14 Technology as a transformative tool in livestock production

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Introduction

In Southern Africa, livestock production is lagging behind the demand for livestock products and services due to the increasing human population, urbanization, competition between food and feed and alternative and competing access to natural resources (land, water, etc.). In addition, there are several production constraints including climate change and the need to operate in a carbon constrained economy, animal welfare concerns and changing socioeconomic values (Thornton, 2010), lack of resources and skills, endemic and emerging diseases and parasites, lack of record keeping and lack of an enabling policy environment. The Southern African Development Community (SADC) has identified several challenges, including:

low productivity, lack of efficient and effective animal disease control, lack of marketing infrastructure, poor market access of livestock products, together with lack of availability of information, and other associated factors.

(SADC, 2014)

Southern Africa has an estimated human population of 277 million people. Sixty percent of the land area is non-arable and is mainly used for livestock production. There are an estimated 64 million cattle, 39 million sheep, 38 million goats, 7 million pigs, 1 million horses and 380 million poultry, 75% of which are produced in extensive smallholder systems (SADC, 2014). Livestock production in the region ranges from extensive resource-poor smallholder systems to highly organized business-oriented intensive systems. Women and children are the major caretakers of livestock resources in smallholder systems.

Because of these differences in the size and scale of these systems, it will be impossible to prescribe a one-size-fits-all type of solution. There are many technologies that are currently employed in livestock globally and in some parts of the region. However, there is no one technology that can be a silver bullet in transforming the Southern African livestock industry. As a matter of fact, we would argue that simple changes in the way we manage livestock (e.g., changing the herd composition to favour more breeding females in ruminant production)

coupled with a few technological and policy interventions are likely to have a bigger impact than simply introducing one or two technologies haphazardly. Many technologies have been introduced into this sector in that manner and have failed spectacularly (Muzari et al., 2012).

Progress in technology and innovation can help in overcoming or mitigating production constraints, especially in developing countries in the global south. Such technology include key multiuse enablers, assisted reproductive technologies, molecular biotechnologies (Jutzi et al., 1999) and social innovation. Social innovation refers to new ideas (products, services and models) that meet social needs more effectively than alternatives and create new social relationships or collaborations. In this case, there is need to create new synergies within the livestock production value chain including sustainable intensification, changes in production objectives and new market linkages.

Enabling technologies

Most critical enablers of livestock systems will be those that enhance information acquisition, analysis, dissemination and use within the value chains. Such enablers include mobile phone technology (information capturing, sharing and management tools), data science, artificial intelligence and machine learning. Though seemingly unrelated to livestock systems, mobile phones are not just about communication but have become a means of enhancing business and socioeconomic connections. This, coupled with an increase in mobile phone penetration in Sub-Saharan Africa (GSMA, 2018), has the potential of improving the livestock systems through reducing market information asymmetry, improving access to production information and enhancing overall participation of hitherto neglected smallholder farmers. Tools can now be developed to enable smallholder farmers, who own most of the livestock in Southern Africa, to participate in livestock recording and traceability schemes, access veterinary and animal health information, access farm management and weather data and, overall, better organize themselves. Such inclusivity will open the window for data science, artificial intelligence and machine learning to be applied to livestock systems in a way that has not been possible before. Mobile phone technology can also be used to spread key information and practices that can transform livestock systems. One of the largest impediments to increasing livestock production in communal areas where large numbers of livestock are kept is the poor offtake associated with these herds. Restructuring the herd composition such that more breeding stock are kept and inclusion of smallholders in the formal markets are important targets here.

Creative use of phone applications (apps) can help in real-time mapping of livestock related issues (diseases and parasites, epidemiology, weather and climate, etc.) that enable quicker interventions. Near real-time livestock health systems have been implemented successfully before, e.g., in Thailand (Yano et al., 2018), and they are evolving (Holmstrom and Beckham, 2017).

Feeds and feeding

Livestock production in Southern Africa is season sensitive due to changes in quality and quantity of feed throughout the year. This unfortunately makes it vulnerable to droughts and climate change. There are many feeding technologies that have been trialled across several countries, but this is an area where there is very little adoption due to competing issues at farm level. There are conflicts between food production on the one hand and feed and forage production on the other. The promotion of proven technologies is usually fragmentary and does not recognize the impact of the technology on the production system as a whole. This is especially true for those aspects of the system that can be negatively impacted by the new technology (Kebebe, 2018). Livestock production cannot improve if the issues related to feeds and feeding are not addressed. Technologies that can be pursued include growing and conservation of forages, use of crop residues, use of biotechnology, grassland and pasture management, new and nonconventional feeds and matching the breeds to available feed resources, including the use of locally adapted and smaller livestock breeds. These are mainly indigenous farm animal genetic resources (AnGR).

Closely related but distinct from the issue of feeds is the issue of water management. Deutsch et al. (2010) and FAO (2018) reported that livestock use approximately 11,900 km³ of global freshwater annually, which is equivalent of 10% of global water flow. The Southern African region is projected to become increasingly water stressed (UN-ECA n.d.). Climate change is a reality in this part of the world as it is in many other parts of the world (see Chapter 2.3). However, the effects of climate change are likely to be felt much more in this region than in many other parts of the world, primarily because of poor mitigation and adaptation strategies. There is competition for water and increasing human and animal populations will, concomitantly, increase demand and competition (FAO, 2018). In livestock production, water use depends on the size, age, ration consumed, activity, productivity and temperature. Some of these can be managed while others are beyond farmer control. The size of the animal takes the argument back to use of locally adapted AnGR.

Assisted reproductive technologies (ART)

Velazquez (2008) defines assisted reproductive technologies as, “techniques that manipulate reproductive-related events and/or structures to achieve pregnancy with the final goal of producing healthy offspring in . . . females”. The technologies have been around for a long time and are being refined and improved. From the definition, ART encompasses a whole suite of unrelated techniques such as manipulation of reproductive physiology (especially female), artificial insemination, multiple ovulation and embryo transfer, in vitro fertilization, cloning, preimplantation diagnostics and sperm sexing. Use of various aspects of ART is common, but not widely adopted, in Southern Africa, particularly oestrus synchronization and artificial insemination (Mugwabana et al., 2018).

However, like other technologies there are social, technological and institutional barriers to its use despite its obvious benefits to herd improvement and breeding.

Molecular biotechnology

Veterinary and nutritional applications

There is a suite of techniques and procedures within molecular biotechnology that lend themselves easily to enhance livestock production and health. These include preventative techniques (vaccines, medicines and metabolic modifiers), nutrition related (in-feed enzymes, probiotics, prebiotics and related products), advanced diagnostics, immuno-castration, etc. (Borroto, 2008). Use of these is confined to the intensive production systems and almost completely absent in the more widespread smallholder systems. There are opportunities for manipulation of the rumen environment given the contribution of ruminants to greenhouse gas emissions.

Genetic selection technologies

For many years, selection for traits of economic importance in livestock has been responsible for the increase in yields that we are observing currently. A classical animal example to mention is that of the poultry industry, where a broiler increased in size at 28 days of age from weighing 0.32 kg in 1957 to 1.39 kg in 2005 (Zuidhof et al., 2014). This was achieved mainly by traditional animal breeding selection. For genetic improvement to be feasible a few things need to be in place. First, there should be genetic diversity within the population. The genetic diversity of smallholder livestock populations in Southern Africa is generally unknown but is directly related to their potential for genetic improvement. Second, good record keeping should be in place. Record keeping allows farmers or breeders to identify the phenotypic variation within the population and also to keep track of changes occurring within the population as a result of the selection applied. Record keeping is important to keep track of the pedigree information. Pedigree allows tracing of gene flow from one generation to the next and to measure its influence on the specific traits of interest that are expressed. With the previously mentioned background in mind we will discuss advanced technologies available in the field of breeding and genetics, the “omics” and the artificial intelligence (AI) revolution as reported earlier.

Genomics

Presently, genomics, proteomics and nutrigenomics are very popular among scientists worldwide. Genomics includes the use of genetic markers whole genome sequencing, RNA sequencing and genome-wide association studies. Genetic markers can be used for various analysis which includes population

genetic studies, genetic diversity studies, marker assisted selection identification of causal variants, genome wide association studies and genomic selection (Kijas et al., 2012; Demars et al., 2013; Qwabe et al., 2013). Genomic selection is a tool that can be used to improve genetic gain in animal or plant populations. The inclusion of genotypic data based on genetic markers and specifically single nucleotide polymorphism (SNPs) allow the estimation of genomically enhanced estimated breeding values (GEBVs). Genomic selection involves the use of phenotypic and genotype records to derive GEBVs for traits of economic importance. The use of genomics in livestock will be of benefit to the traits that are lowly heritable and expressed later during an animal's life. This will enable the ability to predict a sire/dam performance for a specific trait at an early age and so increase genetic gain (Kijas et al., 2012) by decreasing the generation interval. The constraints concerning the implementation of these technologies include obtaining reliable records for traits of economic relevance of an appropriate reference population. Another challenge would be the genotyping costs involved, particularly start-up costs, even though those are falling.

The policy environment

Southern Africa is characterized by different levels of development of policies related to livestock production. There are a lot of policy deficits and conflicts that hinder the development of the sector. Some of the key policy gaps can be summarized, as in Table 14.1.

Further, there are no policies in place in any Southern African country which protect the valuable indigenous AnGR intellectual property rights from illegal exploitation and looting.

To illustrate the issues surrounding policy gaps, we look at two contrasting case studies:

In Malawi there is a new livestock policy (as of 2019) being crafted which is almost complete but not yet available for publication. In discussions with the national focal point and key experts and opinion makers in AnGR it was very clear that the new policy deals with issues around promotion and utilisation of indigenous AnGR. The country has no formal selection and breeding program and the hope was that one would be set up once funding was made available. The major benefit from setting up such a scheme would be to further highlight the benefits of local AnGRs.

In South Africa, the Livestock Development strategy developed a decade ago by the Department of Agriculture is in place. It recognizes the value of genetic evaluation programmes for improvement of livestock. It also recognises adapted local AnGRs but fell short of putting together a strategic plan for utilization of these resources. Selection and breeding programmes are further reinforced by more important legislation like the Animal Improvement Act 62 of 1998

Table 14.1 An analysis of the policy environment and key strategies to mitigate deficits

<i>Policy gap</i>	<i>Strategy</i>
Lack of livestock policies (including improvement and conservation policies)	Better implementation of recommendations by the SADC Food, Agriculture and Natural Resources (FANR) Directorate's recommendations to "develop, promote, coordinate and facilitate the harmonisation of policies and programmes in order to increase agricultural and natural resources production and promote trade, and ensure food security and economic development in the region on a sustainable basis" (SADC, 2011)
Lack of regulations/regulatory bodies to monitor and evaluate the impact of breeding programmes and other interventions	
Non-functional policies due to poor implementation environment	
Lack of harmonization of government legislation and policies (within and between ministries and departments)	Complete review of policies within and between countries to ensure policy consistency and coherence
Lack of strategic plans and action plans and budget allocation for livestock research, animal genetic resource conservation and management	Develop strategic and action plans to implement various livestock related policies, in particular, those that are related to sustainable use and conservation of animal genetic resources
Lack of ring-fenced budget allocation for animal genetic resources by national governments	Invest more in agriculture as envisaged in the Maputo Declaration (AU-NEPAD, 2003)

and Genetically Modified Organisms Act 15 of 1997. A major weakness of these important pieces of legislation is that they do not specifically mention indigenous AnGRs. The Animal Improvement Act creates the Office of the Registrar of Animal Improvement, who oversees the implementation of the act. In discussions with key policy and technical informants, it was evident that even though there were important tools and policies around genetic evaluation, the implementation seemed to leave a lot to be desired in particular due to lack of capacity to execute these instruments.

Potential positive and negative impacts

Positive impacts

Increasing animal yields from smallholder farmers, can result in an increase in income and food security for Southern Africa. Increased consumption of animal-sourced foods can be highly beneficial to households. The positive impacts of suggested technologies can be felt more strongly if they are targeted at livestock species kept by resource-poor farmers including women and youths such as poultry and small ruminants. Furthermore, sufficient local production can curb imports of animal products and help to stabilize regional economies with an added benefit of saving foreign exchange.

Negative impacts

Employing these technologies are expensive and the money could be used elsewhere. As has been observed with commercial agriculture, increasing production through increased technology can have negative effects on the environment (Lichtenberg, 2000). By implementing strict selection to favour specific trait, genetic diversity can be lost; therefore, it is important to ensure that genetic diversity is maintained within genomic selection programmes. Some technologies could result in a decrease of manual labour needed on farms resulting in joblessness and poverty.

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