Genetics for Africa – Strategies & Opportunities

Livestock breeding and other advances in animal, insect and fish genetic research for Africa: Workshop Report

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Cover photo: “Tumaini”, ILRI’s cloned bull, Dr Claudia Canales

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Executive Summary

The Genetics for Africa – Strategies and Opportunities planning grant aims to investigate the extent to which genetic research in and for Africa has a direct relevance to social and economic development, and the extent to which improved communication can assist in public understanding, acceptance and uptake of the research outcomes and to more appropriate regulation.

The project is investigating these matters through three workshops, on new plant breeding technologies, animal and human genetics research respectively.

The second workshop, on animal genetic research in Africa, was held on 10th and 11th September 2015 at the International Live-stock Research Institute in Nairobi, Kenya.

What was abundantly clear from the work-shop was the tremendous social and economic importance of animal genetic research (especially in livestock) for the developing world. Animal products represent four of the five highest value global food commodities, and demand is increasing much faster than in high income countries.

The population of Africa is expected to double by 2050, and the continent also has the highest rate of GDP growth and urbanisation. More urban and affluent populations cause a greater demand for animal source food products, and the challenge will be for the continent to respond to this increased demand without placing addition burden on land use which is already experiencing water and climate stress.

Smallholder farmers raise crops in order to survive. Ownership of livestock is an aspirational goal (and of particularly high cultural importance in Africa), providing not only access to essential nutrition for their own families, but also a ready source of new income. Almost all animal sourced food products in the developing world originate in the same country, are produced by smallholder farmers, and are sold informally in local markets.

Producing high quality, disease resistant, stress-tolerant and higher yielding livestock strains therefore has clear and direct local development consequences.

At the same time, the continent of Africa experiences a particularly high burden of disease (in humans, animals and plants), and insects play a significant role as vectors for those diseases. Research on insect genetics, to try to address their vector traits or population dynamics, is therefore critical for human health, farming and general plant and animal health.

The third pillar for the application of animal genetics lies in Africa's great biodiversity. Both in wildlife and livestock, Africa offers a particularly impressive array of variation and local adaptation. Characterisation and conservation of this genetic diversity preserves resources and knowledge for the entire planet. And some of the unique local adaptations of animals on the African continent (in terms of tolerance to drought, disease resistance, or even physical adaptation such as the giraffe's neck etc) may yield genetic insights that can help researchers address future challenges of adaptation, genetic improvement and ability to cope with new diseases and environmental stress.

And finally, aquaculture also presents significant opportunities for development in the continent. Almost one sixth of all animal protein consumed on the planet comes from fish – and almost one third of animal protein consumed in Africa. With the increase in demand, aquaculture represents a significant source of improved livelihoods in Africa. But the same stresses of densification and yield improvement will occur with fish as with livestock, and therefore efforts to improve the genetic stock of fish – which to date have been quite limited – will necessarily have to be strengthened. To date only 18 out of the 400 species of cultured fish have been subject to significant genetic improvement programmes.

However, there are some particular challenges to genetic research in animals, some general, and some specific to Africa. In addition to animal breeding and improvement taking much longer, and requiring more resources, than crop research, the regulatory environment is much less-well developed and tested.

International research collaboration is key in this field – there is much expertise in the north but little ability to apply it to practical problems, and since animals rarely respect national borders, south-south collaboration is even more important. Funding for research is still a challenge however, and of course there is an even greater challenge in obtaining funding for outreach.

The regulatory situation is a critical issue though. Biotechnology approaches to livestock improvement currently fall under similar regulatory regimes to crop genetic approaches (in addition to regulations on veterinary research and research ethics!). However, these approaches were developed mainly with crops in mind and have rarely been applied to animals.

The best known product of animal biotechnology for the food chain is AquaBounty's genetically engineered atlantic salmon, which incorporated a gene from a different species of salmon in order to grow to market size in half the time. Whilst the salmon have received regulatory approval in North America, the controversy and activist involvement that the technology continues to stir up should raise concerns in the research community.

Of more relevance to Africa, UK biotechnology company Oxitec has produced genetically modified male mosquitos from which, when they mate with wild females, the resultant offspring die before reaching maturity, so reducing the population and controlling the spread of mosquito-borne diseases such as dengue fever, chikunguya and now potentially zika as well. But the technology has only been able to be tested and used in a small number of countries with progressive and technologically-sophisticated regulatory authorities (eg Brazil, the US). The engineered mosquitos are not being used on the African continent, despite the prevalence there of the relevant diseases.

And researchers at Imperial College in London have recently engineered mosquitos using CRISPR-Cas9 and gene drive technology which results in female infertility that spreads rapidly through a population and could therefore eliminate that population after several breeding cycles. These experiments were carried out with the variety of mosquito that spreads malaria. As useful and attractive as this technology appears, it also raises serious questions about ethics and unintended consequences which may be hard to recover from, and therefore need a particularly sophisticated and risk-aware regulatory regime to approve their testing and use.

More benign is the research currently being carried out by ILRI to produce a genetically modified trypanosomiasis-resistant cow. If successful, that trait could then be transferred to multiple local breeds of African cattle, and significantly improve the livelihoods of smallholders in the continent. But the second challenge, after the research itself, will be the regulatory approval.

Animal genetic research finds itself, in a sense, in a similar situation to the crop genetics field *before* the GM controversy broke. Straightforward animal and fish breeding can be carried out relatively straightforwardly (albeit slowly and expensively) under existing regulatory frameworks. But more sophisticated and powerful genetic approaches will push against the limits of the existing regimes and the technical awareness of many regulators. Telling a good story now, and capacity building with regulatory authorities (as well as addressing public concerns around ethics and the different attitudes the public has towards animals as compared to plants) will be essential to ensure way is clear to translate research outcomes into products that can be made available to, and be accepted by, smallholders and the general public.

There is a particular window of opportunity at the present – research in this sector is growing, and will start yielding results that require sophisticated regulatory input within 5 years. Action needs to be taken now to prepare for sensible regulation and adoption to provide the solutions and products Africa needs to support its development, and improve nutrition and livelihoods across the continent, especially for smallholders.

“Africa's farmers are radically practical. Africa's donors are deeply committed. Africa's scientists have the future in their bones—they ask questions they think they have a hope of answering.

Together, these groups have created miracle crops and animals. Together, these groups eliminated famine. It's Africa's turn. It's a big continent. Build a big vision.”

– Susan MacMillan, ILRI

Session 1: Introduction

Genetics for Africa – Strategies & Opportunities (G4ASO)

Dr Bernie Jones, Co-leader, G4ASO

The Genetics for Africa – Strategies & Opportunities (G4ASO) planning grant follows suit of Biosciences for Farming in Africa (B4FA), a three-year project that focused on communication and dialog activities on crop genetic improvement for agricultural productivity. The B4FA media fellowship trained 160 media professionals from four Sub-Saharan African countries: Ghana, Nigeria, Tanzania and Uganda. While the fellowship received very positive comments, several participants bemoaned the lack of inclusion in the programme of livestock, fish and insects genetics, fields that are also critical for farm productivity. In addition, these are also relevant for the control of agricultural pests and diseases; biodiversity conservation (including wildlife); preservation of the environment; and human health.

B4FA also brought attention to the fact that despite the richness in indigenous projects carried addressing important national priorities, few are generally visible to the general public and to other members of the scientific community. Poor visibility is mainly due to lack of funds for communication and outreach activities and the general lack of comprehensive and informative institutional websites. This situation affects not only the information flow to the public and also hinders scientific collaborations and the sharing of research outcomes. Better knowledge of the range of research activities in the continent would also allow streamlining and prioritising international funding for improving productivity and welfare in the continent, and in this way maximising the impact of funding and the uptake of research initiatives.

A follow-on initiative on communication and outreach activities focused on genetics in Sub-Sahara Africa would therefore have three main objectives: 1) Cover genetic research more widely, including in animals and humans; 2) Promote public outreach in more African countries; 3) Uncover and celebrate African research and researchers.

The main objectives of the G4ASO planning grant are to map African genetic research; determine key opportunities for public outreach in African genetic research; and form strong and relevant partnerships for the development of a programme and the eventual implementation of the project.

G4ASO aims to answer three key questions:

1. **Where** – which African countries should be the focus of future genetics communication?
2. **Who** is active in genetics research in the continent? And what are motivations?
3. **What** areas of genetics should be showcased?

The current animal genetics meeting is the second in a series of three focused two-day planning workshops organised for each topic (plants, animals and human genetics). The first, held in Cambridge in July 2015, reviewed recent advances and applications of the new plant breeding technologies (NPBTs) and epigenetics, while the last one, slated for early 2016 in South Africa, will be focused on human genetics.

The changing livestock sector in developing countries: the context for animal genetic research

Dr Shirley Tarawali, Assistant Director General, ILRI, Kenya

The importance of animal source foods is sometimes underestimated. Yet since 2013, four of the five highest traded agricultural commodities in international markets are animal products, and for the first time cow milk overtook then rice as the commodity with the highest net production value. Furthermore the demand for milk and meat is in sharp increase, in particular in developing countries.

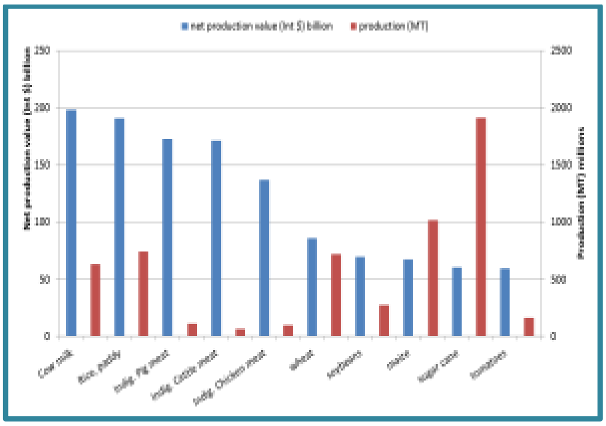

Figure 1: Animal source foods – 4 of the 5 highest value global food commodities

A number of factors will place additional pressure on the food supply. By 2050 the population of Africa is expected to more than double, while in Asia it will increase by a fifth. These two continents are also the ones where GDP is increasing the most, and where the rate of urbanisation is also highest, which translate into a bigger demand for animal source foods.

As a result, gains in meat consumption in developing countries are fast outpacing those of developed countries, and this trend is expected to continue into the next decades. This is despite the fact that per capita meat and milk consumption in developing countries is expected to be three times smaller than per capita consumption in high-income countries. Increases in demand are expected for all main commodities, with the highest increase expected in Asia, in particular for poultry where an 800% increase in demand is forecast.

Is attaining global food security and sustainable food production possible? The

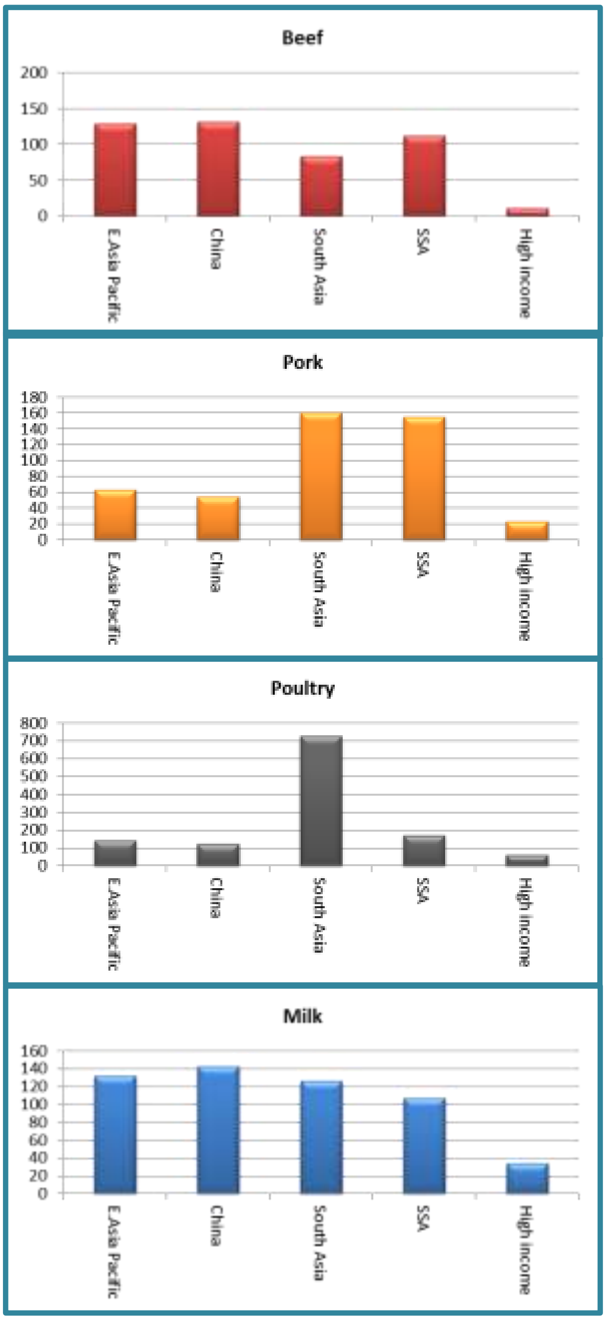

Figure 2: Percent growth in demand for livestock products, 2000-2030

key challenge is the need to produce 60% more food. Crucially, two thirds of the increased production needs to come from the same size of land. Higher production also needs to reduce poverty and address environmental, social and health concerns, and greater production will have to be achieved with temperatures that may be 2−4 degrees warmer than today's. Critically, the demand for animal source foods is rising fastest.

Despite the fact that 72 developing countries have reached the 2015 MDG 1 target of halving the proportion of hungry people, malnutrition remains a huge global challenge: over a third of the world's population suffers from chronic hunger or is under nourished, with an estimated 11% of GNP lost annually in Africa and Asia from poor nutrition. And further third is either overweight or obese, with chronic diseases related to over-consumption likely to cost USD35 trillion by 2030. Only roughly a third of the population has a balanced diet.

The production of animal source products also has important environmental costs, since methane emissions from livestock account for half of total agricultural greenhouse emissions (GHE). This is hence an area of big opportunities for mitigation: currently African and Asian countries have the highest GHE per kg meat (up to a 100 times higher than per kg meat production in industrialised countries).

What is so special about animal production in developing countries? Almost all of the animal products produced are consumed in the same country and sold informally in local markets. And a very high proportion of animal source foods is produced by smallholder farmers (500 million

The John Templeton Foundation

G4ASO project funders

Kevin Arnold, Program Officer, Life Sciences and Genetics, John Templeton Foundation

Established in 1987 by Sir John Templeton, the foundation aims to serve as a catalyst to answer the 'Big Questions' of human purpose and ultimate reality. Support is provided in five core areas of research: Science and the big questions; Character virtue development; Individual freedom and free markets; Exceptional cognitive talent and genius; and Genetics. Activities funded range from basic research to seed development all the way through to engagement in a varied set of disciplines, including all life sciences, anthropology, free market, and philosophy.

The expected aim of the Foundation's investment is to alleviate future poverty and human suffering- addressing not the pressing issues but with a longer-term perspective: where are things going and what can we do to make a difference?

In Genetics, about two thirds of funded grants have focused on genetically modified crops, which was chosen as the first area of focus as considered a good way to address critical food security needs which will be exacerbated in coming years by population growth, and hence a 'low hanging fruit'. The latest funding initiatives in genetics investigate fundamental mechanisms which underpin human identity and genetic determinism; the neuroscience of behaviour and cognition, and epigenetic research.

smallholders produce 80% of the developing world's food), and half of these are women. Livestock production is therefore also a key livelihood activity.

While the increased animal source food could be in theory met by increased imports and by replacing smallholder production by efficient industrial production, replacing the 90% of locally produced animal commodities is not feasible. Africa's food import bill is already over USD 44 million, and animal source foods are the second highest expenditure (after cereals). In addition, almost 1 billion people rely on livestock for their livelihood. Developing sustainable smallholder animal productions is therefore an imperative: productivity and efficiency must be increased while at the same time reducing the environmental footprint of production; improving human health; and reducing poverty.

Attaining this goal will require an integrated set of measures that include research in animal genetics and breeding, and adequate policies, institutions and markets; sustainable livestock systems; improved feed sources; improved animal health (in particular with respect to the emerging challenges of zoonosis and antimicrobial resistance); and increased human capacity in handling livestock. For increased sustainability it is also important to ensure animal source products are safe, are not wasted and are consumed in appropriate quantities.

Discussion session

During the Q&A several topics were discussed. A participant raised the importance of determining the effect of climate change on livestock productivity and on the incidence of diseases (including observed changes in disease vectors). Although the CGIAR system does not currently focus on this area at the research level, this will be an increasingly important topic.

Also noted was the sharp contrast between the insufficient availability of animal source foods for many people in developing countries and the situation in industrialised countries where the problem is over-consumption of animal source products, which has important environmental and human health costs. How can livestock production be increased for those in need without increasing availability for those who already have too much? Increasing the price of animal source products in developed countries is also not a good solution since possibilities of access are not uniform in their populations. Since this is a complex landscape, targeted communication is important to mitigate the broad-brush portrait of the livestock sector and to raise its importance for smallholders in developing countries. Balancing over-consumption in developed countries versus under consumption in developing countries is a key communication objective of the sector.

A participant commented on the achievements ILRI has made on the past 15-20 years in animal genetics research, such as characterising the small ruminant breeds of many African countries. However, in some countries the environment places a big limitation, for example almost all of the cattle in Tanzania is pastoral and owned by the Maasai. The cattle have small body sizes and higher resistance to local diseases, but low productivity. This point raises the importance of working closely with the pastoralists, especially for promoting environmental stewardship and practices increasing sustainability of the sector. Also critical is to address key constraints to production, in particular trypanosomiasis and East Coastal Fever (ECF), and feed quality and availability for improved productivity.

Efficiency was noted as a key issue, since low productivity translates into a requirement of a higher number of cattle to increase production, which in turn translates into increased methane emissions. This is a recurrent argument in the sector, where externalities related to more productive animals (such as manure production and the effect of good grazing management practices on carbon sequestration) are played against industrial agricultural practices. However, there is a middle ground where smallholders engaged in inefficient agriculture can become more efficient. While determining the ideal level of industrialisation is very complex (when should pastoralist systems stop?), a transition period is very important for the livelihood of smallholders and for the preservation of natural resources.

Also discussed was the concept and perception of ‘indigenous’ (most smallholder farmers consider their cattle to be indigenous), and cultural factors in the livestock sector. It was noted that the need to preserve genetic diversity may be eroded if there is an over emphasis on productivity as a breeding trait. The conservation of genetic resources and diversity requires that traditional animal breeds that are not in production are preserved as sources of valuable genetic traits for future breeding programmes.

Why communicate genetics research? For, to or with non-specialists

Susan MacMillan, Team Leader, Communications, Awareness and Advocacy, ILRI

The importance of communicating scientific advances to the wider community can be summed up in the following statement: 'A scientifically educated citizenry and a concerned scientific community is the price of our collective survival’. More specifically, the most obvious reasons *in practice* for communicating science is that a number of critical research-related activities- such as fundraising, establishing partnerships and gaining public support and acceptance- rely on successful communication. Less obvious reasons perhaps include the fact that communicating well is a personally and professionally empowering experience, and that when done well it is fun and energizing for oneself and for others. Critically, it is the single thing that can make the biggest difference to research having an impact, aside from the research itself.

In terms of animal genetics, first some bad news: the topic is neglected, poorly understood and hard to communicate since people need to have a minimum level of education to understand it. For the same reason, most people assume genetics is hard to comprehend, which makes the topic ‘non-sexy’.

However, the flip side of the coin is a wealth of opportunities: stories are fresh to others, since what is blindingly obvious to the researchers in the field is often news to the general public. And human beings enjoy learning new information, provided it is accessible. Even the ‘non-sexy’ aspect of the topic can be an advantage, as readers can be surprised to find out that this really is a ‘hot’ topic. It is important to focus on the positives.

Two (related) questions need to be considered: if the aim of communicating animal genetics resources is to put them ‘on the map’, what map are we referring to? And once we have achieved in bringing attention to the field, what next? What are the bigger ambitions? 'In science, dollars are helpful, but ideas are decisive.'

Key principles for handling communicating controversial topics:

1. **Build bridges:** people have a right to be scared. Especially of new stuff. Especially THIS new stuff. While most people are scientifically illiterate, geneticists are getting their hands on the molecular levers of biology itself. We can already slice and dice the building blocks of life. We'll soon be doing this very fast and at very little cost. Our technologies are getting ahead of our cultural means of managing them, even of comprehending all their implications, which are profound.

   Our job is to help lay people steer a course through diverse ideological stances—to help them move from fear to worry to concern to thoughtful responses to advanced genetics.

2. **Build trust**: long before you give information, give people an understanding that you share their basic values. You, too, want a safe and healthy world. You, too, worry about the fate of your children and their children. You, too, understand that scientists can make mistakes. You, too, see that there are many, many things for people to care about, and that this research is just one small part of a much larger picture.

3. **Build confidence**: we don't have to approach agricultural development as a zero-sum game: My loss is your gain, and vice versa. While we must manage expectations, we should not forget to build big visions. We're working on some of the biggest challenges humanity is facing. We're working to liberate people from the deadening weight of hunger and poverty.

   But our resources are just as big. The energy and potential of Africa’s indigenous livestock—which manage to

“I try to find the smartest people who disagree with me, and then I just listen to them”

– Tamar Haspel, Writer

> produce and reproduce in harsh environments—are prodigious. Africa's farmers are radically practical as well as humanity's very first experimenters. Africa's donors are deeply committed to great African futures. Africa's scientists have the future in their bones—they ask questions they think they have a hope of answering.
>
> Together, these groups have created miracle crops like corn, miracle animals like the Holstein. Together, these groups eliminated famine in India and China. It's Africa's turn. It's a big continent. Build a big vision.

Challenges discussed in the Q&A session included the need to communicate to attract students to read genetics, and the difficulty posed by the short-term nature of research funding, which is particularly ill-suited to animal genetics research.

Session 2: Livestock research, development benefits and outreach

Vision for livestock genetics in Africa

Dr Steve Kemp, Program Leader Animal Biosciences, ILRI, Kenya

The demand for all animal sourced foods is predicted to rise sharply in the coming decades, with the biggest increases expected in the Asian and African continents. Although not always easy to measure, significant yield gaps exists which can be addressed by adequate technologies (in particular with respect to health, genetics and feed constraints) and through non-technical interventions such improving the access to inputs and markets for smallholder producers. There is a need to target the sector both by commodity and by systems.

Genetic selection provides the greatest opportunities to improve sustainable smallholder livestock productivity across the globe. Improvements to animal health would also significantly contribute to productivity in African countries, and benefit human health.

Genetic improvement of livestock in industrialised countries also underpinned huge increases in productivity, leading for example to over a six-fold increase in average milk production of Holstein cows over five decades. However, the livestock sector in industrialised countries differs in a number of important aspects to that in developing countries:

1. Selection schemes operate in *homogeneous environments* with respect to markets, health, regulations and policies
2. They are focused on a number of well-defined breeds, with *homogeneous genetics*
3. They are supported by comprehensive and sophisticated data recording systems

By contrast, although the same biological rules apply in developing countries, the livestock sector is largely in the hands of smallholder farmers and is characterized by a large degree of diversity in all aspects, including environment; climate; available feeds; endemic diseases; local market contexts; infrastructure; institutions; regulations and policies.

Critically, the most important barriers to achieving increases in productivity are the near absence of databases and recording systems to inform selection, and the lack of infrastructure to manage breeding programmes. While replicating the large and expensive data harvesting systems of industrial nations is not feasible in developing countries, the incentive is to find alternative, light and cheaper methods to gather performance data that can effectively skip a generation of technology. Among these are cheap sensors, mobile platforms and crowd sensing technologies, unconventional methods that aim to simultaneously provide management information to the farmer and performance data to the breeder.

While the diversity of environments of livestock systems in developing countries presents some difficulties for breeding programmes, it has also generated high levels of genetic diversity- a very valuable global resource that needs to be preserved. This is in contrast with the situation in developed countries where breeding programmes have forced populations through several bottlenecks, and hence to a loss of genetic diversity.

A major health constraint on livestock and agricultural productivity is African Trypanosomiasis, a disease caused by the extracellular protozoan parasites Trypanosoma and transmitted between mammals by Tsetse flies (*Glossina* sp.). The disease, prevalent in 36 countries of sub-Sahara Africa, is a chronic debilitating and fatal disease in cattle estimated to cost the economy US$ 1 billion annually. In humans it causes sleeping sickness, which claims about 60,000 lives every year. Both wild and domestic animals are the major reservoir of the parasites for human infection.

The disease can in theory be controlled by the use of insecticides against the vector, but the practice is not sustainable due to the high cost of chemicals; their toxicity to humans and the environment; and the widespread incidence of fake products in the market. A drug exists, but it is toxic and expensive and could lead to the development of resistance. No vaccine is available despite decades of research.

Efforts to develop resistant livestock to the disease led to the identification of a resistant breed and to programmes to map the genetic basis of resistance. However, since many genes were shown to contribute to resistance to Trypanosomiasis, it is very difficult and time-consuming to develop resistant animals by conventional breeding.

While ‘traditional’ genetic mapping requires crosses and limits the source of genetic variants to members of a species, a new set of technologies has enable to greatly widen the source of useful traits. Gene editing techniques make it possible to make precise, multiple changes to the genome, and this means that the information previously collected by genetic mapping is suddenly very valuable. These techniques are not only useful for the discovery of new variation, but also provide valuable tools for testing and validation.

A new strategy for combating is to use the ApoL-I gene from baboon encoding a protein that breaks the membrane of the parasites, called the Trypanosome Lytic Factor (TLF). Baboons are naturally completely immune to the disease, and prove of concept that the gene is likely to work in other species already has been obtained in genetically modified mice, which acquired complete resistance to the disease. The project to develop Trypanosomiasis-resistant transgenic Boran cows is a collaborative effort between ILRI, the Roslin Institute in the UK, and New York University and Michigan State University in the US. Tumaini, a cloned Kenya Boran calf made by Somatic Cell Nuclear Transfer (SCNT) from a Boran embryo fibroblast cell line (now a father of several calves) is the proof that the approach chosen is feasible.

Improving livestock productivity and resilience in Africa – application of genetic technologies and challenges

Julie Ojango, Senior Researcher, ILRI.

Issues related to livestock production in developing countries are complex: increasing demands for meat and milk products must be met in a multifaceted and competitive market while at the same time improving the livelihood of the communities engaged in production and preserving finite natural resources such as land and water. Needed are also resilient animals that are able to cope with stress and diseases. The potential of animal genetic variation must be utilised to increase the productivity per animal and preserved to satisfy future needs.

The good news is that a high level of indigenous genetic diversity has been maintained, representing a hugely important global resource. The challenge is to identify and utilize the best sources of genetic traits suited for different environments. Which animals are the best for using in breeding programmes?

Technologies available for these needs include mathematical modelling to predict future scenarios and gene swaps; data gathering and analysis tools to understand the performance of animals in different environments; genomic and ICT tools to identify, improve and deliver desired animals. Improvements to reproductive technologies to multiply desirable animals, such as the development of simplified *in vitro* fertilization (IVF) protocols that requires no special equipment and can therefore be easily established with simple settings for villages.

Changes to the livestock sector are also hindered by a number of factors: production systems are mainly small-scale or pastoral with poor infrastructure, low availability of resources and poor quality feed; the incidence of endemic diseases is high; transaction costs are high; prices at local markets are often skewed; and there an absence of feedback systems to inform management decisions. These constraints means that the approach that was very successful for increasing productivity in industrialised countries (for example, resulting in the doubling of milk production per cow since the 1960s) cannot simply be applied in developing countries. An analysis of milk productivity among cattle of different grades in a smallholder setting indicated that high-grade cattle only out-performed low graded animals in the highest productivity environments. This means that simply introducing improved breeds from industrialised countries alone will not raise productivity.

New technologies can also pose some challenges in terms of public acceptance: Are GM animals OK? Is the use of gene therapy to cure diseases something good and desirable? Furthermore, besides suitable technologies and comprehensive data to guide breeding programmes, appropriate policies to ensure fair access are also needed.

Important technological advances have occurred in the area of reproductive technologies for the production of bovine embryos of desired genetics. These include simplified In Vitro Fertilization (IVF) Systems that are more affordable (10 times cheaper than standard IVF), require no special equipment, shorter cold chains and can be easily be transported to the field. Simple procedures for testing for sperm viability have also been developed. This allows for the establishment of IVF centres in villages. The price for a IVF calf can be up to 3000USD, so increased capacity for production is important to lower prices and make them accessible to smallholder farmers.

Consumption of even small amounts of milk and meat combats under nutrition, improves cognitive development and increases physical growth and activity. Therefore we need to ask whether we have the enabling policies and appropriate policy frameworks in place. These are essential for allowing biotechnology and information technologies to improve Africa's food scarcity and safety problems.

Animal Genetics Research in Tanzania

Prof Paul Gwakisa, Professor of Immunology and Animal Biotechnology, Sokoine University of Agriculture (SUA), Tanzania

The main objectives of the research carried out at the Sokoine University of Agriculture (SUA) are: 1) to characterise local animal genetic resources in order to have a good understanding of their unique attributes, diversity and their socio-economic value to farmers; and 2) to improve local animal genotypes to increase their productivity and disease resistance

Although Tanzania is the 2nd or 3rd country in Africa in terms of number of cattle, livestock populations are genetically poorly characterised. Diseases, including vector-borne infections, represent a major challenge to the sector with large costs to farmers in terms of calf morbidity, mortality and loss in productivity and with serious implications trade (e.g. foot-and-mouth disease- FMD). The genetic basis of disease tolerance is poorly understood.

Since the livestock sector is culturally very important in the country, defining what we really mean when we say 'indigenous' with respect of breeds is important since this will aid attaining a balance between 'indigenous' and 'improved' while respecting the cultural values of the people who own the 'indigenous' breeds. Local breeds of cattle (e.g. *Bos indicus* in Tanzania) often are more tolerant to endemic diseases and better suited to cope with the harsh local environmental conditions. Research to uncover the genetic bases of these characteristics is important. For example, calves born in East Coast fever (ECF) endemic areas usually became immune by natural exposure within their first year of life without showing clinical signs. Research is now underway to compare selected local breeds in terms of their innate and acquired immunological responses following ECF vaccination.

Tanzania is also endowed with a rich diversity of local chicken ecotypes with unique attributes such as fitness to the environment, tolerance to prevalent diseases, and able to cope with poor nutrition. Research on local chickens is now addressing issues pertaining productivity (such body weight and egg laying potential) and resistance to a major chicken disease – New Castle Disease.

Research is also focused on garbage dumping sites in urban and peri-urban areas, since there represent new ecosystems where humans, animals (feral and wild) and microbes interact, with the aim of characterising new anti-microbial resistance genes.

In the Q&A, a participant enquired whether there are any breeds that are resistant to FMD in Tanzania, which is not the case. FMD is a big problem and animals develop a state of endemic stability. While not lethal, the disease greatly affects productivity reducing farmers' income levels. While the government has approved the use of vaccines, the disease is not appropriately tackled. All FMD serotypes are found in Tanzania, and since 80% of the cattle are in the hands of the Maasai who are not sedentary, animals are exposed to new serotypes each year as they travel through the country.

Small and Large Scale Poultry in Mexico, Ghana and Uganda

Dr Sammy Aggrey, Department of Poultry Science, University of Georgia, Athens GA

Mexico is the country with the largest production of eggs. A significant proportion of chicken rearing occurs in a backyard setting. In terms of increasing productivity, a critical question is therefore whether it is more appropriate to introduce exotic breeds in villages or to improve local breeds of backyard poultry. All breeds in Mexico are called creole- but they represent a mix of breeds with different levels of disease resistance and of productivity. The first step for improving the genetic stock of chickens is therefore to characterise and sort the existing mix of breeds, and identify the superior varieties. This analysis will also indicate which traits should be introduced from other breeds, such as ability to dissipate heat, which is important in warm climates (and is conferred by the *frizzle* gene).

> ***Introgression*** *is the movement of a gene from one species or breed into the gene pool of another by the repeated backcrossing of a hybrid (between the two species or breeds) with one of its parent.*

Research in Ghana focuses instead on the introgression (see box) of genes into commercial poultry. Major challenges facing commercial strains in the tropics are heat and diseases. An adaptation to heat in local breeds is the “naked neck” trait that allows the birds to dissipate body heat. Several naked necked breeds have been collected in Ghanaian villages and the genetics basis of this trait is currently under investigation.

The breeding aim is to identify the appropriate genetic signatures for good traits (such as disease resistance and adapted feeding habits) in particular environments. Since the most productive animals are usually not the most resistant to adverse environmental conditions and diseases, optimisation in breeding programmes requires finding a balance, a task that can be improved by the use of genetic signatures.

Research activities in Uganda have instead focused on the Kuroiler chicken (a hybrid produced in India based on 5 strains from the US, adapted to Indian conditions). Kuroiler are very productive, laying about 150-200 eggs versus 40 by native breeds, and with significantly higher body weights. The objective of the breeding programme (funded by the Bill and Melinda Gates Foundation) is to develop a breed for villages rather than for large-scale commercial purposes, requiring no food supplements. Primary breeding in Uganda requires the acquisition of pure parental lines (grand parents stock) to generate parental stocks and the commercial chicks to increase productivity and income in rural areas.

Partnering to outfox crop-infecting viruses and insect vectors in Africa

Dr Jagger Harvey, Senior Scientist, BecA-ILRI Hub, ILRI

The BecA-ILRI Hub aims to develop an integrated research for development pipeline for agricultural improvement. It engages in basic plant science research in collaboration with leading research institutions in the world, while also focusing on the application of such research for the development of market products targeted to African farmers. The Hub aims to build the bridge between cutting-edge research in developed countries and African national research organisations (NARS), and to promote the application of such research to empower smallholder farmers in Africa. Partnerships are the thread for a more integrated research pipeline.

Beans are important: they provide food and nutrition security (as a source of proteins) and are also often grown and sold by women as a cash crop, providing income that is directly invested in the household.

There are three major aphid-transmitted viruses of common bean in East Africa: 1) bean common mosaic virus (BCMV), with worldwide incidence; 2) bean common mosaic necrosis virus (BCMNV), which is the dominant virus in the fields and is endemic to East and Central Africa; and 3) cucumber mosaic virus (CMV). Wairemu', a bean variety preferred by many farmers, is susceptible to all viruses. In addition, aphids pose a big problem by themselves in the continent reducing productivity and exposing the plant to other pests and diseases.

How do plants react to viral infections? Work carried in Europe in a model plant had established that viruses change the type of volatile 'signal' chemicals (called semiochemicals, from the Greek semeon = signal) of the plants they infect. In plain words, infected plants smell and taste differently from healthy plants. In the case of beans these changes help the virus spread: infected plants smell better to insects, so these are attracted and start feeding, but they also taste worse, so the repelled aphids leave to feed on other plants, carrying the viruses on their mouth parts and spreading the infection.

Key questions are: Can we exploit aphid behaviour to instead protect the crop? How do we develop resistant bean lines? Could we use semiochemicals and mathematical modelling techniques to design field plots that protect crops from virus disease?

On-going research work is focusing on the following aspects:

1. Surveying bean virus and aphid populations in Kenya and Uganda
2. Identifying plant genes involved in virus-mediated aphid behavioural changes, with the view of informing breeding and management strategies
3. Capacity building for local partners in the project

4. The dissemination of tools and information to increase bean productivity

Q&A for Session 2 presentations

Items raised in the discussion for the second morning session include the importance of understanding the set of issues around a breeding objective fully, including national breeding programmes; disease resistance; system dynamics; and the use of molecular markers. A holistic approach (understanding the livestock sector) is key to harnessing the potential of genetic improvement.

There is general consensus that in breeding programmes 'you can't have it all', since the amount of resources available to the animal is finite and required both for productivity and for resistance to stress and diseases. Some improved breeds, such as the Kuroiler chickens, develop faster than indigenous breeds reducing the time it takes for farmers to have returns on investment. This is a trait that will be incorporated into other breeds in the future.

Local breeds and ecotypes harbour a large amount of genetic potential, although what is 'indigenous' or 'improved' is not often well defined. Breeding work should not focus on replacing existing varieties but rather on adding value (e.g. improving the quantity and quality of milk). Any improvement program should take into consideration the ecological conditions in which the animals live, since adaptation to local stresses and prevailing disease is critical. And improvements should not be associated with the overall loss of genetic diversity.

Real-life scenarios are very complex, and characterising them genetically and environmentally is difficult. While the importance of the microbiome[1] was widely acknowledged, participants agreed it is in practice very difficult to address its impact in breeding programmes.

Broader topics such as market requirements, incentives for quality and quantity of animal sourced products and the availability of services and infrastructures were also discussed.

Session 3: African animal genetic research – outreach approaches

Biosciences for Farming in Africa

Dr Claudia Canales

The importance of applying existing knowledge and solutions to address pressing concerns of our time cannot be underestimated. For example, African agricultural productivity could double and even triple if smallholder farmers would have access to existing advances ant technologies. Biosciences for Farming in Africa (B4FA) was set to develop a model for promoting dialog and communication in the field of crop genetic improvement to increase the uptake and impact of research initiatives, focusing in four target countries: Ghana, Nigeria, Uganda and Tanzania.

B4FA consisted of three main activities:

1. Production and dissemination of two publications – Insights and Viewpoints – containing personal accounts with information and views from global

[1] *The ecological community of microorganisms that inhabit an ecological niche, which may be also animal and plant bodies.*

opinion leaders about the potential benefits, concerns, applications and consequences of new genetic technologies for farming in Africa. The development of the B4FA website to a) explain the science that underpins plant genetics and plant breeding with a clear focus on African crops; b) serve as a platform to broadcast the publications of B4FA media fellows (see below).

2. Effective Communication of Genetics: due to a lack of focus on science reporting as a skill in Africa, and a scarcity of funding for outreach activities, the technical knowledge and understanding of science by journalists and editors in Africa is generally low. B4FA ran two long-term, professional development Media Fellowships on the new genetics of plant breeding, and a round of master classes for the best Fellows. A total of 160 journalists and editors from print, radio and television were enrolled by competitive application in a programme that offered technical training combined with field-visits, mentoring and support. The Fellowship also provided opportunities for long-term networking amongst the Fellows, and between them and the research community of their country. B4FA Fellows attended, by competitive application, field trips to 50 research institutions and commercial and experimental facilities in their own countries, and to nine international conferences in the UK, the USA (World Food Prize conference); Kenya; Ghana (the FARA African Agricultural Science Week); and Ethiopia. As a result, more than 1,000 journalistic pieces were published during the three years, and several fellows are still actively reporting on the topic.

   Most journalists were themselves farmers or at least came from a farming family background, which meant that they had a very close understanding of the needs and challenges of the sector and contribute important insights in the topic. This added immense value to the programme.

3. Effective agricultural extension services are critical for making sure new advances and technologies are known and used by farmers. For this reason the third activity of B4FA consisted of three studies addressing how to strengthen extension services, or their alternatives, targeting smallholder farmers. These studies were carried out in collaboration with the National Institute of Agricultural Botany (NIAB), UK; Reading University, UK; Makerere University, Uganda and the NGO Farm Africa.

Issues discussed included strategies to increase the interaction between research activities focusing on different systems (such as animals, humans, plants and microorganisms); the need to improve sustainability of projects.

ILRI communications strategy

Susan MacMillan, ILRI

There are four key recommendations for addressing controversial issues:

- Stay on message
- Stay with the (big) problems
- Raise the level of the argument wherever possible
- Be patient and don't get defensive

And five things to remember about 'stories':

- A story is a force of nature. (The picture of one drowned 3-yr-old Syrian boy did more to open Europe to the plight of the Syrian and other refugees than all the numbers.)
- The context is decisive. (And ILRI and partners have a compelling context—widespread and absolute poverty and hunger—to communicate.)
- The main job of the storyteller is to 'make me care'
- Find the humanity in every story you tell.
- Emotion inspires action.

Inputs from the participants:

1. For better internal communications, use regular but impromptu 'tea and cake' 'flashmob' sessions to ensure the social side of research groups is supported. Use these social sessions to introduce new people, say goodbye to those leaving. Have the courage to go up to those you don't know and say, 'I'm sorry but I don't remember who you are.' Have people introduce themselves in 3-minutes. Invest your time in others. Democratize these events so the youngest get a go.
2. Get scientists to tell a story, describe how (and why) they got into a particular kind of research.
3. Create safe and attractive innovation spaces for scientists and partners and beneficiaries.
4. Don't waste time trying to get extreme anti-science people to see your point of view—go for the middle 'swing voters'.
5. Remember that the 'enemy' of science communications is slippery—it's easier to do and say the wrong thing than the right thing.
6. Remember that known controversies can be drivers of development, because they have momentum all their own.
7. To connect with others, first build trust.
8. Make first funding requests in restaurants, not in offices.
9. When people say your research already gets a lot of funding, have a response ready to give them an overview of the vast differences in funding (medicine vs agriculture, crops vs livestock, etc.)
10. Have a 'ask' ready at all times. And make the ‘ask’ whenever they opportunity arises.
11. Develop a personal story of why (not what) you do what you do.
12. Don't spoon-feed people; let them work out some of the issues themselves.
13. Provide interactive, practical interactions (rather than presentation after presentation) to inspire ownership in your audience.
14. Focus on the problems, solutions—not on the genetics or math.
15. Focus on the positive.
16. Link your messages to people. Real people.
17. Leave out the research details. Omit jargon.
18. Use received ideas to bust myths.

"... researchers should focus on using genetics to help farmers"

– Alberto Leny, reporting on www.scidev.net

Science journalism in Africa

Alberto Leny, SciDev.Net Africa

The role of a journalist is – in greater or lesser parts – to inform, educate and entertain. Journalists are therefore expected to be jacks of all trades – nowhere more so than in Africa.

Science journalists find they need to be "experts" themselves and to have to translate and bridge the research to their audience and readership. No easy task when the scientific literacy of the general population is low. The basic message is to "keep it short and simple". However, things that are easy from a communications and a media point of view tend to be HARD for scientists. Keeping things short and simple tends to involve stripping away much of the scientific detail, the context and the technical nuance of the research being communicated. It is a constant struggle between then science journalist and their scientific sources to maintain this balance whilst keeping the content essentially factually accurate.

The medium is also an important context in Africa – to communicate with farmers and rural populations, radio tends to be the favoured medium. However, this means no images to help explain the story, and often the broadcasts will have to be in local languages which might lack the appropriate technical vocabulary. The journalist therefore becomes not only the transmitter of the story, but also responsible for shaping the vocabulary and background explanations to help convey it – making it even more important that they understand the basic science involved. In the case of stories about agriculture and livestock, the journalist essentially also becomes an agricultural extension worker.

Theories of change and communication strategies

Nick Manson, Change Through Partnership UK Ltd

Some of the biotechnology animal breeding initiatives we are talking about are very cutting edge, and therefore may require us to think about them, and talk about them, in quite a different way to usual.

In the case of the ILRI research on trypanosomiasis-resistant cattle, for example, an approach may be to start from the issue the research is trying to resolve.

“Trypanosomiasis is a huge issue in Africa and South American livestock farming, And it has been implicated in human sleeping sickness too, Current control methods are either too expensive or toxic to users. Yet baboons and some other animals are totally resistant. Research has shown us that a single gene is primarily responsible for this resistance.”

And comments can also be made about the research and research methodology – “all the products of this research are for the public good”; “it follows golden rules on long-term monitoring and evaluation accessible to the public, education and information provision”.

But it is also very helpful to build a complex map of stakeholders, who is opposed to an idea and why, and what are their concerns.

Media influence and approaches

Tamar Haspel, Writer and journalist

“When did you last change your mind? (about something of substance)” It isn’t easy, and it happens rarely. So we should not expect the media to be a deliverer of magic bullets that – by conveying science to the general public – will automatically change their mindset. There are some things that we, and the media, should watch out for though:

1) Confirmation bias – everyone tends to look for and prefer information that confirms their existing position, whilst paying less attention to information suggesting alternative interpretations.
2) Backfire effect –People will often dig their heels in when faced with a strong argument seeking to disprove their position.
3) Source/story credibility – we tend to evaluate stories and sources based on whether or not we agree with them, rather than on objective criteria.
4) Do not call stories or groups “anti-science” – no-one says or believes that they are anti-science. They all say that science supports them
5) Beware the “science literacy” argument – scientific literacy and better education do not automatically lead to agreement with the scientific consensus. In fact, scientific literacy polarises opinion (cf arguments about climate change). This seems to be because better education makes people better at filtering out things that they don’t agree with!

To successfully report controversial technical subjects to the widest possible range of subjects, a smart journalist may wish to employ “science caution” – and adopt a balancing act in their reporting.

Finally, context also matters hugely – arguments about animal research and use in farming differ in the EU, US and Africa, due to cultural differences and the whole farming systems. Therefore it is naïve to think that one reporting approach will work across all those areas.

Figure 3: Alberto Leny, Nick Manson and Tamar Haspel in discussion

Group discussion on key issues in animal genetics outreach

These discussions were followed by a Samoan circle session: a leaderless but structured meeting designed to help negotiations in controversial issues[2]. Key issues discussed are briefly described below.

Scientists are cautious about clarity and correctness of facts, and while detail is critical for communications with other scientists, it can hamper public outreach efforts. Scientists should try to avoid including and excessive level of detail when communicating with the public. Excessive information is difficult for non-specialists to absorb, and can hamper communication by clouding the critical messages ('sometimes information is an elephant!'). It is important for journalists to understand the basic science and use the right information in their stories.

Science is hard to share across because facts by themselves do not convince people or lead to a change of opinion, especially in controversial topics. What's the role of journalists? Communicators need to be ready and develop a strategy to share the facts. And a critical consideration needs to be how to tailor messages around a common value base to start communication. Messages need to be tailored to their intended audience, and animal genetics provides a good example: the messages for African countries and European countries need to be very different (not sufficient access to animal based products in developing countries versus unsustainable over-consumption in developed countries).

Africa provides a big opportunity for engagement because animal genetic research directly impacts the livelihood of millions of people in the continent. How can we increase linkages with communities? What traits in an animal are needed farmers? What important information should be shared? Examples would include communicating to pastoralists the availability of breeds resistant to disease or drought and the importance of vaccination programmes.

A universal problem in scientific outreach programmes in a lack of funds available for this purpose, and hence innovative approaches are important to bridge this gap. These include the use of ICT to increase the interaction with media professionals (in forums, for example), and increasing linkages to other professional communities, such as sociologists and anthropologists. Scientists sometimes fail to recognise the importance of teaming up with other specialists to increase the impact of their research.

The discussion also focused on strategies to communicate controversial topics, such as GM animals. While it was proposed that scientists should communicate only with other scientists and politicians on these topics to avoid a backlash, most participants rejected the idea of a closed circle about science. Food is a topic very close to all human beings, and transparency and inclusion are therefore critical. Interacting with ‘smart’ people holding different views is important for dialog. It is important to also

[2] *While there is no ‘leader’, a professional facilitator welcomes participants and explains the seating arrangements, rules, timelines and the process. The Samoan circle has people seated in a circle within a circle, however only those in the inner circle are allowed to speak. The inner circle should represent all the different viewpoints present, and all others must remain silent. The process offers others a chance to speak only if they join the ‘inner circle’.*

bear in mind that it is very difficult for everybody, scientists included, to change deep held values and opinions: it is very hard to change our minds! An effective strategy may be to try to bring the sceptic from a negative to a neutral stance, and to target the middle ground, not the whole world. There's no hope for the fringes: i.e. people with very extreme views on both sides of the spectrum.

Session 4: African animal genetic research, development benefits and outreach

Taking the bull by the horns (if it has horns)

Dr Jasper Rees, Group Executive: Research and Innovation Systems, Agricultural Research Council of South Africa.

Projects focusing on livestock genomics in ARC include: population diversity studies using molecular markers (short nucleotide polymorphisms- SNPs) in cattle, goats and chicken, and genomic sequencing tools in Nguni Cattle, buffalo; genetic studies in Swakara sheep and pigs; and genomic selection through the *Livestock Genomics Consortium*. Sequencing technologies are being applied to whole genomes, transcriptomes (see box) and small RNAs, while the use of molecular markers is applied to many breeding programmes and genetic diversity studies.

An example is an analysis of the genetics structure of SA indigenous goat populations, which compared commercial breeds such as Savanna, Kalahari Red and Boer to indigenous breeds kept by breeders in Kwazulu-Natal and referred to by different names, and to Tankwa feral goat populations. Principal component analysis (PCA) of genetic data indicated that these three groups are clearly distinct from each other and shows that commercial goat breeds were genetically quite close. Population structure studies further confirmed that the populations cluster according to their production systems, and that feral goats are very distinct from the other two groups. The implications? Feral goats represent a unique genetic resource containing a diverse and unique gene pool separated from both the commercial and village ecotypes. Further studies are needed to identify which of these genes/alleles are important for conferring genetic adaptation in specific production environments, for example by increasing tolerance to local stress factors and endemic pests and diseases.

The genetic fitness of a breed may also be influenced by structural changes to the DNA (Copy Number Variations, CNV) such as deletions, duplications, variants and insertions. A study aimed to determine associations between specific CNVs and productivity levels, disease resistance and incidence of congenital defects in Nguni

*The **transcriptome** is the set of all RNA molecules transcribed (when genes are expressed the information they contain is first used to make an RNA molecule in a process called transcription) in one cell or a population of cells with an indication of the concentration of each molecule. Transcriptomes vary according to the developmental state and environmental conditions of an organism, and provide an indication of the level of gene expression (=activity).*

cattle, which is recognized for its ability to sustain harsh environmental conditions and enhanced resistance to disease and parasites. The analysis showed that pathways enriched by genes covered by CNV regions in Nguni cattle are involved in a number of biological processes and molecular functions. The significance of these correlations remains to be ascertained.

Further work in the research centre is focused on determining the signatures of selection (genes in the genome under selection) in indigenous cattle, comparing Afrikaner and Nguni breeds to Holstein. These include genes in important traits such as milk fat and protein percentage; milking speed; body weight and height; meat tenderness score; teat placement and resistance to ticks.

Wildlife genetics is the focus of interesting, if opposed work exploring both the commercialization of wildlife with exotic game trophy breeders and wildlife conservation. Both efforts focus on the same trait: horns, because the longer the horn the more prized an animal is for recreational wildlife hunters. So while exotic game breeders are looking for the gene/s for Big Horns, work is also underway to introduce the No-Horns *Polled* gene into animals by genetic engineering to reduce their appeal as trophies and protect the species.

Figure 4: Is there a gene for big horns? (No...)

Stress resistance is a very important area of research. In one example, resistance to heat stress in Senepol cattle (a heat resistant temperate zone breed) is associated with a mutation that truncates the PRLR (prolactin receptor) protein, which confers to the animal short hair and the ability to sweat – making them better suited to cope in the heat. A key question is whether engineering this trait into other breeds will result in heat tolerance.

In terms of insects, research is being carried out to control disease vectors for human, plant and animal pathogens; agricultural pests (fruit flies); parasitoid wasps and other predators.

In a more recent application of the sterile insect technique, which was originally developed in the 1950s, GM is used to introduce a *Self-Limiting Gene* in transgenic insects. GM mosquitoes develop normally only if supplemented with tetracycline (an antibiotic), so once they are released in the wild to mate with wild populations for the control of malaria their offspring are unable to survive.

Genomic selection in smallholder systems: challenges and opportunities

Raphael Mrode, Principal Scientist, Quantitative Dairy Cattle Genetics, ILRI

The livestock sector in African countries presents key differences to the large, commercial systems of developed countries. In Europe and the US the livestock sector consists mostly of genetically characterised pure breeds, with large reference populations and defined phenotypes. Using the association between genetic markers and important economic traits, genomic breeding values (GEBV) were estimated for animals and used to guide breeding programmes. Benefits of selection include increased accuracy, higher rates of genetic gains, and reduced generation intervals.

By contrast, in African countries livestock is largely grown in a smallholder setting, and consist mostly of cross-bred animals. Available datasets are small, there is little data available for pure breeds, and it is difficult to define good reference and validation populations. Despite the challenges this poses, the sector offers good opportunities for exploring alternative methods for data collection and analysis. Genotyping methods allow determining the origin of mixed breeds, and provide the opportunity to match different genotypes to different management systems. They can also play a role in the future traceability of animal products.

In order to demonstrate the challenges and opportunities offered by the analysis of small data sets, a population of 1038 cows (with known test day milk records) from 5 random sites in dairy production areas in Kenya were genotyped with the 777K Illumina High density chip. The accuracy of genomic prediction from subsets of the population with different breed composition was determined, and yield deviations for milk production were generated using a repeatability model. The results indicate that, given data structure and size, accuracies of genomic prediction obtained are encouraging, and the data can be used to identify extreme animals on performance to select team of young bulls to use as sires.

Looking ahead, there is a need for more data. In view on the constraints on available resources, developing innovative ways for gathering information and establishing collaboration across countries (in the continent and abroad) are both important, as is linking data from smallholder systems to data from medium to large farms. Policies that promote easy flow of data across country boundaries while maintaining data security and ownership will also be needed.

African Wild Genetic Resources for Livestock and Agricultural Productivity

Dr Morris Agaba, Research Scientist in Molecular Genetics, BecA-ILRI Hub, Nairobi, Kenya.

Africa offers an impressive array of variation and adaptation strategies in ungulates. For example, the endangered Addax inhabiting the Sahara desert is extremely well adapted to extreme drought conditions and obtains all the water it needs from its food, not needing to drink. And differences in body size are also very marked: the small Royal Antelope of the central humid forest weighs just 1-2kg, while the body size of the Eland in the Savannahs can be 1000kg. Wild animals are also resistant to important diseases (for example, Eland and the Congo Buffalo are both resistant to Nagana), and some readily interbreed with livestock, such as the Nubian Ibex, which inter-cross with domestic goats. Additional traits of interest are related to productivity: the milk produced by Springbok is highly nutritious, with 7% protein and 14% fat content.

The genetic study of wildlife also opens a window into the evolution of animal lineages.

The giraffe has unique physical attributes, including a very long neck, that pose physiological challenges such as high blood pressure. Their body frame requires very strong bones. Furthermore, giraffes are resistant to some diseases lethal to livestock. The sequence comparison of the giraffe and other ungulates is likely to shed light on the genetic bases underlying important adaptive traits, such as animal's long neck. Genomic data from giraffes, okapi and 50 other vertebrates is currently being analysed.

In view of the increasing water scarcity afflicting the continent, solutions for increasing the sustainability of fish farming are also being sought. African lungfish can survive buried in the mud even when water bodies dry temporarily during droughts. Current studies are using genetic data to determine diversity of lungfish populations; their phylogeny; and quantifying gene-flow within lungfish populations, all aimed to develop climate-smart fish farming.

In the Q&A it was noted that interesting traits to further investigate are the genes controlling ventilation in giraffes and genes controlling nerve cell generation in Okapi.

Also discussed was the ability of the lungfish in western Kenya to estivate in mud and dirt for months when ponds dry up. The lungfish has a huge genome and the genetic control of estivation is very complex. Other organisms use very small genomes to suspend life. Cellular processes are shut down when an organism transits into estivation or hibernation. Such genetically controlled traits could be useful, for example, in bringing frozen cells back to life.

CGIAR research programs aim to focus on livestock genetic repositories and comparative genomics, and the information generated is intended to inform breeding programmes and genome editing projects in the next 5-7 years.

African Chicken Genetics Gains

Dr Tadelle Dessie, Project Manager, ILRI, Addis, Ethiopia.

The African Chicken Genetics Gains (ACGG) is a platform for testing, delivering, and improving chickens adapted to tropical conditions for productivity growth in sub-Saharan Africa. The five-year project (2015-2019) is implemented in Nigeria, Tanzania and Ethiopia and aims to benefit mostly women and the youth. ACGG is funded by the Bill and Melinda Gates Foundation with in-kind contributions from ILRI and partners.

Chicken production systems in Sub-Sahara Africa are heterogeneous in size (from village home production systems to small-scale through to commercial systems) and also differ in terms purposes, the number of types and animals, and the type of management. Village chicken production systems offer unique possibilities because they are part of balanced farming system. Chickens have also high reproductive rates and can greatly benefit from the advances of breeding and genetics and from technology developments. Within breed selection, cross-breeding and the development of breeds with good egg and meat production traits are both relatively straight forward.

Why chickens? Despite the current low productivity in the African continent, there is a high potential for growth across a range of systems. Chicken leads the global meat trade with 40% of exports to Africa and the Middle East, and the meat and eggs are often the highest value agricultural product globally. Importantly, chickens have great potential for women's empowerment improving both income and the household nutrition, potentially offering a path out of poverty.

Compared to hybrid commercial strains, indigenous chicken breeds show substantial yield gaps in all environments, from set-ups where the animals rely on scavenging for food to intensive rearing systems. The focus of the project is not limited to genetic improvement of chickens, but aims also to improve semi-scavenging production systems; promote dietary diversification; empower women; improve access to markets, with the ultimate goal of improving livelihoods. The vision of this program is to catalyze public-private partnerships for increasing smallholder chicken production and productivity growth as a pathway out of poverty in sub-Saharan Africa.

In more detail, ACGG's objectives are:

1. Identify, characterize, and test *tropically-adapted chicken* germplasm to determine productivity across agro-ecologies and management conditions and to define farmer preferences;
2. Develop IP models and MTA to facilitate private and public sector access to the farmer preferred germplasms and *establish stable multiplication lines* through a long-term genetic gains program focused on continual improvement; and
3. Develop and nurture Innovation Platforms to facilitate private sector engagement and business model development focused on empowering poor smallholder farmers, especially women, to improve their livelihoods.

Partnerships are crucial in the programme and integrated into ACGG's core business in three main areas: 1) Communication – to move beyond informing to engagement; 2) Support provision to partners; 3) Service provision to assist key partners in capacity building, resource mobilization, etc. The role of ACGG's team in ILR is to provide leadership and technical support and coordinate the identification, sourcing and testing of productive strains. National ACGG country teams are instead responsible for managing the implementation of the project at the country level; perform baseline surveys; carry out on on-farm and on-station testing; management of IP resources and of PPPs; and assist capacity building of key partners.

ACGG is guided by a Scientific and Industry Advisory Committee (SIAC) comprised of six leading professionals in business, research, and development. These individuals will be a key driver of ACGG's goals of a high standard of responsibility, culpability, and superior governance.

In the Q&A session, a participant enquired about the strategy to reach women entrepreneurs. The current aim is to assess over 1000 households. The breeding programme will be set up in each country, involving the private sector to multiply the animals and take the work to scale, and to reach producers. The project does not have funds for jumpstarting private sector companies, so work will be done with established businesses. The project works with at least one big player in each of the countries.

In response to a question regarding the IP, in the livestock sector this approach has not been done before. A binding document is being drafted and will be shared with the innovation platform members. The Foundation will acquire IP rights over the Kuroiler chicken to improve and change it but the current owners will continue owning parts of the IP. National governments will play the major role in this and ILRI will keep the right to distribute the germplasm to Rwanda and other countries in the region.

And the time scale for the project? Five years for the test phase, and depending on progress of the breeding program the project might extend into a second phase. Non-partner countries will also benefit from the project. Information will be disseminated and effects are expected to spill over to neighbouring countries. The approach will differ in each country taking into consideration requirements and agro-ecological zones. So while in Nigeria the target will be 50 chickens per household to be kept in controlled conditions, in Tanzania and Ethiopia the birds per household will be fewer in numbers and free-range.

Session 5: Other research, development benefits and outreach

Strategies and opportunities for improving outreach and public understanding

Dr Richard Osei-Amponsah Lecturer at the University of Ghana; CAPREx Post-Doctoral Research Fellow, Cambridge UK.

An important focus of research initiatives is the characterisation of local animal resources and their production systems, which provides relevant data for their conservation and sustainable use. The Ashanti Dwarf Pig (ADP) is breed from Ghana which has good adaptive traits, is tolerant to endemic diseases, survives under poor management, heat stress and is also able to handle fibrous feeds much better than exotic breeds. A study was carried out to determine the origin and phylogenetic status of ADP and their crosses with modern commercial breeds based on their mitochondrial DNA (mtDNA – see box) sequence polymorphisms with the aim to preserve its decline and prevent genetic dilution of the breed. Genome-wide association was also performed to identify important genes involved in disease resistance, growth, meat quality and reproduction traits.

> ***Mitochondria** are the cellular organelles that convert chemical energy from food into a form that cells can use, and they contain their own DNA. Because mtDNA evolves at a slower rate than genomic DNA, its sequence data is often used to determine the evolutionary history of populations.*

Over 160 animals with dark coats where sampled from six regions in the three agro-ecological zones of Ghana (the Guinea Savannah, Forest and Coastal Savannah zones) and a fragment from their mtDNA was sequenced to determine the genetic distances among individuals; the frequency of each haplotype in each population; and the overall frequency of Asian and European haplotypes. The genomic DNA of 72 animals was genotyped and analysed, and the results were mapped to published genetic data on European and Chinese pigs.

The results indicate that the ADP is genetically closer to European than to Asian pigs, with strong European influence on all the lines sampled. However, the allele responsible for the dominant black coat is of Asian origin, which indicates that colour is not a good trait to characterise Ghanaian ADP. Future work will focus on isolating more genetic signatures of selection for adaptive and economic traits of the ADP to develop a genomic selection scheme.

Communication and public engagement are important activities for the university, and events organised include stakeholder workshops; seminars and special lectures; and conferences and technical meetings, in addition to academic publications (journal articles and book chapters). The main challenges to communication are the wide array of stakeholders (including policy makers; farmers; extension agents; and media professionals) each requiring tailored communication campaigns and each with their own needs and demands (e.g. politicians are not always accessible, and farmers demand compensation for their time to attend events). Also a challenge is the lack of funding and human and institutional capacity. However challenges translate into opportunities: there is scope for training animal scientists in public communication; building the capacity of livestock farmers; and engaging more effectively with the media, perhaps through outreach programmes and media soirees.

The need for establishing a breeding farm for the ADP was raised during the Q&A session. There is already one in the north of the country, but another is needed in the south. Advice on how to derive more information on the genetic data available would be welcomed. There is also a need to sample a larger number of local pigs and to gather relevant information from the farmers, including how they perceive the animals and what would motivate them to keep them in the future. The availability of performance data would also enable researchers to make better use of the existing genetic data.

Genetic Improvement in Aquaculture in Africa

Professor John Benzie, Genetics Flagship Leader, World Fish, Penang, Malaysia

Fish is an important source of food for mankind. It comprises 16% of the animal protein we consume globally, and nearly a fifth and third of animal protein intake in Asia and Africa, respectively. Although the fact that a large proportion of the globe is occupied by oceans may give the impression that the potential area for aquaculture is vast, areas of high primary productivity are restricted to specific geographical zones (e.g. around in the Pacific islands) and in coastal areas. In addition, open ocean conditions can be very challenging, so despite the fact that innovative engineering solutions are improving the prospects of deep-sea fishing, production is likely to continue to occur near the land. Large inland aquaculture facilities have also been developed, particularly in Asia, such as the 3000 ha onshore ponds established in Indonesia for shrimp cultivation which employ 40000 workers. However, onshore aquaculture places additional demands on available land, and competes with other potential activities such as crop production.

In order to meet expected demands in fish a threefold increase in production is needed, and in view of the spatial and environmental constraints this will require increases in efficiency, husbandry, and domestication and genetic improvement programmes.

To date efforts to improve the genetic stock of fish have been quite limited. Of the 400 species cultured 90 are domesticated, and of these only 18 (5%) have been the subject of significant genetic improvement programs. Market penetration is also low (less than 10%). 76 fish species provide the near totality of production (99%) and of these, 21 (6%) account for 80% of production. In terms of finfish production 65% is derived from 5 species of freshwater carps, and 4% from marine. There are only 3 major commodities: salmon, tilapia and white shrimp.

Nonetheless, the current figures represent a big change from the situation a few decades ago: while 50% of the fish consumed today originates from aquaculture, only 40 years ago this was nearly zero. And while about 400 fish species have been domesticated[3] to date, 60 years ago this number would have been 70. Most of the newly domesticated species are from Asia.

Why have there been so few efforts to improve the fish germplasm? A reason is the fragmented and dispersed nature of farming systems and the difficulties associated with managing genetic improvement programmes in aquaculture systems. Most fish farming systems, especially in Asia, occur in small freshwater ponds and rivers and are managed by smallholder farmers. These systems are also characterised by a close association and interdependency with crop agricultural systems. Furthermore, although the required legislation exists, it is poorly implemented.

Genetic improvement has nonetheless a great potential: it results in 8-10% per year improvement of growth (most breeding programmes have focused mainly in growth), levels unheard of in cattle or birds breeding programmes.

The Genetically Improved Farmed Tilapia (GIFT) programme is an example of a very successful programme, which led to a very large growth in production. As a result tilapia ranks now 4th worldwide and represents 70% of the market share in the Philippines. GIFT grows 50-80% faster than unimproved strains, and has high survival rates. The technology has a very high capacity to scale up if the infrastructure for dissemination is available. It has been distributed to fourteen other countries, including four African countries: Côte d'Ivoire, Egypt, Ghana and Kenya. One of the reasons the GIFT programme has not been more widely accepted in Africa is that tilapia is endemic to the continent, and therefore the management of the introduction to prevent genetic contamination of endemic fish stocks is a big issue, with some concerns justified in view of the regional environments.

Despite the success of the tilapia programme and the very large increases in productivity genetic improvement can offer, the use of improved strains in aquaculture is still limited. While the proportion of fish production derived from aquaculture is 35% of total production worldwide, in sub Saharan Africa it is only 3%, and almost none of this (less than 0.3%) is from genetically improved fish.

Work in Egypt (where 65% of fish is derived from aquaculture) provides lessons for the rest of Africa and a platform for scaling

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[3] *Domestication is here defined as three generations in culture.*

production in Sub-Saharan Africa through continued work on:

- genetically improved performance, resilience in the face of climate change (aquaculture in Egypt is only done in water that has already been used once, e.g. for irrigation)
- integrated research on breeds, feeds and farming environment
- This provides a strong capability to assist the development of greater sustainable production of nutritional fish in sub-Saharan Africa

Genetic improvement of fish in Africa is focused mainly on tilapias (*Oreochromis niloticus*): the Abassa strain in Egypt; Akosombo strain in Ghana; and *O. shiranus* in Malawi. The African catfish is also the focus of limited improvement programmes. While creating a small population of genetically improved fish is relatively straight forward, for impact improved strains have to be disseminated to farmers and village production systems. This requires effective multiplication and dissemination mechanisms and infrastructure, such as multiplier hatcheries.

Genetic improvement programmes face important choices with regards to introductions, indigenous improvement and risk management practices. Informed choices of whether to introduce high performing strains or to develop indigenous ones can be made through appropriate evidence based risk assessments. Stronger governance processes that are able to enforce regulations and prevent illegal introductions would greatly benefit the sector.

2nd State of the World's Animal Genetic Resources for Food and Agriculture

Dr Badi Besbes, Animal Production Officer, Animal Genetic Resources Branch, The Food and Agriculture Organization of the United Nations (FAO), Nairobi, Kenya

The Second Report on the State of the World's Animal Genetic Resources for Food and Agriculture (2nd SoW-AnGR) provides a comprehensive global assessment of livestock biodiversity and its management, with updates on the first report, published in 2007. Drawing on 129 country reports; 15 reports from international organizations; 4 reports from regional focal points and networks for animal genetic resources; the input from 150 individual authors and reviewers; and breed-related data from FAO's Domestic Animal Diversity Information System[4], it sets out the latest available information on:

1. The state of livestock diversity
2. Trends in the livestock sector
3. Current capacity to manage animal genetic resources
4. Gaps and needs in animal genetic resources management

The proportion of the world's livestock breeds classified as being at risk of extinction increased from 15% to 17% between 2005 and 2014. The number of breeds classified as being of unknown risk status because no recent population data have been reported remains very high (58% from 57% in 2006), which means that the number of breeds at risk is therefore likely to be underestimated,

[4] *DAD-IS – http://fao.org/DAD-IS*

although no increase in the number of extinct species is reported.

Top 8 reported threats to animal genetic resources are:

1. Indiscriminate cross-breeding
2. Introduction/increased use of exotic breeds
3. Weak policies or institutions
4. Lack of profitability/competitiveness
5. Production system intensification
6. Diseases
7. Loss of pasture or production environment
8. Poor control of inbreeding

What needs to be done to prevent further loss of genetic resources? Critical is improving the knowledge of animal genetic resources (AnGR) and their production environments, including knowledge on: 1) the roles of different types of livestock in the supply of goods and services, particularly in the livelihoods of poor people; 2) the impact of different types of livestock and of livestock keeping on ecosystem functions; and 3) the adaptive characteristics of individual breeds, in particular the ability to cope with harsh conditions (e.g. extremes of temperature, restricted water supply, poor quality feed).

Livestock-sector trends and their potential effects on AnGR management need to be identified and monitored more effectively so that action can be taken to ensure that livestock populations are able to meet the demands and genetic diversity is maintained. In particular it is important to:

- Monitor trends in the **size, structure and distribution of breed populations** needs to be improved for identifying breeds that are at risk of extinction and prioritizing conservation activities.
- Identify **threats to animal genetic resources** and their potential effects needs to be better assessed so that action can be taken to minimize the risk they pose to diversity.
- **Institutional frameworks** for AnGR management need to be strengthened, including mechanisms that allow for better communications among stakeholders and facilitate the participation of livestock keepers in the planning and implementation of policies and programmes.
- **Awareness, education, training and research** need to be improved in all areas of AnGR management, including in the emerging fields of access and benefit sharing, ecosystem services and climate change adaptation and mitigation.
- **Breeding strategies and programmes** need to be strengthened so as to enable full advantage to be taken of available genetic diversity and ensure that livestock populations are well matched to their production environments and to societal needs.
- **Conservation programmes** need to be expanded and diversified, where possible combining support for on-going use of breeds in their usual production environments with the maintenance of backup collections of genetic material
- Countries that have not yet developed a **national strategy and action plan** should consider doing so as a means of translating the provisions of the Global Plan of Action for Animal Genetic Resources into well-targeted activities at country level.

- Countries that have already developed strategies and plans should ensure that they are implemented.
- In many countries, **National Focal Points** for the Management of Animal Genetic Resources also need to be strengthened.
- **International cooperation** in AnGR management needs to be improved at both global and regional levels, including activities related to the management of shared resources (breeds kept in more than one country) and to the transfer of technologies and knowledge.
- Funding shortfalls that constrain improvements to the management of AnGR need to be addressed.
- To maximise the impact of using **genomic technologies** there is a need to develop performance and pedigree recording programmes that can be implemented in local conditions. These initiatives should be complemented by efforts to raise livestock keepers' awareness of the benefits of genetic improvement programmes and strengthen their capacity to collect and use data.
- The **public and private sectors** should cooperate to establish infrastructure for the distribution of improved germplasm and efficient markets for the inputs and outputs of livestock production.

In the Q&A session follow on steps from the publication were discussed. The publication of the original SoW-AnGR report led to the adoption of a policy document by member countries: the Global Plan for Action. The same process will be repeated with the second edition of the report, which is expected to lead to amendments to the Global Plan for Action. Also discussed was the discrepancy in different published accounts on the numbers of indigenous/locally-adapted breeds versus the number exotic breeds. This reflects the varying criteria adopted by different countries to classify a breeds, the FAO simply reports the data provided.

The BecA-ILRI Hub

Dr Jagger Harvey, Senior Scientist, BecA-ILRI Hub, Nairobi, Kenya

The future of the African continent represents not only challenges, but also many opportunities: a growing private sector; and a growing middle class; new intra-continental trading markets. The application of biosciences can add value to African genetic resources, but to achieve impact research products must be liked to the intender end-users: farmers.

In addition to research, the BecA-ILRI Hub is engaged with capacity building; laboratory management, technology platforms and research related services; and communications and partnerships. After two phases of establishment and implementation, the centre has entered a phase of innovation, with a business plan for 2013-2018 supported by a large number of international funding organisations. It aims to function as African Centre for excellence in the biosciences, with the following objectives:

1. Link research to impact – at the national, regional and continental levels through the appropriate partnerships *(ASARECA, CORAF, FARA/S3A)*
2. Provide support to African NARS (National Agricultural Research S) beyond the eastern and central Africa region), in research and outreach activities

3. Link African NARS with other agricultural research institutes, including centres members of the Consultative Group for International Agricultural Research (CGIAR)
4. Provide opportunity to access high end biosciences facilities including state-of-the-art technologies to accelerate delivery of research outputs (such as the Genomics platform 2015 – 2019)
5. Influence policies, donors and countries investments

The Africa Biosciences Challenge Fund (ABCF) is a visiting scientists training programme aimed to raise institutional capacity in the continent. Fellows who have benefited from the award have come from Kenya, Cameroon, and Uganda and carried out research on topics including chicken genetic diversity; cavies breeding; passion fruit rapids diagnostics; and staple crops hybrids. The Hub aims to operate as a 'transit point' of advanced technologies between international, European and US research institutes and African NARS. Technologies include synthetic biology; genomics; protein expression in plants; and proteomics and metabolomics. The Hub offers opportunities for sabbaticals and joint research, successfully having link several NARS researchers with scientists outside the continent.

Neglected and underutilized livestock are considered key contributors to food security in Africa offering alternative solutions to food and nutritional security. Cavies, for example, have a high protein value (over 20%) and mineral content, and are also low in fat. Targeting women and children in cavies rearing programmes can improve the income and nutritional status of vulnerable households. Current genetic data available for this species indicates that breeding programmes to improve productivity and resilience would be very successful since levels of genetic diversity are high.

Communication/outreach initiatives are also essential to increase the impact of research carried out in the Hub. Future priorities include increasing participation in strategic forums on agricultural research and technology priorities in Africa; sharing insights from experience gained while partnering with national scientists; improving the capacity of NARS scientists and development partners to communicate with end users exploring areas that need strengthening; and advocating for more government resources to be invested in agricultural research to ensure sustainability.

Animal genetics and biotechnology

Carol Kamau, United States Department for Agriculture (USDA)

Foreign Agricultural Service (FAS) is an agency of the United States Department of Agriculture (USDA). The FAS regional office at the US Embassy in Nairobi covers the five East African Community countries (Kenya, Uganda, Tanzania, Burundi and Rwanda) and Malawi. Other FAS offices in Africa are located in Accra, Ghana; Dakar, Senegal; Addis Ababa, Ethiopia; Pretoria, South Africa; and Cairo, Egypt. The main goal of FAS is to promote U.S agricultural trade and global food security through market development, capacity building, trade policy and financing programs. USDA addresses research through another agency, the Agricultural Research Service (ARS).

USDA's interest in animal biotechnology has focused on capacity building in the recent past. More focus has been on training in plant biotechnology through two flagship programs, the Cochran Fellowship Program (CFP) and the Borlaug Fellowship Program (BFP). These aim to enable participants to gain to new agricultural knowledge, technologies and best practices in the United States that would assist them develop agricultural systems in their home-countries. Details on the programs can be found at: http://www.fas.usda.gov/programs

Other capacity building activities include workshops, conferences, and exposure tours. In the last two years, we have organized groups of East African animal scientists to participate in Animal Biotechnology workshops/conferences in Brasilia, Brazil (2014), and in California, USA (2015).

Session 6: Research outcomes and uptake- lessons to be learned

1. Why is animal genetic research important for African development? What makes it relevant?

The African continent is very rich in animal genetic resources, and these play an important role in the livelihood of millions of farmers. Increasing the characterisation and use of this wealth is critical for improving productivity, resilience to changing environmental conditions and human health. Meeting future demands for animal source products is also required to provide a cheaper source of protein, needed for adequate human nutrition and obtain food and protein self-sufficiency in the continent. Animal husbandry can also generate additional sources of income for poor households, contributing to wealth creation and economic diversification. Although prioritising research objectives is a challenge, key areas are disease control (the current biggest threat to productivity) and nutritional improvements in meat and milk quality.

The animal genetic diversity of Africa is however also a hugely important global resource, in particular pertaining traits linked to resilience and adaptation to stress- in particular drought- with many unique attributes and traits. Since livestock in Africa also often needs to survive with low food availability, they also harbour traits for the efficient use of resources. Characterising and preserving this resource is critical, not only for agriculture, but also for health and medicine, since many species provide good model systems for certain diseases and conditions (e.g. osteoporosis or hypertension in giraffes versus humans).

Environmental issues associated with animal rearing need to be considered, with a focus of improving livestock genetics to reduce the environmental footprint of animal husbandry. What are the risks and challenges? Animals are central to systems, hence a holistic approach mindful of the system as a whole and of unintended consequences.

Animal genetic technologies offer the ability to improve animals with precision, and since many breeds have not been the focus of breeding programmes the potential benefits of doing so are very big, as such advanced genetic technologies could constitute leapfrog technologies. A challenge is to prioritise breeding objectives. It is important that the continent is able to benefit from technological advances in the field.

Several requirements were established as important for Africa to fully benefit from advances in animal genetics. One is increased human resources and capacity to manage genetic diversity, required for establishing responsible research programmes. Also important is educating farmers and other stakeholders to maximise the impact of genetically improved animals: a holistic approach is needed to achieve transformative effect. In addition to improve linkages in the whole value chain, this dialog is a requisite for advising breeding programmes so that priorities for farmers are taken into account, addressing the disconnect sometimes observed between research and practice. Mechanisms for channelling information back from users to researchers need to be developed, also as a way of preserving the wealth of information held by this group, which is slowly being eroded. In addition, since livestock plays a central cultural role in the continent, understanding the values associated with keeping animals is important. Strategies for promoting co-existence between improved and indigenous breeds should be developed for the conservation of genetic diversity.

2. Is there value in and how to go about international research collaborations?

International collaborations are very important, and more are needed for improving synergies and impact, and avoiding missing good opportunities. Since resources for research, both human and financial, are never enough, collaborations can improve the impact of initiatives and avoid duplication of efforts. Traditionally there have been few institutions to partner with and little or no funding available for collaborations, and although this type of funding is now more widely available, funding opportunities usually have a narrow focus that sometimes leads to competition instead of collaboration. Research and donor calls tend to be competitive but often also compartmentalised and constrained, so changes are required to enable the integration of different applied science disciplines and to promote a holistic and interdisciplinary approach to solving problems. A focus on issues rather than countries should be favoured.

Since there are more research initiatives but also a greater degree of funding stagnation in the north, collaborations provide an opportunity for win-win interactions. South-south collaborations, critical since many challenges and research priorities are shared, are nonetheless less frequent at the moment than north-south collaborations, due to the fact that the latter are often enabled and mediated by international funding organisations. These rarely support south-south collaborations, or provide funding for personnel and infrastructure in the south. The asymmetry of funding available for research in countries in Europe and North America versus national research budgets in most African countries is also a problem. More investment is needed since the current level of funding in only sufficient to cover the running of basic facilities and staff salaries, but often is not enough to do new research. This also impacts the degree to which individual African countries are able to set their own research agendas and priorities.

While research in northern countries is sometimes theoretical with little focus on real practical issues, in contrast in many African countries there is no funding available for basic research and most initiatives focus on applications, which is sometimes limiting. Forging new partnerships can be challenging, as successful collaborations require that: all partners are considered equal and actually contribute to the work (sometimes it may just involve adding new author names and affiliations in research papers); Southern countries are able to set their own research priorities; and both partners place a strong emphasis on capacity building and the sharing of skills and ideas. The purposes of partnerships need to be also well defined, and go beyond the objective of accessing research funds. An important consideration is whether institutes in the south have the institutional capacity to start collaborations, and possible interventions to achieve higher standards. Institutional solutions, such as the BecA-ILRI Hub may help improve capacity in national research organisations, and institutions with a mandate to establish partnerships, such as the member centres of the GCIAR may also facilitate the establishment of new partnerships.

Also discussed were options for evaluating the effectiveness of collaborations, and participants agreed the critical question is whether partnerships are changing something on the ground.

3. What short-term communication approaches can we mobilise and what long-term advocacy/public awareness plans do we have to put animal genetic research on the map?

Public engagement and outreach can be problematic for some scientists. Some people are simply better than others at communicating with a wider audience, and this skill does not always go hand to hand with the skills required to do good science. And while scientific training places a big emphasis on communications skills, these are typically focused on communicating with other scientists, not the public. Scientists also tend to be cautious, a trait that is good to move scientific research further, but that hampers communication with a public who wants clear, simple answers. In addition, many scientists also feel they can afford the time it takes to engage in public outreach.

The guidelines for effective communication are the following:

- Keep it short and simple (KISS)
- Make research entertaining and relevant (= interesting)
- Show empathy and understanding to people's values

4. Are there any controversies ahead of us?

Controversial areas in animal genetic research abound. These include:

- Loss of genetic diversity, especially pertaining indigenous breeds and traits related to resilience and taste
- Food safety (is there a potential human health tragedy about to happen?), including lack of appropriate standards and how they are managed
- Cultural issues, including acceptability (e.g. the idea of eating genetically improved animals may originate public resistance)
- Religious controversies (ideas of people playing God)
- Environmental objections, including the impact of intensification of animal rearing

practices and the genetic exchange between domestic and wild stock

- Ethical issues, especially animal welfare
- Ownership of intellectual property rights.
- Fear of big companies and developed countries controlling food production in developing countries
- Fear of bio piracy and of losing IP
- Public versus private sector control of research / livestock improvement focus

5. What makes animal research different from plant research?

There are a number of broad and more subtle technical differences. Some of the most obvious ones, however, include:

- Different biology, genetics and different research models
- Biodiversity – greater in plants
- Bioethical issues – more concerns and “antis” in animals than plants
- Timescale for research/breeding – have to wait longer in animal research
- Space required for research and cost of maintaining the space and the research “subjects”
- Numbers/diversity of research subjects – can easily grow 1000 seedlings, but raising 100 calves is challenging!
- Policy issues – animals and meat are less well covered than plants
- Attitudes – people are more particular about the equivalence of a plant to food. Meat is just meat, and eggs are eggs – people think less about the animal they originate from.
- More focus globally on plant and human science than animal research

Session 7: Regulatory considerations

Academy of Science of South Africa (ASSAf) Panel: Regulatory Implications of New Genetic Engineering Technologies

Dr Jasper Rees, Agricultural Research Council of South Africa and ASSAf working group

Why address new GM technologies in African countries now? While at the moment there are only three 3 GM crops in commercial production in the continent, 7 countries are carrying confined field trials; 14 countries are engaged in contained research and development; and 27 countries are building up their capacity for biotechnology R&D.

The ASSAf Panel was convened in 2015 to ensure an independent process to determine the regulatory status of New Genetic Engineering Technologies (NGETs), inspired in part by the report published by the JRC in 2011. A Consensus Study Panel will be active 2015-2016 to determine the regulatory implications of the NGETs, with the aim to provide credible, independent and unbiased evidence-based policy recommendations. Consensus is reached through study panel deliberations, in a process that is free from the influence of study sponsors or others with a vested interest in the outcome of the study findings, although sponsors may be invited to present to the panel in order to discuss their expectations and to provide relevant information to the study.

Deliberations of the panel group, chosen to comprise a comprehensive and balanced set of experts), are private, although they may be informed by public conferences, workshops, debates and hearings. The mandate of the Panel includes:

- Evaluate the risk/benefit implications and ethics of all relevant new technologies (generally, but also with specific reference to their ability to sustain the diversity of agricultural crops, their ability to improve the agronomy, production and/or value of the crops).
- Determine – with justification - which new technologies should fall under the GMO Act and which do not.
- Outline a framework that can be used to assess the applicability of future technologies to the existing GMO Act & regulations.
- Assess the appropriateness of South African biosafety regulatory framework for biosafety risk evaluation and management of all relevant new technologies.
- Where appropriate, recommend modifications/revisions and/or additions to the existing regulations, individually or collectively, for the new technologies.

Possible policy recommendations include: to leave the GM Act and Regulations as they are; recommend minor changes to the regulations; recommend changes to exclude some or all of these technologies from regulation; or recommend a major review of GMO Act to address review and regulation of novel traits.

In the Q&A session a participant enquired bout the timeline for this document: it should be produced in the next nine months. How influential has South Africa been in terms of regulation? Historically it has been very influential, but the effect of the panel work remains to be determined.

A participant also mentioned the importance to include a wide variety of points of view in similar activities carried out by the US Academy of Science. To what extent are people opposed to GM technologies likely to jeopardise the integrity of the process? The problem is that the ASSAf Panel was convened with the mandate to reach consensus, which eliminates the possibility of engaging in discussion with anti-GM organisations, and this exclusion may also affect public opinion on the study. This means that the study will have to focus on technologies and technical issues, not the political issues. The panellists are tasked to assess the technology landscape broadly and if effective we'll include other views.

Biosafety regulatory framework in Kenya

Doris Wangari, Programme for Biosafety Systems Kenya (PBS-Kenya)

The Kenya Biosafety Act of 2009 established the National Biosafety Authority (NBA) as the National focal point of all Biosafety matters in Kenya. The Act makes provision for the establishment of a legal framework for the safe handling, use and transfer of Genetically Modified Organisms (GMOs), and establishes that the NBA is to exercise general supervision and control over dealings in GMOs with a view to ensuring safety to human and animal health and protection of the environment.

The Biosafety Act aims to facilitate responsible research into GMOs and minimize the risks that may be posed by these. It also seeks to establish a transparent, science - based and predictable process for reviewing and making decisions on transfer, handling and use of GMOs.

The NBA has the following mandate:

- To consider and determine applications for approval for the development, transfer, handling and use of GMOs
- To co-ordinate, monitor and assess activities relating to the development, safe transfer, handling and use of GMOs
- To co-ordinate research and monitor activities on all GMO work in the country
- Strengthen national technical capacities and capabilities for biosafety
- Develop regulations to operationalize the Biosafety Act
- Establish and maintain a biosafety clearing house (BCH) mechanism- web based information sharing of national database linked to the international BCH;
- Promote public awareness on biosafety and biotechnology
- Enforce the provisions of the Biosafety Act
- Provide advisory services on matters of biosafety.

The NBA collaborates with eight agencies:

- Department of Public Health
- Department of Veterinary Services (DVS)
- Kenya Bureau of Standards (KEBS)
- Pest Control Products Board (PCPB)
- Kenya Plant Health Inspectorate Service (KEPHIS)
- National Environmental Management Authority (NEMA)
- Kenya Wildlife Service (KWS)
- Kenya Industrial Property Institute (KIPI)

The regulatory agencies are in charge of monitoring approved GMO activities to ensure compliance with the conditions of approval; and informing the NBA of any significant new scientific information indicating that an approved activity pose biosafety risk not previously known. They are also responsible for informing the NBA of any unintentional or unapproved introduction of a GMO into the environment and propose mitigation measures.

Regulations that would be important for the implementation of the Biosafety Act 2009 filed to date are for:

- Contained Use (August 2011)
- Environmental Release (August 2011)- typically apply during commercialisation
- Import, Export and Transit (August 2011)
- Labelling (2012) of food and feeds consisting of or derived form of GMO or derived from GMO. Exemptions include where the proportion of GMO is below the 1% threshold level; and highly refined foods devoid of GMO

Projects approved for confined field trials to date include: Bt cotton; drought tolerant maize (Event MON 87460)- WEMA Project; African Bio-fortified Sorghum (ABS) Project; Bt Maize (MON 810) Project; Bio-fortified Cassava (B-Plus Project); Cassava Mosaic virus Resistant cassava (VIRCA); Cassava Brown Streak Virus Resistant cassava (VIRCA); Gypsophila Project for Pink colour flower stability; and Cassava expressing African cassava Mosaic virus (ACMV) and cassava brown streak virus (CBSV) resistance.

Topics discussed in the Q&A session included the price of applications. These are currently being reviewed, but now cost 25000 KSH (USD 250) for confined used, and 800.000

KSH (USD 8.000) for environmental release which included advertising, expert review, and public participation.

There is a plan to harmonise biosafety regulations in the region through Common Market for Eastern and Southern Africa (COMESA) and also to be able to use biosafety data obtained in a different African country on a specific crop/event so as to avoid the duplication of efforts and save resources.

In terms of labelling requirements, for GM products or ingredients their presence will be mentioned. However, many products will not be labelled. The feasibility of determining traces of GMOs in products was also discussed. The current threshold is 1%, but what does it mean and how can this be measured? How would this regulation be applied to GM animals? There is very limited experience with GM animals, so the human and technical capacity and appropriate regulations will have to be developed. There will likely be more public opposition to GM animals than to GM plants.

A participant also asked whether large commercial seed companies had also sought regulatory approval. They cannot do so independently but need to go through a local institution, such as the Kenyan Agricultural and Livestock Research Organisation (KALRO), since the applicant has to be Kenyan. What be the costs of developing a new GMO from scratch in Kenya? The price in Europe and the US would be approximately UDS30 million. It is difficult to tell, but it would be very expensive.

Is it correct that Kenya has currently a GM ban that was not set by the NBA but by the cabinet from the Secretary of Health. The expectation is that the ban is going to be revoked soon by the deputy president.

Collective reflections on regulation

The group discussed the relevance of the 1% labelling threshold for animals. How would this threshold be tested for animals and their products? And how would different animal products be considered for regulation? How would GM wool be regulated with respect to GM meat? These points highlight the fact that the current regulations were developed with plants products in mind and therefore would need to be revised for animals.

An issue that did not pertain GM crops but is likely to play a central role in any debates regarding GM animals animal suffering. Defining how to measure animal suffering standards may be measured and to demonstrate how acceptable levels of animal welfare have been achieved will require careful consideration. Animal welfare is already a field that is regulated.

With respect to labelling, even if technically it may be possible to test for 1% GM content, companies may opt to use the label 'may contain GMOs' due to the impracticality of testing large volumes and the difficulty in enforcing regulations, such as the case of South Africa where labelling regulations were developed but not enacted. A further problem is that the human and institutional capacity for testing GM products differs largely among SSA countries and requires strengthening and some countries may not be able to assess levels and determine the appropriate measures.

A central question with respect to regulation is ‘What is a GMO?’ One definition of transgenic pertains to living organisms into which 'foreign DNA' has been introduced. But does DNA from the same or closely related species, such as in intragenesis and cisgenesis, qualify as foreign? And what is the length of the introduced DNA that would constitute the threshold for triggering regulation? With the latest gene editing techniques the changes made to the DNA of an improved plant or animal can be identical to those expected from natural genetic variation: point mutations and very small insertions, deletions and inversions. Is the current regulatory system obsolete? Should we not establish the level of natural genetic variation to determine the degree of diversity considered permissible? Focusing on the traits of improved organisms rather than on their DNA may constitute an alternative: regulation would be triggered by traits that may have implications for public health and/or the environment. But would there be sufficient human and institutional capacity and level of resources for this approach?

The points made above highlight the importance of setting the objectives of regulation. What do we want to achieve? A balance is required between satisfying pressing demands on food production and guaranteeing no adverse consequences for human health, animal welfare and the environment. Inclusion of all stakeholders in formulating appropriate regulatory frameworks is likely to make implementation easier. And implementation should be focused on ensuring safety rather than on the punishment of infringers. Furthermore, it was noted that if regulations are enacted in a country, such country should have the capacity for implementing them. Currently in SSA countries new technologies in animal research cannot be assessed properly due to lack of personnel training. Likely socio-economic implications also need to be determined. Obtaining regulatory approval for transgenic animals is likely to be expensive, even more so than for plants.

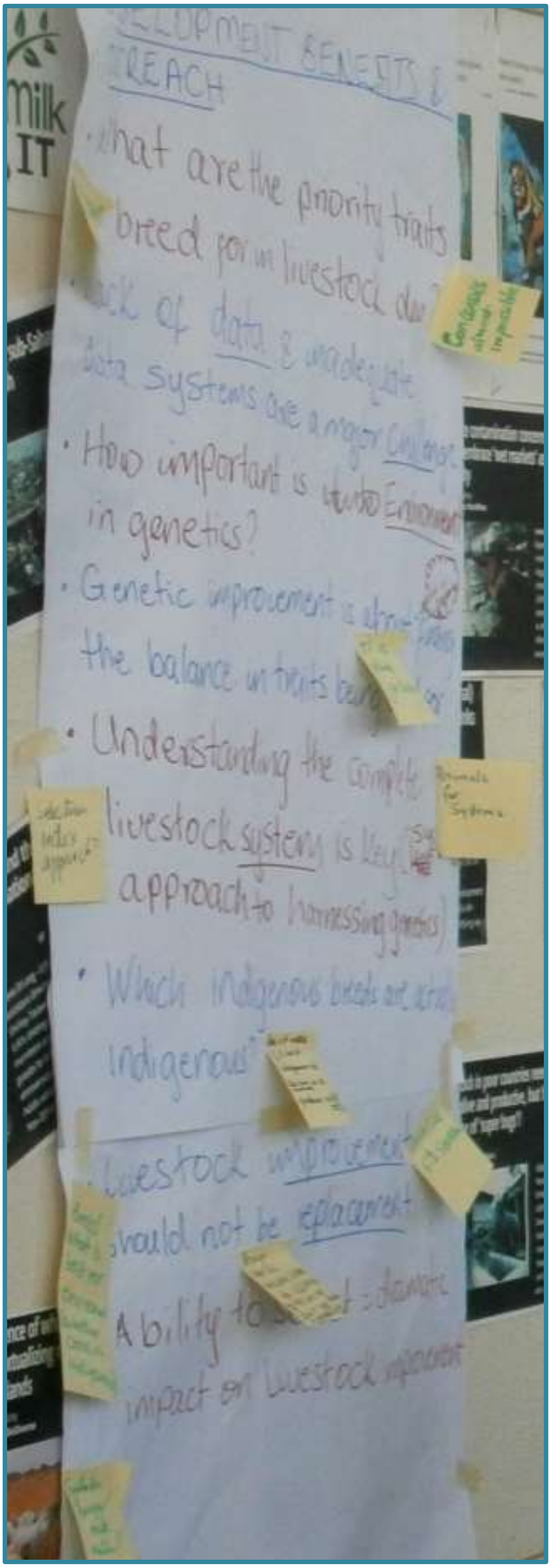
Session 8: Workshop recommendations

Increased production of animal source foods offers great potential for poverty reduction in SSA and in developing countries in general for two reasons: 1) consumption of even small quantities of milk, eggs and meat provide a source of protein and can significantly enhance the nutritional status of resource-poor individuals; 2) livestock in SSA is largely in the hands of smallholder farmers and hence represents a very important livelihood option. In addition, livestock plays a very important cultural role in the continent.

Improving the productivity of smallholder systems to close existing yield gaps is hence a very important priority. But many threads need to come together for this to happen. Research initiatives need to focus on developing improved livestock breeds with respect to productivity; quality and quantity of animal source products (e.g. milk and eggs); disease resistance; and tolerance to environmental stresses, in particular drought and disease. However this needs to be done while preserving the genetic diversity of livestock in the continent, a hugely valuable global resource, and while reducing the environmental footprint of rearing animals. In addition, for smallholder farmers to benefit from such advances in research product delivery pipelines need to be improved; supporting infrastructure and access to markets have to be strengthened, and existing regulations need to be enforced, in particular those pertaining to animal health. And for animal products developed using advanced breeding methods such as GM and gene editing technologies existing regulations need to be altered. These were not only developed before recent technological advances made them partly inadequate, they were also made with plants products in mind. Effective communication to all stakeholders both in the African continent and abroad is crucial to galvanise support for the deep transformation needed.

With respect to research, workshop participants agreed it is important to tailor breeding priorities to specific environments, as a 'one fits all' approach would fail. Since the resources available to the animal are finite, a balance between important traits needs to be sought, in particular between productivity and stress and disease resistance. Therefore a good understanding of the system as a whole is essential. It was also agreed that livestock improvements should not erode indigenous genetic diversity, perhaps by promoting breeding programmes targeting local, indigenous breeds. Improvement should add value to existing breeds rather than replace them.

Research in insects, especially as disease vectors and agricultural pests was also identified as a key area of priority. Examples discussed were the control of fruit fly and the use of the sterile insect technology (using GM in its more recent development) to eradicate malaria insects. Caution was advised in fully considering the ecological implications of significantly altering population structures to minimise unintended consequences.



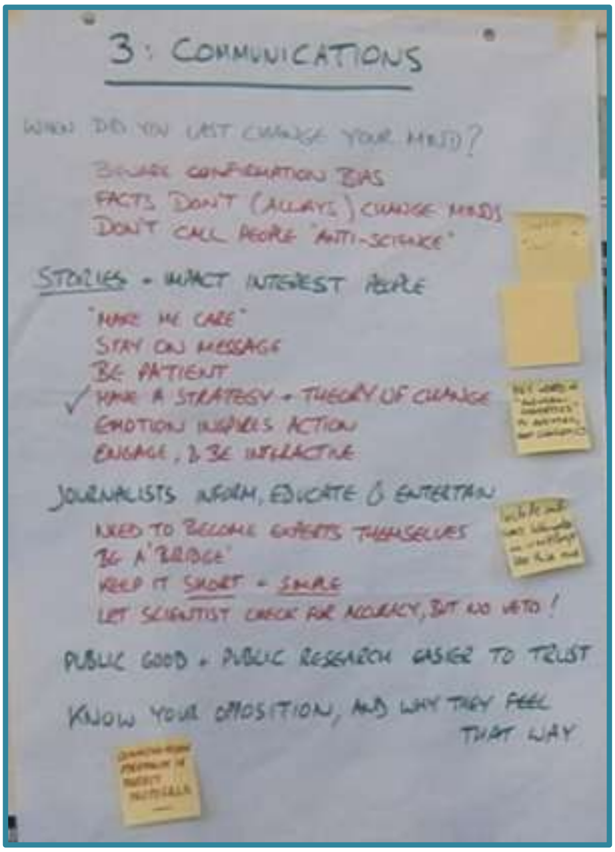
A critical obstacle in breeding programmes is the current lack of pedigree and performance data, and hence developing alternative cheap and fast data collection systems is a also key priority. These include ICT-based platforms and crowd sourcing applications, a new generation of technology that would provide the dual function of gathering performance data for breeding programmes and provide management advise to farmers.

Also important is to bring to the reach of smallholder farmers genotyping and improved reproductive technologies (such as less expensive IVF protocols for cattle), which would however also require developing the supporting infrastructure.

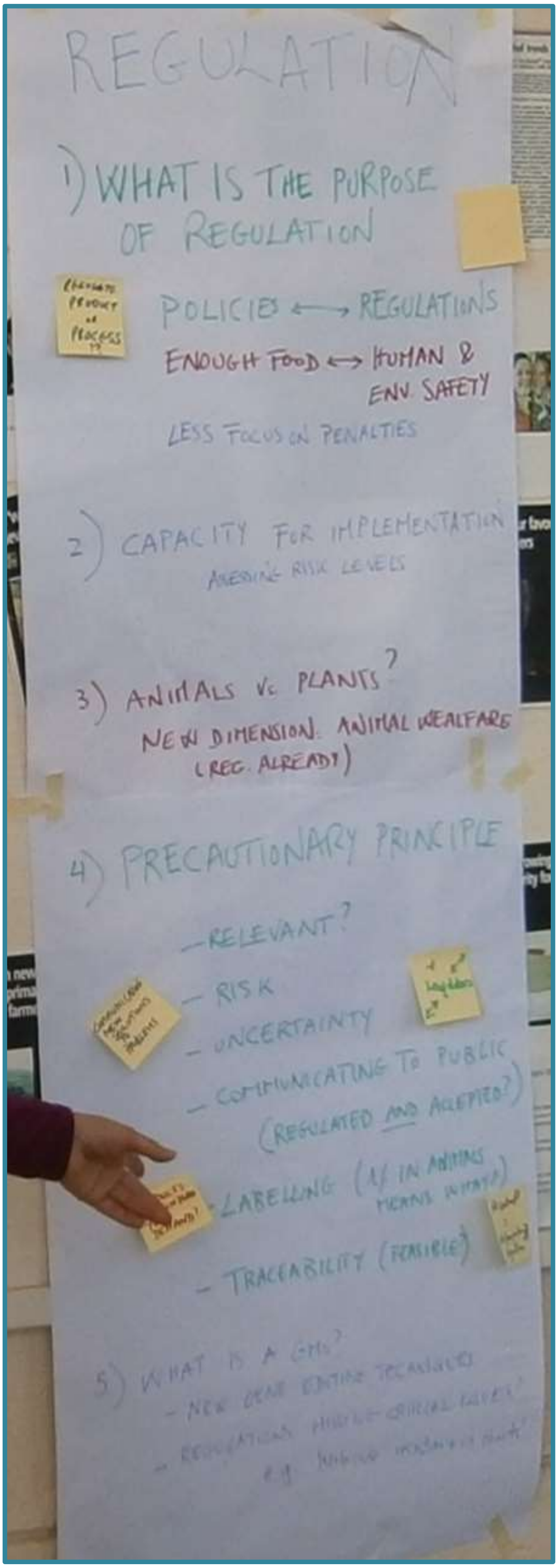
Participants agreed animal genetics is a field with great potential for poverty reduction, since small investments can translate into large gains in productivity. In some sectors, notably fish, such potential is largely unexploited.

Participants also agreed that communicating effectively animal genetics to the wider public is important (although perhaps the word genetics should be replaced by more neutral terms). A key objective is to design communication campaigns that balance the need to increase the production and consumption of animal source foods in developing countries *and* at the same time decrease such consumption in industrialised nations where it is associated with human health problems and with environmental degradation.

Animal genetics represents a great source of good stories. And the fact that the topic has received relatively little attention also provides good opportunities since it allows developing fresh and interesting ideas. It was also agreed that the first step in designing effective communication campaigns requires establishing clear goals and priorities (what and why and to whom should we be communicating?) and using novel approaches to ensure sustainability of programmes. The guiding principles of communicating genetics should be: build bridges (from fear and concern to thoughtful consideration, build



trust on common values and build vision. And perseverance: small steps forwards are important. It is difficult for all human being to change their opinion on their values. Stories with impact that are both informative and engaging (science journalists have the dual role of educating and entertaining) can be very powerful and succeed in making more people 'care' about the subject. And although it will always be very challenging to change the opinion of people with values in the extreme ends of the spectrum, this strategy may help move more people from indifference to reflecting on the topic. Participants agreed communication strategies should be developed and funded alongside research proposals, rather than operating *at hoc* as afterthoughts.



"Throughout the developing world, [animals] are the means for hundreds of millions of people to escape absolute poverty. Livestock in developing countries contribute up to 80 percent of agricultural GDP; 600 million rural poor people rely on livestock for their livelihoods"

– ILRI

Appendix 1: Workshop programme

Animal genetic research for Africa – strategies and opportunities for improving outreach and public understanding

September 10th – 11th 2015; ILRI, Nairobi

Public agenda

Day 1 – Thursday 10th September
08.00 Registration

Session 1: Welcome and introductions

- 08.30 Welcome and introductions - Introduction of the speakers by Professor Sir Brian Heap.
- 09.00 Genetics for Africa – Strategies & Opportunities: Dr Bernie Jones, Co-leader G4ASO
- 09.30 Animal genetic research and why animals matter – livestock perspective ('The changing livestock sector in developing countries: the context for animal genetic research'): Dr.Shirley Tarawali, ILRI
- 10.00 Why communicate animal genetic research - Susan MacMillan, ILRI
- 10.15 Q&A

10.45 Coffee Break

Session 2: African animal research, development benefits and outreach

Presentations of livestock/fish research ongoing in or with Africa, with regard especially to development outcomes/potential

- 11.15 Steve Kemp, ILRI: Vision for livestock genetics in Africa
- 11.30 Julie Ojango, ILRI: Improving livestock productivity and resilience in Africa: application of genetic technologies and challenges
- 11.45 Paul Gwakisa, Sokoine University of Agric, Tanzania: Animal genetic research at Sokoine University of Agriculture, Tanzania
- 12.00 Participants' interactions
- 12.05 Sammy Aggrey, University of Georgia: Small and large scale poultry in Mexico, Ghana and Uganda
- 12.20 Jagger Harvey, BecA: Partnering to outfox crop-infecting viruses in Africa
- 12.35 Discussion and questions across all presentations

13:00 Lunch

Session 3. African animal genetic research – communication approaches

Presentations of approaches to outreach and communications of research

- 14.00 parallel and rotating groups to attend presentations by:
    - B4FA – Dr Claudia Canales
    - ILRI – Susan MacMillan, ILRI
    - African media – Alberto Leny
    - Media - Tamar Haspel
    - Change Through Partnership (UK) Ltd - Nick Manson

Discussion and questions (see notes below)

15.40 Coffee break

Session 4: African animal research, development benefits and outreach

Presentations of biodiversity/ insect research ongoing in or with Africa, with regard especially to development outcomes/potential

- 16.10 Jasper Rees, ARC South Africa - Livestock genomics, experiences from South Africa
- 16.25 Raphael Mrode, ILRI: Genomic selection in small holder systems: challenges and opportunities
- 16.55 Morris Agaba, NMAIST/ILRI
- 17.10 Tadelle Dessie, ILRI: African Chicken Genetic Gains
- 17.25 Discussion and questions

17.40 Close

19.00 Reception/Dinner – ILRI

Day 2 – Friday 11th September
08.15 ILRI lab tour for any interested participant

Session 5: Other research, development benefits and outreach

- 09.00 Badi Besbes, FAO [*This presentation is copyright-embargoed until further notice*]
- Richard Osei-Amponsah, University of Ghana - Animal genetic research for Africa - Strategies and opportunities for improving outreach and public understanding
- John Benzie, WorldFish
- Jagger Harvey, BecA: The BecA-ILRI hub: B4FA animal genetics for Africa
- Carol Kamau, USDA

10.30 Coffee Break

Session 6. Research outcomes and uptake - Lessons to be drawn *(Breakout groups)*

- 11.00 Collective discussions about development contributions of research outcomes, need for public understanding to promote uptake, and ethics
- 12.30 Report back and discussion on out-of-the-box ideas to address engagement and outreach

13.00 Lunch break

Session 7. Regulatory considerations

Presentations of regulatory approaches, particular challenges in animals, policymaker awareness

- 14.00 African perspective – Jasper Rees: ASSAf panel: regulatory implications of new genetic engineering technologies
- 14.15 Kenyan policymaker - Doris Wangari: Biosafety regulatory framework in Kenya
- 14.30 ILRI – Steve Kemp
- 14.40 Discussion and questions on plant/animal regulatory differences

15:30 Coffee break

Session 8. Implications and recommendations of the workshop

- 16.00 Plenary review and discussion on key implications and recommendations of workshop to funders, practitioners and other stakeholders, and next steps
- 17.00 Report back

17.30 Close

STI4D