Dairy Genetics for Sustainable Productivity Improvement

Dairy Asia—Towards Sustainability – March 2015

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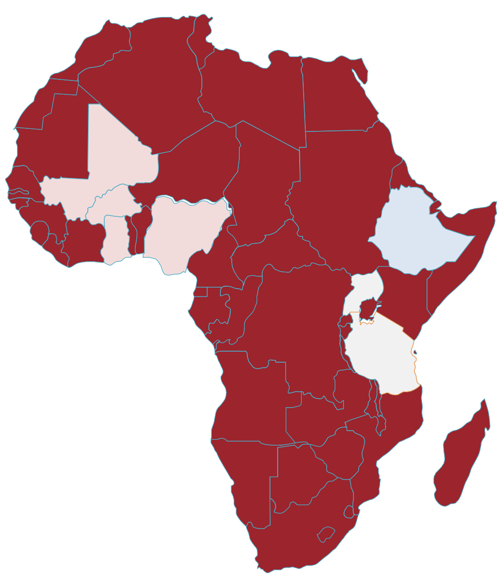
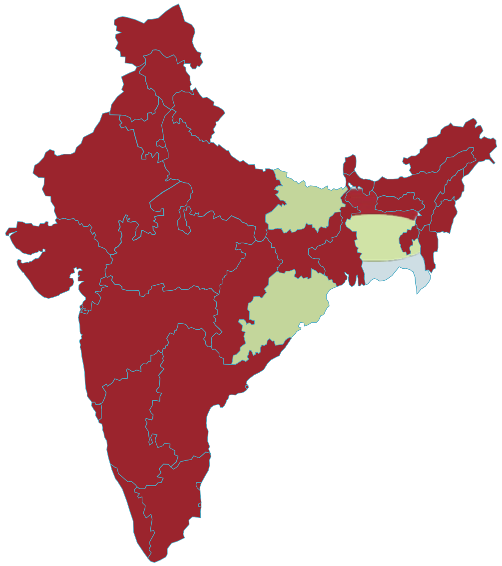
BILL & MELINDA GATES foundation

Focus Geographies for Agricultural Work

Burkina Faso, Ghana, Mali, & Nigeria



Ethiopia, Tanzania & Uganda

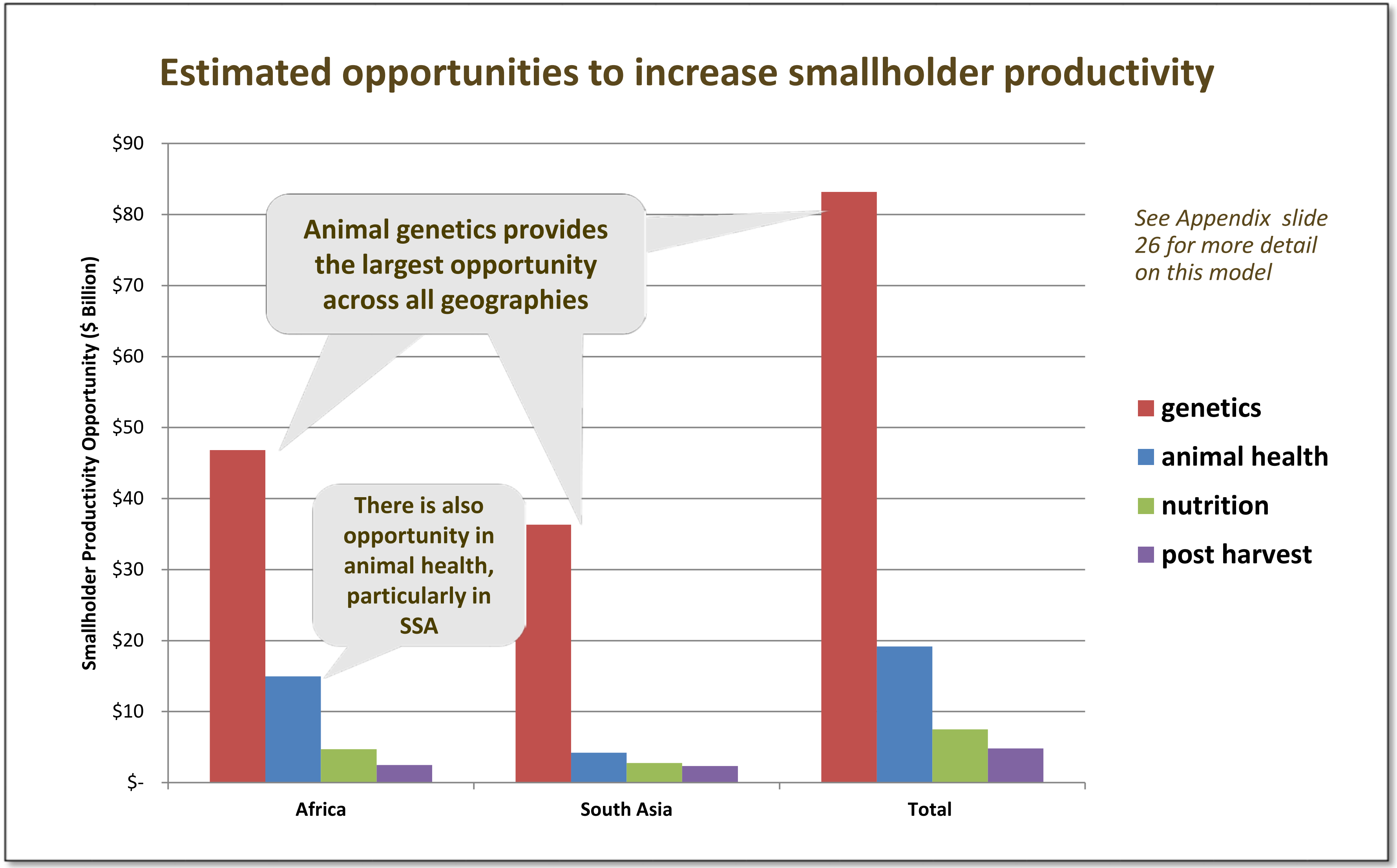


Bihar, Odisha, UP, & Bangladesh

- ❑Dedicated to discovering and disseminating innovative approaches to increase smallholder productivity

- ❑POC investments in a few select geographies to grow smallholder livestock productivity

Genetics provides the greatest opportunities to sustainably improve productivity



Sources: Based on BMGF analytical models referencing multiple data sources including: Oct 4-5 Livestock Landscape Analysis Expert Panel Workshop; Oct 27 Livestock Foundation Genetics Workshop; Expert Interviews; FAOSTAT; OIE Technical Disease Cards; the Center for Food Security and Public Health Animal Disease Information; OIE-WAHID database; Merck Veterinary Manual; 2011 Market Probe market research for Kenya, Ghana, Nigeria, Ethiopia

Dairy Development at the Gates Foundation

- **Principles**
  - Dairy development is a **route out of poverty**
  - Genetic improvement could help millions of poor farmers gain **access to more productive animals**
  - Success comes from access to **appropriate genetics** plus ability and inputs to manage health, **feeding**, and general husbandry
- **Strategy:**
  - Increasing **realized productivity** through getting improved animals (crossbred cattle and high-producing buffalos) to farmers
  - Accelerating and sustaining **potential productivity** through genomic and other tools for on-farm genetic gains
  - Expanding smallholder access to input and output **markets**

Outline

- **Helping smallholders gain access to optimal dairy genetics**
  - Access to reliable breeding services
  - Sorted semen and other reproductive technologies
  - Heifer multiplication systems – crossbreds, local dairy cows, and buffalos
- **Accelerating the rate of on-farm dairy genetic gain**
  - Optimizing performance of crossbreds
  - Making use of existing DNA and historical phenotypic data
  - Taking advantage of existing and emerging genomic tools
  - ICT-based on-farm recording by smallholders
- **Developing the next-generation of precision breeding tools**
  - Genomic profiles of exotic bulls suited for crossbreeding
  - Accelerating the rate of tropical adaptation

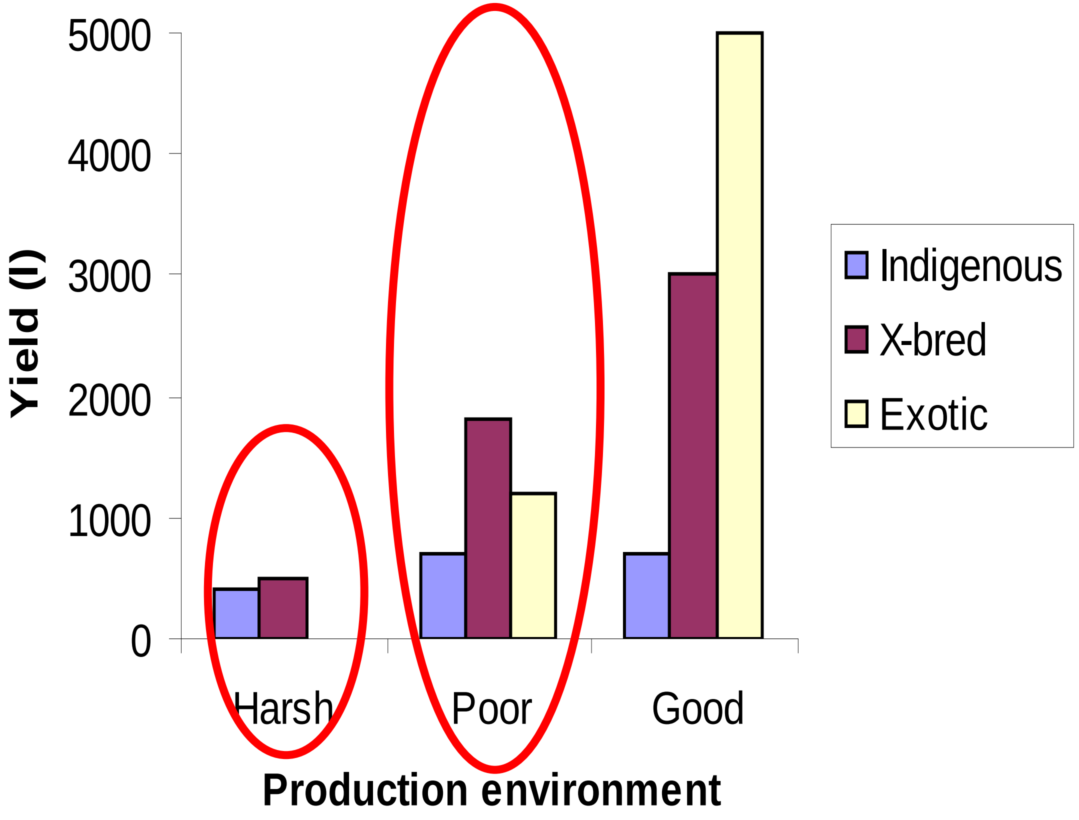
Summary – There are many genetics opportunities to create impact

- **Optimizing smallholder productivity involves:**
  - Access to the right genotypes and breeding services (**AI and planned natural mating**)
  - Access to input and knowhow to manage health, feeding, general husbandry, and markets.

- **Many opportunities for impact today:**
  - Access to advanced reproductive technologies – **sorted semen**
  - Genomics-based determination of optimum breed composition
  - Genomics-assisted planned natural mating of crossbreds
  - Using existing DNA and phenotypic resources to select better AI bull genetics
  - ICT platforms for on-farm data capture from smallholder systems
  - Testing of existing and NEW chips and genomic tools to accelerate the rate of genetic gain
  - Investments in NEW biotech tools to accelerate the rate of tropical adaptation

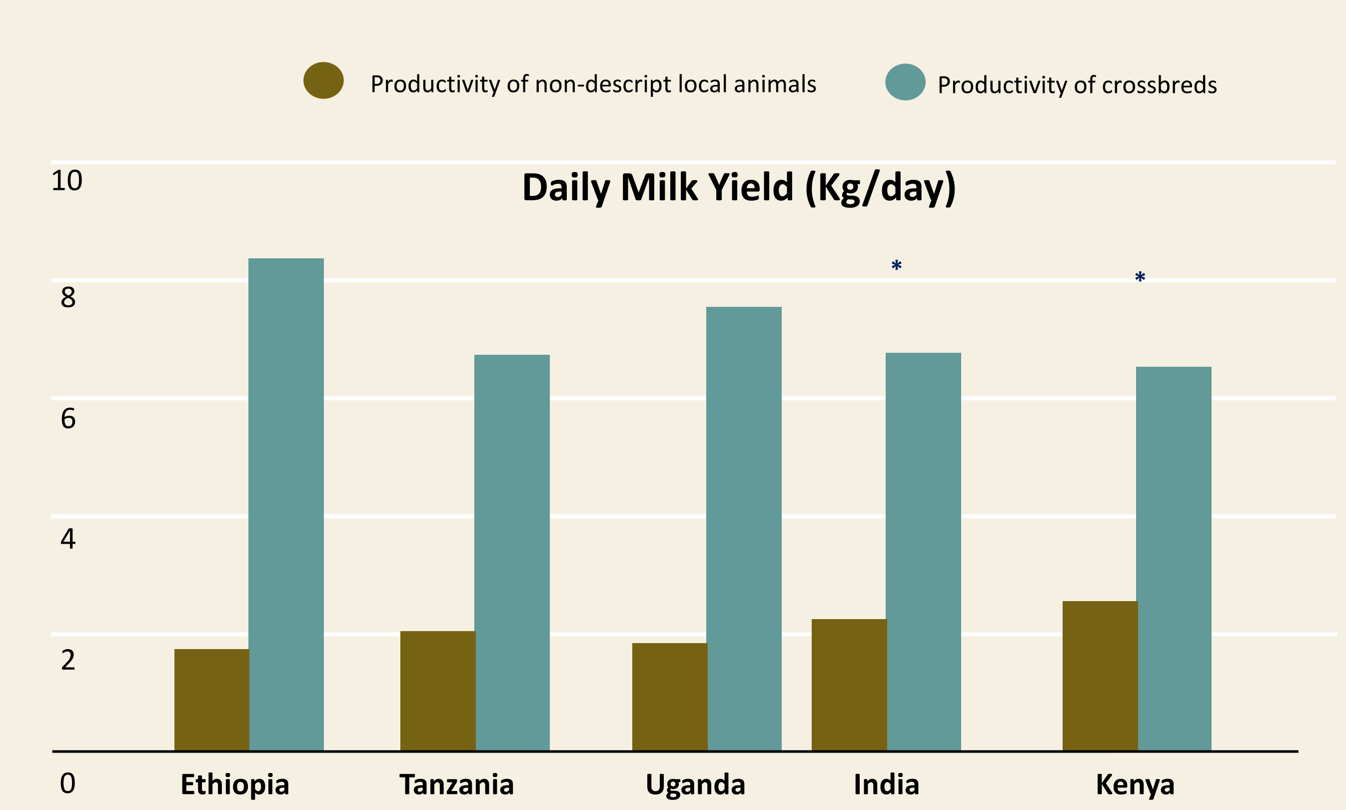
Optimum genotype depends on production environment

- **Indigenous breeds:**
  - Highly adapted to harsh conditions, but often little potential to increase milk yield under better feeding.
- **Crossbreds:**
  - Respond to better feeding with increased milk yield; moderately adapted, but low tolerance to endemic diseases
- **Exotic dairy breeds:**
  - Very high genetic potential for milk yield, but only expressed under the most favourable conditions; tend to be poorly adapted and very low tolerance to endemic diseases



Sustainably matching available feed resources to the genetic potential is a major challenge

The promise of crossbreeding



*** National averages tend to be higher in countries with fewer crossbreds because most are in the hands of commercial farmers**

- **Crossbreds generally show higher realized yield under tropical smallholder dairy systems**
- **Three fundamental challenges**
  - How do you ensure reliable breeding services?
  - What is the optimum management system?
  - What is the optimum breed composition...?

Source: FAO 2010, TechnoServe, government central statistics agencies (Ethiopia 2010, Tanzania 2008, Uganda 2008 & 2011, Kenya 2009-10), Njombe et al 2011; BAIF, 2014; Gibson et al 2014; Madalena et al., 2012

Ensuring access to reliable cattle development services

- **AI currently accounts for about 20% of all bovine inseminations in India**
  - Near zero cost bull service
  - Local semen @ $0.30
  - Imported regular semen @$1.50 (~$3.00 without Govt subsidy)
  - Imported sexed semen @ $12 per straw (~$25.00 without Govt subsidy)

- **Reached 212,000 farmers with 106,000 poor families, covering more than 4,000 villages in 14 districts**
- **More than 650,000 AIs performed with conception rates of ~ 48%**
- **More tha 2,300 Community-based Dairy Interest Groups (DIGs); 14,468 out of 23,918 members were women**

BAIF Godhan Project:

- ***A financially sustainable model for delivering cattle development services to poor farmers to increase productivity***
- **Empowering women through community-based dairy interest groups (DIGs)**

BAIF, 2015

Ensuring effective natural mating with crossbred bulls…?

- **Even with reliable AI delivery, most countries will probably only achieve 50% maximum coverage**

- **Today, nearly 80% of breeding is through planned or unplanned natural mating to local and crossbred bulls**

  - Genotype of the bull is generally unknown

  - Use a low-cost genotyping assay for testing and certifying the breed composition of crossbred bulls…??

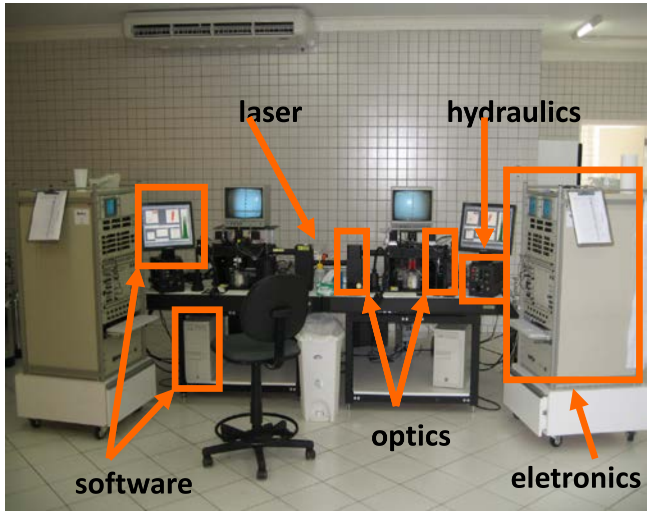
  - Create farmer awareness and hence a market for use of bulls of certified breed composition..??

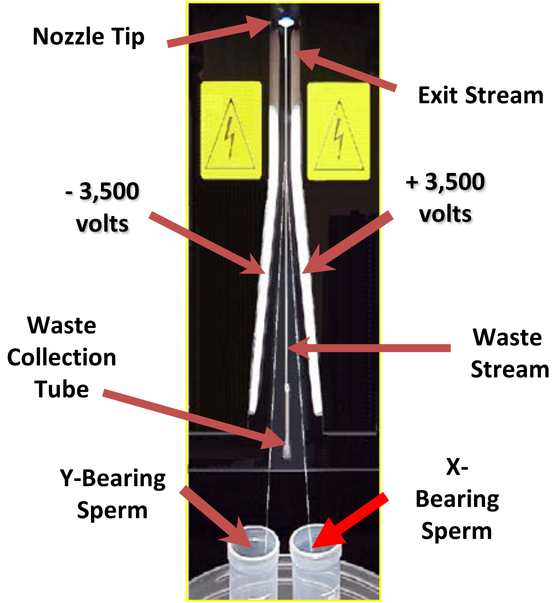
Delivering reliable sorted semen AI

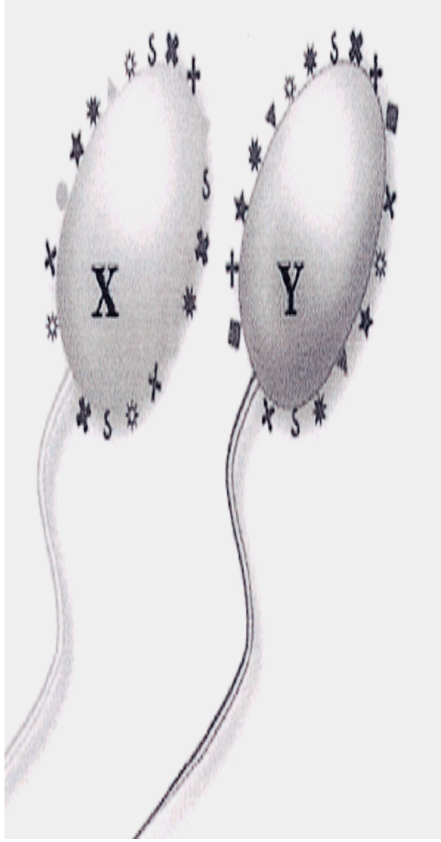
- **Switching from regular AI ($0.30) to sexed semen (@ $12-$25) is a major economic challenge for smallholder farmers**

- Testing models for delivery of sorted semen to smallholders
  - ***Sexing Technologies; NDDB; BAIF; UNE, Others…***
  - On-farm conception rates
  - On-farm sex ratios
  - Economics of sexed semen use by smallholders
  - Protocols to produce local bulls and buffalos sexed semen

- Expecting increased availability of crossbred heifers, buffalo heifers, and high-producing local dairy heifers through sorted semen AI, IVF and ET.







X Chromosome carries

~3.8% + DNA

What is the value of sexed semen…?

- **Sexed semen delivers >90% calves of desired sex, but conception rate is often lower than normal semen**
  - Opportunity and need to produce F1 females from indigenous cows on large scale

- **Cowboy Math: A farmer with one cow**
  - An extra heifer for sale or to expand herd becomes available once every 2.4yr with sexed semen vs 5.9yr with normal semen.

- Sexed semen could double the impact of crossbreeding
  - Number of female calves born
  - Value of heifers (if sold) or the increase in milk production (if ownership is retained)

Poor smallholder starting with single cow over 10 years	Crossbred cow from regular semen-AI	Crossbred cow from sorted semen-AI
Lactation Yield, Kg / lactation	1,650	1,650
Extra heifers over 10 years [1]	2	4
Net Revenue (Over 10-Years) if extra heifers are retained	**$3,685.8**	**$6,577.3**

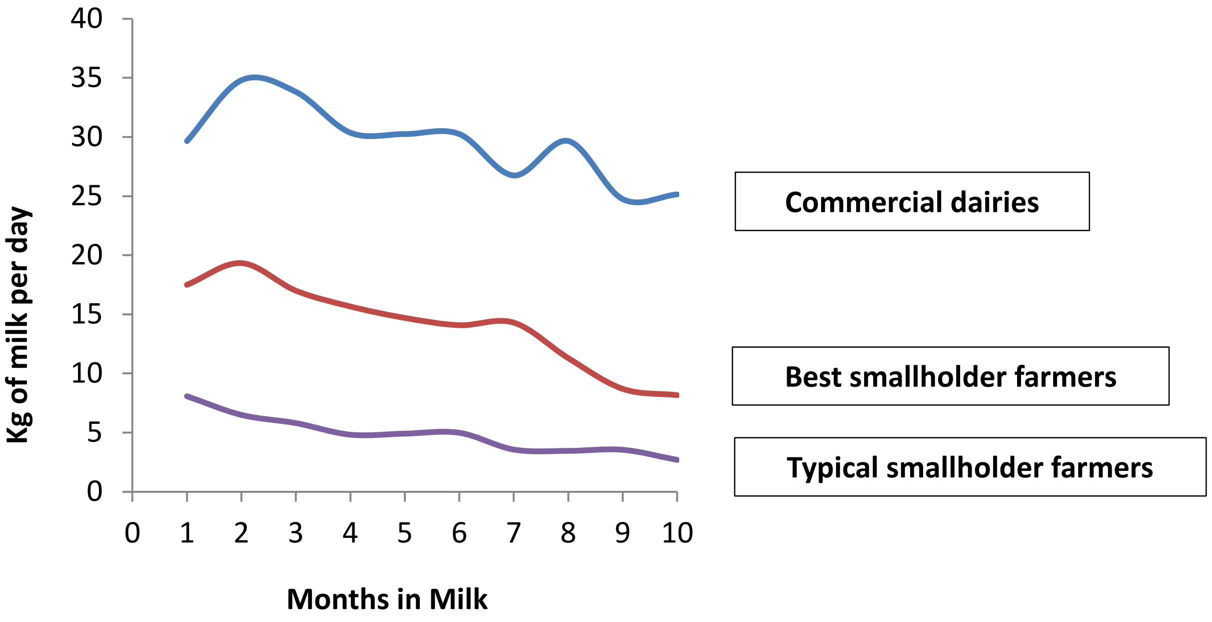
[1] Yrs/assumed CI x Calving% x Sex Ratio)-(Replacement Rate)

What is the value of sexed semen…?

MDVL, 2013

What is the optimum management system?

- Large variations in productivity within and between genotypes
- Probably reflects differential abilities of farmers to manage **feeding**, animal health, and general husbandry



Kenya: Realized lactation curves of improved cows achieved by different farmer types

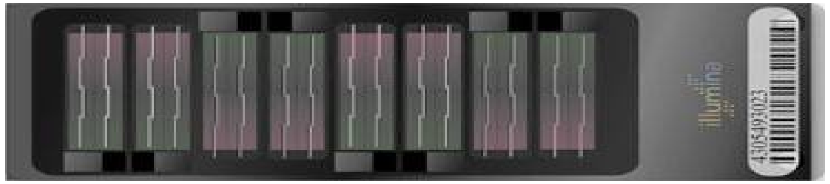
- This is why Ration Balancing is such a **Brilliant Idea**

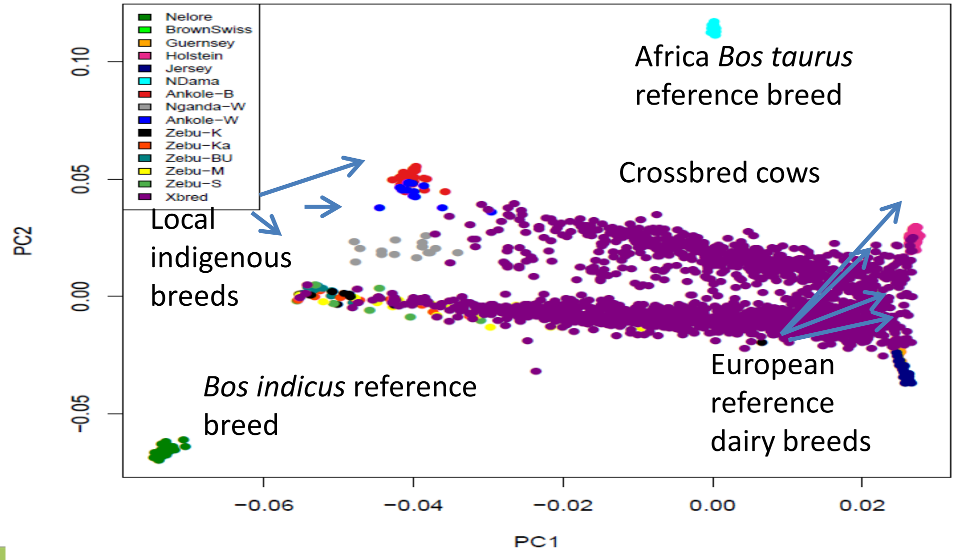
Ojango et al 2015

What is the optimum breed composition?

- **New genomics-based applications**
  - Work with crossbred cattle owned by smallholders
  - Record on-farm performance across agro-ecologies
  - Use high-density SNP chips to determine breed composition
  - Match performance to breed composition and production system

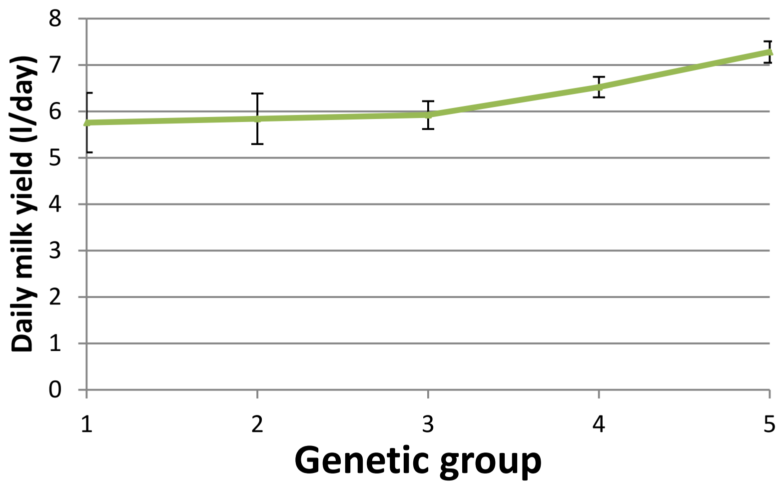
I. **Time to answer:** Short
II. **Cost:** Moderate to high
III. **Accuracy:** Higher than old approach
IV. **Risk of not completing:** Very Low
V. **Relevance of results to smallholder system:** Very High





Gibson et al., 2014

What is the optimum breed composition – Recent results from Kenya



Genetic group 1 = 12% exotic

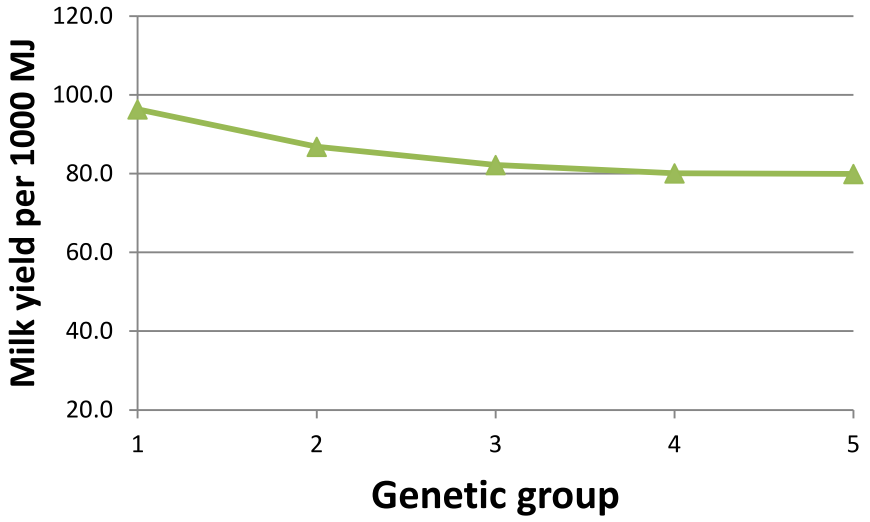
Genetic group 2 = 25% exotic

Genetic group 3 = 50% exotic

Genetic group 4 = 75% exotic

Genetic group 5 = 95% exotic

- ❑ On similar feed resources, mid-grade crossbred cows produced nearly 100% more milk than high-grade cows
- ❑ Mortality rates in high-grade (≥75%) exotic was 2.7 times higher than in other crossbreds



	Percent Holstein-Friesian Genetics					
Management	0.25	0.50	0.62	0.75	0.875	0.969
High-input	1,396	2,953	1,401	2,981	2,821	3,147
Low-input	1,180	2,636	1,423	2,251	1,672	1,226

Brazil: First lactation yields of animals with different Holstein-Friesian x Guzerá genetics

Gibson et al 2014

Accelerating genetic gains – making use of existing resources

- **Genetic improvement of milk productivity is yet to materialize**
  - Slow increase in crossbred yield from 5.65 kg/d (1992) to 6.52kg/d (2007)
  - Long history of highly effective crossbreeding from Military Farms
  - Significant variation in performance of buffalos and crossbreds
    - Holstein-X – Range: 8 to 26 Kg
    - Jersey-X – Range: 5 to 20 Kg
    - Murrah – Range: 5 to 17.5 Kg
- **Potential opportunities :**
  - Utilize existing DNA from historical bull semen and performance data within and across regions?
  - Apply genomics to identify superior buffalo genetics
    - Eg: Using the 90K Affy Axiom Buffalo Genotyping Array, which included Murrah and Jaffarabadi markers
  - Take advantage of the 770K cattle chip and existing or emerging cattle genomic equations to increase the impact of crossbreeding or for local dairy bulls

Accelerating genetic gains – ICT-based on-farm recording by smallholders

- **Fact: Most recording systems fail because they are run by geneticists, primarily for genetics objectives --- *John P Gibson, UNE***

- **Fact: Significant penetration of ICT systems across smallholder farms**
  - Possibilities for capturing on-farm data on economically relevant traits and variation in management systems from smallholders
  - **Potential to provide dynamic cow-management feedback to smallholder farmers to significantly optimize realized productivity**
  - Build a genomic profile of imported bulls whose daughters perform optimally under current smallholder systems
  - Inform the way we import exotic bulls for crossbreeding?
  - Inform efficient selection of crossbred or buffalo bulls for AI?
  - Better targeting of genotypes to different agro-ecologies through AI systems?

- **A functioning genetics and genomics computation and analytics systems for processing and using the information.**

Accelerating genetic gains – applying multiple omics tools

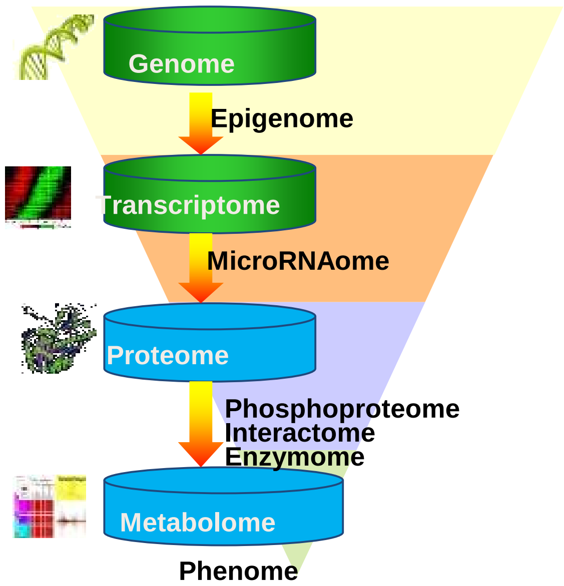
1. On-farm performance recording and helping farmers to use that data to optimize productivity

2. Developing "omics" tools to select the right bulls and target the right genotypes to production systems

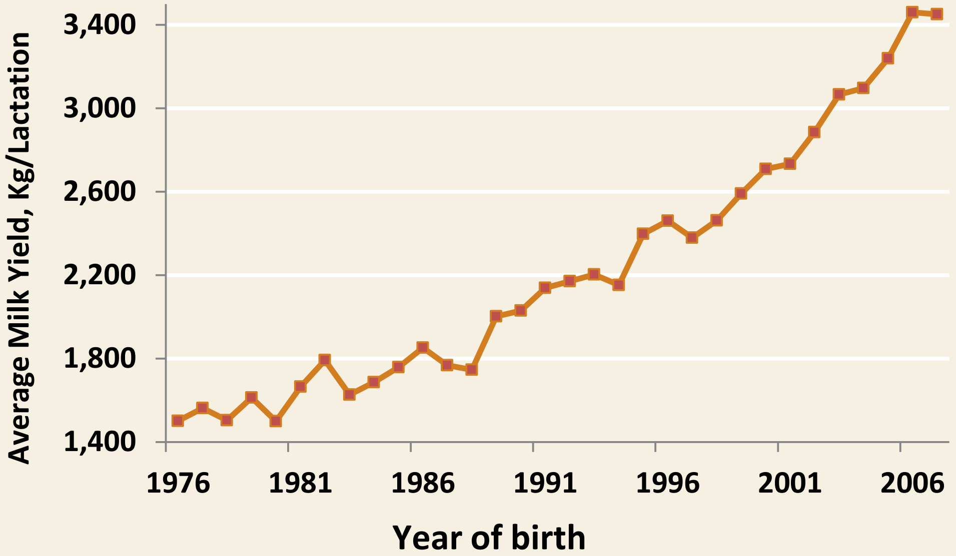
3. Application of the resulting information to accelerate the rate of genetic gain

On-farm recorded economically relevant traits

Age at First Calving
Survival/Hardiness
Lactation Milk Yield
Disease tolerance
Reproductive Performance
Longevity
Number of lactations in herd life
Number of services per year herd life



Brazilian example shows genetic gains in tropical cows is possible



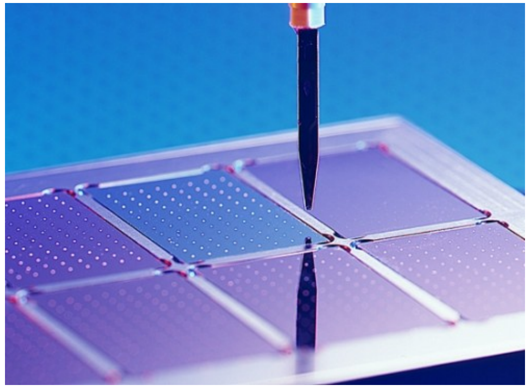
Sources: Silva et al., 2010; Zhao, 2013;

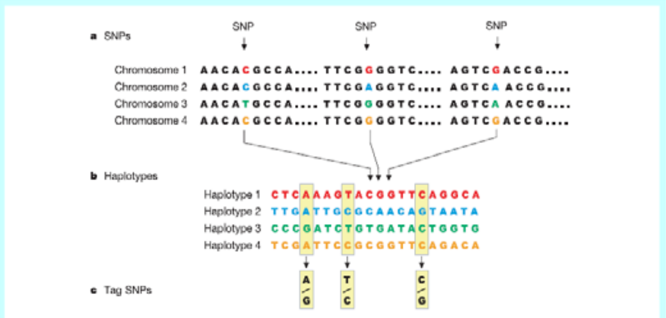
Addressing inefficiencies of conventional crossbreeding – Precision breeding..?

- **A major challenge with crossbreeding –** significantly reduced tolerance to diseases
  - Source of frustration for smallholder farmers who have adopted crossbreds
  - ***Stimulation of Innate Immunity***: Activation of the innate cellular receptors in calves could mitigate disease severity and restore full disease tolerance in crossbreds

- **Precision breeding:**
  - Specific and effective transfer of favorable genetic variants onto a more desirable genetic background using biotech approaches, without the drag of ill-adapted genetics associated with crossbreeding
  - ***Cisgenesis***: Precise within-species transfer of economically relevant genetic mutations from one individual to another of the same species.
    - Could happen naturally, so they are less controversial..???
    - Eg: within-species genome-editing, using specific nucleases (TALENs, CRISPRs).

- **Applications of precision breeding technologies:**
  - Acceleration of tropical adaptation via transfer of genes conferring tropical adaptability to high-producing exotic cattle (eg: SLICK genotype in cattle)
  - Rapid introgression of desired alleles from elite animals into tropically-adapted animals





TOGETHER, WE WILL REACH OUR GOAL OF RAISING MILLIONS OF FARMING FAMILIES OUT OF POVERTY