Applying Genomics to Enhance Production Efficiency of Cattle in Tropical Regions

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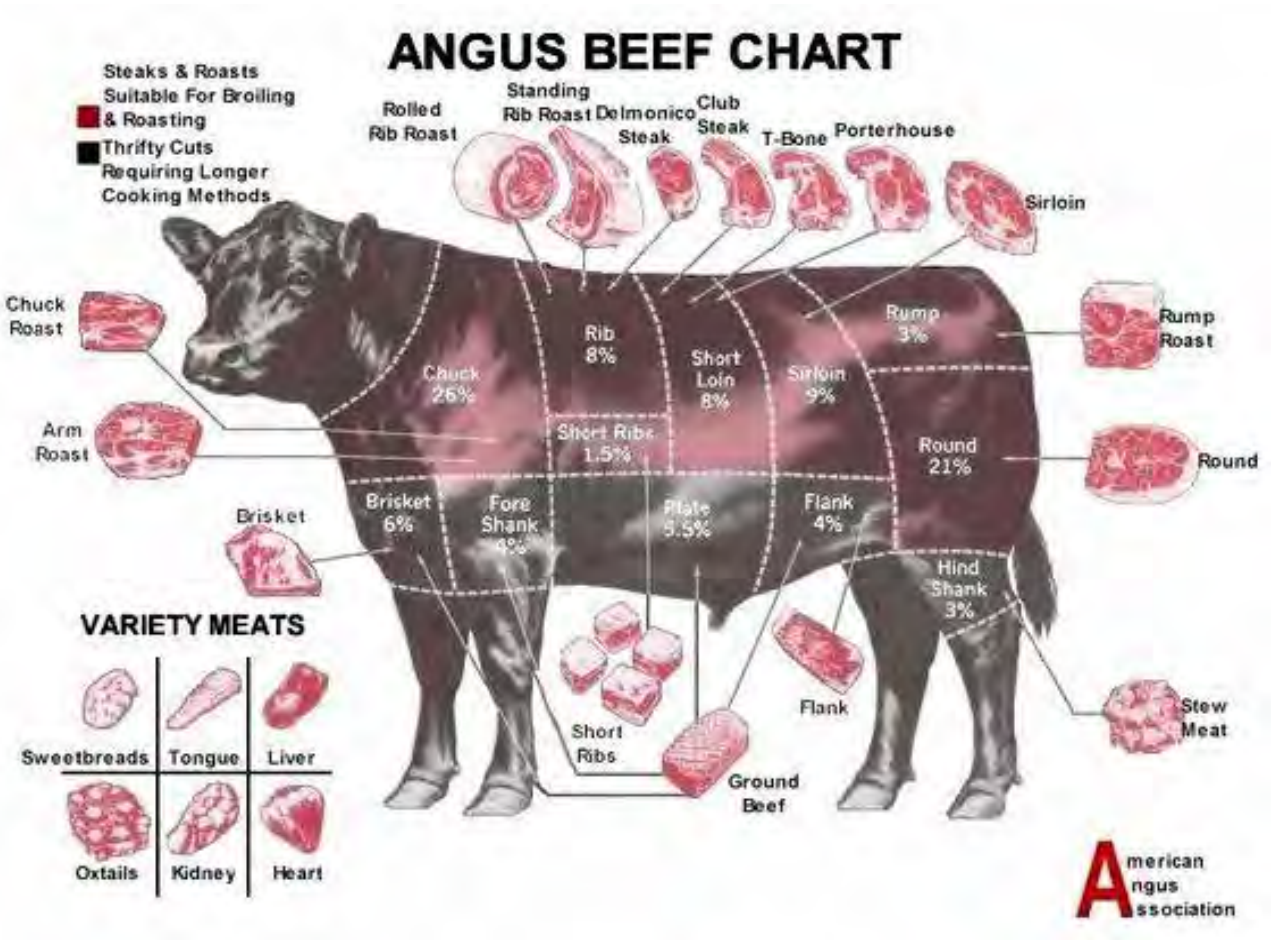
Outlines

- Cattle production & the need for their products
- Tropical Regions & limitations
- Challenges for cattle genetic improvement programs under Tropical conditions
- Applying genomics to enhance production efficiency of cattle

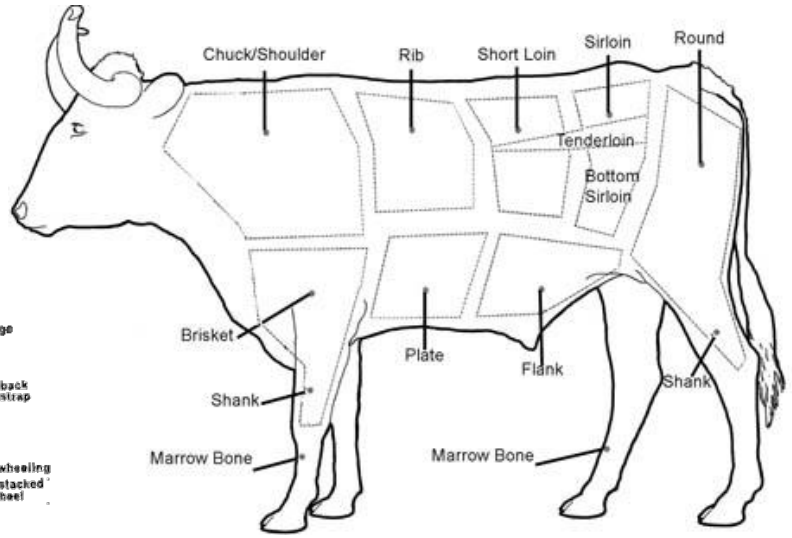
Cattle Products : Milk & Dairy Products

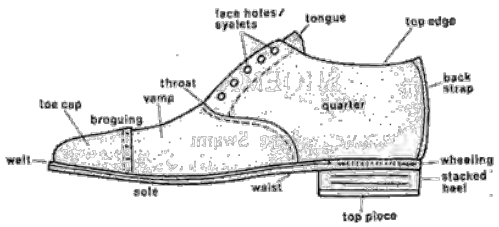
- Drinking milk (e.g., pasteurized, UHT, Sterilized; whole, skim, 2%, 1%, flavored, cream, etc.)
- Butter & cheese
- Cultured dairy (e.g., yogurt, cottage cheese, sour cream, dips and other cultured dairy foods)
- Frozen desserts
- Ice cream/Novelties
- Whey
- Milk powder
- Cosmetics
- Special ingredients

Cattle Products : Meat & Beef Products



Cattle Products : Leather Products





By-Products from Cattle

From Brain
- Anti-aging cream medicines

From Blood
- Pasta
- Cake mixed
- Dyes & inks
- Adhesives
- Minerals
- Medicines
- Laboratory research materials

From Hair
- Air filters
- Brushes
- Felt
- Insulation
- Plaster
- Textiles

From Internal Organs
- Instrument strings
- Tennis racquet strings
- Hormones, enzymes, vitamins & other medical material

From Milk
- Adhesives
- Plastics
- Cosmetics
- Medicines

From Internal Organs
- Instrument strings
- Tennis racquet strings
- Hormones, enzymes, vitamins & other medical material

From Bones
- Refined sugar
- Charcoal
- Fertilizer
- Glass

From Skin
- Gelatin
- Flavorings
- Emery boards
- Sheet rock
- Wallpaper
- Adhesives
- Medicines
- Candies & confectionary

From Hooves and Horns
- Adhesives
- Plastics
- Pet food
- Plant food
- Photo film
- Shampoo & conditioner
- Emery boards
- Lamination
- Wallpaper
- Plywood

From Manure
- Fertilizer
- Nitrogen
- Phosphorus

From Fat
- Chewing gum
- Candles
- Detergents
- Fabric softener
- Deodorant
- Shaving cream
- Perfume
- Pet food
- Cosmetics
- Creams & Lotions
- Crayons
- Paint
- Oil & Lubricants
- Biodiesel
- Plastics
- Waterproofing agents
- Cement
- Ceramics
- Chalk
- Explosive
- Fireworks
- Matches
- Fertilizer
- Antifreeze
- Insulation
- Linoleum
- Rubber
- Textiles
- Medicines

Cattle Business

Demand

Quality/Quantity

Supply ability

Profit / Sustainability

ANIMAL PRODUCTION SYSTEM

Fast genetic & Suitable
Management Improvements

Input

Feed
Labor
Genetics, Germplasm
Drugs and Medicines
Technologies
Facilitates
Etc.,

Environment

Genetic

Management (process)

(Production Efficiency)

Economic competition
Limited natural resources
Large demands

Output

(Quality and Quantity)
Meat, milk, egg, animals, and others

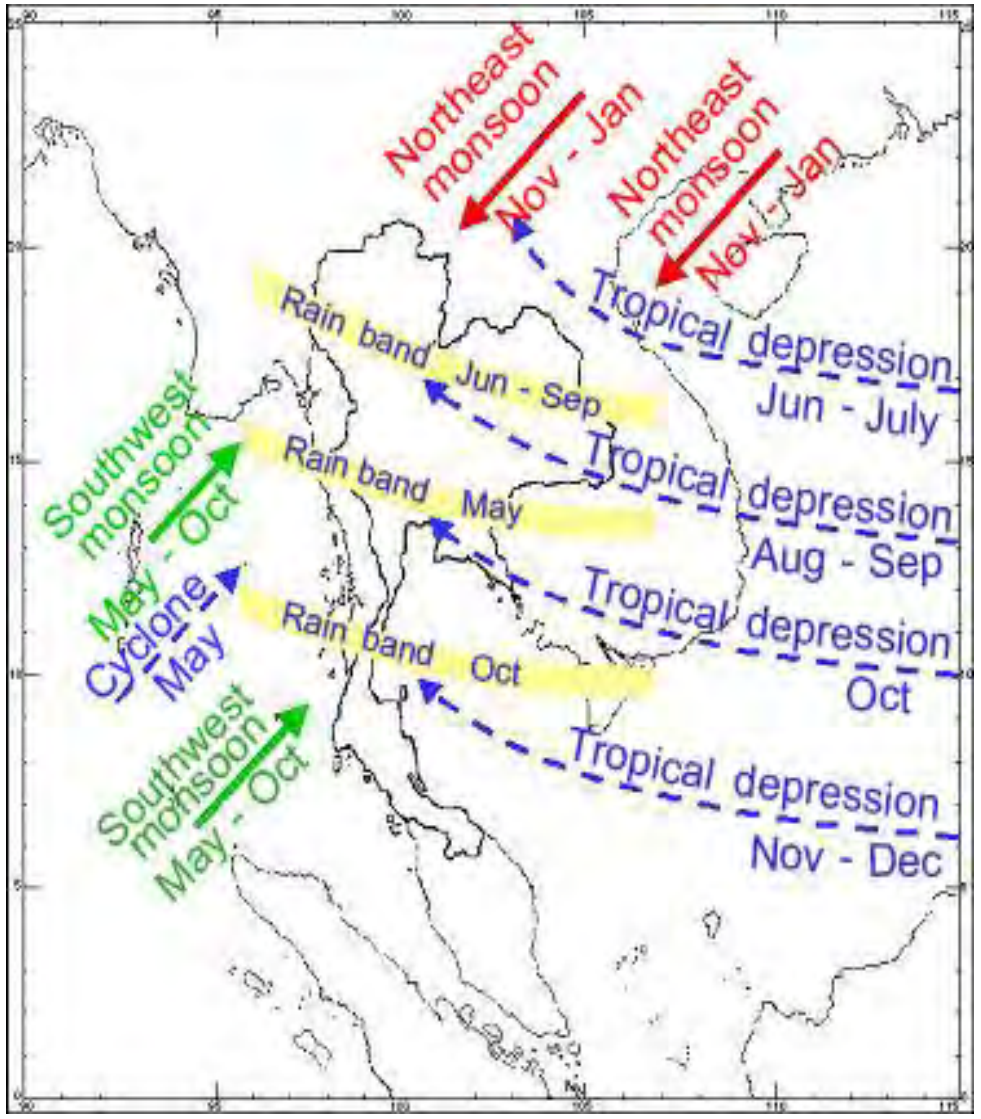
Business and Marketing

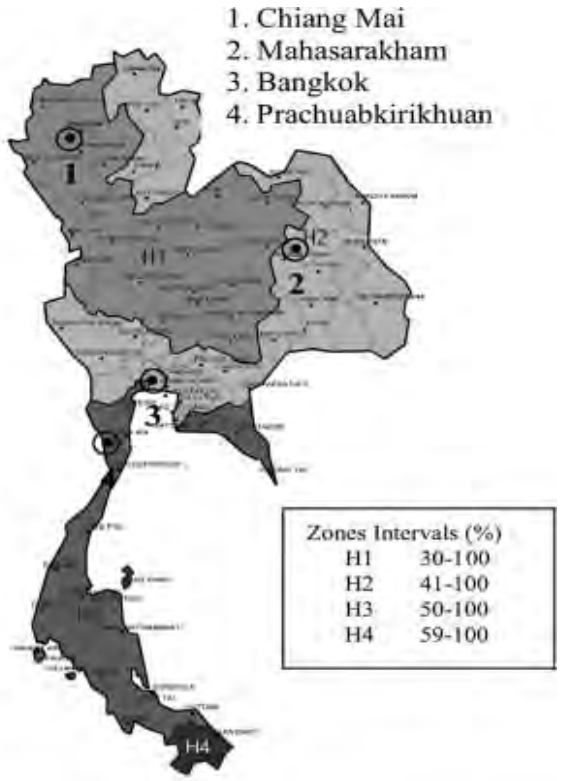
Efficiency of cattle production
Satisfaction of the consumers

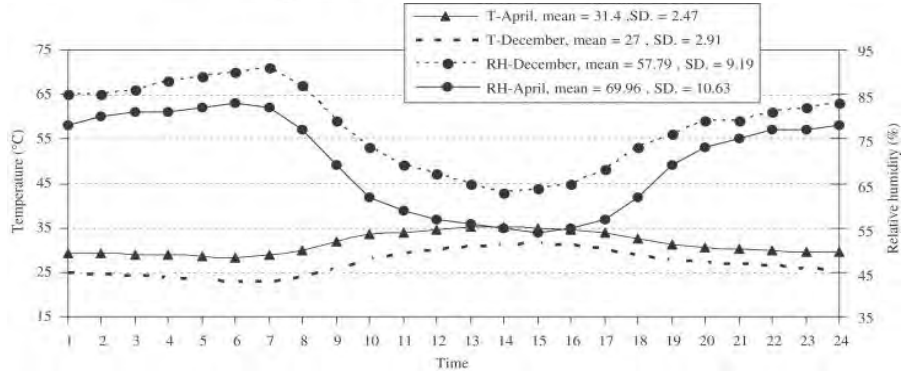
Outcome

Profit, Credit
Strength, Competing ability, Sustainability

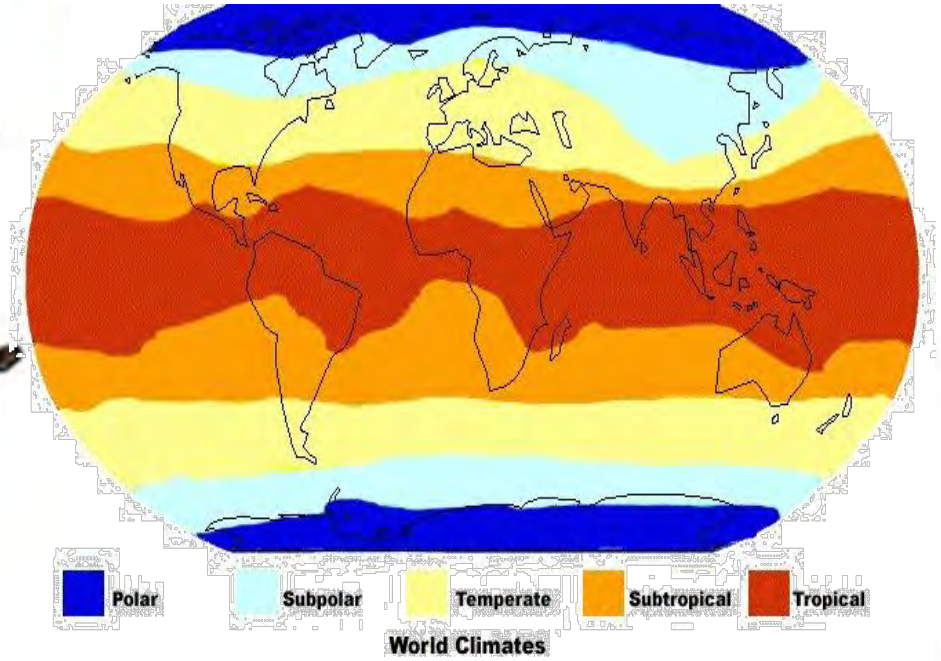
High temperature and high humidity in Tropical regions







Adaptability
Production Efficiency



Bos indicus

- Living in the heat
- Reproduction
- Tolerance
- Management driven

Bos taurus

- Meat & Milk production
- Maternal & Terminal
- Carcass traits
- Adaptability

Cross breeding
Upgrading

Cross breeding & Upgrading

Angus

Brahman

Holstein

Native

½ Angus – ½ Brahman

1/2 Holstein – 1/2 Native

Holstein

3/4 Holstein – 1/4 Native

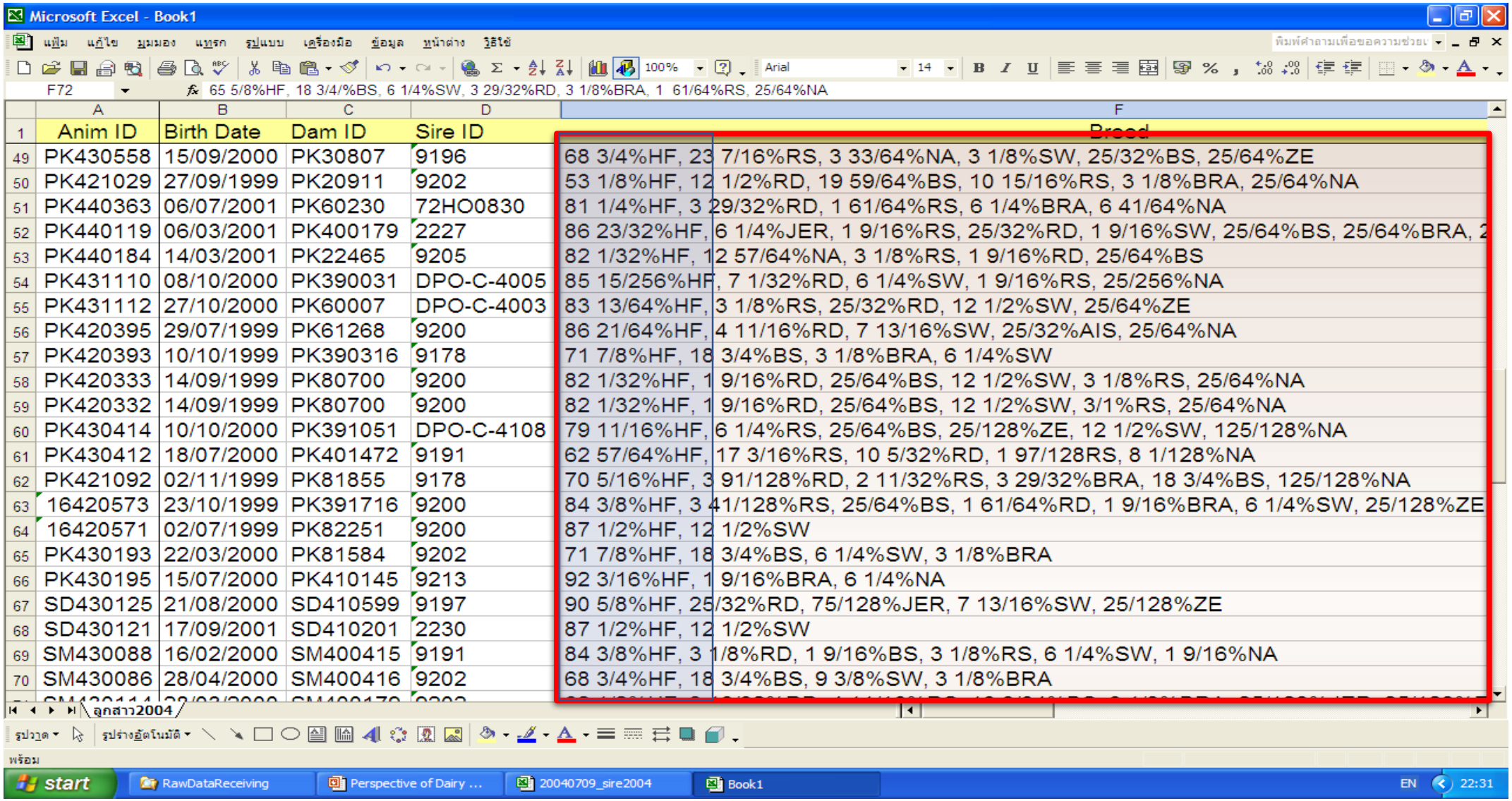
Holstein

7/8 Holstein – 1/8 Native

Holstein

15/16 Holstein – 1/16 Native

Dairy Population in Thailand



	A	B	C	D	F
1	Anim ID	Birth Date	Dam ID	Sire ID	Breed
49	PK430558	15/09/2000	PK30807	9196	68 3/4%HF, 23 7/16%RS, 3 33/64%NA, 3 1/8%SW, 25/32%BS, 25/64%ZE
50	PK421029	27/09/1999	PK20911	9202	53 1/8%HF, 12 1/2%RD, 19 59/64%BS, 10 15/16%RS, 3 1/8%BRA, 25/64%NA
51	PK440363	06/07/2001	PK60230	72HO0830	81 1/4%HF, 3 29/32%RD, 1 61/64%RS, 6 1/4%BRA, 6 41/64%NA
52	PK440119	06/03/2001	PK400179	2227	86 23/32%HF, 6 1/4%JER, 1 9/16%RS, 25/32%RD, 1 9/16%SW, 25/64%BS, 25/64%BRA, 2
53	PK440184	14/03/2001	PK22465	9205	82 1/32%HF, 12 57/64%NA, 3 1/8%RS, 1 9/16%RD, 25/64%BS
54	PK431110	08/10/2000	PK390031	DPO-C-4005	85 15/256%HF, 7 1/32%RD, 6 1/4%SW, 1 9/16%RS, 25/256%NA
55	PK431112	27/10/2000	PK60007	DPO-C-4003	83 13/64%HF, 3 1/8%RS, 25/32%RD, 12 1/2%SW, 25/64%ZE
56	PK420395	29/07/1999	PK61268	9200	86 21/64%HF, 4 11/16%RD, 7 13/16%SW, 25/32%AIS, 25/64%NA
57	PK420393	10/10/1999	PK390316	9178	71 7/8%HF, 18 3/4%BS, 3 1/8%BRA, 6 1/4%SW
58	PK420333	14/09/1999	PK80700	9200	82 1/32%HF, 1 9/16%RD, 25/64%BS, 12 1/2%SW, 3 1/8%RS, 25/64%NA
59	PK420332	14/09/1999	PK80700	9200	82 1/32%HF, 1 9/16%RD, 25/64%BS, 12 1/2%SW, 3/1%RS, 25/64%NA
60	PK430414	10/10/2000	PK391051	DPO-C-4108	79 11/16%HF, 6 1/4%RS, 25/64%BS, 25/128%ZE, 12 1/2%SW, 125/128%NA
61	PK430412	18/07/2000	PK401472	9191	62 57/64%HF, 17 3/16%RS, 10 5/32%RD, 1 97/128RS, 8 1/128%NA
62	PK421092	02/11/1999	PK81855	9178	70 5/16%HF, 3 91/128%RD, 2 11/32%RS, 3 29/32%BRA, 18 3/4%BS, 125/128%NA
63	16420573	23/10/1999	PK391716	9200	84 3/8%HF, 3 41/128%RS, 25/64%BS, 1 61/64%RD, 1 9/16%BRA, 6 1/4%SW, 25/128%ZE
64	16420571	02/07/1999	PK82251	9200	87 1/2%HF, 12 1/2%SW
65	PK430193	22/03/2000	PK81584	9202	71 7/8%HF, 18 3/4%BS, 6 1/4%SW, 3 1/8%BRA
66	PK430195	15/07/2000	PK410145	9213	92 3/16%HF, 1 9/16%BRA, 6 1/4%NA
67	SD430125	21/08/2000	SD410599	9197	90 5/8%HF, 25/32%RD, 75/128%JER, 7 13/16%SW, 25/128%ZE
68	SD430121	17/09/2001	SD410201	2230	87 1/2%HF, 12 1/2%SW
69	SM430088	16/02/2000	SM400415	9191	84 3/8%HF, 3 1/8%RD, 1 9/16%BS, 3 1/8%RS, 6 1/4%SW, 1 9/16%NA
70	SM430086	28/04/2000	SM400416	9202	68 3/4%HF, 18 3/4%BS, 9 3/8%SW, 3 1/8%BRA

Thai Multibreed Dairy Population

HF = Holstein Friesian; BS = Brown Swiss; BRA = Brahman; JER = Jersey; NA = Thai Native;
RD = Red Dane; RS = Red Sindhi; SW = Sahiwal; ZE = Other Zebu

Cattle Production

Economically Important Traits

- Growth
- Reproduction
- Production
- Health & Longevity
- Adaptability

Cannot be transferred

Transmittable (Additive Genetic Effect; Breeding Value, BV)

In-transmittable (Non Additive Genetic Effects; heterosis)

Phenotype = **Genetic** + **Environment**

Income

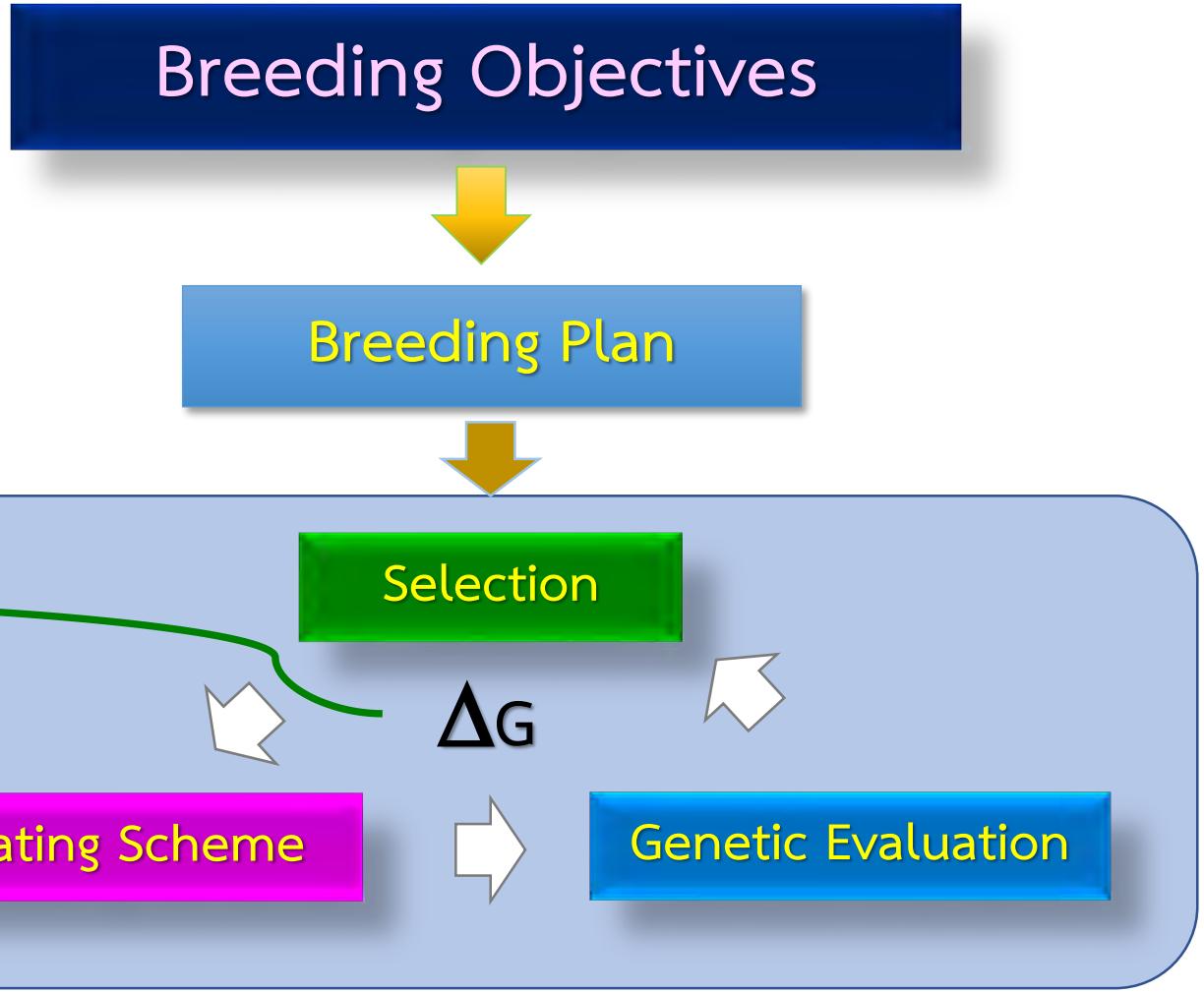
Cost / Investment

Profit = Income – Cost

Increase production efficiency → reduce cost → increase chance to get high profit

Animal Breeding / Genetic Improvement

Definition:
Genetic management (selection and mating) in order to improve the desirable traits of **the progeny** to be better than **the parent generation**



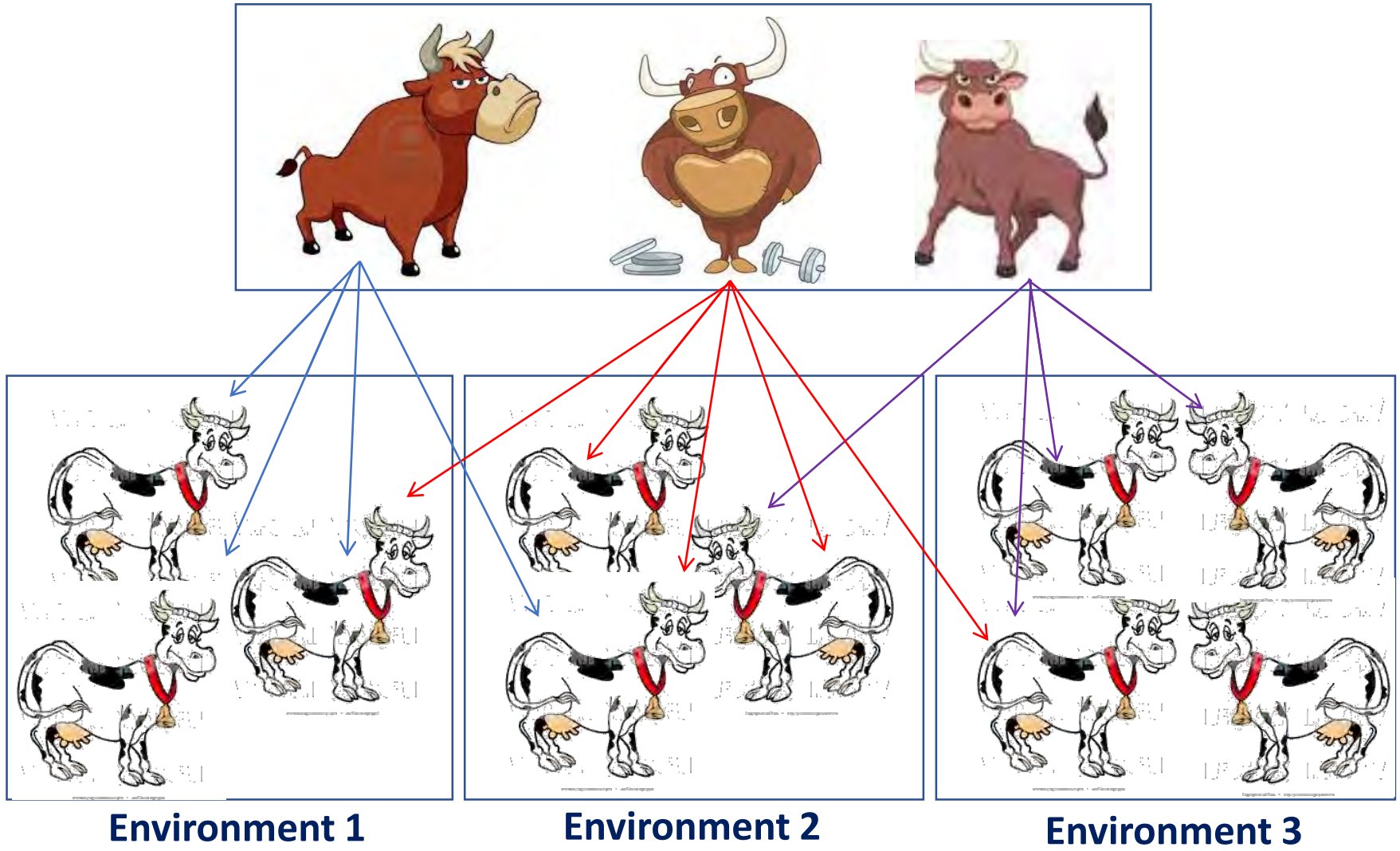
Increase genetic progress

- Increase **selection accuracy**
- Increase **selection intensity**
- Increase **selection difference**
- Shorten **generation interval**

Genetic Improvement (Breeding) = Selection + Mating

(Koonawootrittriron et al., 2008)

Genetic / Genomic Evaluations



Produce efficiently high yield

Produce consistently high yield

Good adaptability & easy to take care

Great genetic & transmittable most

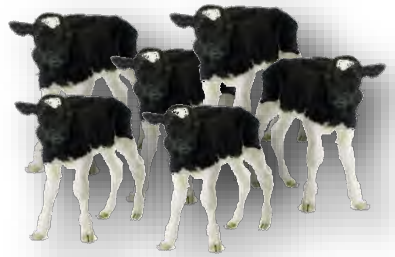
Breeding Strategy to Enhance Milk Production and Other Economically Important Traits

Semen Production

Fertility and Libido Tests
(Selection / Culling)

Performance Tests

Growth, Appearance, Health
(Selection / Culling)



Male

Thai Dairy AI Bulls

(Young bulls, Proven bulls,
or Elite bulls)

Farm D

Female

Farm A

Progeny Tests (Bull proving)

Genetic – Genomic Evaluation,
Multiple Tropical Environments Test
(Selection / culling)

Farm B

Farm C

Female

Tropical Adapted Dairy Genetics

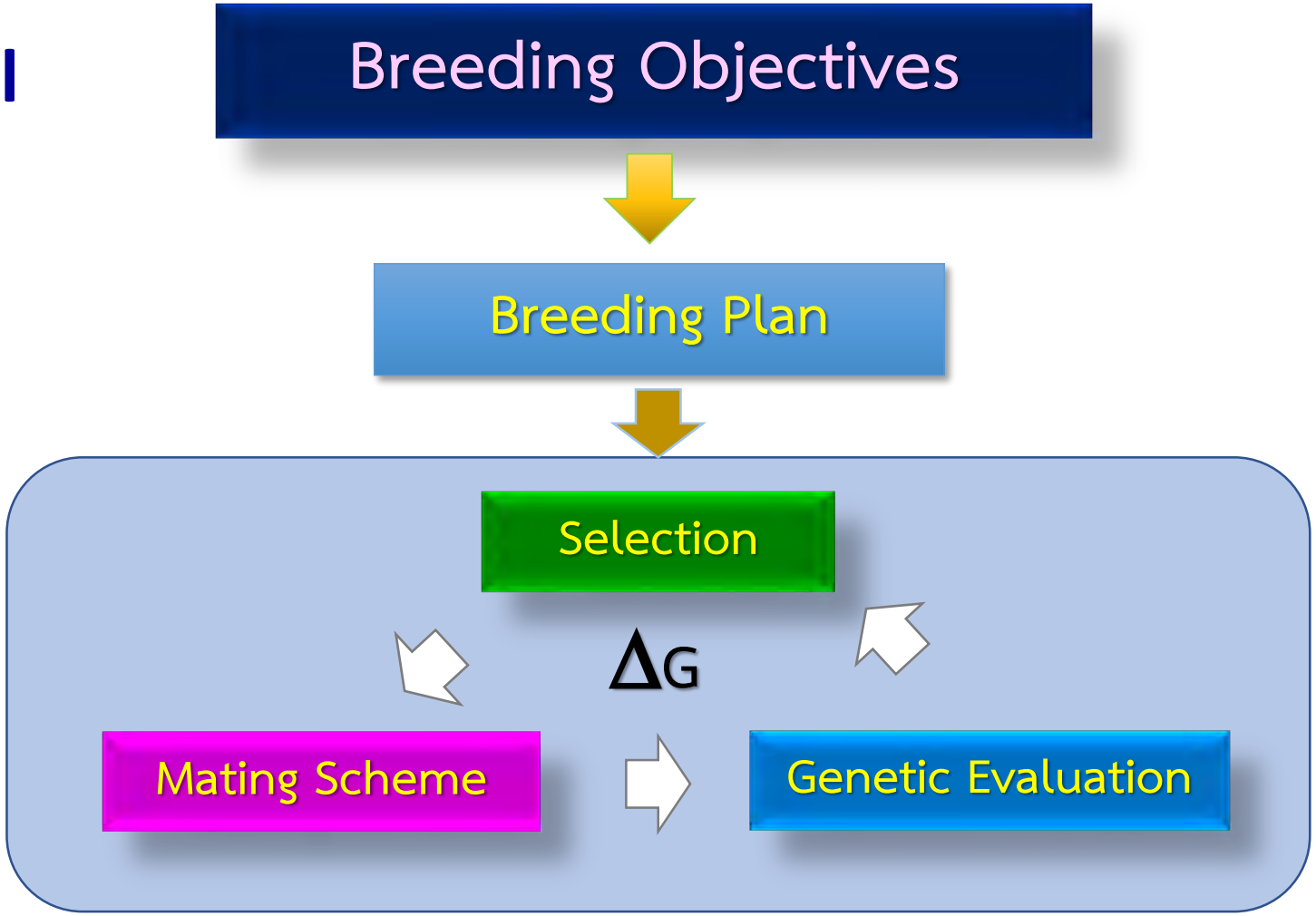
Animal Breeding / Genetic Improvement

Animal Mixed Linear Model

$$y = Xb + Za + e$$

- Estimable function?
- Reasonable assumption?

Trait (s)
= contemporary group
+ fixed effects
+ random additive genetic effect
+ other random effect(s)
+ residual



(Koonawootrittriron et al., 2008)

Challenges of Genetic Improvement of Thai Economic Animals with Genomic Technology

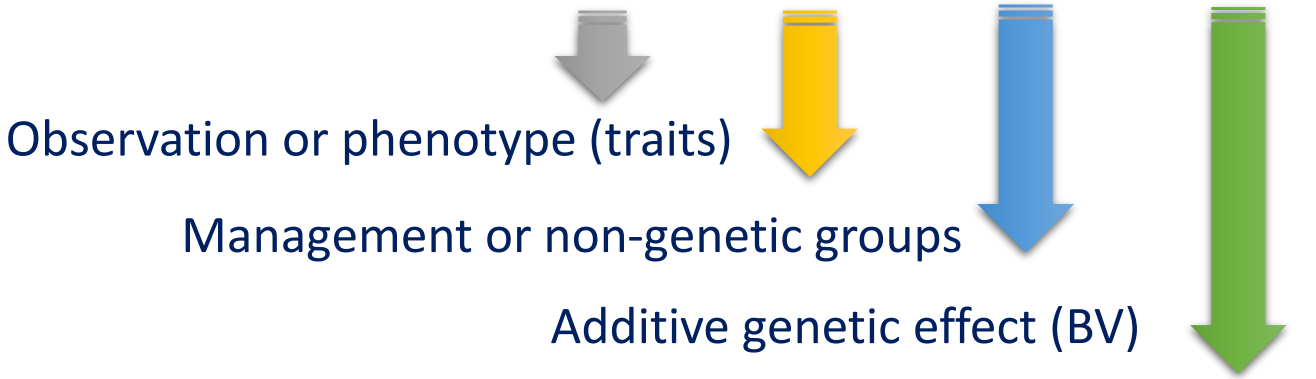
Phenotype = Genetic + Environment

Considerations

1) **Breeding objective**(s) - Target traits
2) **Breeding plan** (genetic parameter, facility, personnel, budget, etc)
3) **Data recording of the individuals** (Pedigree, Phenotype, other related data) & ID (Tagging)
4) **Selection criteria & tools** (experience, P, BV, Index, etc)
5) **Mating (and management) design** (contemporary group & assumptions)
6) **Genetic evaluation** (accuracy, un-bias)

$$y = Xb + Zu + e$$

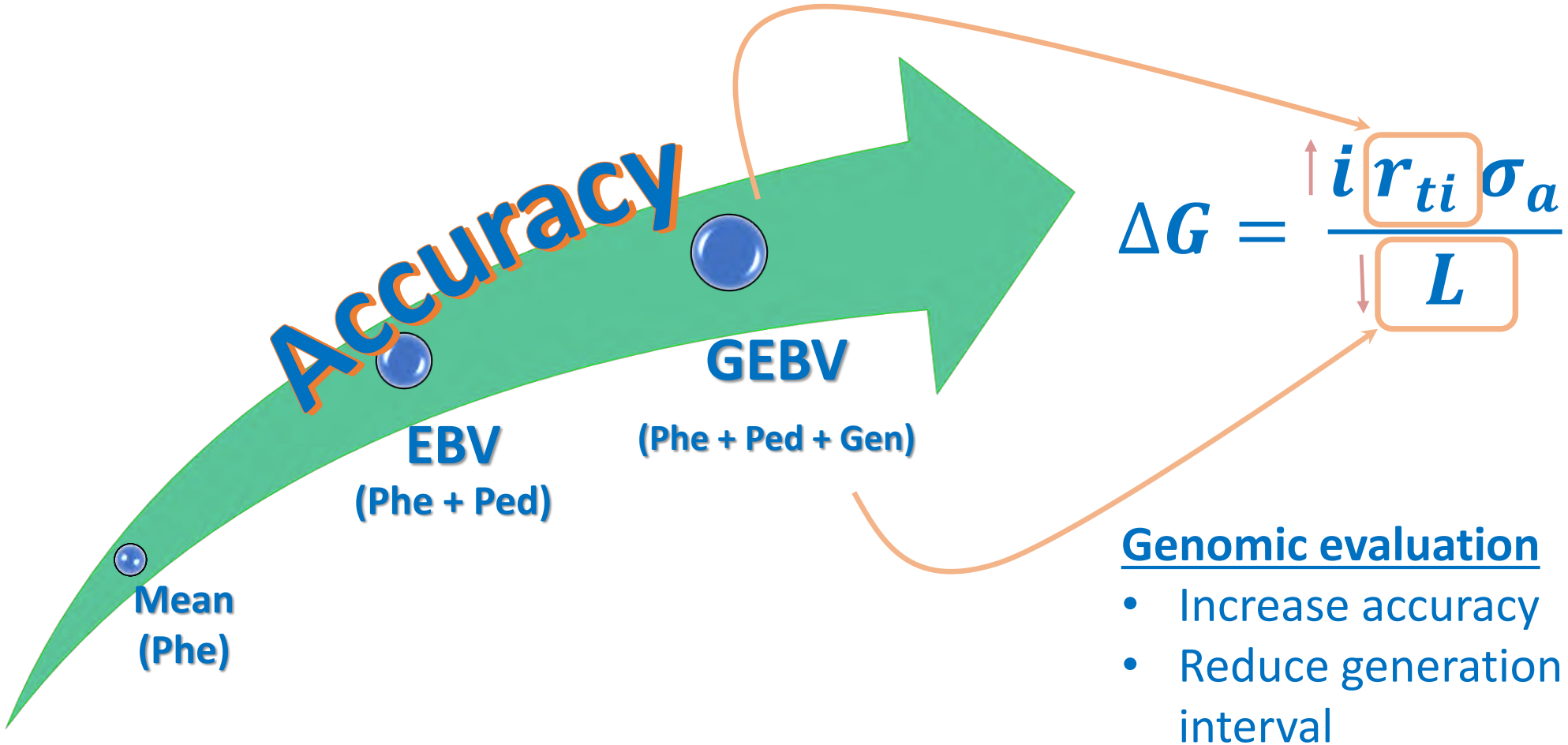
Best Linear Unbiased Prediction - BLUP



Key success:

- **Breeder** (understanding, capability, willingness)
- **Pedigree and phenotype data of individual animal** in the population
- **Other supports**

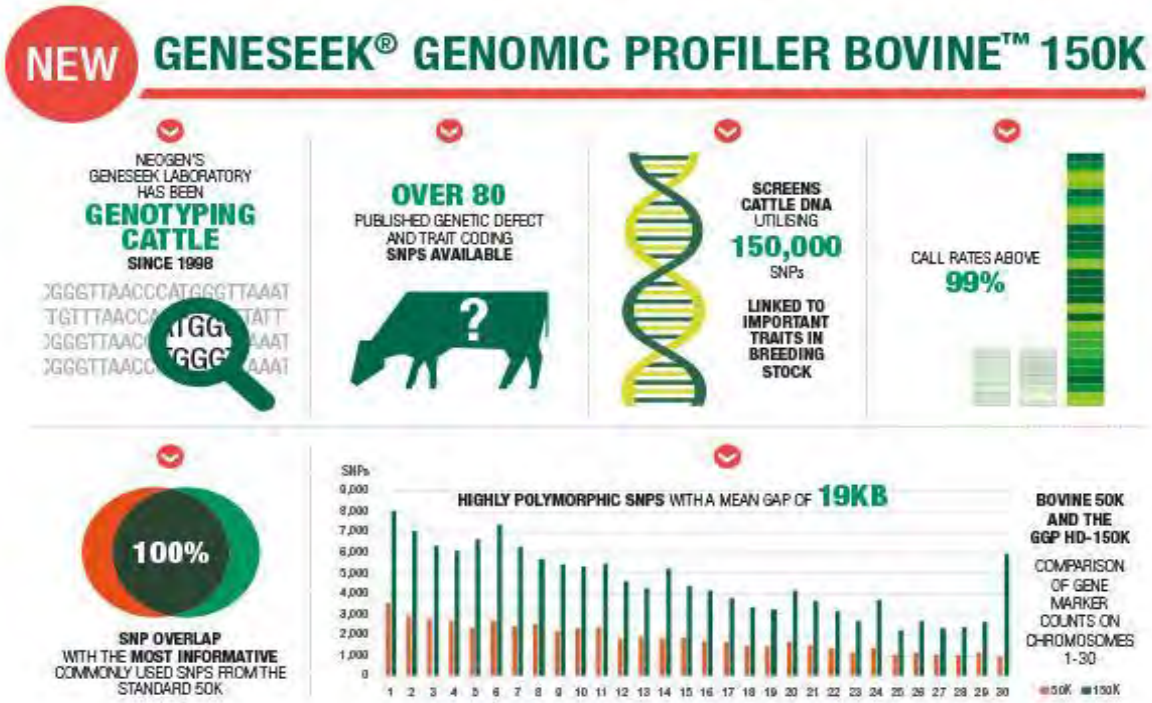
Genetic evaluation technologies



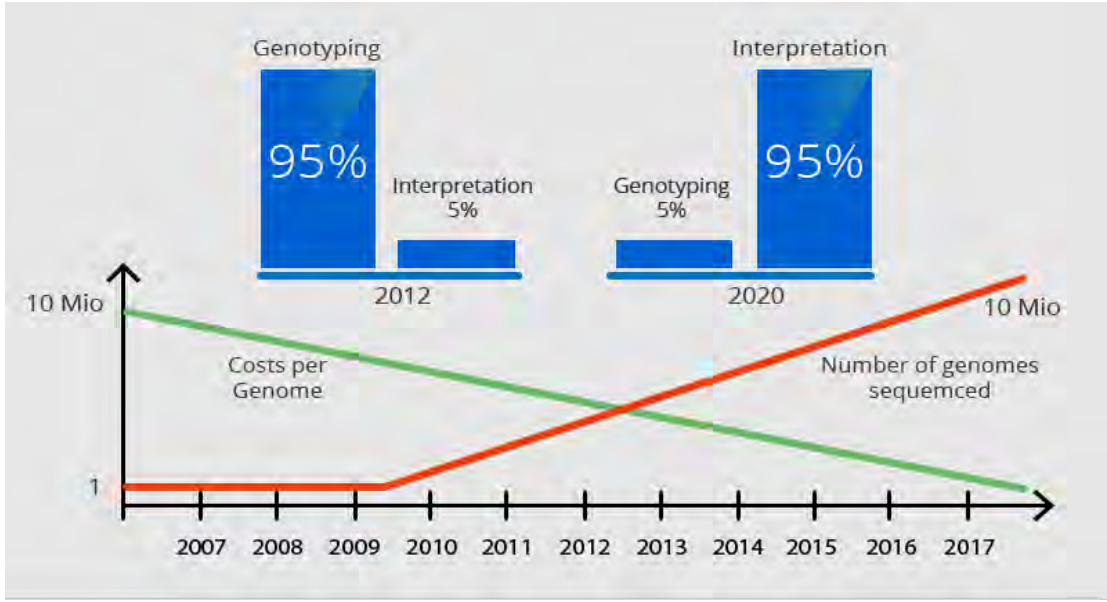
Genomic evaluation

- Increase accuracy
- Reduce generation interval

Advanced Genotyping Technology



https://twitter.com/hashtag/geneseek



Cattle Genetics

Thai Native

Brahman

Brahman crossbreds

Holstein

Commercial Breeds

Angus

Charolais

Brown Swiss

Genomic Differences between Cattle Breeds

- ❑ Economically important traits
- ❑ Adaptability
- ❑ Disease resistance
- ❑ Etc.,

Map of participated dairy farms

DNA repository at central laboratory of Faculty of Agriculture, Kasetsart University

-20 °C **-80 °C** **-196 °C**

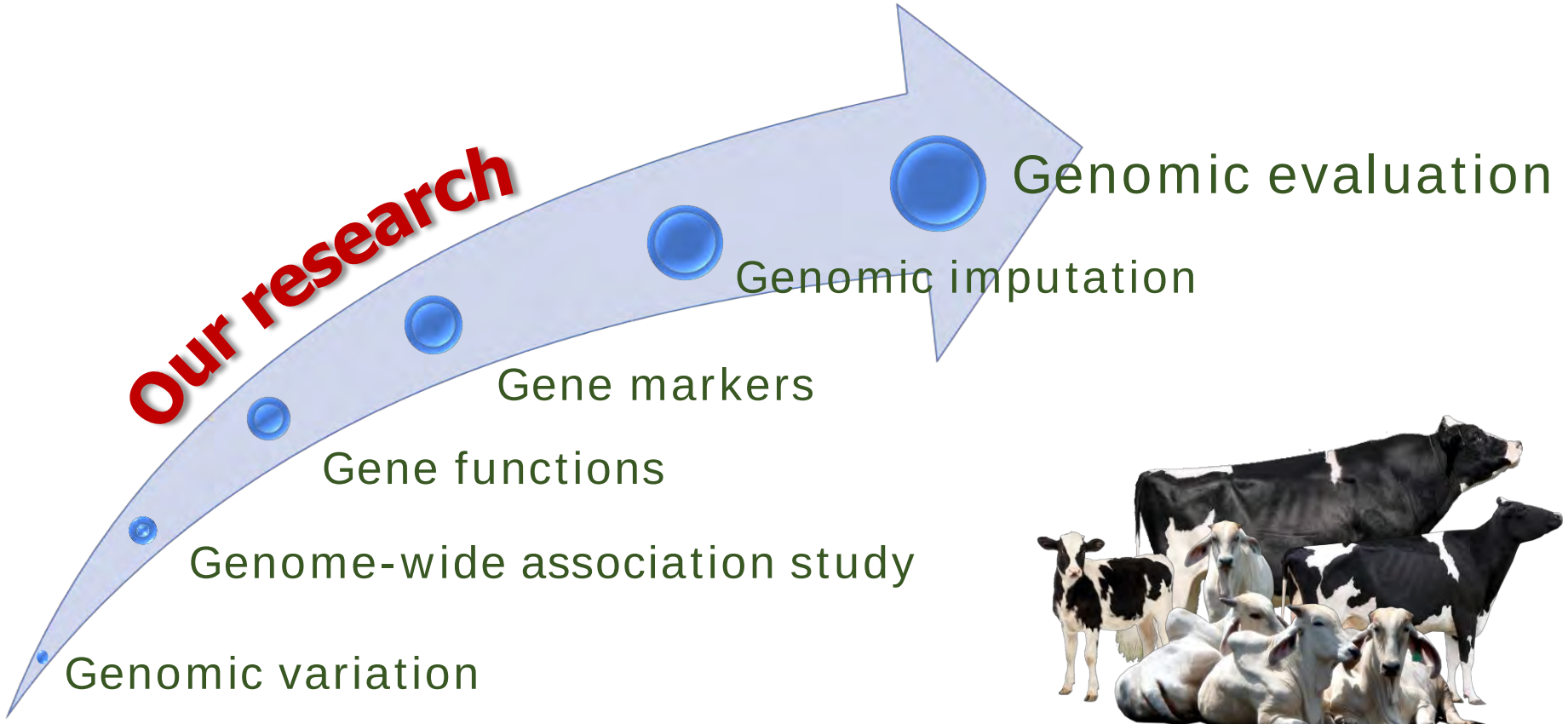
Our achievement (Since 2012)

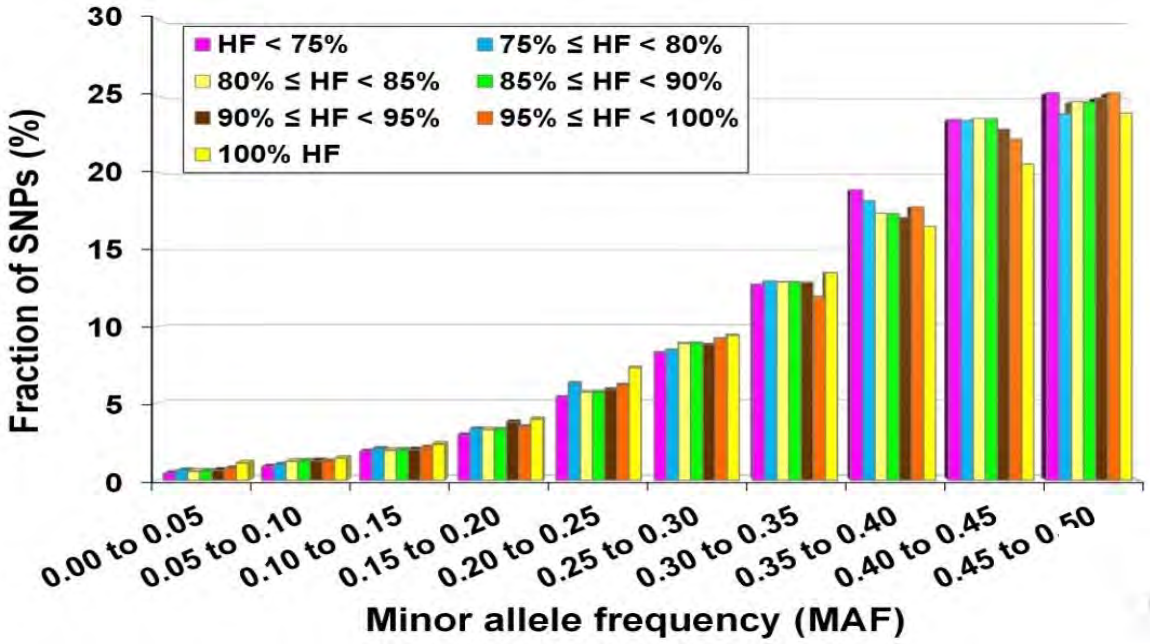
Number of cattle in the dataset	5,312
Number of sires	531
Number cows	4,781
• Number of first lactation cows	2,416
• Number of dams	2,365
Number of completed phenotypic and pedigree animals	2,510
Number of cattle farms	310
Number of cattle cooperatives	31
Number of locations (Central, North, Northeast and South)	4

Our achievement (Since 2012)

Number of dairy cattle that were collected for their DNA sample	4,104
• Number of sires	132
• Number of dams	3,972
Number of SNPs genotyped dairy cattle (cattle)	3,931
• GGP-9K (cattle)	1,412
• GGP-20K (cattle)	570
• GGP-26K (cattle)	540
• GGP-36K (cattle)	563
• GGP-50K (cattle)	501
• GGP-80K (cattle)	139
• GGP-150K (cattle)	206

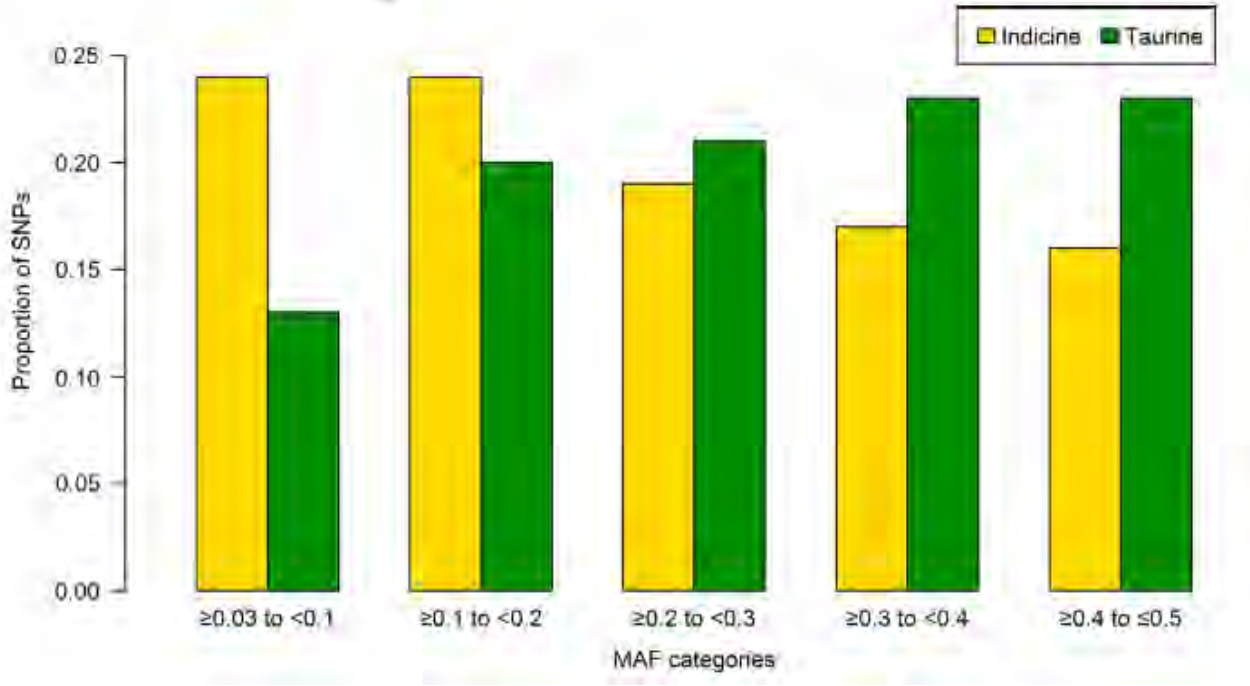
Widespread genotyping in tropical cattle populations will both increase the accuracy of genomic EBV and yield faster rates of genetic progress for production and adaptability





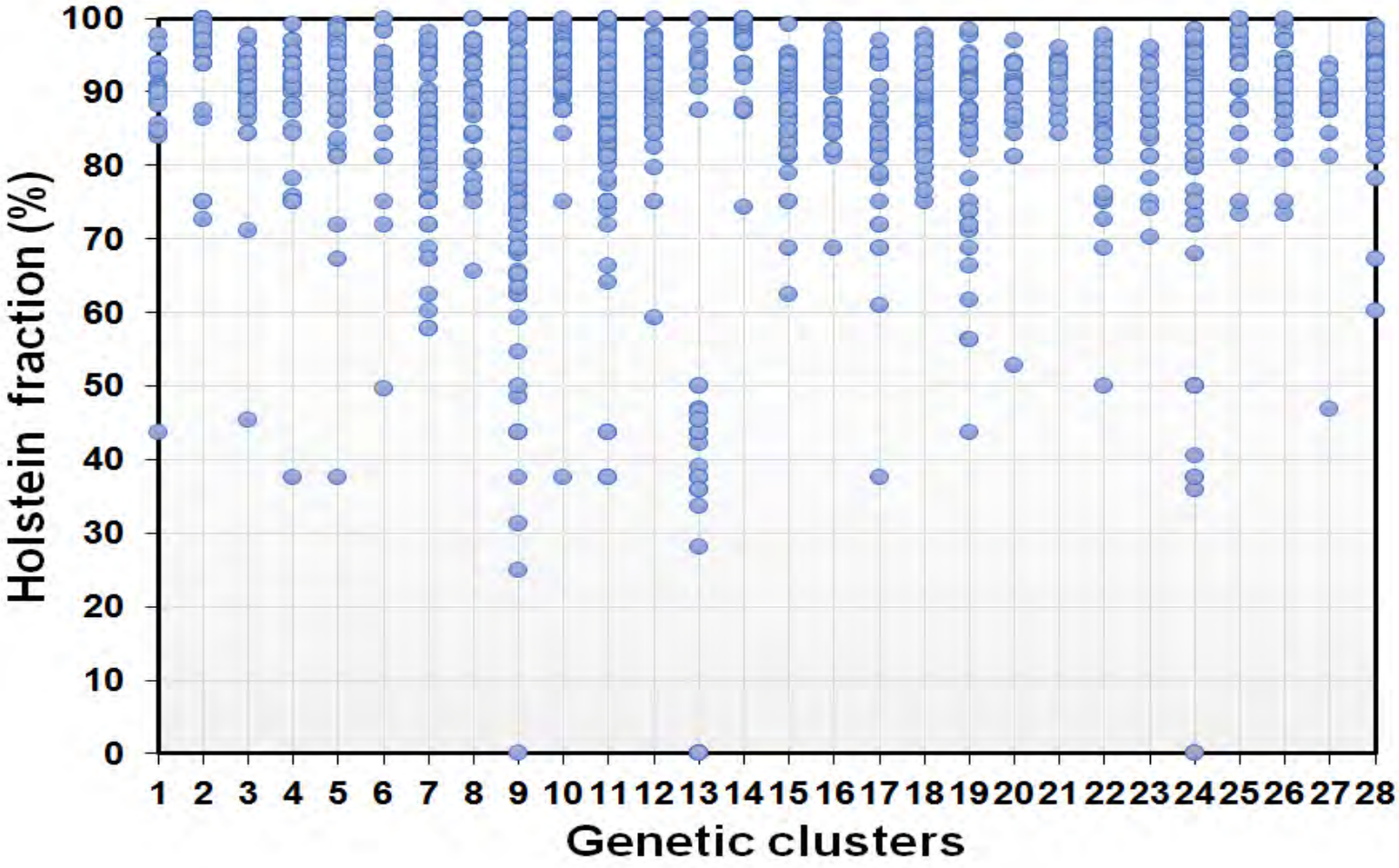
Similar to Taurine breed

Different from indicine breed



Laodim *et al*. (2015)

Genomic Variation



The correlation between genetic cluster and Holstein fraction was close to zero (r = 0.00025) indicating that there was no correspondence between breed composition of animals and their allocation to SNP-based genetic groups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Identification of SNP markers associated with milk and fat yields in multibreed dairy cattle using two genetic group structures

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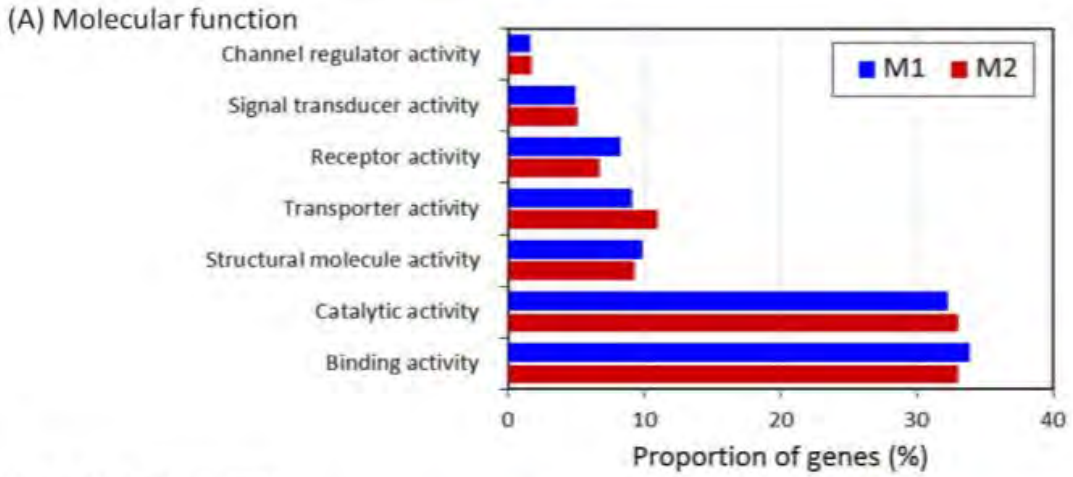
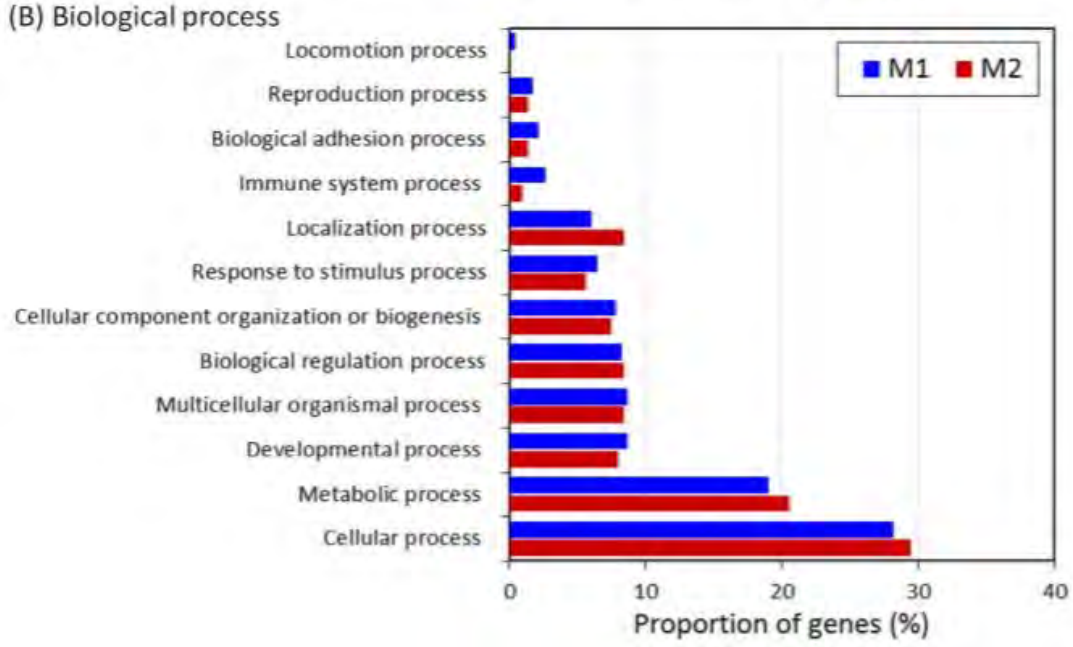
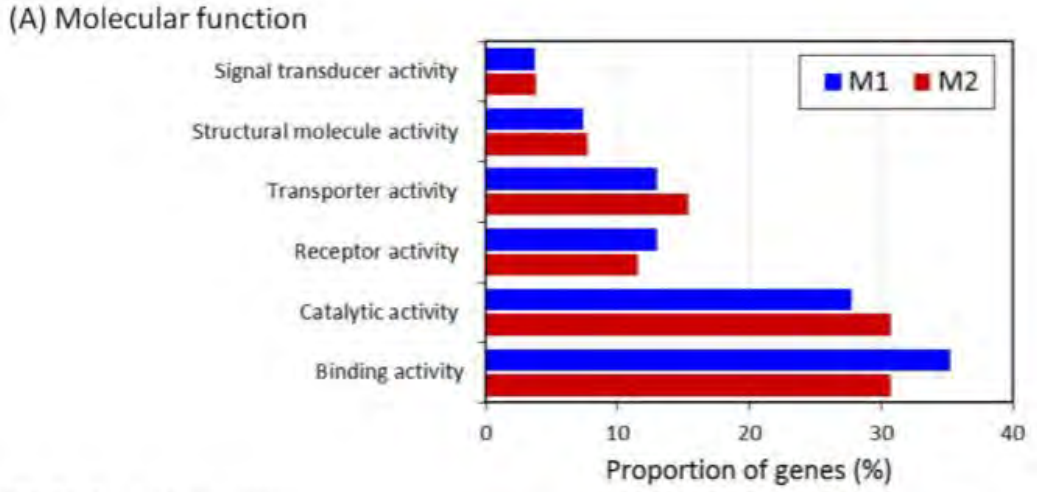
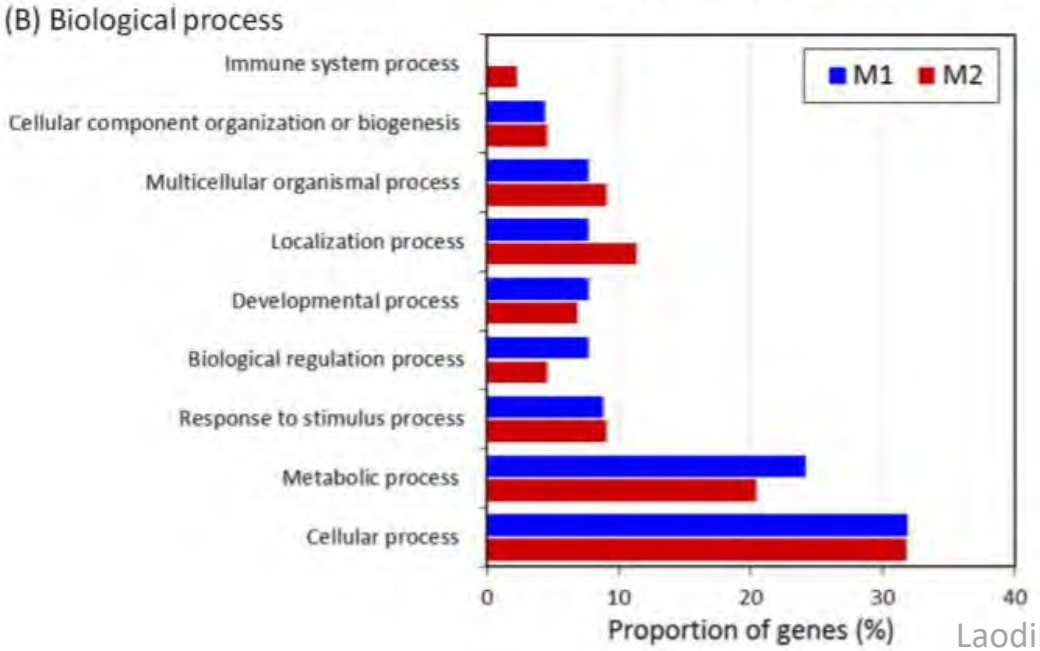
Laodim *et al*. (2017)

Proportion of genes associated with
milk yield and fat yield







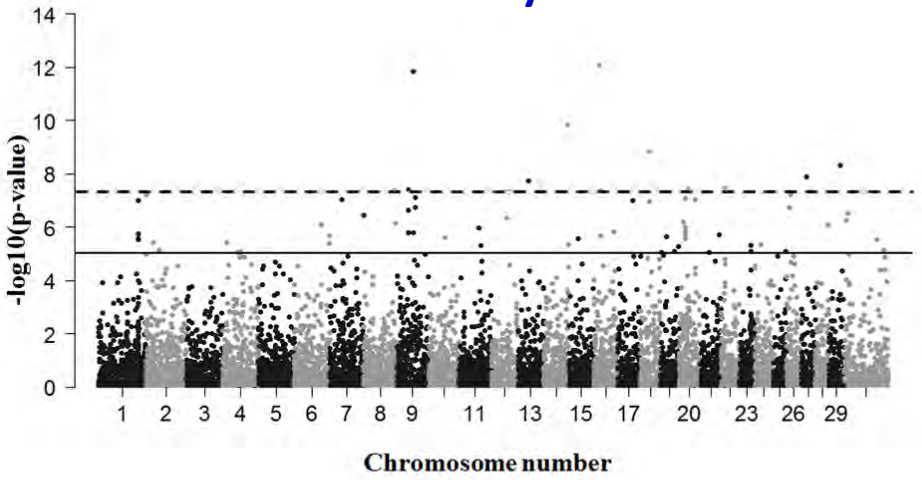


Laodim *et al.* (2017)

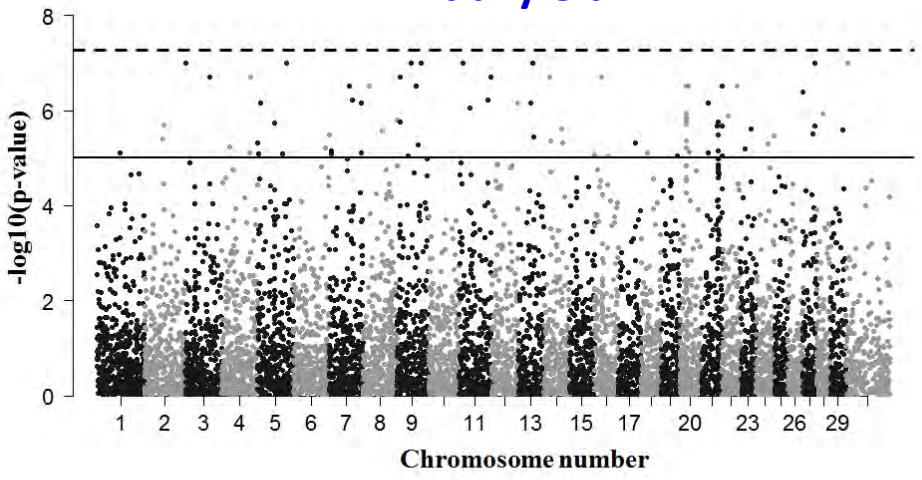
Genome-wide Association Study
for milk yield and other economic traits

KU KASETSART UNIVERSITY

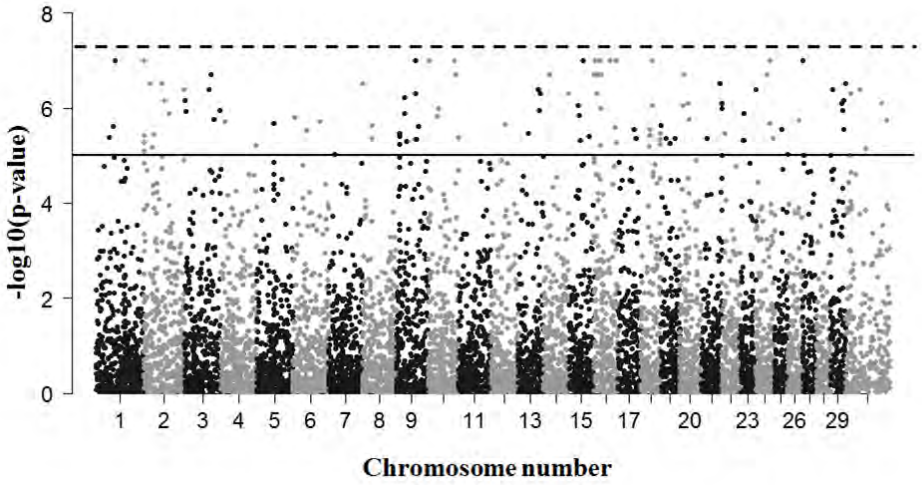
Milk yield



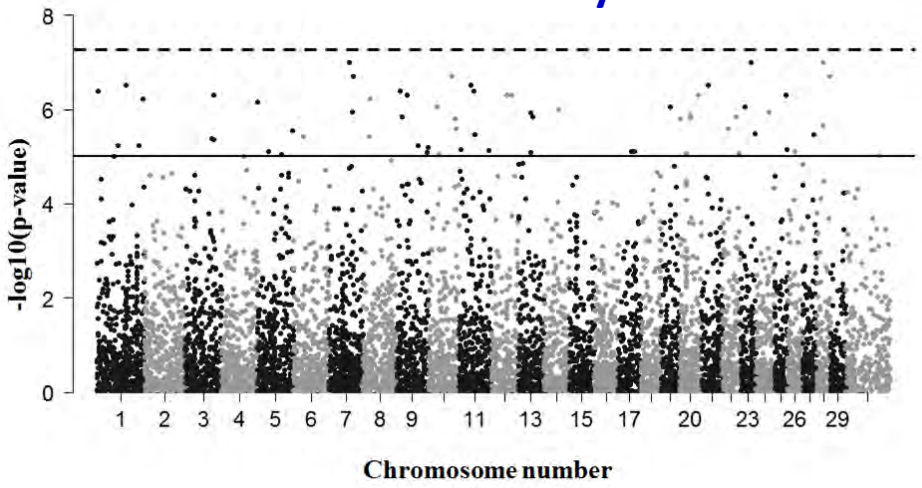
Initial yield



Peak yield

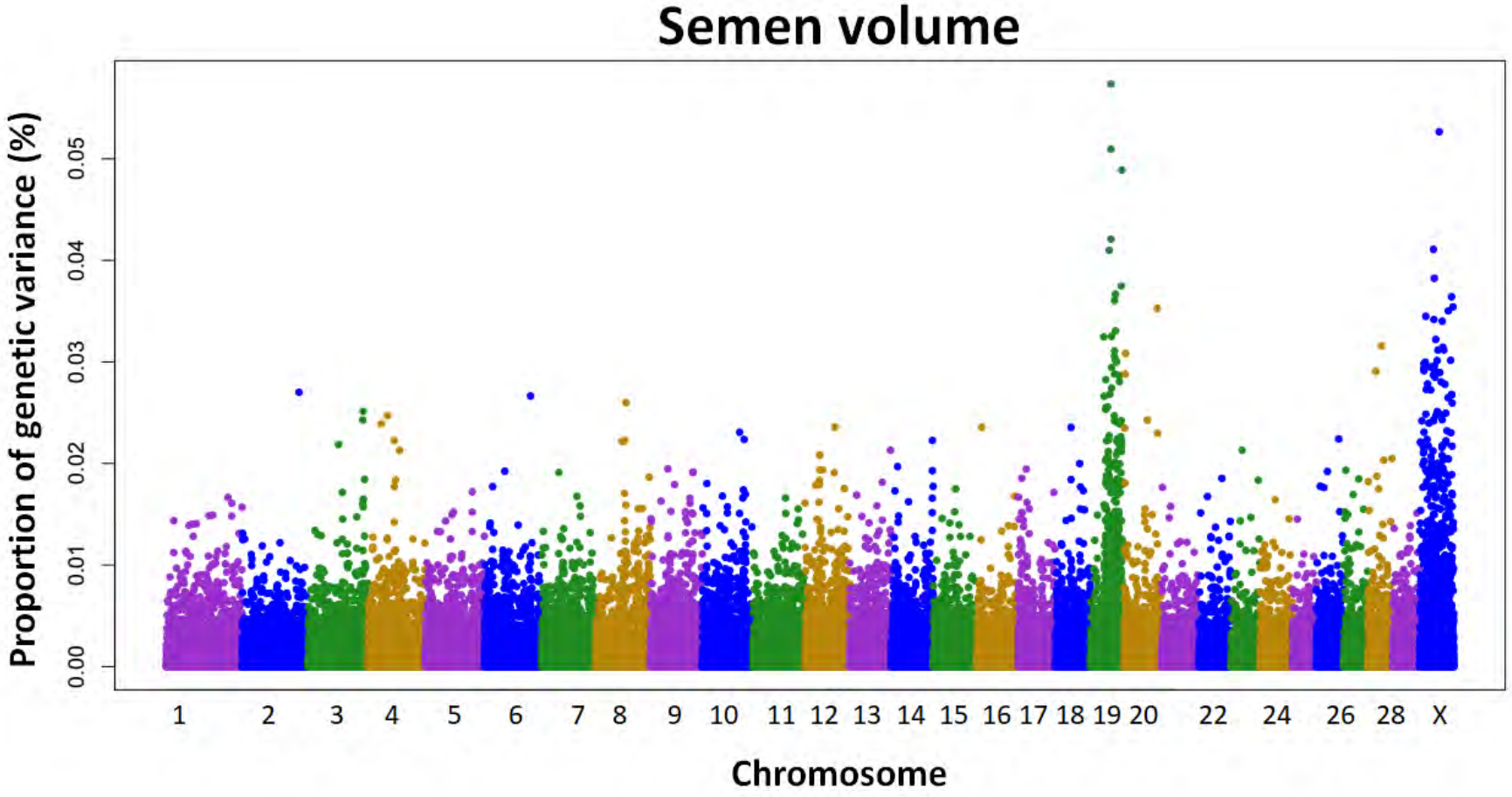


Persistency



Yodklaew *et al*. (2017)

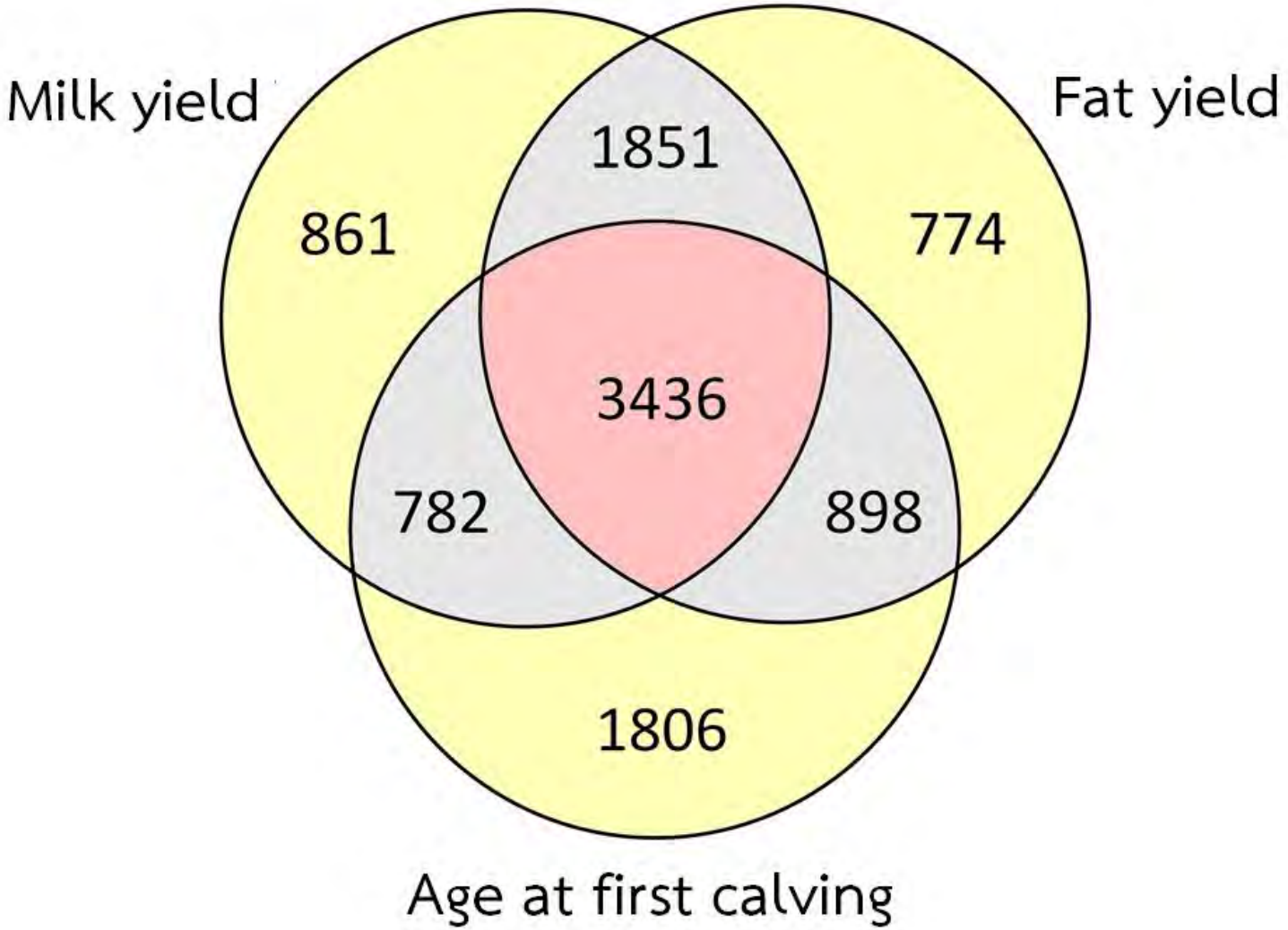
Genome-wide Association Study
For semen production traits



Sarakul *et al*. (2018)

Numbers of Associated Genes

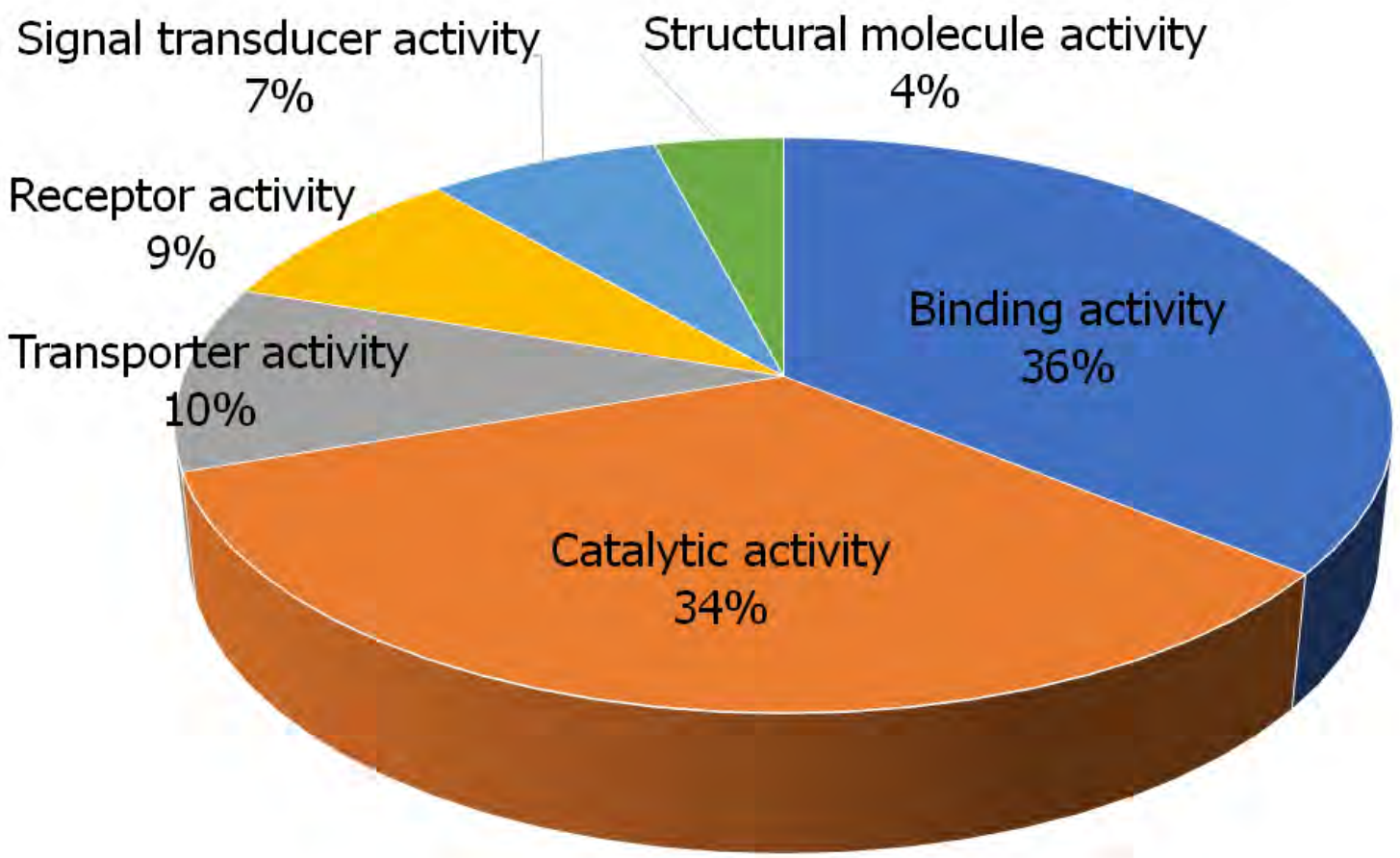
For Milk Yield, Fat Yield and Age at First Calving



Laodim *et al.* (2018)

Molecular Functions of Genes

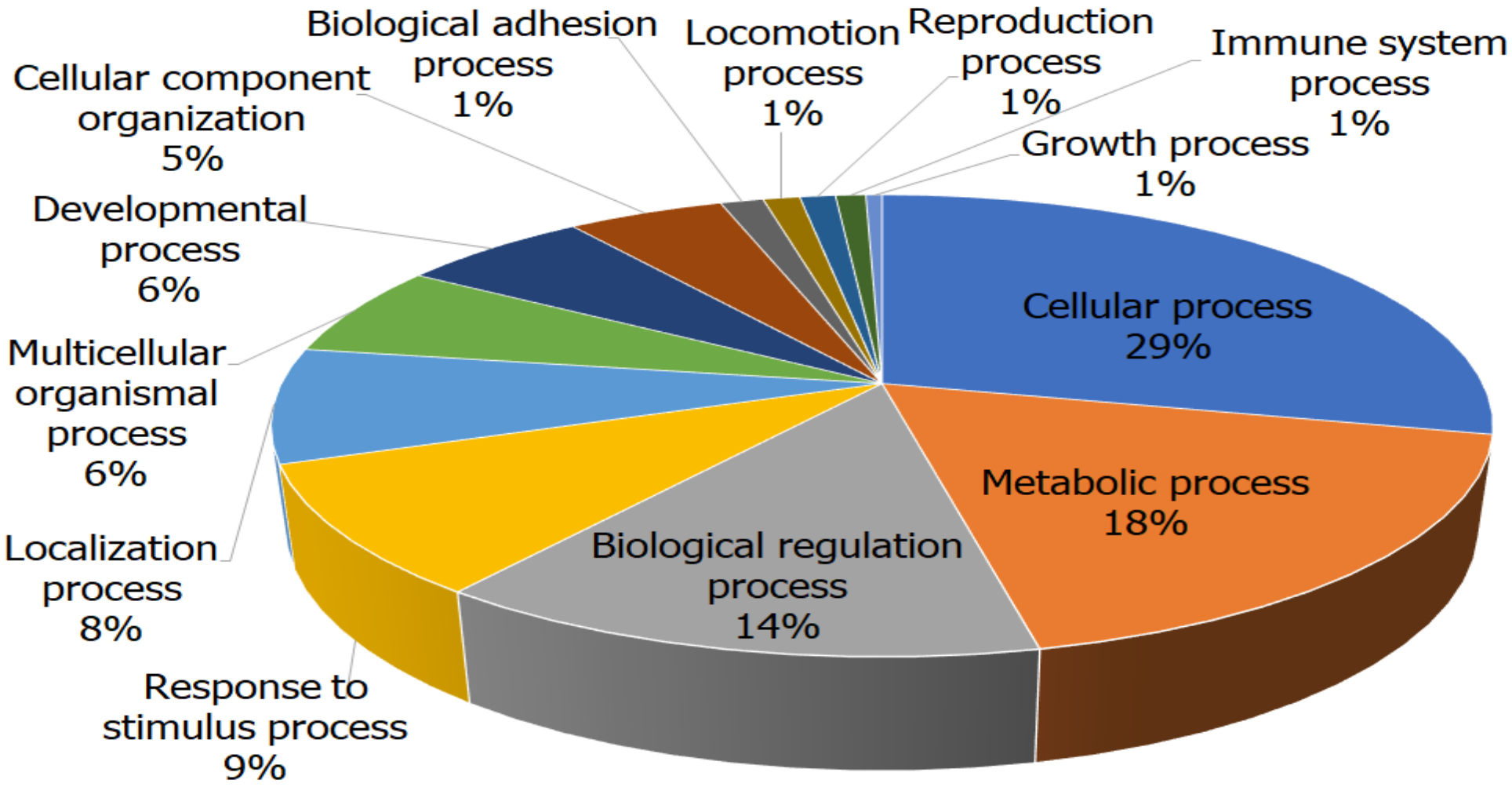
Associated with Milk Yield, Fat Yield and Age at First Calving



Laodim *et al*. (2018)

Biological Processes of Genes

Associated with Milk Yield, Fat Yield and Age at First Calving



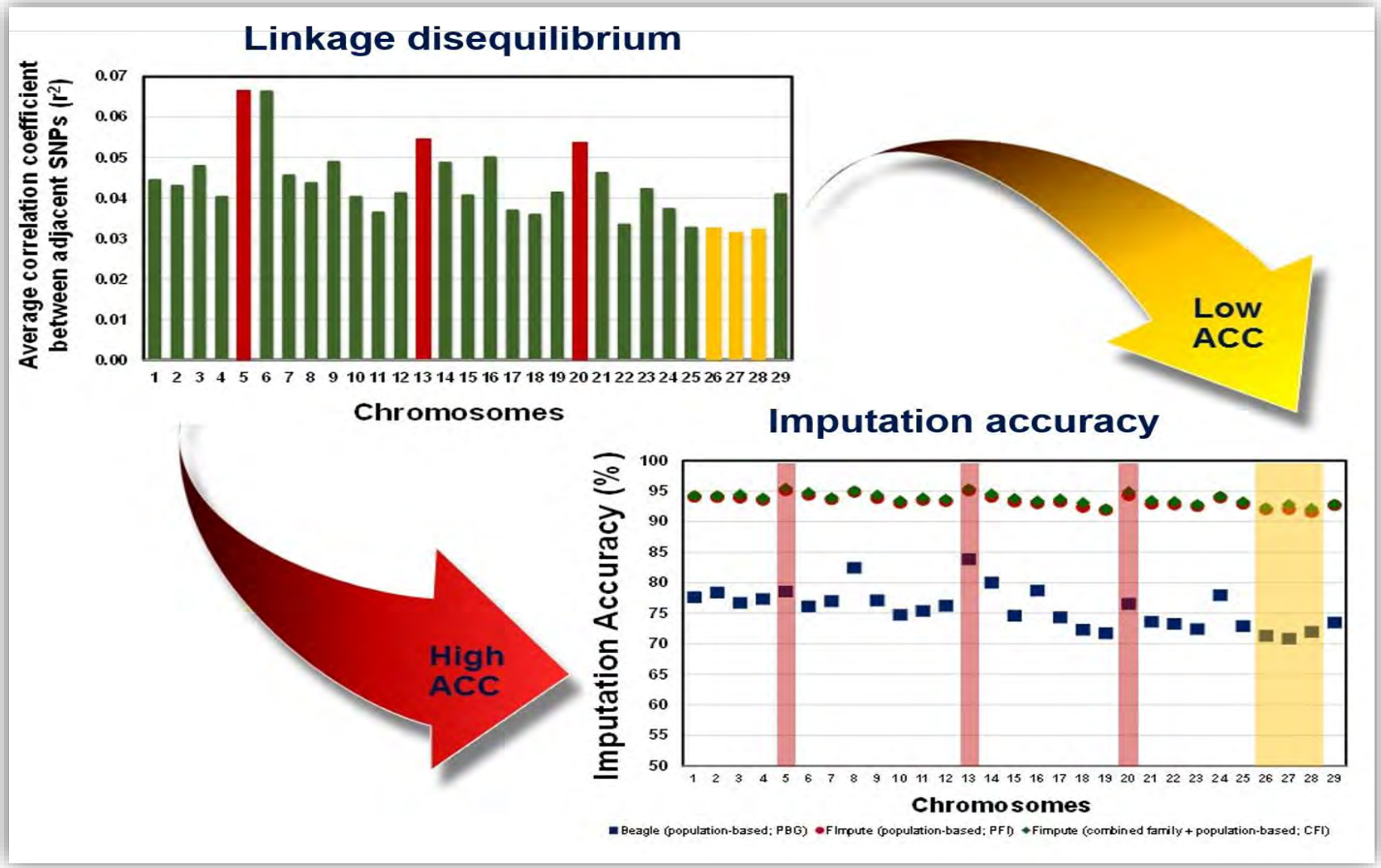
Laodim *et al*. (2018)

Biological Pathways related to
Milk Yield, Fat Yield and Age at First Calving

Category	Pathway	P-value	Number of genes (n)	Genetic variance (%)		
				MY	FY	AFC
Cellular processes	Rap1 signaling	8.9×10^{-8}	63	0.5113	0.6292	0.6437
	Calcium signaling	1.3×10^{-7}	58	0.5018	0.5157	0.5381
	Phospholipase D signaling	2.8×10^{-6}	47	0.4691	0.4361	0.4657
	Focal adhesion	1.6×10^{-5}	55	0.4087	0.3868	0.4621
	MAPK signaling	0.0002	62	0.4847	0.523	0.4807
	Ras signaling	0.0075	55	0.3982	0.4333	0.4639
	Wnt signaling	0.0077	38	0.3062	0.3016	0.2848
	cGMP-PKG signaling	0.0085	41	0.4702	0.483	0.4668
	Sphingolipid signaling	0.014	32	0.2295	0.2561	0.3181
	Oxytocin signaling	0.016	38	0.3528	0.3538	0.376
	Gap junction	0.021	26	0.3223	0.2973	0.3667
Nervous system	Glutamatergic synapse	1.9×10^{-8}	42	0.4857	0.4409	0.4886
	Dopaminergic synapse	0.0036	36	0.4004	0.3415	0.4037
	GABAergic synapse	0.011	26	0.3182	0.2633	0.2692
Digestive system	Pancreatic secretion	0.03	27	0.2748	0.2902	0.3216
Environmental adaptation	Circadian entrainment	0.0018	30	0.3818	0.3593	0.3672
Total			303	2.6282	2.5916	2.4893

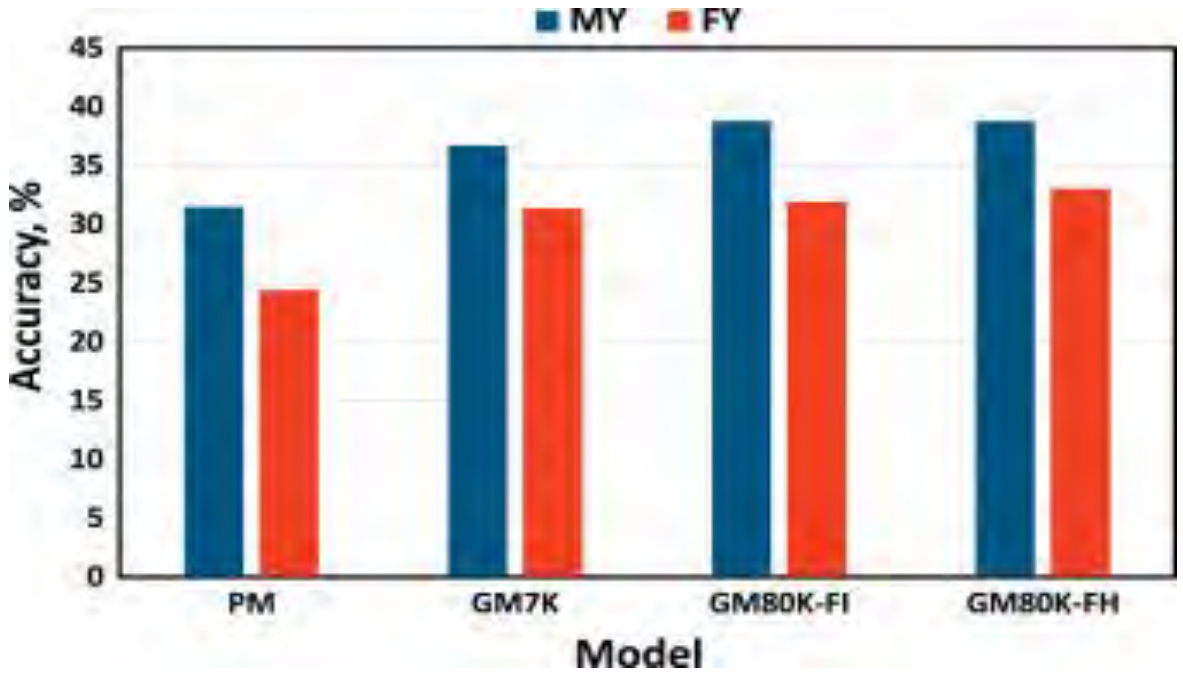
Laodim *et al.* (2018)

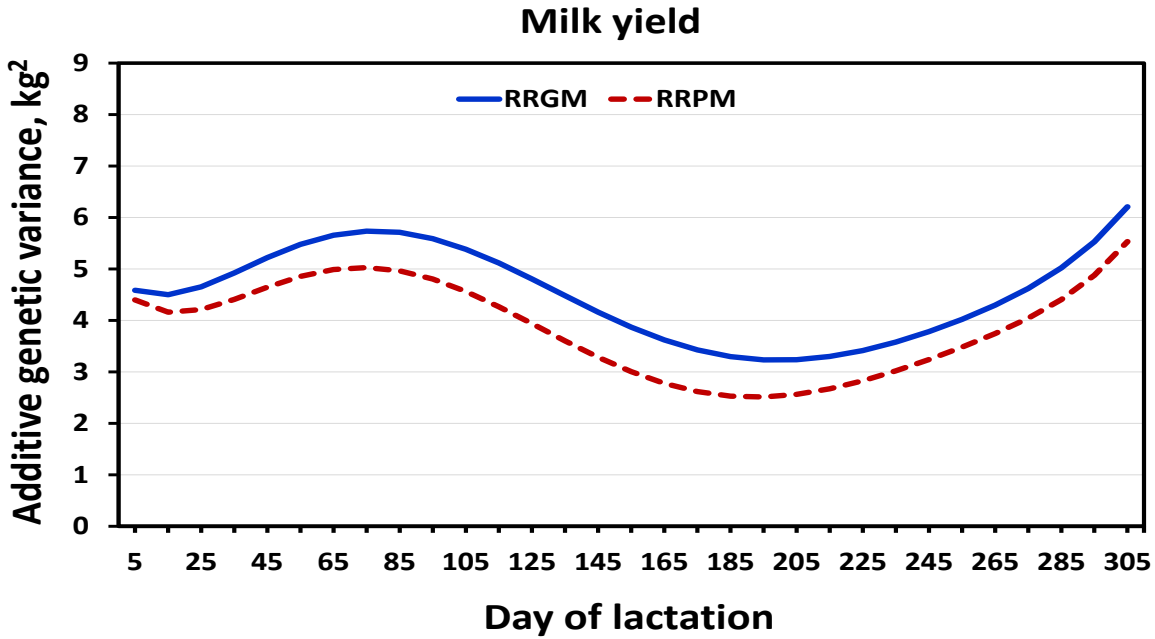
Imputation Techniques



Jattawa *et al.* (2015)

Accuracy of Genomic Prediction





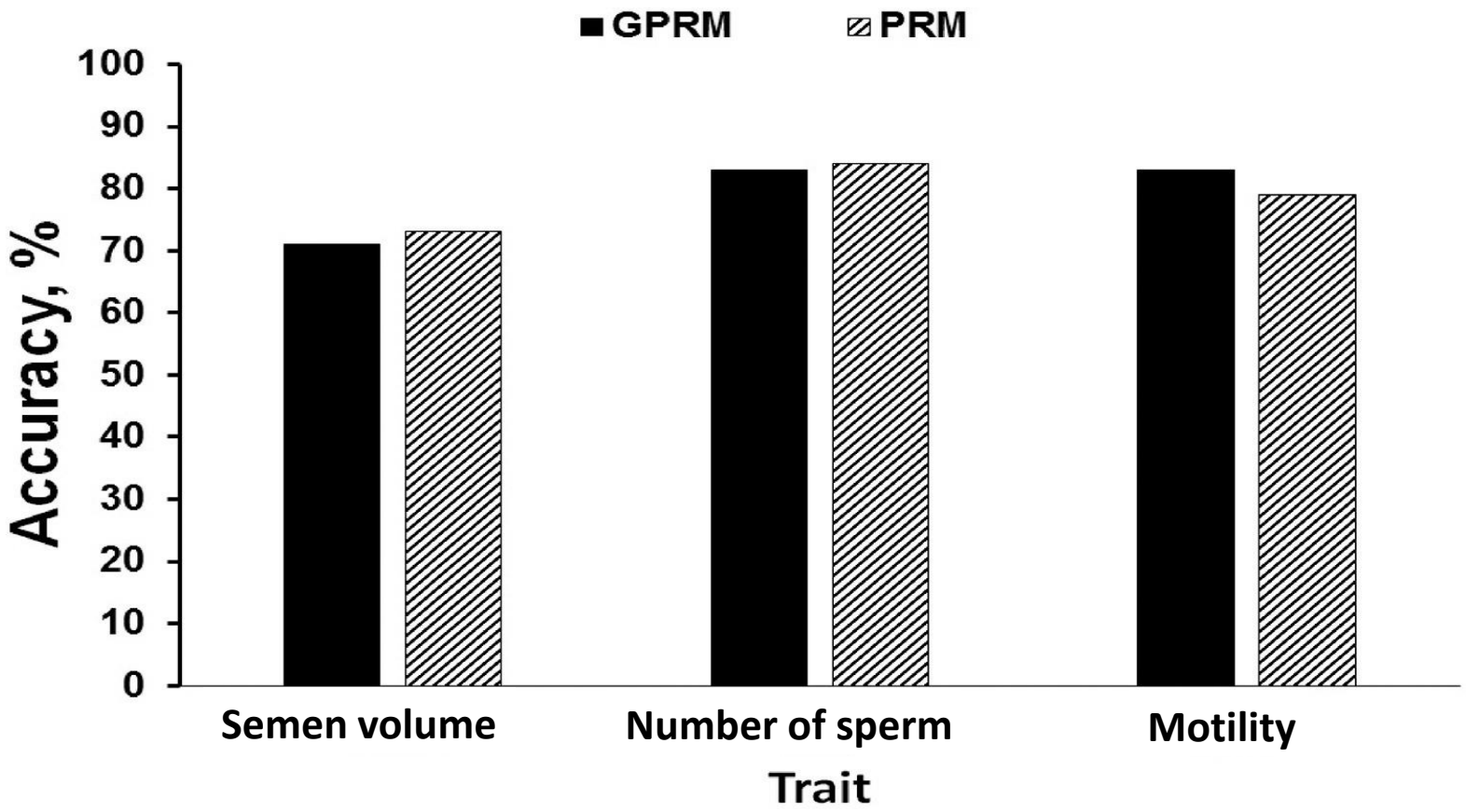
Genomic model yielded higher prediction accuracy than conventional model

Random regression genomic model had higher accuracy than accumulate lactation model

Increase accuracy → More accurate selection → High genetic gain

Jattawa *et al.* (2015)

Accuracy of Genomic Prediction



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Genetic parameters, predictions, and rankings for semen production traits in a Thailand multi-breed dairy population using genomic-polygenic and polygenic models

Mattaneeya Sarakul[a], Mauricio A. Elzo[b], Skorn Koonawootrittriron[a,*], Thanathip Suwanasopee[a], Danai Jattawa[a]

[a] Department of Animal Science, Kasetsart University, Bangkok 10900, Thailand
[b] Department of Animal Sciences, University of Florida, Gainesville, FL 32611-0910, USA

Mean EBV accuracy for semen volume (VOL), number of sperm (NS) and motility (MOT) for all bulls (n=131) evaluated with **a genomic polygenic repeatability model (GPRM)** and **a polygenic repeatability model (PRM)**

Sarakul *et al.* (2018)

Dairy Genomic Evaluation System in Thailand

Phenotypes

Pedigree

Genetic evaluation (EBV)

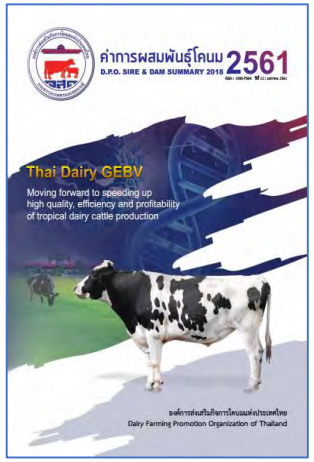
KU-UF-DPO

Blood / Tissue Samples

DNA preparation

Genomic SNPs Genotyping

Genomic Evaluation

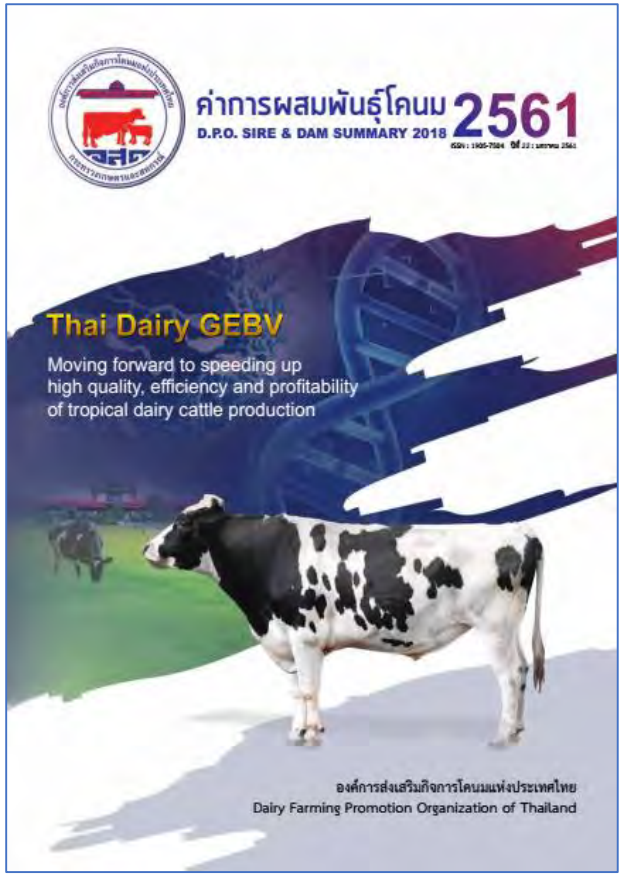


Genomic Estimated Breeding Values (GEBV)

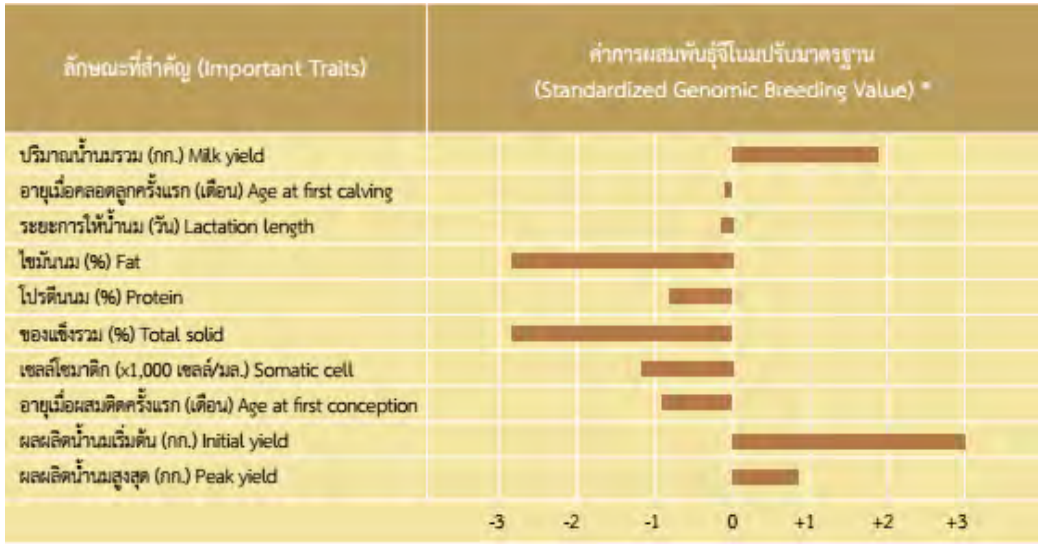
Genetic - Genomic Evaluation System

(Koonawootrittriron et al., 2012)

Publishing GEBV for selection by producers



ชื่อ (Name of Bull)	: พุช (PUSH)	พันธุ์ประวัติ (Pedigree)	
หมายเลข (ID No.)	: C5008	พ่อ (Sire Name)	: PROSPECT (029HO10312)
วัน เดือน ปีเกิด (Date of Birth)	: 10 ตุลาคม 2550 : 10/10/2007	แม่ (Dam Name)	: MC451014
		ปู่ (PGS Name)	: WINCHESTER (7HO04637)
พันธุ์ (Breed)	: 93 3/4 %HF, 2 11/32 %RD, 3 1/8 %SW, 25/64 %BS, 25/64 %ZE	ตา (MGS Name)	: KED JURIST (1HO2737)
		แหล่งกำเนิด (Birth Place)	: อดิเรกผล ฟาร์ม



Traits	GEBV	Acc
Milk yield	427	64
Age at first calving	-0.09	60
Lactation length	-0.64	35
Fat (%)	-0.19	
Protein (%)	-0.02	
Total Solid (%)	-0.06	
Somatic Cell (x1,000 cell)	-13.6	
1st Conc. Age (month)	-0.39	
Int. Yield (kg)	0.2	
Peak Yield (kg)	0.11	

Genomic information helps reduction cost of proving sire

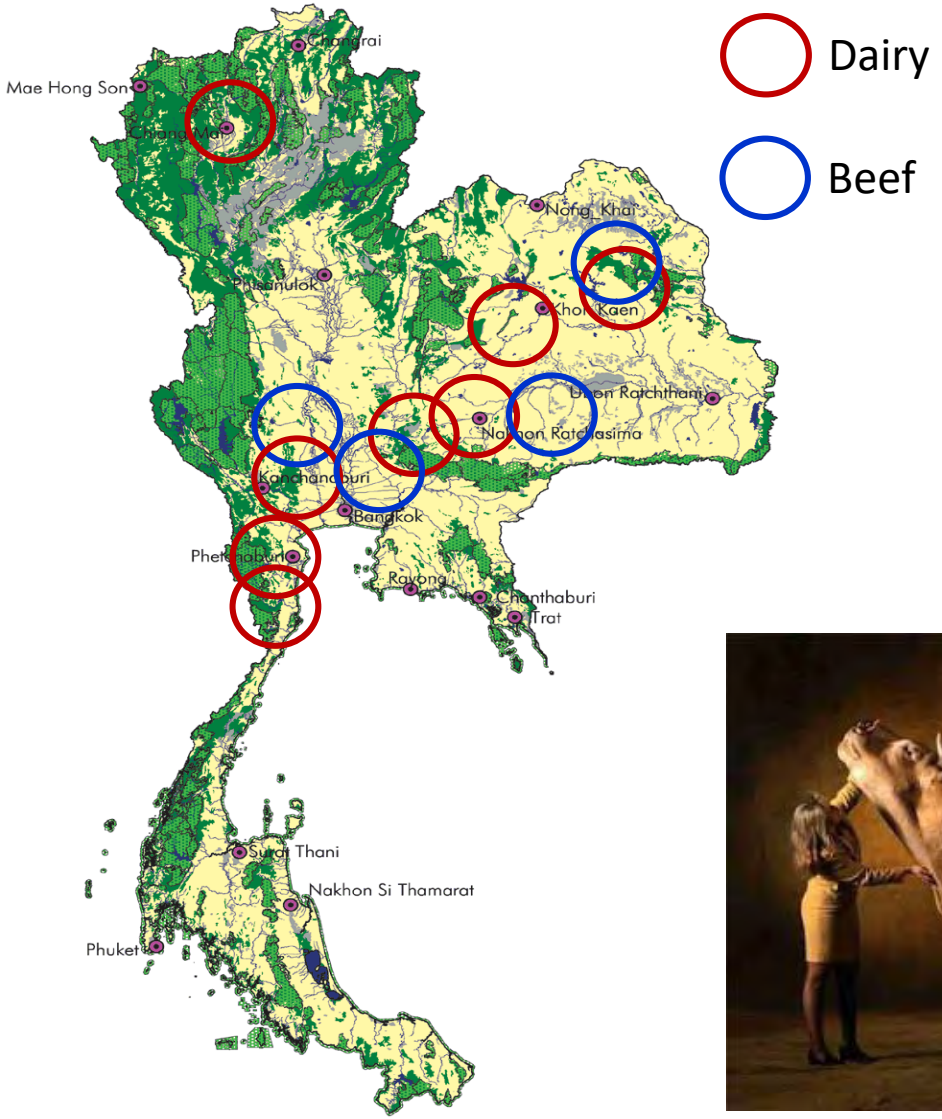
Conventional practice

Month 9	Month 21	Month 30	Month 45	Month 57	Month 64
Male calve born	Mating ability Test	Daughter born	Daughter is mated	Daughter calve	Daughter complete lact

With Genomic Information

Month 9	Month 21	Month 30	Month 45	Month 57	Month 64
Genetic Analysis	Mating ability Test	Reduce *for* 3 years			

Cattle Genetic Improvement Consortium



Kasetsart University
University of Florida
Dairy Farming Promotion Organization of Thailand
National Science and Technology Development Agency
National Research Council of Thailand
Thailand Research Fund
Kasetsart University Research and Development Institute

Dairy and Beef Producers
Pon Yang Kharm Beef Cooperative Ltd.
Thai Serve Co. Ltd.
Loongchao Brahman Co. Ltd.
Buriram Beef Producer Network
Smile Beef Co. Ltd.
Muak Lek Dairy Cooperative Ltd.
Midland Dairy Limited Partnership