Climate change adaptation in livestock systems

Brief 5: Animal breeding and genetics

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Leveraging improved genetics and breeding to support climate adaptation for livestock keepers in low-income countries

ILRI's objectives

ILRI will support increased availability of productive, adapted and resilient livestock breeds/genetics for livestock keepers in developing countries by utilizing a wide range of tools and approaches to identify the right breed/genetics for the right environment, scale up sustainable breeding programs for the delivery of adapted genetics and support the conservation of adapted genetics for future use.

1. Livestock breeds/crossbreeds, traits, or genes adapted to specific environments identified and utilized in livestock genetic improvement programs.
2. New tools developed to support inexpensive and rapid identification of breeds that are adapted to specific environments.
3. National governments, farmers' organizations and private companies supported to design and roll out sustainable breeding programs.
4. Selected breeds, traits and/or genes conserved for future use in breeding programs.

Situation analysis

Gaining access to livestock breed types that are adapted to specific environments under the changing climate will support livestock keepers in low-income countries to maintain or increase productivity, increase their resilience and contribute to mitigation. There are almost 5000 local breeds of cattle, sheep, goats, pigs and chickens globally—some of which thrive under extreme conditions—representing huge genetic diversity and serving as resource for breeding programs targeting increased productivity and resilience (Boettcher et al. 2015). Breeds currently produced in harsh climates could have a role in other geographies as the climate changes. Breeds and lines that have been heavily invested in improvement (mostly in developed countries) and are now used in breeding programs globally can be assessed for resilience and adaptability. In some production systems, indigenous breeds may remain optimal under climate change. In others, crossbreeding of local breeds with exotic breeds will result in animals that are both productive and well adapted to the local environmental conditions. Still in others, the introduction of new breed types altogether may represent the biggest opportunity for livestock keepers (Marshall et al. 2014).

Farmers, companies and governments need empirical information on the adaptive capacity of different livestock breeds/genotypes to select breeds/crossbreeds that will perform the best under a changed environment in the future. Limited resources have been invested in understanding the adaptability of different livestock breeds to the environments of developing countries (Marshall et al. 2014). Traits that are "adaptive" vary in relative importance depending on production systems and the objectives of producers but could include heat tolerance, disease resistance, feed efficiency under low quality diets, walking ability, diet selection (e.g. ability to select high quality diets from different plant species or component), behavioral flexibility (e.g. acceptability of night grazing when temperatures are lower) and general robustness (the ability of animals to adjust to a range of environmental conditions) (Hoffman 2013; Boettcher et al. 2015). The lack of performance recording systems in low-income countries hampers efforts to identify and breed superior genetics. To select the right breed for different environments, information is needed on phenotype and performance, the environment the breed is performing in, how the breed is managed and breed attributes as perceived by their keepers. ILRI's African Dairy Genetic Gains program (ADGG) is pioneering successful on-farm performance recording utilizing digital and genomic tools and linked with environmental data to identify superior bulls and breed types in Ethiopia and Tanzania. This needs to be scaled up to additional countries to benefit dairy farmers more widely (Rege et al. 2011; Mrode et al. 2019). ILRI's Africa Chicken Genetic Gains program (ACGG) has successfully demonstrated that basic and inexpensive GIS technologies can be leveraged for matching poultry breeds to environments where they can thrive (Lozano-Jaramillo et al. 2018), which could dramatically reduce the time and cost of identifying the best breeds for specific areas under a changing climate. ACGG is also evaluating heat tolerance and performance in poultry.

Modern genomics can be leveraged to select and develop genetically superior breeds for the changing climate. Genotyping costs are 100X lower than 10 years ago making it possible to apply in breeding programs in low-income countries. ADGG has demonstrated that Estimated Breeding Values (EBVs) with useful accuracy can be obtained from a combination of phenotype data and genomic data (Brown et al. 2016), overcoming the challenges posed by the lack of smallholder pedigree information. This work can be expanded to accelerate selection for adaptive traits. In more upstream research, information on an animal's genome can be utilized to identify the genomic regions (and eventually genes) underpinning adaptation. For example, a genomic assay has been developed to aid selection of dairy cattle for high milk production under anticipated climate change scenarios. An Australian study identified the slick hair coat (SLICK) haplotype which is associated with the sensitivity of milk production to feeding level and the temperature humidity index (Hayes et al. 2009). Holsteins with the SLICK haplotype are better able to maintain milk production during high heat (Dikmen et al. 2014). ILRI plans to test SLICK cattle for performance in sub-Saharan Africa production systems.

National governments, private companies, farmer organizations and livestock keepers need support to successfully design and implement breeding programs that can deliver breeds that are both productive and adapted to different environments in low-income countries. There are few functional and sustainable breeding programs in sub-Saharan Africa; and breeding programs in South Asia need support to link breed to environment in the face of climate change. ILRI is successfully piloting the design and roll out of breeding programs, including ADGG and ACGG, through public-private partnerships.

Supporting the conservation of indigenous breeds can advance adaptation to climate change in the future. Low-income countries hold vast amounts of livestock genetic diversity produced under a wide range of environments (Boettcher et al. 2015). This resource provides opportunities to identify animals with unique adaptive abilities, to match breeds to the changing climate and to restock with adapted breeds after events such as droughts or disease (Hoffman 2013; FAO 2015). But extinction is occurring rapidly; almost 20% of remaining breeds are at risk and more than 60% are of unknown status. Conservation of local breeds is possible through use and in biorepositories. ACGG is one example demonstrating that local poultry breeds can be conserved by freezing embryos.

ILRI's solutions

These solutions apply across all livestock species.

Solution 1: Through both discovery and applied research, and by utilizing modern genomic technologies and other tools, identify livestock breeds/crossbreeds, traits or genes adapted to specific environments that can be used in livestock genetic improvement programs.

- Determine what traits contribute to productivity, adaptive capacity and resilience and build into breeding objectives.
- Characterize livestock breed types via a landscape approach that considers the relationship between performance/phenotype (on-farm herd/flock recording and monitoring systems), genotype (high-throughput single nucleotide polymorphism—SNP—arrays or genome sequencing) and the environment (global or regional databases on climate, soil, vegetation, water and disease).


Photo: ILRI/Fulani Media

- Determine the value of adaptive traits to farmers by using economic modeling and trade-off analysis approaches that consider impacts on livelihoods, gender equality and the environment.
- Develop tools to predict phenotypes using cheap and indirect digital and robotics technologies.
- Utilize advanced genomic approaches to select specific genomic regions underpinning important adaptation traits.
- Evaluate the role of the microbiome in enabling animals to cope with climate change.
- Utilize transgenesis when appropriate to use genes from more adapted species to improve other species.

Photo: ILRI/APaul Karaimu

Solution 2: Support the design and implementation of sustainable genetic improvement programs in low-income countries aimed at producing genetically superior, climate-resilient livestock that meet the objectives of women and men livestock keepers and other value chain actors.

- Utilize characterization studies and genomic and physical environmental profiling (e.g. temperature humidity indexing) to make recommendations on the right breed for the right environment.
- Determine the right breeding strategy to make productive breeds more adapted, or adapted breeds more productive.
- Design, stimulate investment in, and roll out breeding programs in partnership with private genetics companies, national agricultural research organizations and farmers' organizations.
- Build the capacity of national governments to develop enabling policies for effective and sustained implementation of breeding programs.

Solution 3: Support conservation of livestock genetics for future use in breeding programs.

- Utilize the characterization studies in Solution 1 and work with local actors to determine what breeds should be conserved in a given country and/or production system.
- Support national partners to develop and implement conservation programs.
- Support efforts to conserve specific traits of value through their use in breeding programs.

Roll out ready approach: Scaling up African Dairy Genetic Gains

ADGG is working to establish sustainable dairy breeding programs in sub-Saharan Africa to ensure that smallholder dairy farmers can access more productive, adaptive and resilient dairy genetics, breeding services and education to grow profitable businesses. ADGG and its partners will scale out a multi-country dairy genetic gains platform by identifying, promoting and delivering superior crossbred and other suitable tropical dairy bulls through artificial insemination and planned natural mating. ADGG uses on-farm performance information and basic genomic data to identify superior breeds, including bulls from international genetics companies. The best bulls are being certified on an annual basis in each country for use to breed future cows. Currently, more than 600,000 dairy cattle from small-scale farms in Ethiopia and Tanzania are enrolled. Digital platforms for on-farm data recording and timely, actionable cow and herd management feedback to farmers is in the pilot phase, with six million messages recorded to date. Farmers make immediate production gains based on this feedback. National dairy performance recording centres and National artificial insemination centres are receiving capacity support to become effective and sustainable. ADGG is working with farmers' organizations and private companies to design and roll out models for multiplication and delivery of superior genetics to farmers.

ADGG is in its pilot phase with funding from the Bill and Melinda Gates Foundation to operate from 2015–2020 in Ethiopia and Tanzania. ILRI implements ADGG with its partners—the University of New England, Scotland Rural College, Green Dream Technologies, Tanzanian Livestock Research Institute, National Artificial Insemination Centre-Ethiopia and Land O' Lakes International Development.

ILRI will leverage the ADGG platform to develop and promote climate-resilient breeds. ADGG is already working to include adaptive traits, such as heat tolerance, in the breeding program objective to ensure that the selected genetics will perform well under the changing climate. In Tanzania, temperature and humidity data are being linked with cow performance and this data is being included in bull evaluation and selection. In partnership with the dairy cattle genomics companies and Centre for Tropical Livestock Genetics and Health's dairy genomic program, ADGG will use the phenotypic and genomic data to identify the genomic regions associated with heat and humidity tolerance; and where feasible, tick resistance, to develop a temperature and humidity index system for ranking breeding bulls.

ADGG is ready to scale to additional countries and regions and the model can also be used for application to other species. ADGG has the potential for scale out across sub-Saharan Africa and South and Southeast Asia to countries that want sustainable dairy breeding programs that can deliver climate-resilient dairy cattle. In addition, the platform can be adapted to other species, such as dual-purpose beef.

ILRI's capacity and impact

ILRI is a founding partner of the Centre for Tropical Livestock Genetics and Health—CTLGH (ctlgh.org). CTLGH is a strategic alliance between ILRI, the University of Edinburgh and Scotland's Rural College. It aims to improve livestock-based livelihoods in the tropics by using various technologies including genomic approaches.

Establishing a genomics reference resource for African cattle (https://hdl.handle.net/10568/77173), which will be a collated set of sequence and genotype information on indigenous cattle breeds in Africa.

Maintains a livestock biorepository with almost 470,000 biological samples that are geo-referenced and available as a research resource.

Has a substantial livestock research farm divided between two locations: one at ILRI's headquarters in Nairobi (48 hectares) and the other on the Kapiti plains outside of Nairobi (12,959 hectares).

Establishing platforms for gene editing in cattle, using the latest and most precise technology in this area called CRISPR/Cas9. ILRI has successfully cloned cattle of an indigenous East African Zebu breed.

Working towards establishing sustainable breeding programs through public-private partnerships in East and West Africa through the African Dairy Genetics Gains (africadgg.wordpress.com) and African Chicken Genetic Gains (africacgg.net) programs.

Strategic partnerships with key international research institutions, genetics companies and national agricultural research institutes that enable access to cutting-edge genomics technologies and sustainable delivery pathways for getting superior genetics into the hands of farmers.

Leads the Livestock Genetics component of the CGIAR research program on Livestock Agri-Food Systems (Livestock CRP).

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