From Bioinformatics to Geoinformatics:
Big Data in Oil Palm R&D

Presented by
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ICBAA 2017
Felda Global Ventures: Introduction
• Felda Global Ventures Holdings Berhad (FGV) is a global, diversified and sustainable integrated agri-business leader.

• Incorporated in Malaysia in 2007, FGV progressed into a diverse agri-business company and rapidly established itself as Malaysia’s leading global agri-business player.

• Today we are the world’s largest producer of crude palm oil (CPO), a leader in Malaysia’s sugar industry and a pioneer of cutting edge green technologies, anchored by a 18,000 strong workforce and a global integrated supply chain.
An Expanding Presence

Felda Global Ventures Holdings Berhad (FGV) operates under three main business sectors namely Plantation sector, Logistics & Others (LO) sector and Sugar sector.

With operations in more than 10 countries across North America, Europe, Asia and the Middle East, FGV aspires to be one of the top 10 agri-business conglomerates in the world by 2020.

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FGV’s world class R&D and Agri-Services Cluster is anchored on four decades of research and development. The Cluster’s key objective is to generate cutting-edge agri-business technologies to enhance operational performance and commercial utilisation across all facets of FGV. The company’s award-winning Yangambi oil palm planting material, which has 40 percent market share in Malaysia, is just one of R&D’s innovative products.
Big Data in Agriculture
Big Data in Agriculture

Genomics

Genetics/Breeding

Agronomy

Farm management

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### Connected assets covering a broad range of agricultural activities

<table>
<thead>
<tr>
<th>Soil</th>
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<tbody>
<tr>
<td>• Soil moisture sensors enable more precise and efficient irrigation management.</td>
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<tr>
<td>• Chemical analysis enables fertilizer optimization, including informing variable rate prescriptions for fertilizer applications.</td>
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<table>
<thead>
<tr>
<th>Plants</th>
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<tr>
<td>• On-plant sensors for hydration monitoring, minimize drought-related yield and quality losses.</td>
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<tr>
<td>• Remote imaging sensors can monitor (and often predict) nutrient deficiencies, insect pest infestations, and disease outbreaks.</td>
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<thead>
<tr>
<th>Livestock</th>
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<tr>
<td>• Geolocation sensors attached to livestock animals can prevent theft and wandering losses.</td>
</tr>
<tr>
<td>• Sensors monitoring internal temperature and rumen pH can predict fast-moving diseases.</td>
</tr>
<tr>
<td>• Behavior analysis through movement tracking can accurately predict estrus for breeding.</td>
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<table>
<thead>
<tr>
<th>Environment</th>
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<tbody>
<tr>
<td>• Weather sensing combined with modeling offers growers advance notice of weather events.</td>
</tr>
<tr>
<td>• Intra-field sensors help orchards identify temperature inversion areas with high frost risk.</td>
</tr>
<tr>
<td>• Precipitation monitoring is a valuable data point in irrigation planning models.</td>
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<table>
<thead>
<tr>
<th>Equipment</th>
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<tbody>
<tr>
<td>• Engine monitoring sensors allow service providers to offer predictive maintenance services.</td>
</tr>
<tr>
<td>• Geolocation sensors on machines allow for fleet tracking, efficiency monitoring, and theft prevention.</td>
</tr>
<tr>
<td>• Real-time activity and performance sensors on ag equipment enable automation.</td>
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<tr>
<th>Farmers</th>
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<tbody>
<tr>
<td>• Geolocation sensors in/on individual workers feed data into ERP software platforms for accurate tracking.</td>
</tr>
<tr>
<td>• Connected data-entry systems help workers input activities in real-time, minimizing errors.</td>
</tr>
<tr>
<td>• Sensor-enabled workforce management automates the record-keeping process for regulatory compliance.</td>
</tr>
</tbody>
</table>

Source: Lux Research, *The Internet of Agricultural Things*, June, 2016
Challenges in Managing Breeding Data
i. Component Breeding Research

28 Parameters

- Germplasm
- Mother palm
- Research project
- New Crosses/Progeny
- Ortets
- Clonal
- Location
- Father palm
- Yield Improvement
- Commercial Deli Dura
- Control pollination
- Seed process
- Germination
- Seed Store
- Pollen Store
- Crossing Process
- Bagging
- Specific Traits study
- Introgression Improvement
- Nursery and Field Planting
- Oil Content: GLC
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Yield Component: BNO & BWT

Bunch Component: MSW, MFW, MKW, etc.

Vegetative component: Height, rachis, leaf number, etc.

Fruit colour, Palm census, Abnormal
ii. Complexity: Seed Production Processes

16 Steps

- Crossing request
- Palm Census
- Request to HOD
- Received by Operation Team
- Harvest inflorescence
- Bagging inflorescence
- Inflorescence Assessment
- Information validation
- Pollen collection
- Inflorescence census / bagging
- Control pollination
- Bunch Harvesting
- Process and storage
- Field Planting
- Nursery (PN / MN)
- Germination
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iii. Exponential Growth of Breeding Data

Growth of FGV data breeding over 50 year

For the next 50-100 Years?

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iv. Big Data Criteria: 3 V’s

**Volume**
- Number and size of data generated
  - Consist of 11 Project & 150 Active trial, Image, Document

**Variety**
- Various types of data generated
  - Yield, Bunch, Progeny, Origins

**Velocity**
- Speed of data connectivity and accessibility
  - Seamless connectivity

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FGV Integrated Breeding System (FIBS)

Unleash The Unlimited Power of Molecular Breeding

Are you missing out on technological advances in commercial breeding?
iv. Integration of Multiple Parameters – Single Relational Database

- Trial Information
- Parental Origin
- Research Data
- Progeny Information

FIBS

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## Component I: Breeding Information Management

<table>
<thead>
<tr>
<th>Trial Information</th>
<th>Progeny</th>
<th>Location</th>
<th>Documentations</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>State</td>
<td>Pahang</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Station</td>
<td>JENGKA 25-1B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage</td>
<td>Jengka 25, Pkt B</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Block</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location Size</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil Type</td>
<td>INLAND</td>
<td></td>
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</tbody>
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Component I: Breeding Information Management
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Component I: Breeding Information Management
Building on the oil palm genome
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• Development of visualisation capability
ElaiesBase Objective

• To host biological data (genome, transcriptome, gene models, markers, etc) into a systematic database

• To allow biologists in navigating the genome for downstream analyses (visualisation)
GENOMICS + BREEDING + FIELD SCIENCE (AN EXAMPLE)
Ganoderma Tolerance Seeds (Yangambi GT1)

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Development of Ganoderma Molecular Marker(s)
Characteristics of GTM Markers

a) GTM markers were designed to target a fragment of NBS-LRR disease resistance protein homologue within an oil palm.

b) Either individual or in combinations of GTM primers will able to predict the susceptibility of oil palm against *Ganoderma* BSR disease.
Example of PCR Results with FP3 Marker

- Potential Tolerant (PT): both bands are present (green arrows)

- Potential Susceptible (PS): either one or both bands are absent (red arrow)

- Internal control – control indicator for PCR

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Patent Pending: Markers for *Ganoderma* Disease Diagnosis and a Use of Thereof (PCT Application No.:PCT/MY2011/000228)
Ganoderma marker (Correlation)

- A total of 5,295 phenotypes data from 5 different nursery trials were analysed.
- Ganoderma marker Vs Nursery phenotype = 70.31%
- The combinations of YangambiGT1 and the patented marker allow FGV to make a more systematic and pragmatic approach.
Ganoderma Nursery Screening

Dedicated 8.40 hectare nursery located at Ulu Belitung (Johor)

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A = 6,000 palms
B = 2,800 palms
C = 3,000 palms
D = 8,000 palms
E = 10,000 palms
F = 8,000 palms
G = 7,000 palms
Total = 44,750 palms
High Throughput Ganoderma Nursery Trials

• Screening capacity for planting materials (35 + 6 control crosses)
• Conventional strategies to identify resistant / partial resistant PM
• Platform to validate the Ganoderma tolerant marker (GTM) – genomics
High Tolerance Palms

Susceptible Palms

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Mean Tolerant for *Ganoderma* control crosses (100%)

TK5818
TK5816
TK5729
TK5857
TK5849
TK5853
TK5815
TK5728

138% - 168%

TK5820
TK5822
TK5737
TK5809
TK5819
TK5821
TK5727
TK5750
TK5717

114% - 131%
Evolution of Digital Agriculture

Accumulated large amount of dataset in the Cloud:
- Agronomic data
- Environmental data
- Genetic-based data

Modelling:
Data-driven operational decision to optimize yield and boost revenue.

Minimizing:
- Operational expenses
- Crop failure (wrong genetic background for different soil/environment)
- Environmental impact (nutrient run-off)

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Understanding agriculture: Complex and differing applications

- Different crop types have unique growing environments and requirements, which create unique sets of priorities within each application.
- Digital ag alignment of a digital ag solution to these priorities will dictate if the solution is a good fit.

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Space Applications For Environment (SAFE) Prototype

“Efficient Oil Palm Management Prototyping Using 3D GIS For Replanting Program”

A Collaboration with UPM, Japanese Aerospace Exploration Agency (JAXA), Keio University & University of Tokyo

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Purposes of Oil Palm Replanting Program:

- To replace un-economic and old palms (>25 years old);
- To improve inherent estate infrastructures;
- To optimize the land within the allocated cost;
- To apply GAP aspects for better yield performance for the next 25 years.

Example of mistakes and irrelevant condition of oil palm replanting from the previous planting activity that leads to loss of productivity, cost and time:

1. Wrong direction and distance of stacking row. **Effect**: Slow degradation of chipped trunk.
2. Bending of planting lining & vacant point. **Effect**: Inefficient light interception & reduced palm stand.
3. Uneven terrace alignment. **Effect**: Waterlog in palm circle.
4. Palms are planted on the wrong lines. **Effect**: Additional cost on development process to transfer the pile of chopped trunks.

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Objectives of this prototype:

1. To create **DIGITAL 3D MODEL** for efficient representations of the plantation

2. To **IMPROVE** the conventional replanting method by using state of the art methods of terrain representation.

3. To **COMPARE** the conventional method with the new 3D GIS & remote sensing technique
Test Site:

- FGVPM Krau 2 Estate, Bentong, Pahang

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Oil Palm Replanting
flow of works:

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Completed with new technologies Dec. 6, 2017
Complete planned replanting program with Good Agricultural Practice (GAP) applied

Pest & Disease Management
Putting it all together
Satellite

Remote sensing to monitor plant health

UAV

Remote sensing to monitor plant health & early detection of disease spread (Phenotyping)

Weather station

Wireless connection

Right genotype (variety) for the right soil & environmental condition

Wireless Sensor:
- Soil moisture
- pH
- Nutrients

Wireless network for data transmission to Cloud

Visualisation of geospatial data

Data-driven decision making to minimize operation cost & maximise profit

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In summary....

• Big-data in R&D
  – Collecting various types of data
  – Curating
  – Analysis and interpretation
  – Translating into meaningful information

• Opportunities for value-added service
  – Increasing yield potential
  – Right input, right time, right location
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   Haryati Abidin
   Lee Yang Ping

.......... rest of FGVRD team

Thank you for your attention