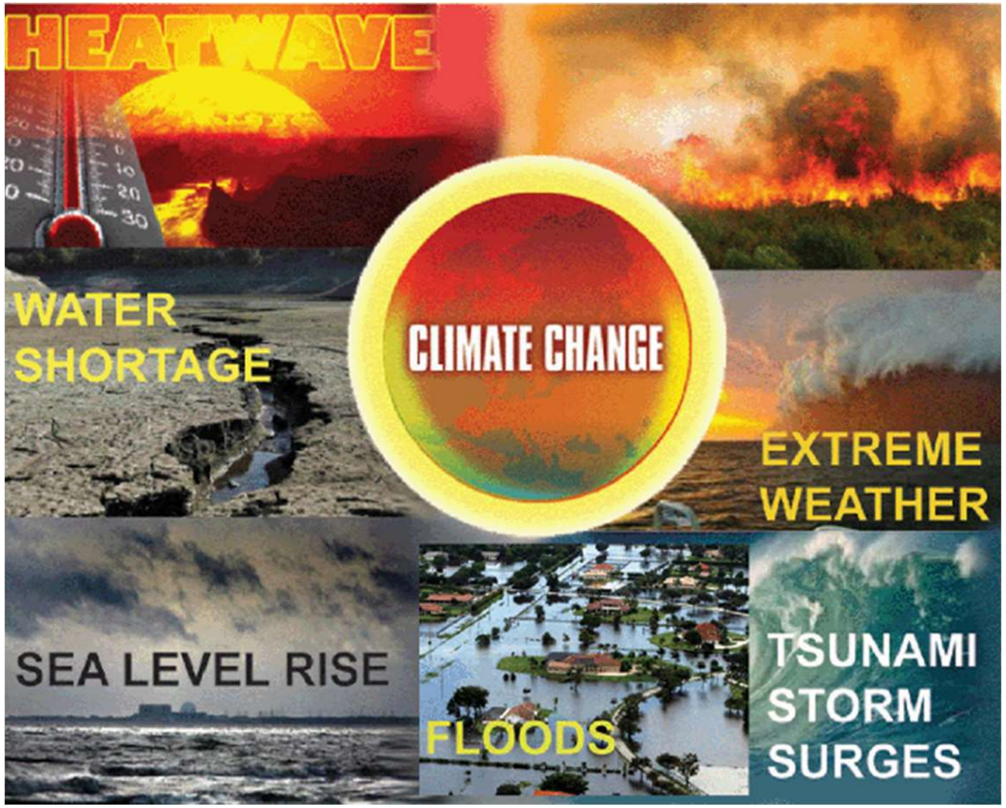
Extending the cassava harvest window





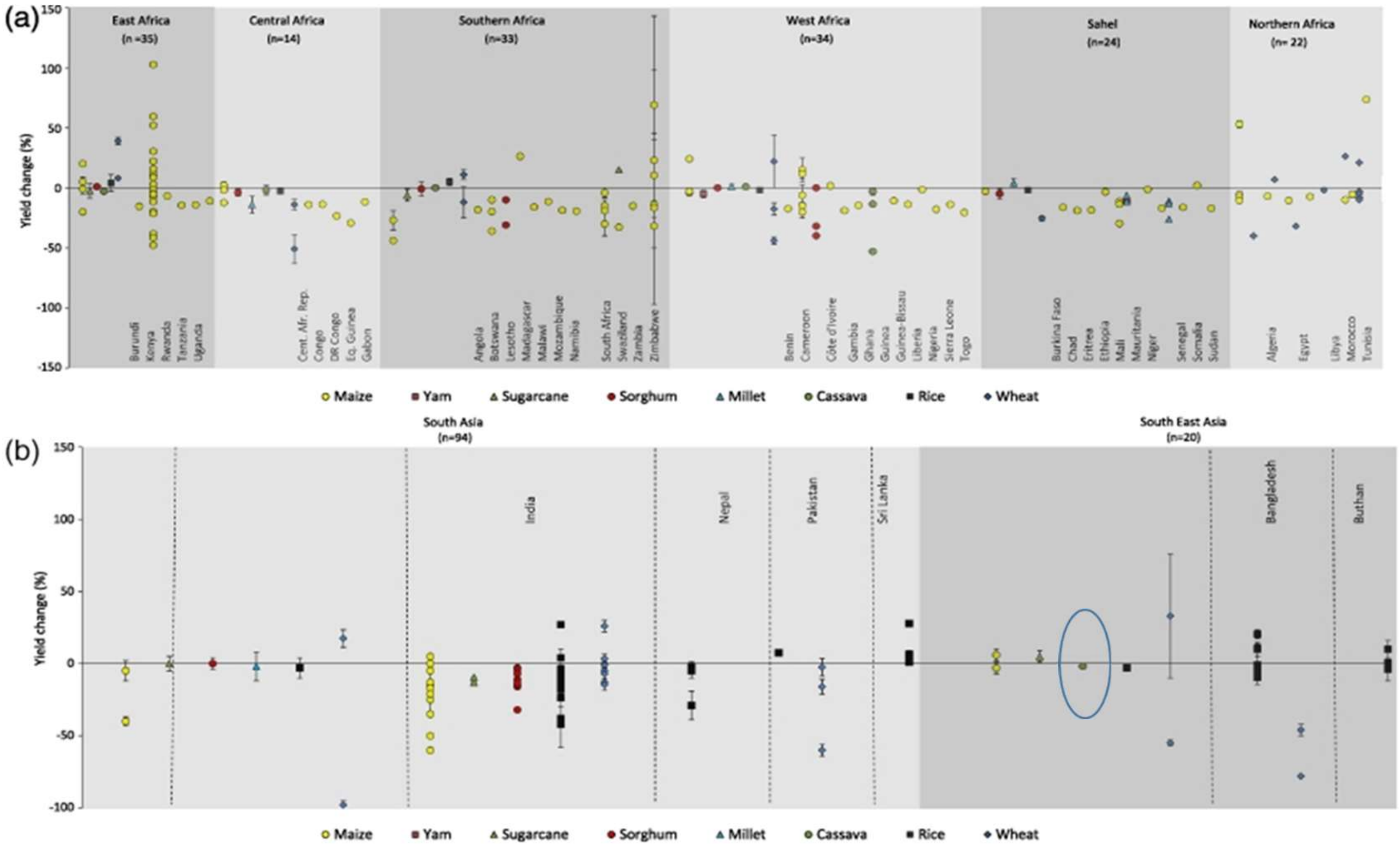
- Fresh root yield of cassava increased with the duration of the crop.
- During rainy season, the starch content was lowest for both varieties
- Risk of disease – especially root rot

Effects of Climate change



- Change in precipitation pattern
- Incidence of drought and heat waves
- Elevated CO_2

Cassava has been identified as resilient crop



Summary of reported mean yield variations (%) in Africa (a) and S. Asia (b). Data shown are for all observations for each crop type, for all crop modelling approaches, all GCM climate models and all time slices.

Climate change impacts on crop productivity in Africa and South Asia
Jerry Knox et al 2012 Environ. Res. Lett. 7 034032 doi:10.1088/1748-9326/7/3/034032

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Wide adaptability of cassava

Grow at sea level up to above 2000m asl

On marginal and highly-eroded low fertility acidic soils

- Cassava yields world wide are 11t ha^{-1}
- ~9tha^{-1} in Africa and ~22 t ha^{-1} in Asia.

Some improved cassava cultivars under near-optimum condition yields as high as 90t ha^{-1}

The most diverse utilization of cassava in Asia

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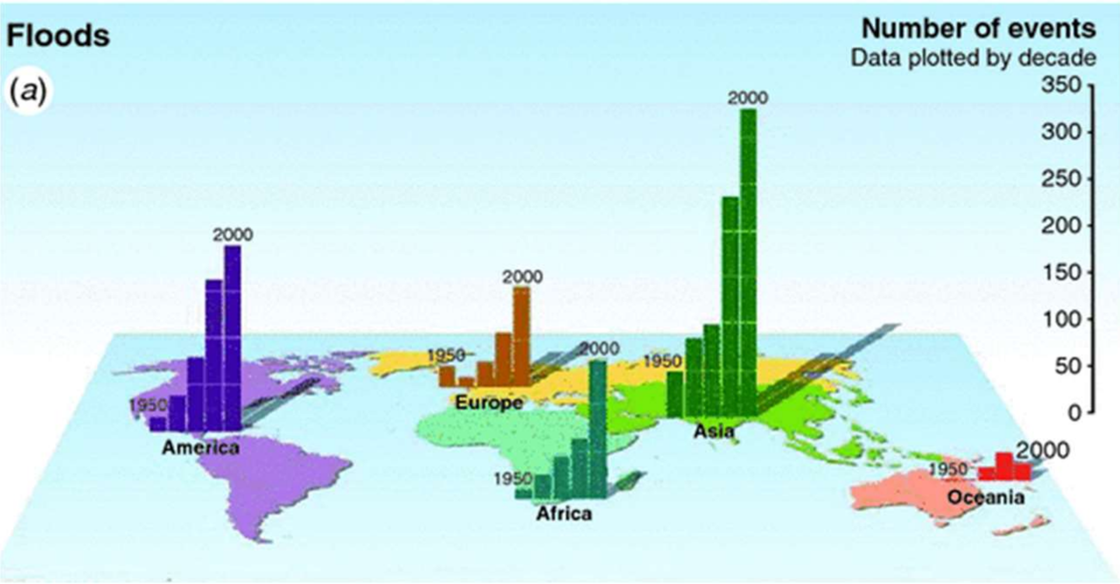
Challenges

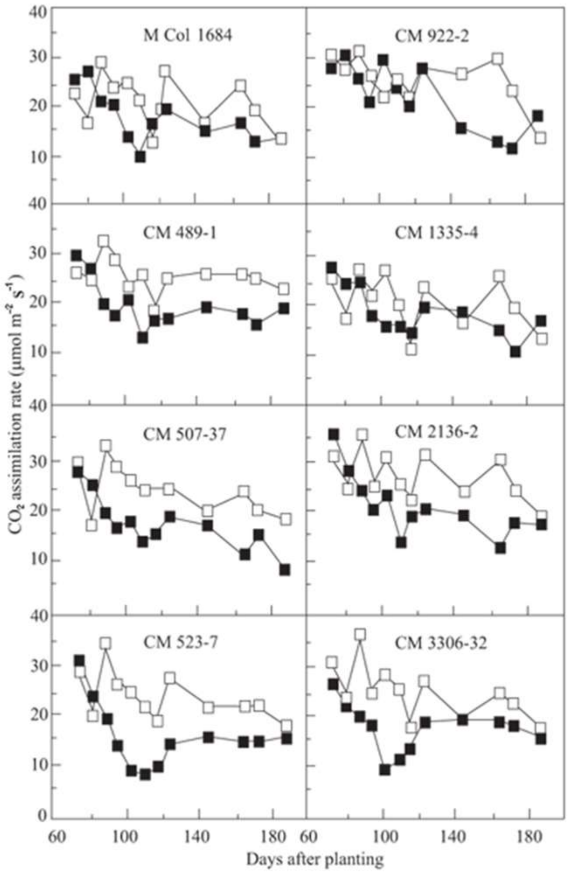
- Abiotic stresses:
- Biotic Stresses:

Abiotic stresses:

- Longer drought
- Increase flooding
- Frequent cold and heat wave
- Stronger storms, cyclone and hurricanes
- Green house gas and elevated CO_2



High photosynthetic capacity of cassava leaves in favourable environments



Response of Cassava leaf photosynthesis to prolonged water stress (120 days), imposed at 60 DAP

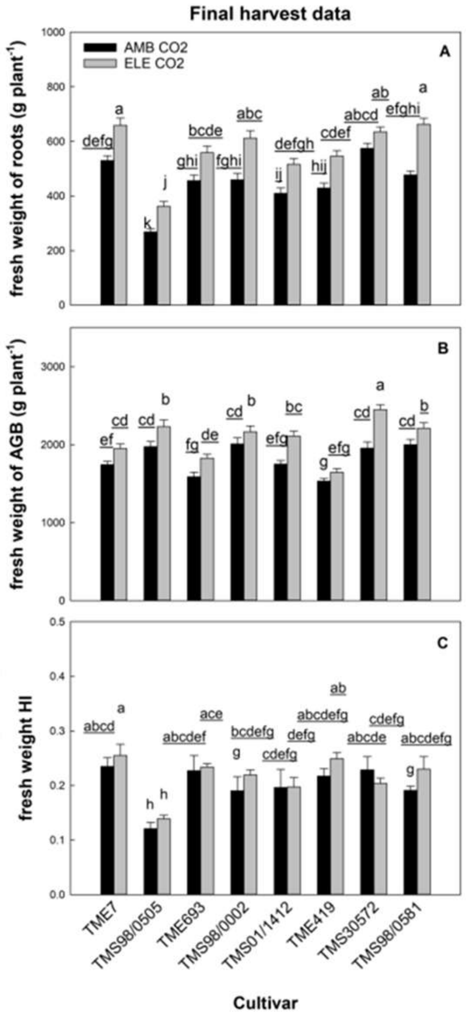
El-Sharkawy (2007) Braz. J. Plant Physiol. vol.19 no.4, doi.org/10.1590/S1677-04202007000400003

Some earlier work on photosynthesis

- El-Sharkawy, M.A. (2006). International research on cassava photosynthesis, productivity, eco-physiology, and responses to environmental stress in the tropics. Photosynthetica 44(4): 481-512.
- El-Sharkawy, M.A. (2010). Comparative photosynthesis, growth, productivity, and nutrient use efficiency among tall-and short-stemmed rain-fed cassava cultivars. Photosynthetica 44(4): 481-512.

Effect of Elevated CO_2 on Cassava

Free-Air Carbon Dioxide Enrichment (FACE experiment)



Ursula M. Ruiz-Vera et al (2020) Journal of Experimental Botany, doi.org/10.1093/jxb/eraa459

Table 2. Direction of change in net carbon dioxide (CO_2) assimilation rate and root:shoot ratio of cassava plants grown in experimental conditions, with different concentrations of atmospheric CO_2 (ambient and elevated) and soil N supply, from three published studies.

CO_2 concentrations	Duration & Experiment type	Net CO_2 assimilation rate	Root: shoot ratio	N supply	Reference
350 ppm 700 ppm	3 months, Glasshouse	Lower at elevated CO_2 (measured after 2 months)[a]	Increased	Supplied as compound fertiliser twice during experiment	Imai *et al.* 1984 [191]
360 ppm 550 ppm 710 ppm	9 months, Glasshouse	Lower at 710 ppm than 550 and 360 ppm *, N.S. between 550 and 360 ppm (measured after 3 months)[b]	Decreased	1 mM & 12 mM N in Hewitt's solution, 3 times per week	Gleadow *et al.* 2009 [169]
480 ppm 680 ppm	8 months, Field	Higher at elevated CO_2 but N.S (measured after 2.5 and 7 months)[c]	No change	N:P:K:Mg (18:18:18:3) 4.1 kg/ha, once at beginning of experiment	Fernandez *et al.* 2002 [192]

* $P < 0.05$; N.S.: not significantly different; a. See Figure 1 of [191]; b. see Figure 3 of [169]; c. see Figure 1 and Table 2 of [192].

Burns et al. 2010, *Sustainability 2:* 3572-3607; doi:10.3390/su2113572

Genetics study on traits resilient to climate variables is important

European Journal of Agronomy 115 (2020) 126031

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Importance of genetic parameters and uncertainty of MANIHOT, a new mechanistic cassava simulation model

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Sobol
DSSAT
Sensitivity analysis

ABSTRACT

We identified the most sensitive genotype-specific parameters (GSPs) and their contribution to the uncertainty of the MANIHOT simulation model. We applied a global sensitivity and uncertainty analysis (GSUA) of the GSPs to the simulation outputs for the cassava development, growth, and yield in contrasting environments. We compared enhanced Sampling for Uniformity, a qualitative screening method new to crop simulation modeling, and Sobol, a quantitative, variance-based method. About 80% of the GSPs contributed to most of the variation in maximum leaf area index (LAI), yield, and aboveground biomass at harvest. Relative importance of the GSPs

Tropical Plant Biology
https://doi.org/10.1007/s12042-020-09255-2

Is Cassava (*Manihot esculenta Crantz*) a Climate "Smart" Crop? A Review in the Context of Bridging Future Food Demand Gap

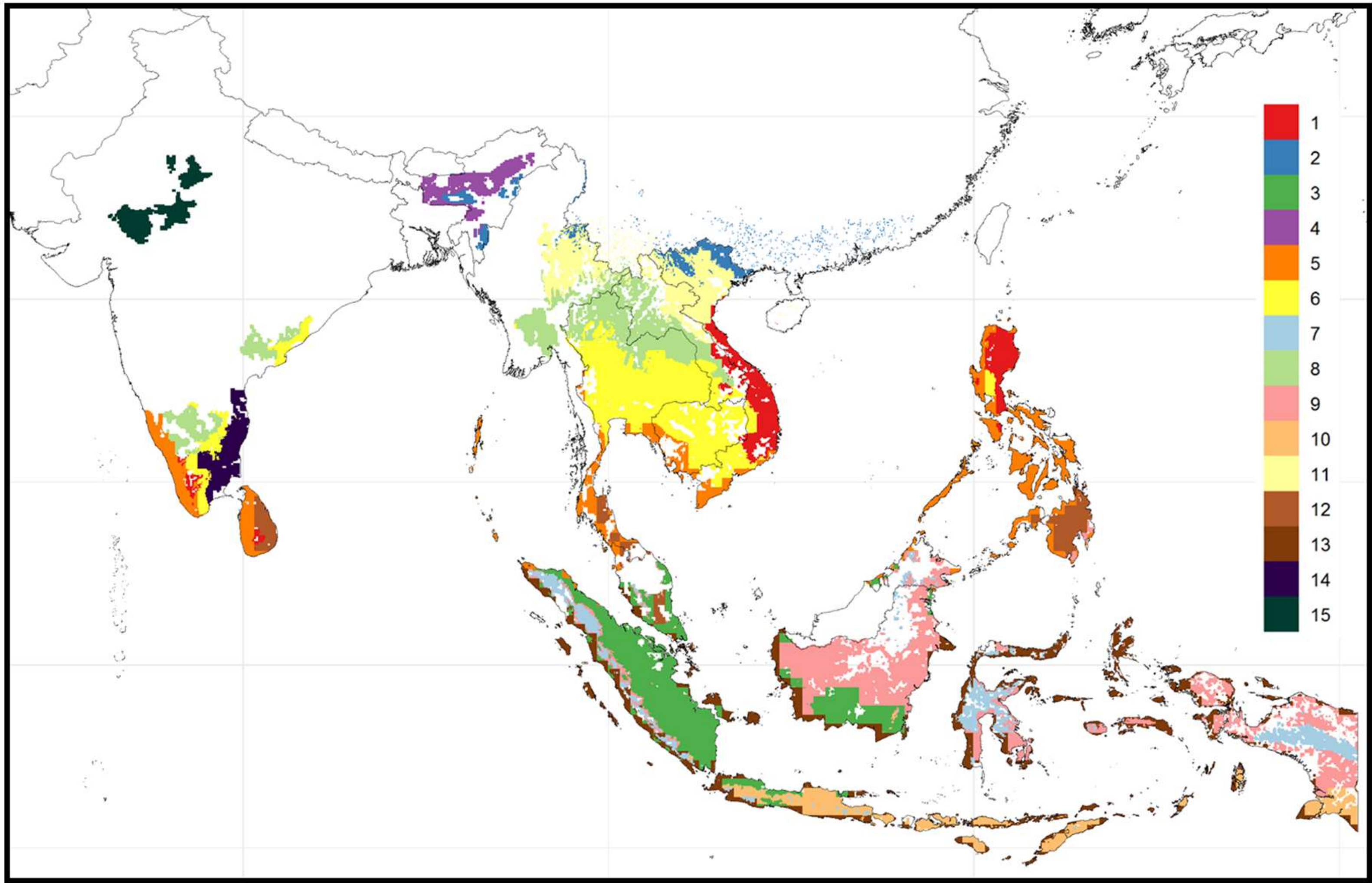
Raji Pushpalatha[1] · Byju Gangadharan[1]

Received: 17 June 2019 / Accepted: 13 February 2020

Abstract

Climate change and its impact on agriculture are one of the ongoing research areas, and the major task among agricultural managers is to meet the food demand in the future in the context of the production gap of major food grain crops. Literature analysis is carried out to understand the climate resilience of cassava, one of the major tuber crops and is considered to bridge the food demand gap in the near future. Systematic analysis of literature includes influence of changing environmental parameters such as temperature, solar radiation, photoperiod, air humidity, soil water deficit, salinity, elevated ozone and CO_2, combined effects of elevated CO_2 with temperature, water deficit and salinity to the growth and yield of cassava along with its resilience to

Environments in Asia

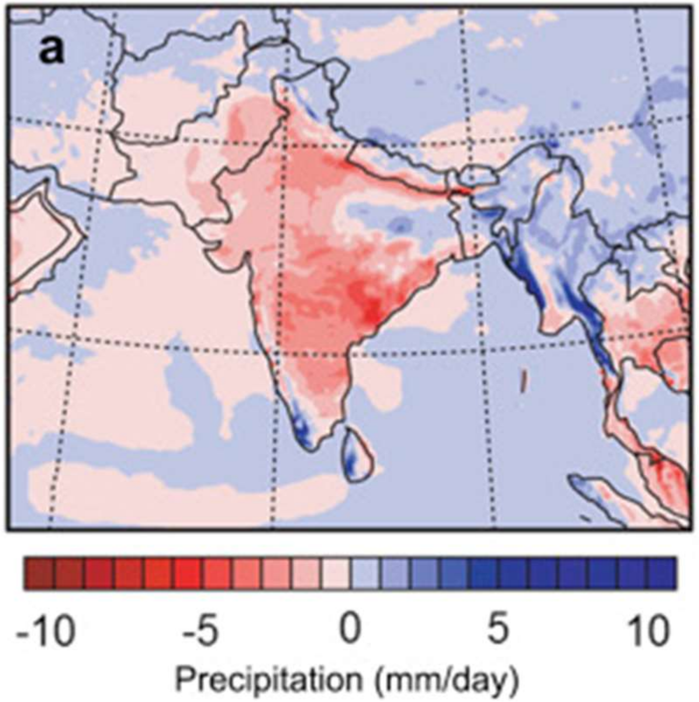


Change in weather pattern in South Asia

Monsoon rainfall determine the sowing time for rain-fed cropping systems

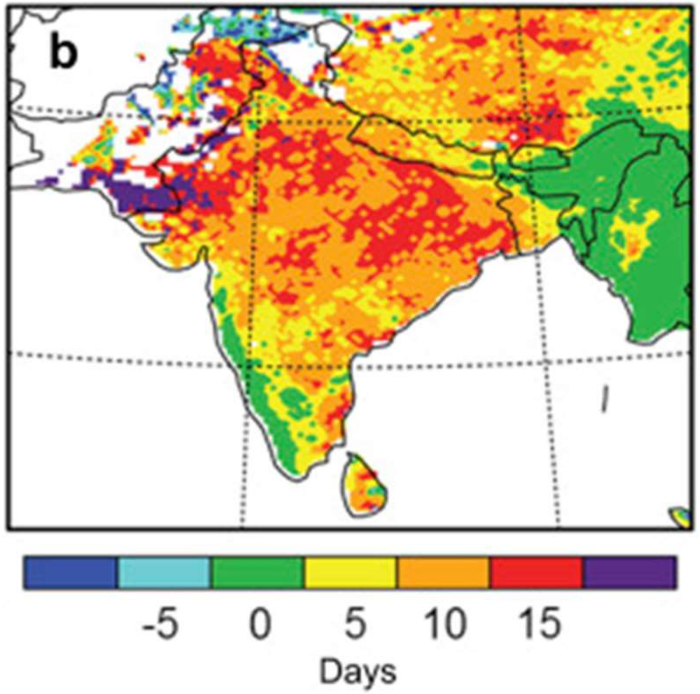
In India during 1901 to 2015, total rainfall decreased and its distribution has changed.

Bushra et al., (2020) Scientific Reports, 10:10342, doi.org/10.1038/s41598-020-67228-7



Monsoon precipitation up to 70% below normal levels by early 22nd century

Schewe and Levermann (2012) Environmental Research Letters, 7 : 1-9



Monsoon in Southeast Asia may be delayed up to 15 days

Ashfaq et al. (2009) Geophysical Research Letters, 36, L01704, DOI: 10.1029/2008GL036500

Soil waterlogging

Flash flood

- How long cassava can withstand flash flooding?
- Potential yield and quality penalty?

Summary Abiotic Stress

- Resistant to drought and heat waves
- Highly vulnerable to soil waterlogging
- Elevated CO_2
- Cropping pattern likely to shift

Screening for traits resilient to climate variability should be a priority research

Biotic Stresses

Pest and disease a new challenge for cassava industry in Asia

Pest occurrence and population dynamics may change

Cassava mealybug
Phenacoccus manihoti

Cassava witches broom
phytoplasma

Cassava Mosaic Disease
Geminiviruses

What are the options to combat biotic stresses

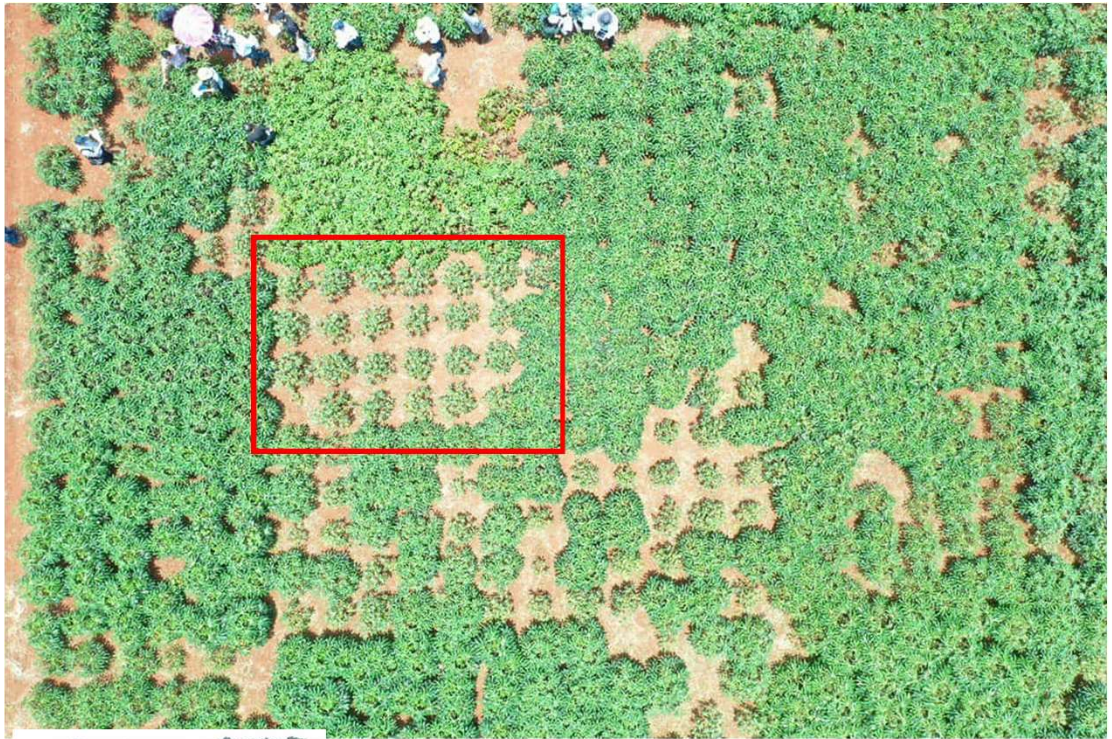
Genetic resistance (screening for resistance)
Multilocation trials….

Biological control (i.e. parasitoid wasps for controlling cassava mealy bug)

Change cultural practice (i.e. crop rotation, intercropping)

Rapid multiplication of disease free planting material

Screening for disease resistance and seed degeneration



CMD Cambodia

CWBD Laos

Similar work is going on in Vietnam

Water cost for Cassava production

- Irrigation
- KU50 and Rayong 11

Different Harvest Date

Different Planting Date

Water use efficiency of cassava to convert to fresh root yield and potential economic benefit

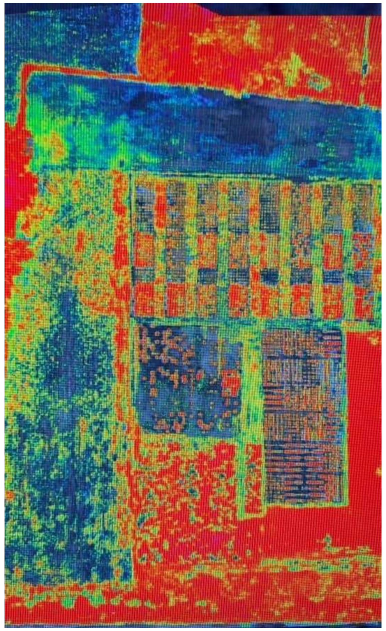
Different Harvest Date

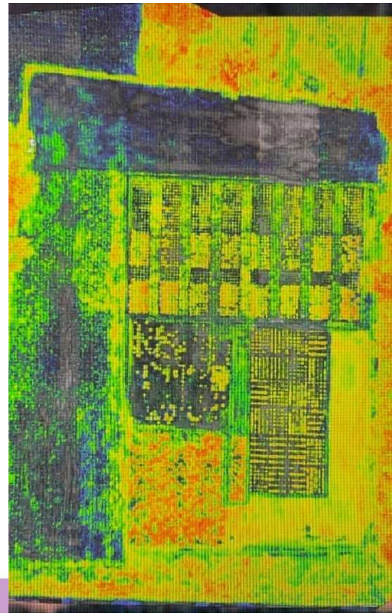
Harvest (months after sowing)	KU50				Rayong11			
	Fresh root Yield (t ha^{-1})		Starch content (%)		Fresh root Yield (t ha^{-1})		Starch content (%)	
	Irrigation	No irrigation	Irrigation	No irrigation	Irrigation	No irrigation	Irrigation	No irrigation
6.5	28.6 ± 3.07	23.6 ± 0.89	30.5 ± 1.27	27.5 ± 2.50	22.6 ± 1.58	17.2 ± 1.09	29.9 ± 2.09	27.4 ± 1.15
8.5	35.0 ± 1.06	28.3 ± 2.33	32.6 ± 1.16	28.3 ± 0.69	21.4 ± 2.40	15.4 ± 1.95	33.2 ± 0.38	33.1 ± 0.63
10.5	41.1 ± 3.54	37.1 ± 1.78	31.1 ± 0.54	25.3 ± 2.32	38.7 ± 2.74	22.7 ± 3.70	32.6 ± 0.36	30.8 ± 1.02



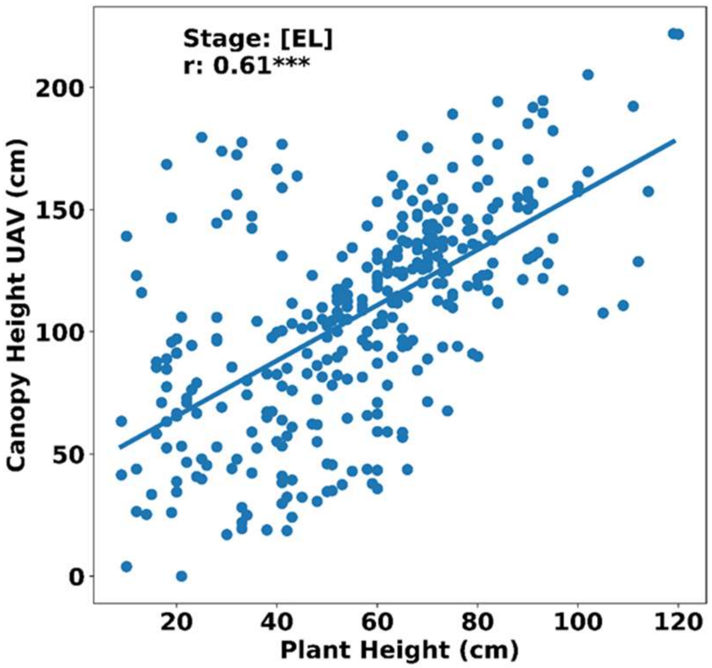
Arial image capture and data analysis

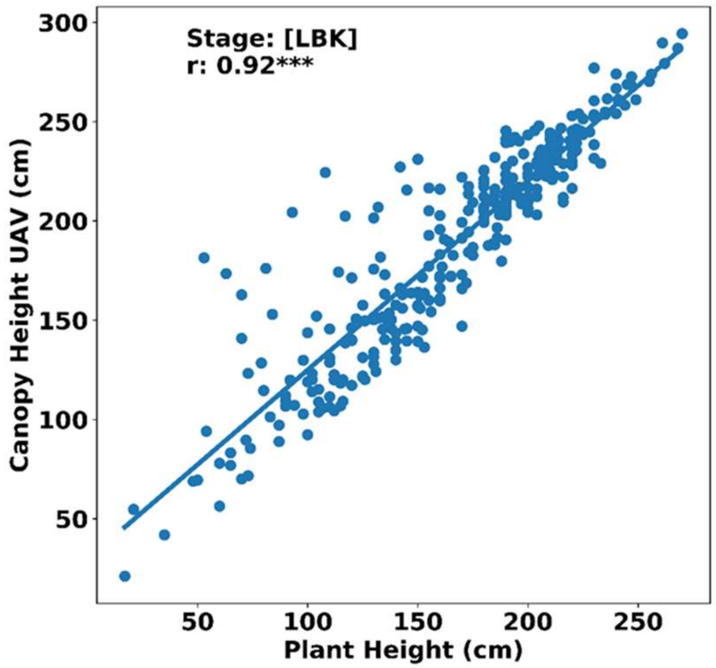
Courtesy Dr. Jonathan Newby





Plant Height Correlation Drone vs Ground Truth



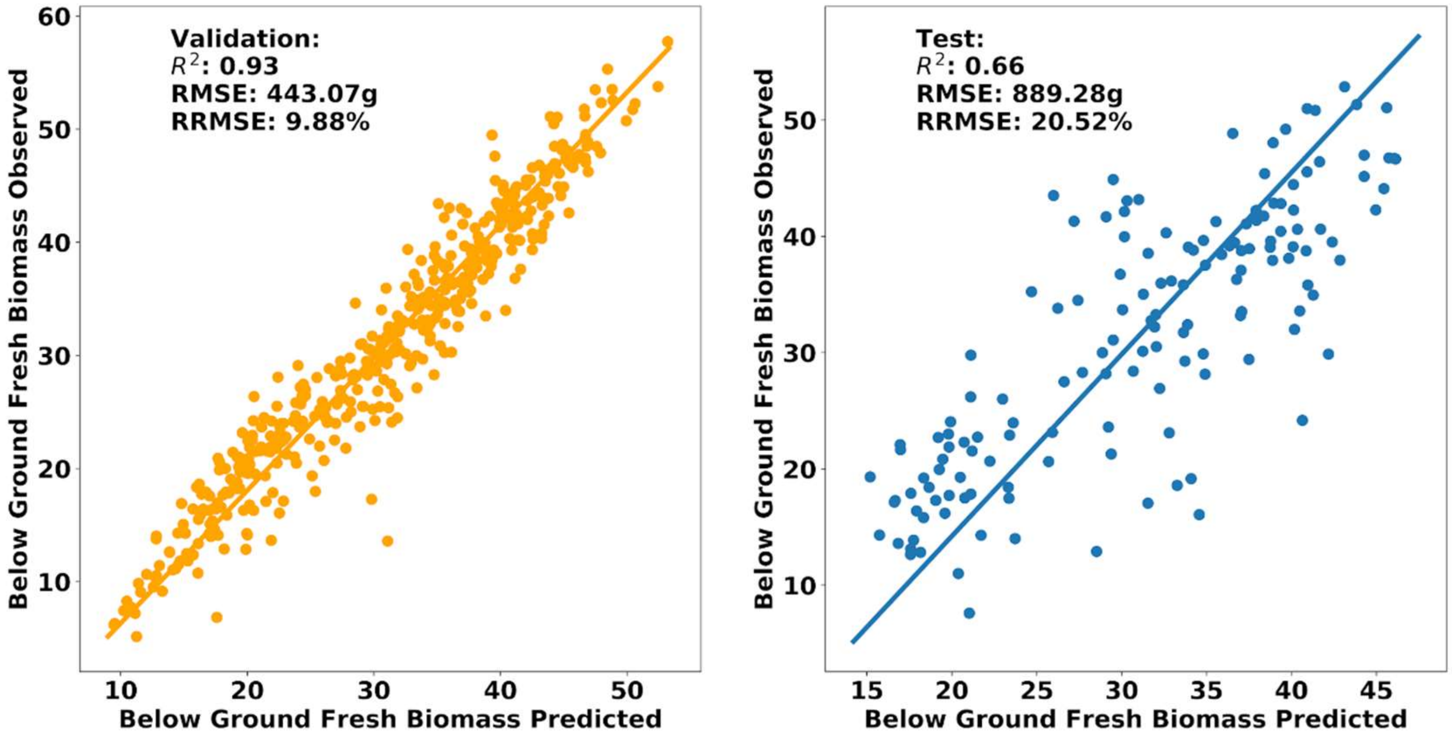


Selvaraj et al 2019

Field protocols: ground penetrating radar

Slide: Dr. M.G. Selvaraj

Random Forest – Root Yield Prediction



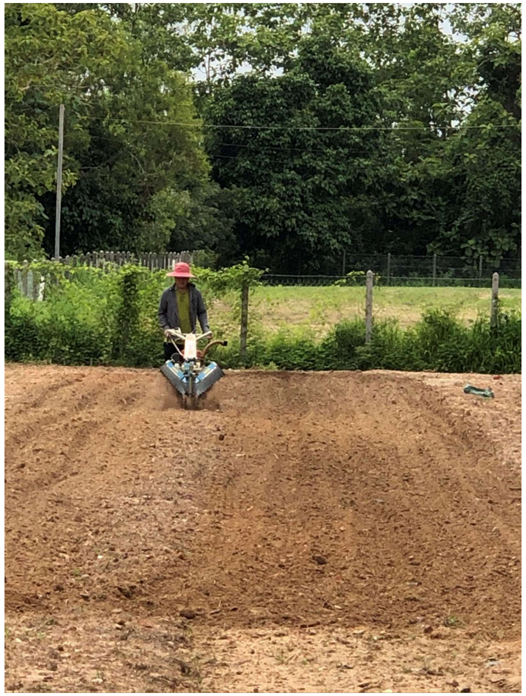
Selvaraj et al 2019

Rapid multiplication of disease free planting material

In vitro plants are in Laos, Cambodia and Vietnam: protocols are optimised

Mechanization

Planter and ridges maker
Courtesy: Dr. Nguyen Van Minh, TNU

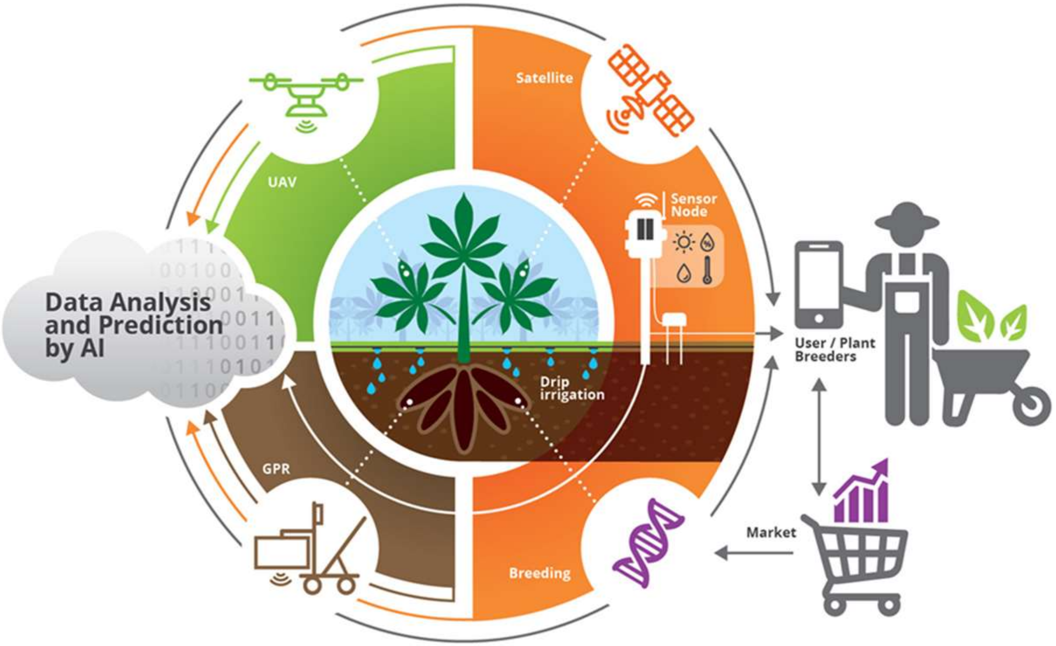


Land preparation

Weeding

Need optimization mechanize planting and weeding

Summary and collusion



- Understanding the effect of changing weather pattern on cassava cropping systems
- Nutrient input use for sustainable cassava production
- Optimize agronomy for healthy planting stake production for seed system
- On-farm data analysis (i.e. gathered through multi-sensor technology and modelling) and
- Communicate to stakeholders to make informed decision

https://cassavadiseasesolutionsasia.net/

http://cassavavaluechains.net/

Transdisciplinary cassava team in Asia

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Thank you!

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Cassava Program in Asia

1. Aggressively introduce **700+** LAC germplasm for screening
2. Map **cassava varieties** to production areas in Cambodia, Laos and Myanmar
3. Lead breeding efforts to **develop high starch productive varieties** with **CMD and CWB** resistance
4. Establish a **Pest and Disease surveillance** system for rapid response to potential outbreaks (i.e. PestDisPlace)
5. Develop a robust and sustainable **cassava seed system** to secure access to cost effective clean planting materials
6. Effective **plant nutrition** scheme
7. Understanding cassava value chains and markets

Cassava Program's mission and objectives

<u>Mission:</u> Create a sustainable cassava production system through agricultural innovations that will increase cassava production without increasing environmental pressures.

What are the options to combat biotic stresses

- Early detection and timely data sharing
- Rapid multiplication and deployment of disease free planting material
- Change cultural practice (i.e. crop rotation, intercropping)
- Biological control (i.e. parasitoid wasps for controlling cassava mealy bug)
- Genetic resistance (screening for resistance)

Conclusions

- Start with clean planting material
- Rapid identification and multiplication of promising varieties is the key for interim period
- Long solutions -CMD resistant varieties

https://cassavadiseasesolutionsasia.net/

http://cassavavaluechains.net/