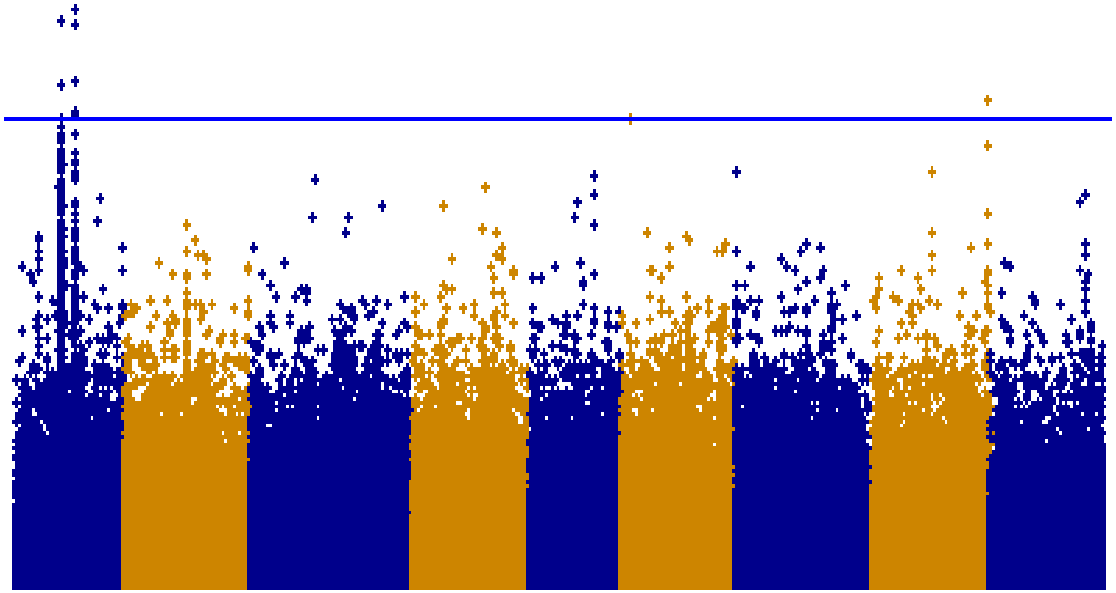
NUS National University of Singapore

# Agri-Food @NUS



**CHEW Fook Tim (dbscft@nus.edu.sg)**
**Vice Dean Faculty of Science**
**National University of Singapore**

NUS National University of Singapore

# Kale Germplasm@NUS

## >600 accessions from around the world*

*from Australian Grains Genebank, Australian Seeds, Baba Seeds, Baker Creek Heirloom Seeds, UK Vegetable Seed Bank, Leibniz Institute of Plant Genetic and Crop Plant Research Collection, Nordic Genetic Resource Centre, Tohoko University Collection, World Vegetable Centre Seed Bank, local and overseas commercial and private collections

# NUS Innovation Strategy in the Agri-Food Sector

## Farm to Fork to Health

Create Value & Deep Innovations:

**Value Chain**

| Pre-production inputs | Farm-production | Post-harvest technologies | Food & Nutrition | Good health & active ageing |
|---|---|---|---|---|
| **Expert Areas for Innovation** | | | | |
| • ***Customized varieties*** | • Production systems | • LED-based enhancements & retention (flavor, aroma, spoilage reduction) | • High-density nutritionally packed foods | • Diet-health clinical outcomes |
| • Novel crops for indoor farms | • Systems engineering (design, optimization) | • Edible coating for extended shelf-life | • Age-sensitized foods | • Diet-based disease reversals |
| • ***Waste-to-agri-resources*** | • Nutritionally defined/locked produce | • Smart packaging | • Functional & therapeutic foods | • Age & ethnicity based custom dietary responses |
| • Composite soil | • Sensors & IoT/IoE | • Source tracking (biomarker bar codes) | • Novel & sustainably-sourced foods | • ***Diet-microbiome-clinical interventions & outcomes (health, ageing, dysbioses)*** |
| • ***Microbial consortia (fertilizers & pesticides)*** | • Robotics & automation | • Traceability | • Precision analytics | |
| • Consumer preference intelligence | • Waste-to-resource conversions (Water, nutrients, biomass) | | | |

Value Chain Verticals

**Innovation Platforms & Fields**

- Plant genome biology, Systems Biology, Microbiome, SynBiol, Agriculture, Ecology, Clinical Science
- Soft Polymers Chemistry, Sensors Technologies, Analytics, Optical and Spectroscopy Physics
- Robotics, Data Science, AI-based Deep Learning, IoT/IoE, Mathematical and Statistical Modelling
- Consumer and Market Intelligence, Futures Prediction, Life Cycle Analysis, Bioeconomic Analysis

Platform and Expertise Horizontals

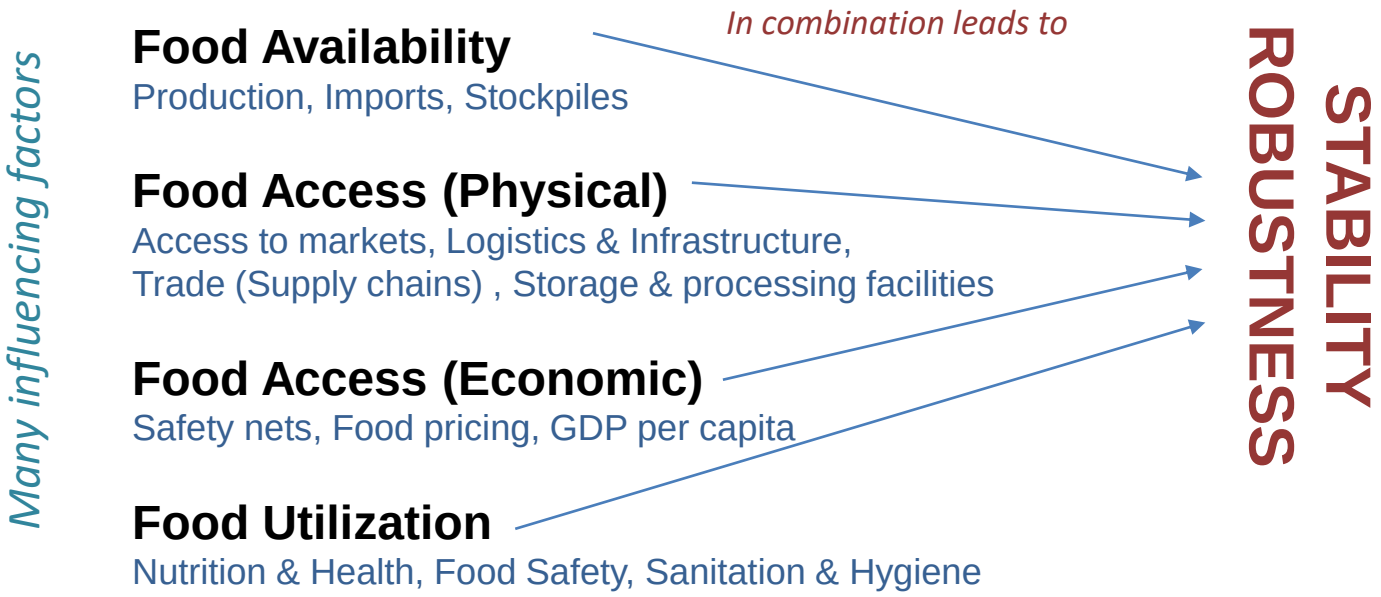
# What is food security?

earth.org

*"Food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active life."*

World Food Summit 1996. Rome Declaration on World Food Security, Rome: FAO, 1996

# Dimensions of Food Security




World Food Summit 1996. Rome Declaration on World Food Security, Rome: FAO, 1996

# Disruptors on Food Security

Severe Weather
Natural Calamities
Pest & Disease Outbreaks
Input Shortages
Pandemics

Rising Energy Prices
Sudden Policy Changes e.g. Trade
Lower Holdings of Grain Stocks (Hoarding)
Diversion from Staple to Cash Crops
Conflict or Terrorist Activities
Artificial Price Hikes
Alternative Uses of Biomass
Trade Wars

Food Safety, Contamination
Diet Changes from Urbanisation Human Health
Crises (e.g. SARS, COVID-19)
"Adventitious" Presence

*In combination reduce*

*And in combination influence*

**Food Availability**
Production, Imports, Stockpiles

**Food Access (Physical)**
Access to markets, Logistics & Infrastructure,
Trade (Supply chains) , Storage & processing facilities

**Food Access (Economic)**
Safety nets, Food pricing, GDP per capita

**Food Utilization**
Nutrition & Health, Food Safety, Sanitation & Hygiene

**STABILITY**
**ROBUSTNESS**

World Food Summit 1996. Rome Declaration on World Food Security, Rome: FAO, 1996

# Mid to Long Term Disruptors on Food Security

- Climate change
- Demographic changes (Urbanisation, Declining no. of farmers)
- Poverty (Increasing gap between “haves” and “have-nots”)
- Underinvestment in infrastructure/technology
- Degradation of land and water resources for agriculture
- Unfriendly policies towards farmers
- Attracting new players into agrifood systems with strong livelihood and economic incentives
- Food Fraud

**Food Availability**
Production, Imports, Stockpiles

**Food Access (Physical)**
Access to markets, Logistics & Infrastructure,
Trade (Supply chains) , Storage & processing facilities

**Food Access (Economic)**
Safety nets, Food pricing, GDP per capita

**Food Utilization**
Nutrition & Health, Food Safety, Sanitation & Hygiene

STABILITY
ROBUSTNESS

World Food Summit 1996. Rome Declaration on World Food Security, Rome: FAO, 1996

NUS National University of Singapore

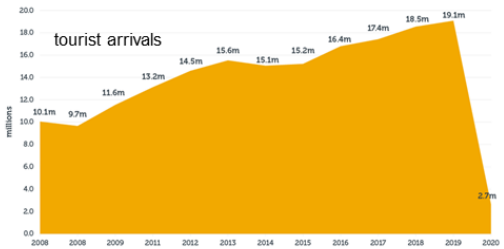
# Singapore/Area
# 728.6 km²

**In 2021, one person in Singapore consumed an average of around 390 eggs, 100 kg of vegetables, 22 kg of seafood, 62 kg of meat (i.e. chicken, pork, beef, mutton) and 76 kg of fruits.**

Average per capita Consumption per year (2017)


**To feed**

cir. 5.5 million resident consumers
+ >19 million tourists (*transient*)




Singapore Tourism Statistics

**Less than 1% of land is agricultural**


**Over 90% of food is imported**

# Singapore Food Agency & the 3 Food Baskets

**What methods and strategies are being explored to address our food security needs?**

Singapore Food Agency

Formed in April 2019 to **help farmers build capabilities** through

- technical support
- R&D tie-ups
- transfer of technology

To strengthen Singapore's food security, SFA is pursuing three broad strategies called the **3 Food Baskets**:

**Diversify import sources**

**Grow local:**
30% of our nutritional needs by 2030 **(30 by 30)**

**Grow overseas**

# We are seeing technologies maturing – making it possible to overcome our land and labour constraints

**Multi-storey/multi-tier** to maximise land productivity, with automation that reduces reliance on labour, and **environmental controls** to produce independent of extreme weather

| | Vegetable farms | | Sea-based fish farm | | Land-based fish farm | | Alternate protein |
|---|---|---|---|---|---|---|---|
| | Median existing local farm | Model farm using ideal technology | Median existing local farm | Model farm using ideal technology | Median existing local farm | Model farm using ideal technology | Lab-cultured meat |
| Tech-nology | Conventional soil-based vegetable farm with basic netting greenhouse | Indoor lighting farm, 4 storeys, 4 tiers per storey (overseas high-tech veg farm) | Farming in coastal sea space with small, shallow net-cages, rely on tidal movement for dilution of waste | Farming in deep sea with large, deep net-cages, stronger currents to flush away waste (local high-tech aqua farm) | Pond or concrete tanks; minimal water treatment; paddle wheel for pond aeration | Recirculating Aquaculture System (RAS), oxygen generator for super saturation of dissolved oxygen (local hight-tech aqua land farm) | Growth of meat cells in culture media within bioreactors (AP company) |
| Produc-tivity | **140 tonnes/ha/yr** | **2,500 tonnes/ha/yr** | **40 tonnes/ha/yr** | **245 tonnes/ha/yr** | **34 tonnes/ha/yr** | **500 tonnes/ha/yr** | **20,000 tonnes/ha/yr** |







# Some of our local farms are paving the way, investing in technologies that are resource efficient

## Kalera builds vertical mega-farm in Singapore

3 March 2022


Kalera has finalised phase one of construction for its new fully-automated, multi-layered vertical mega-farm in Singapore.

The US-headquartered vertical farming specialist has now completed the core structure of the facility located at the Changi Logistics Centre.

Henner Schwarz, chief commercial officer of Kalera, said the farm will allow crops to grow throughout the year in any climate, in a controlled environment that mitigates the risk of pathogens and maximizes taste and texture appeal. 'The new indoor farm will change consumption of locally-grown and harvested greens in Singapore as we know it," said Schwarz.

We'll be producing 500 tonnes of greens each year, which can be harvested right before consumption, resulting in higher nutritional value, less food waste and reduced CO emissions. We're expecting the first harvest in the third quarter.

Kerstin Kohler, Kalera's country manager, Singapore said the farm would contribute towards Singapore's push to expand local fresh produce production.

'The new farm will offer holistic support to Singapore's long-term food security plan, which gained added significance during the Covid-19 pandemic,' said Kerstin Kohler. 'By changing the way food is grown and eaten, our Singapore farm, paired with our R&D centre, will continue to drive the global urban farming revolution.'

This initiative is made possible through the Singapore Food Agency's 30x30 Express Grant, which supports the local agri-industry to produce 30 per cent of Singapore's nutritional needs locally and sustainably by 2030.

The grant will help to ramp uplocal production of leafy vegetables through Kalera's patented 'Dryponics' cultivation method which keeps the plants alive with roots intact and allows consumers to harvest the plants just before consumption for better-tasting greens.

In our 50-foot-tall indoor farm we use a fully automated advanced farming system that covers the seeding to harvesting process, has full climate control, and enables compact, modular and high-quality plant growth,' Kohler added.


With a mission of 'growing a resilient future for people and planet', Sustenir has been making headlines since the company was founded in 2014.

Tapping on hydroponics, a controlled environment agricultural system and the wonders of technology, this high-tech indoor farm produces over 90 tonnes of crops annually. The farm's bounty includes myriad plants and vegetables that one would not expect to thrive in the tropics, from ice plant and lettuce to Curly and Tuscan kale.

Tapping on technology has myriad benefits when it comes to agriculture. Besides allowing the farm to cultivate up to 3.2 tonnes of lettuce in a 54-square metre space, Sustenir is able to tweak the taste of its produce during early stages of growing.

As a result, the farm's signature kale is crispier, zestier and sweeter than regular varieties.

# Research & Innovation Capacity: SG Food Story R&D Plans to plug the gaps that current technologies are not able to solve

Potential research areas include the use of smart sensors in climate-resilient farming systems in **tropical aquaculture** and **urban agriculture**

**Problem areas in urban food production will be how to:**

(i) Raise land productivity
(ii) Reduce operation costs to make indoor farming and aquaculture more commercially viable
(iii) Improve nutritional quality of fresh produce

**Production technologies for alternative proteins are nascent and require further research:**

(i) Discover more sources of feedstock
(ii) Develop commercially viable animal-free culture media for cultured meat
(iii) Optimise protein extraction from feedstock
(iv) Improve texture and sensory properties of alternative proteins
(v) Large-scale commercial production methods

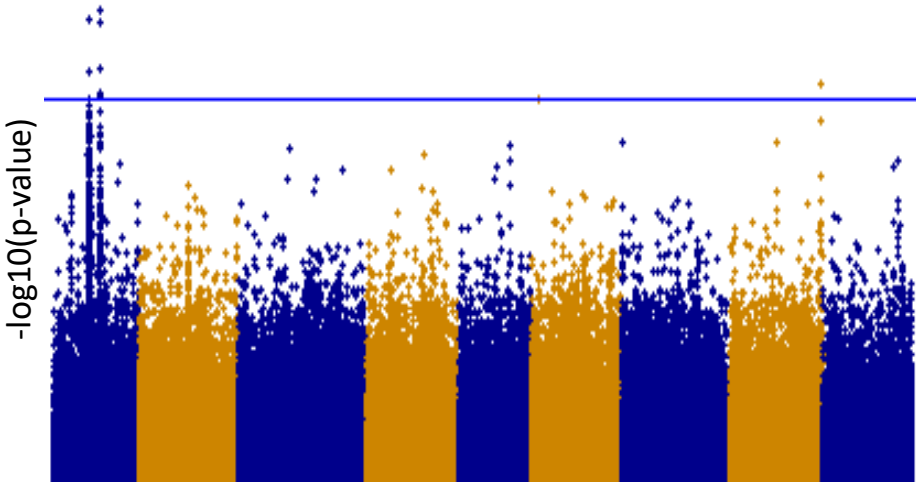
**Research is required to address gaps in food safety capabilities and technologies:**

(i) Ascertain food safety of novel foods and new food processing solutions
(ii) Develop intelligent supply chains
(iii) Understand consumer behaviour towards food

NUS National University of Singapore

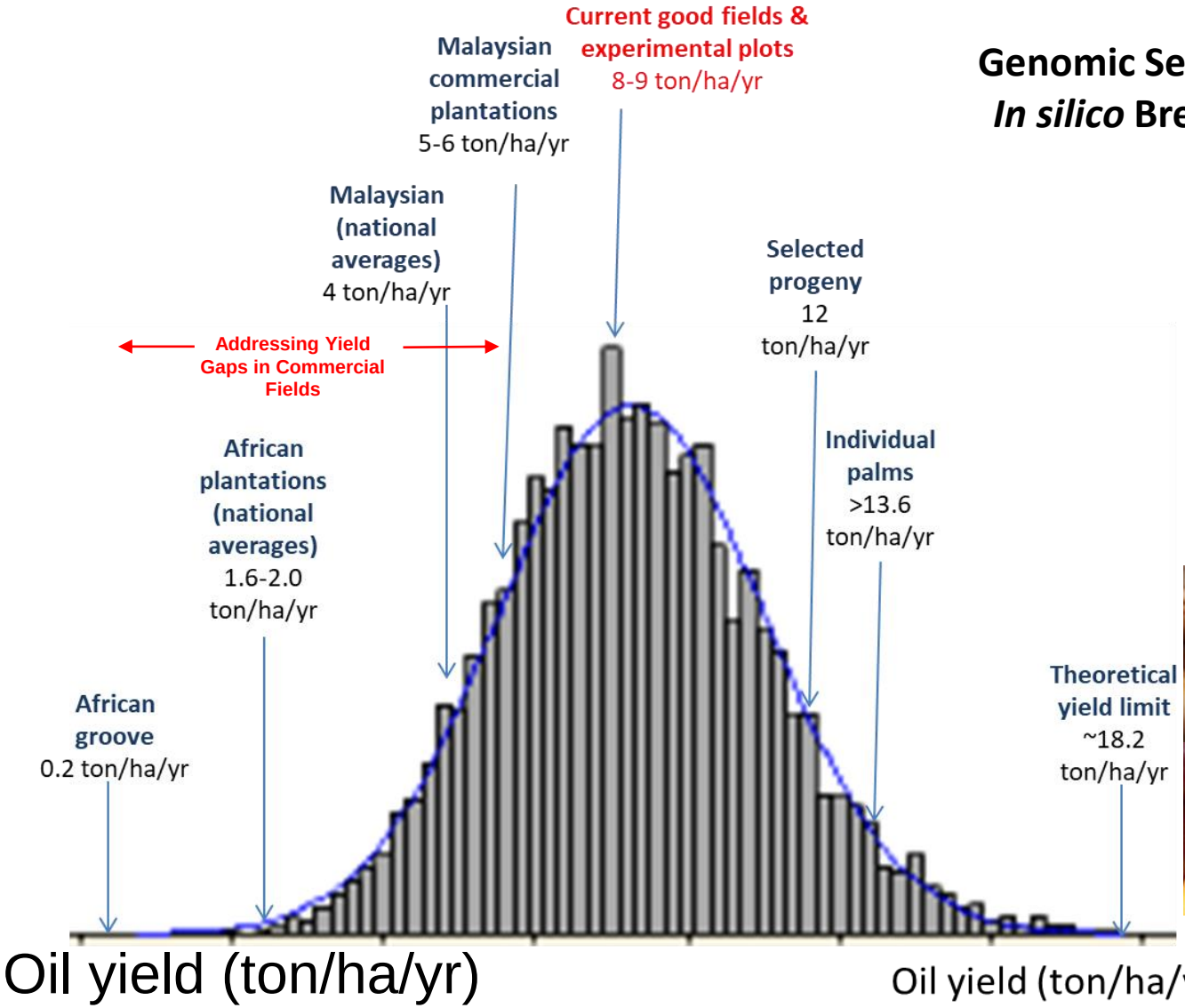
**Example of an SG Food Story R&D Programme:**

*Molecular Breeding for Indoor Farms and Green Houses*

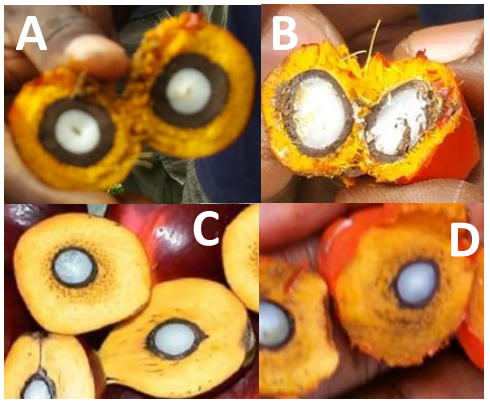



4-week post germination Kale grown indoor combining the highly associated vegetative growth markers identified from our large scale Genome-Wide Association Studies (GWAS) on hundreds of accessions of Kale (*Brassica oleracea*) from around the world

# Examples of Large Scale Industrial Collaborations to Improvement of Yields

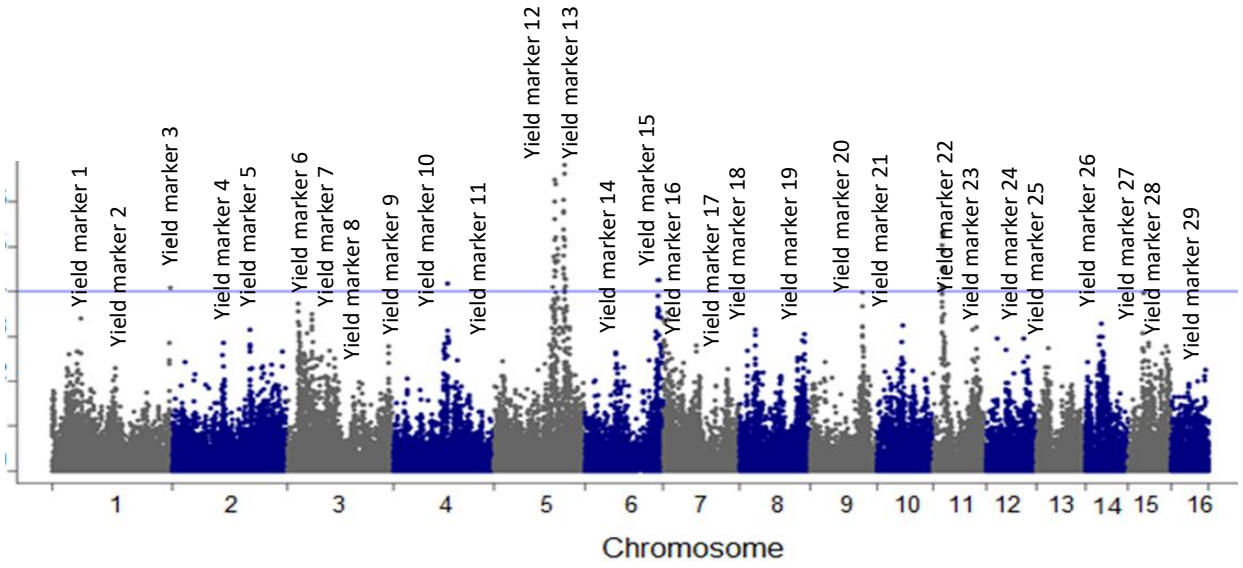



**Genomic Selection**
***In silico* Breeding**

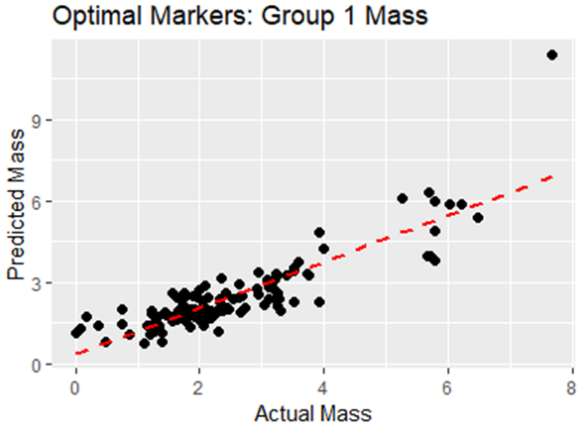


# Genomic Selection / Digital Twinning

**Fully utilize the marker capabilities with the incorporation of *in silico* breeding, marker-based specific combining ability determination, and marker-assisted inbreeding and hybrid vigour assessments**




**Genome-wide genetic variation associated with yield**



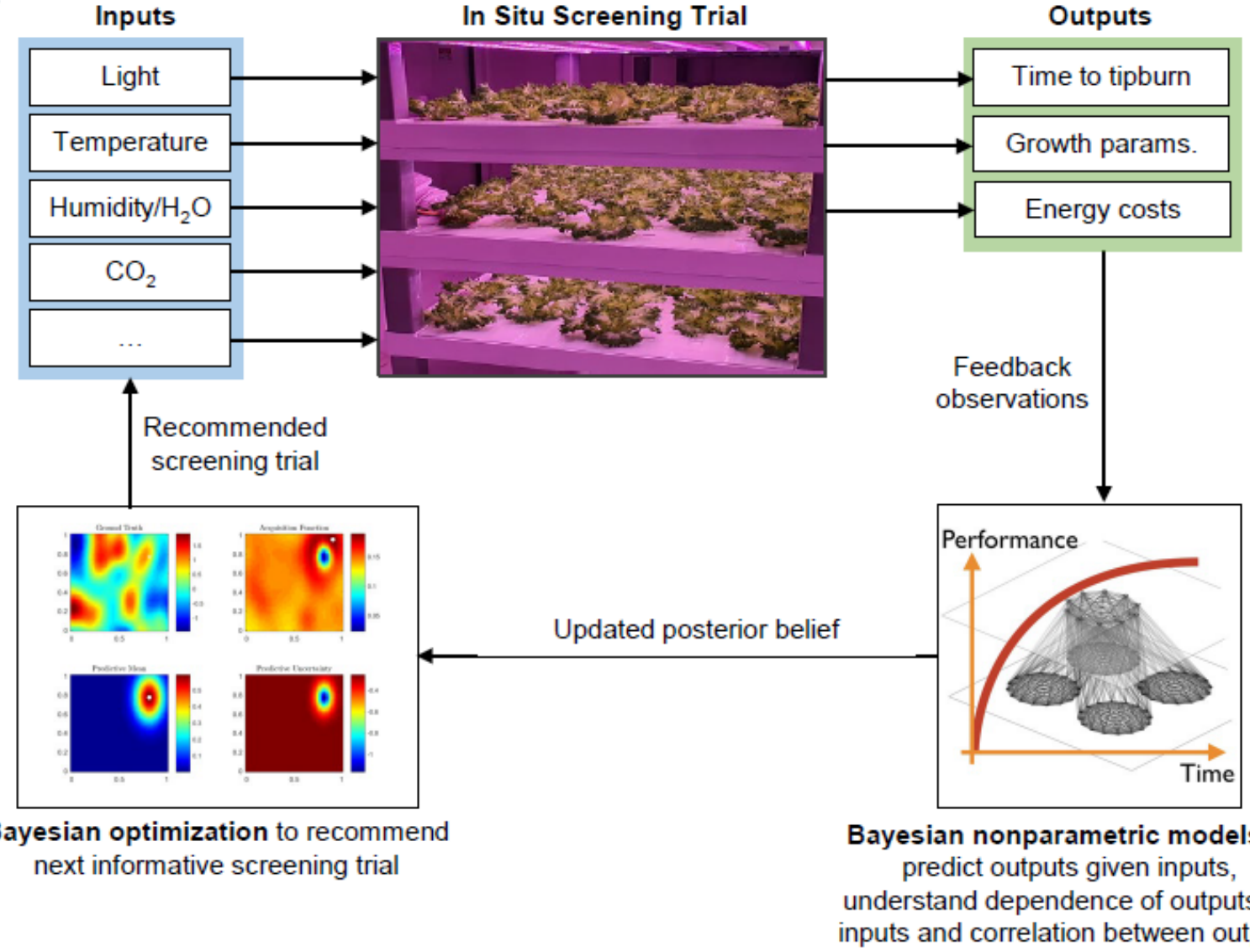

## *in silico* breeding

**Maximize the capturing of useful genetic variation**

Conventional breeding or simple markers assisted breeding will not be able to capture the effect of the combinatory effect of the genome

**We can look into the potential agronomic value of billions of genotypes even before we put any plant into the field**

# AI Digital Twinning and Indoor Farming Optimization




**Bayesian optimization** to recommend next informative screening trial

**Bayesian nonparametric models** to predict outputs given inputs, understand dependence of outputs on inputs and correlation between outputs

Illustration of how Bayesian optimization is designed and developed to automatically select/ recommend the most informative screening trials for rapidly finding the optimal environmental parameters to maximize vegetable yield per unit cost.

# Future Food Trends

Resource Optimization  Consumer empowerment  Supply Chain Adaptability

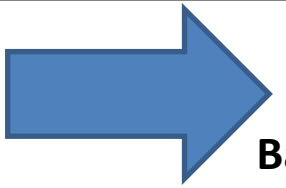
Robotics and Automation  Digitalization of Food

# Future Food Transformation

| Industry 4.0 | | Industry 5.0<br>Society 5.0 |
|---|---|---|
| Product Development Cycles | → | Reduced Product Development Cycles |
| Food Security | → | Food Resilience |
| Food Analysis | → | Foodomics |

# Advanced Manufacturing with Future Food Trends

| | Industry 4.0 | Industry 5.0<br>Society 5.0 |
|---|---|---|
| **Industry Trends** | **Machine-centric** | **Human-centric, AI-enabled; Full integration of Cyberspace & Physical space** |
| **Robotics and Automation** | Automation, Robotics, Additive Manufacturing | AI-enabled automation, Mass food customization, Robotics across the food supply chain |
| **Consumer empowerment** | Functional Foods, Plant Proteins | Personalised Health, Novel Foods |
| **Digitalization of Food** | Traceability, Sensors, Foodomics | Complete foodome |
| **Resource Optimization** | Waste Valorization, Waste reduction | Carbon reduction, Smart Packaging, Water reduction |
| **Supply Chain Adaptability** | Last-mile delivery | Supply chain resilience |



**Agile Manufacturing,**
**Digital Twins,**
**Balanced human-machine interface teams**

# Re-inventing Product Development Cycles with Future Food Trends

**Challenges in the Food Industry**

Need to reformulate existing products

Slow product development cycles

**1. Healthy & Tasty**

**2. Clean labels**
Minimal, natural ingredients

**3. Sustainability**
Plant based ingredients
Ingredients 'resilience'

**Each food product is complex**

**Ingredients:** Fat, Proteins, Carbohydrates, Micronutrients, Bioactives

**Sensory:** Color, Texture, Aroma, Taste

**Consumer:** Visual, Tactile, Olfactory, Gustatory

**Re-formulation, Formulation**

**Imagination, Creation**

Product Understanding, Data Analytics, Optimization, Consumer Understanding, Design

Reduce product development cycle, food processing time, costs

**Value-capture for Food Industry**

Tunable Food Structures, New Food Solutions, New Nutrient Delivery Systems, New Workflows, New Food Experiences

# Food Crisis Preparedness with Future Food Trends


**Circular Economy**

**6. Science, Engineering & Urban Design**
*Food waste and side streams back to urban farms as feed and fertilizer or novel food products*

**Urban Farming**

**1. Agri-tech & Aqua-tech**
*More food with less space*

**Advanced Food Processing & Packaging**

**2. Food Engineering, Materials Engineering & Design**
*Shelf-life extension*
*Post-harvest technology*

**Food Bioactives**

**5. Food Chemistry & Data Analytics**
Macro-, micro-and phyto-nutrients of food products

**Food Safety**

**4. Microbiology, Toxicology & Immunology**
Parallel evaluation of food safety aspects of novel foods and novel technologies
Development of NAMs (New Approach Methodologies)

**Novel Food Sources**

**3. Food Science & Biotechnology**
*Alternative sources of food and food ingredients*

# Urban Aquaculture

Program and Platforms

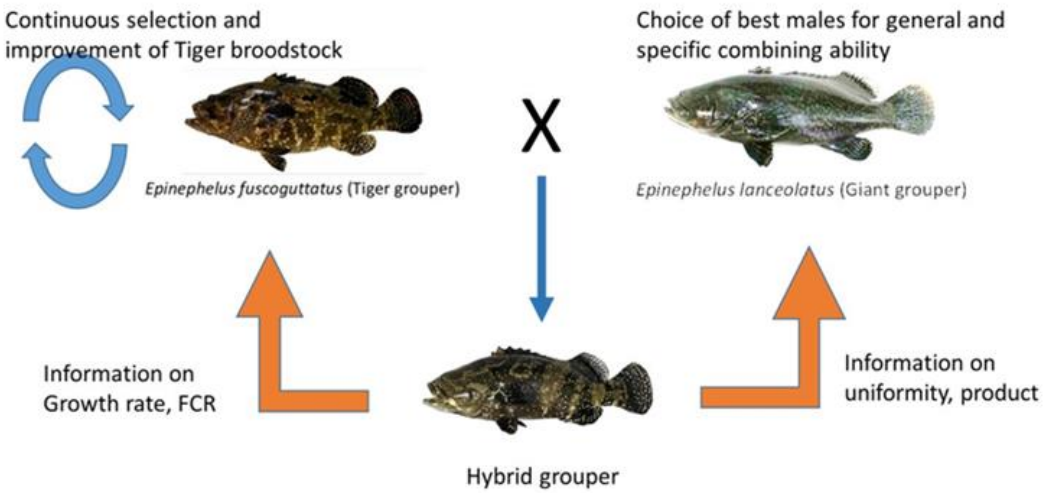
## Urban RAS

Energy efficient

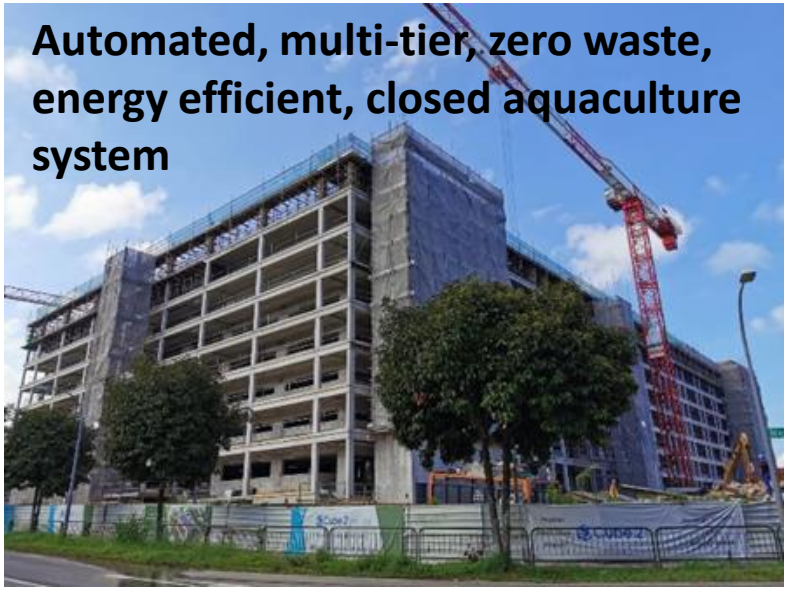

APOLLOAQUACULTURE

NUS National University of Singapore

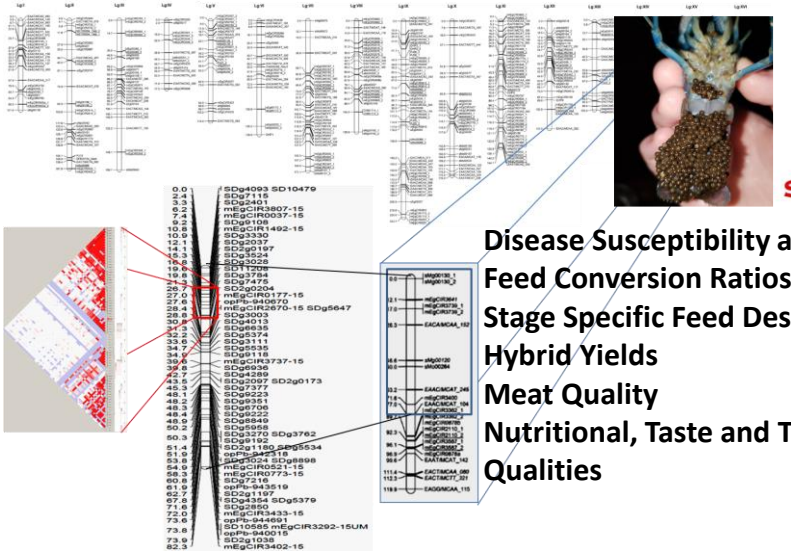
## Unique Hybrid Breeding Program




Technologies and Genetics




## Deep Genetics and Novel Reciprocal Recurrent Genomic Selection Breeding System



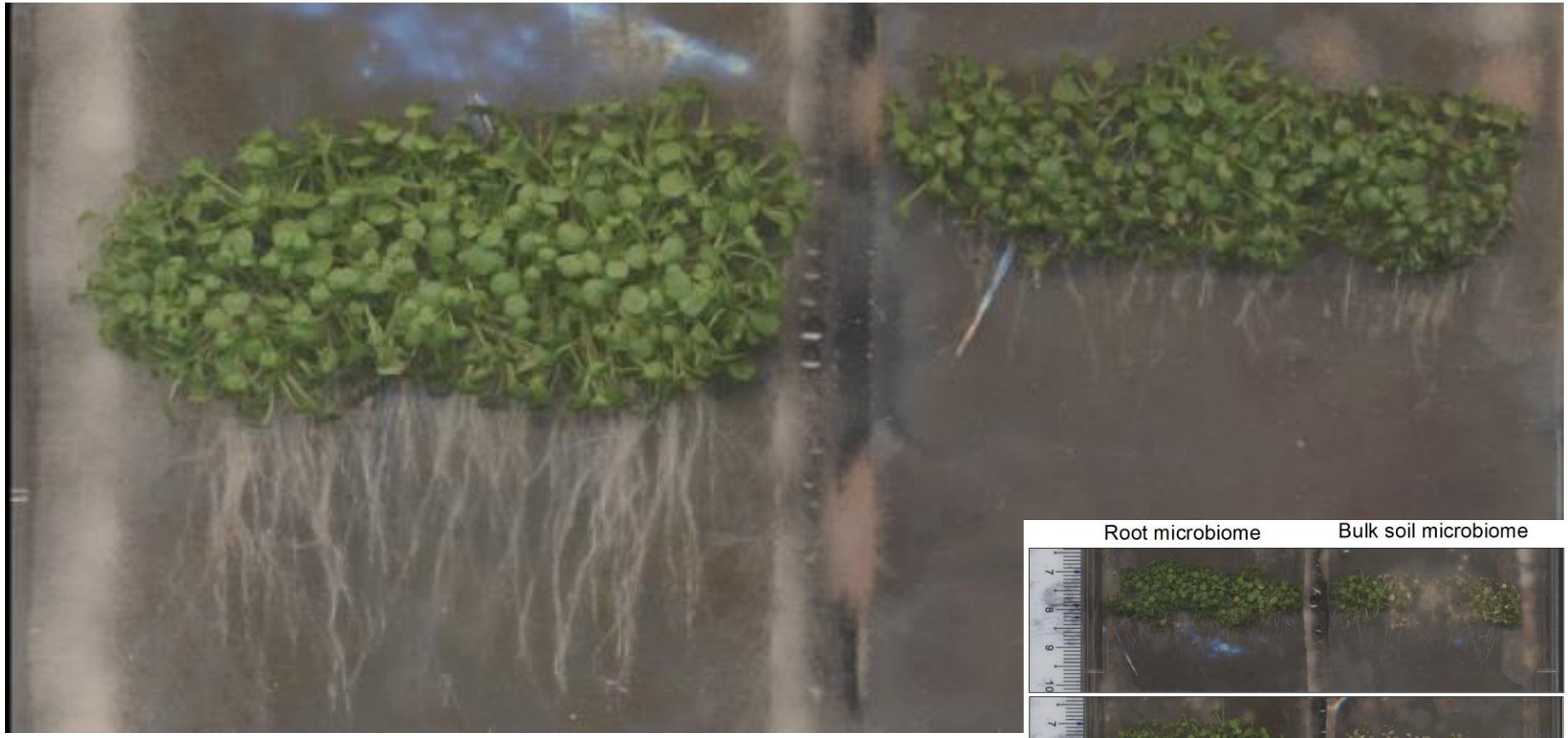
SINGAPORE CRAWFISH

- Disease Susceptibility and Diagnostics
- Feed Conversion Ratios
- Stage Specific Feed Design
- Hybrid Yields
- Meat Quality
- Nutritional, Taste and Texture Qualities

# Microbiomes that promote growth

Rhizosphere microbiome

Bulk soil microbiome






and disease suppression as well

NUS National University of Singapore

# Foodomics: Food Produce, Food Product, Food Impact

**Food Ingredients**

Chemical Foodome
Physical Foodome
Genome
Transcriptome

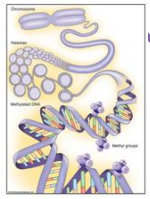
**Food Processing**

Chemical
Physical
Biological

**Food Product**

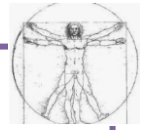

Chemical
Interactome
Food Structure
Bio-accessibility
Sensory
Evaluation

**Human**



Genome
Epigenome
Transcriptome
Metabolome
Microbiome
Behavioral Patterns

**Health**



Immunity
Cognition
Performance
Mood
Chronic Disease prevention

**Chemical Analytical Platforms**

**Sequencing Platforms**

**Physical Measurements**

**Physiological & Behavioural Measurements**

Urban farming
Optimized breeding

Food authentication
Food traceability

Optimised, sustainable processing methods

Novel processing methods

Novel products

Food Safety
Toxicity
Allergenicity

Clean labels

Bioavailability

Public Health Interventions

Epidemiological Studies

Wearables Design

Personalised Nutrition

**Machine Learning Predictions**

Complete Foodome

Product Formulation and Reformulation

Food Safety Surveillance

Novel nutrient delivery systems

Designer Food

# Can we be food resilient?

*"The global food challenge has become more pressing. But continued investment in agri- and food-tech remains a bright spot. Singapore is keen to do our part, for ourselves and the region. We are doubling down on the Singapore Food Story to strengthen our food resilience goals.*

*We are also committed to improving lives in the region working in collaboration with partners from around the world to shape how food is developed and produced ranging from traditional, to modern, to future foods.*

*The potential to create positive change is tremendous."*

**Deputy Prime Minister Heng Swee Keat at the Singapore International Agri-Food Week Gala Dinner on 26 October 2022**

# Can we be food resilient together?

# Driving Asian food security amid Covid, climate change and conflict

https://www.businesstimes.com.sg/opinion/driving-asian-food-security-amid-covid-climate-change-and-conflict
13 October 2022

With rising food insecurity, a partnership across the food value chain to make regional food systems more resilient is crucial. BY TAN SIANG HEE

WE HAVE grown accustomed to Asia being a global leader in a host of categories, including innovative technologies and digital transformation. Sadly, our region also has the dire distinction of leading the world in another area entirely: being home to the most hungry people.

According to the *State of Food Security and Nutrition in the World 2022* (Sofi) report issued earlier this year by the United Nations (UN), the number of people in Asia affected by hunger rose last year to 425 million, up from 418 million, making the region top of this most disconcerting category. This has been a rising trend, up from 398 million in 2020 and 340 million in 2019.

In Asia and around the world, we're simply not making progress on reducing hunger, malnutrition and food insecurity. In many instances, we're actually losing ground. According to the Sofi report, 8 per cent of the world's population – or 670 million people – will be facing hunger at the end of the decade. That's the same number of people that were facing hunger in 2015, the year the UN first introduced the Sustainable Development Goals (SDGs) as a road map to ending extreme poverty and hunger.

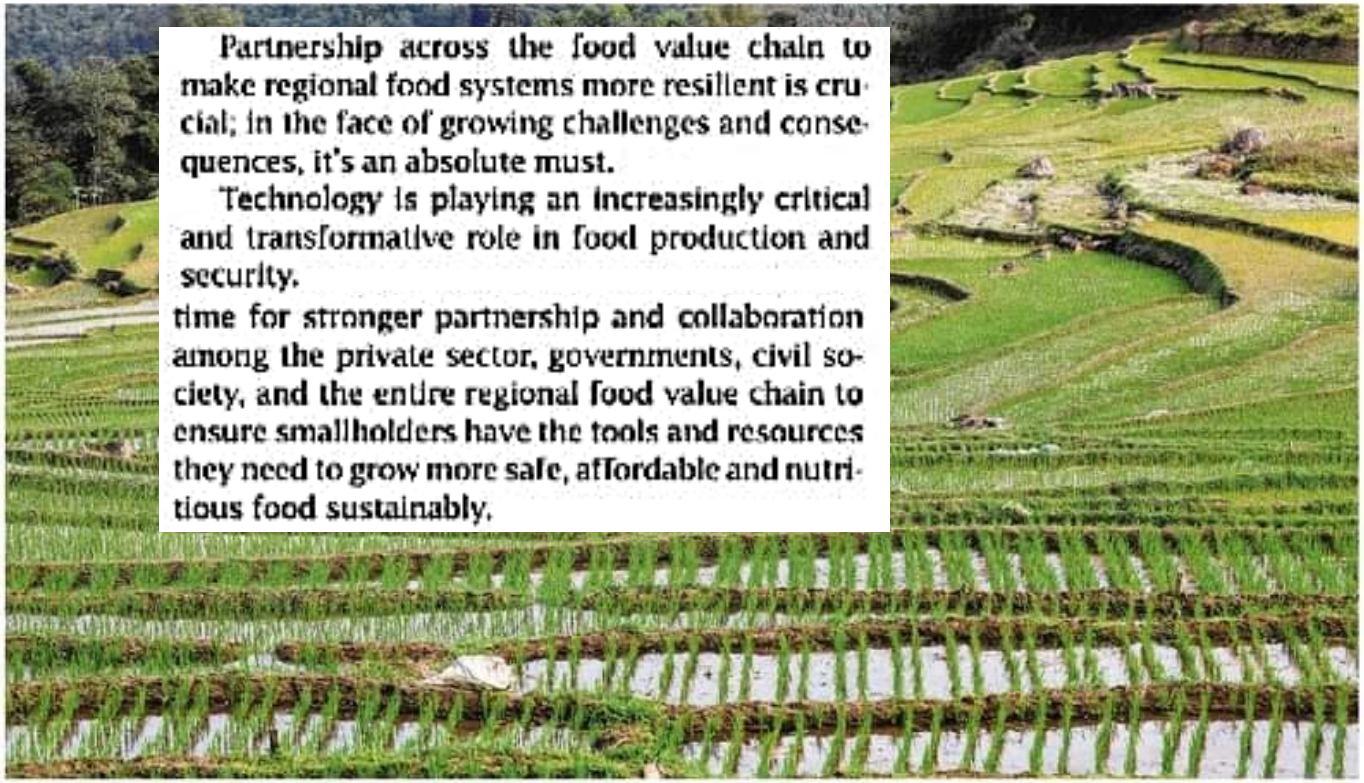
Why is this happening? Myriad problems continue to plague food systems, but three harsh realities have created particularly strong headwinds in recent years: Covid-19, conflict, and climate change.

The global pandemic caused unforeseen disruption to food systems around the world. Through movement restrictions, border lockdowns and similar policies understandably instituted to stop Covid's spread, the pandemic ex-

**Partnership across the food value chain to make regional food systems more resilient is crucial; in the face of growing challenges and consequences, it's an absolute must.**

**Technology is playing an increasingly critical and transformative role in food production and security.**

**time for stronger partnership and collaboration among the private sector, governments, civil society, and the entire regional food value chain to ensure smallholders have the tools and resources they need to grow more safe, affordable and nutritious food sustainably.**



**Rice fields in Thailand. Asia is home to the world's smallest-sized farms and largest number of smallholder farmers, generally defined as those with fewer than two hectares of land.** PHOTO: REUTERS