Food Research International 76 (2015) 971–979

Contents lists available at ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

Genomic technologies for food security: A review of challenges and opportunities in Southern Africa

Esté van Marle-Köster [a,*], Carina Visser [a], Mahlako Makgahlela [b], Schalk W.P. Cloete [c,d]

[a] Department of Animal & Wildlife Sciences, University of Pretoria, Private Bag X20, Hatfield 0028, South Africa
[b] Agricultural Research Council-Animal Production Institute, Private Bag X2, Irene 0062, South Africa
[c] Department of Animal Sciences, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa
[d] Directorate Animal Sciences: Elsenburg, Western Cape Department of Agriculture, Elsenburg 7607, South Africa

ARTICLE INFO

Article history:
Received 26 January 2015
Received in revised form 20 May 2015
Accepted 27 May 2015
Available online 29 May 2015

Keywords:
Genetic improvement
Genotyping platforms
Hard-to-measure traits
Indigenous livestock
Reference population

ABSTRACT

The Southern African Development Community (SADC) region includes 15 member states which all face growing population numbers and a possible protein shortage within the next 20 years. Although these countries have a wealth of livestock genetic resources and mostly are quite agriculturally dependent, there exist clear limitations and challenges regarding animal recording, genetic improvement, production efficiency and the implementation of new technologies, such as genomic selection (GS). Genomic selection incorporates genomic information with phenotypic information (breeding values) to derive genomic estimated breeding values (GEBVs) and leads to an increased rate of genetic improvement. The countries within the SADC region are in several stages of development with regard to agriculture and infrastructural development and this limits the implementation of advanced technologies. The establishing of reference populations seems beyond the capacity of most of these countries at present, mainly in terms of financial viability, infrastructural support and national cohesion. Genomic technology however holds potential for the introgression of favourable genes in resource-poor livestock production systems and traceability of livestock products. Furthermore, identification of traits associated with adaptability and disease resistance and unique products would contribute to food security on various levels. This review discusses interventions that may mitigate constraints, and proposes key research areas needed for addressing the limitations mentioned.

1. Introduction

The growing demand for protein originating from livestock has been widely discussed and is well documented (Kahi & Rewe, 2008; Pica-Ciamarra, Baker, Bedane, Emwanu, & Morgan, 2010; Van Marle-Köster & Webb, 2014). The world population is expected to grow to approximately 9 billion by 2050 (United Nations, 2011), with approximately 8 billion of the world population living in developing countries (Capper, 2013; Thornton, 2010). In sub-Saharan Africa alone, the human population is expected to grow at a rate of 1.2% per year with a two-fold increase in the demand for meat and milk. Southern Africa is facing palpable challenges to meet these demands considering the large number of constraints that these countries are already subjected to. These constraints vary from biological and environmental effects including periodic drought, shortage of grazing as well as ecto- and endo-parasites (Gwaze, Chimonyo, & Dzama, 2009) to a range of socio-economic and political factors (Iñiguez, 2011). In most of the literature on livestock development in Africa (Herrero et al., 2013; Rothschild & Plastow, 2014; Wurzinger, Sölkner, & Iñiguez, 2011), these limitations have been highlighted as major issues in preventing the countries to increase productivity and produce much needed protein. Livestock production is also under pressure due to the envisaged effects of climate change which is foreseen to impact upon its sustainability (Nardone, Ronchi, Lactera, Ranieri, & Bernabucci, 2010; Rust & Rust, 2013).

Over the past few decades, developments in the field of molecular genetics and animal breeding have opened new avenues for accelerating genetic progress and increasing the accuracy of selection of superior genetic stock (Rothschild & Plastow, 2007). For most livestock species, whole genome sequences have been completed and deoxyribonucleic acid (DNA) markers have been commercialised in useful diagnostic applications such as DNA-based parentage testing (Van Marle-Köster, Visser, & Berry, 2013), the identification of genetic defects and marker assisted selection (Blasco & Toro, 2014). Commercial single nucleotide polymorphism (SNP) chips have recently been developed for use in genomic selection (Blasco & Toro, 2014). As these genomic developments have mainly been used in the developed world the question could be raised if it will contribute to increased production in developing countries.

* Corresponding author at: Private Bag X20, Hatfield, Pretoria 0028, South Africa.
E-mail addresses: evm.koster@up.ac.za (E. van Marle-Köster), carina.visser@up.ac.za (C. Visser), MMakgahlela@arc.agric.za (M. Makgahlela), SchalkC@elsenburg.com (S.W.P. Cloete).

http://dx.doi.org/10.1016/j.foodres.2015.05.057
0963-9969/

Africa is a diverse continent with an agricultural sector that has to function within certain limitations that will remain relevant and real for some time to come (Van Marle-Köster & Webb, 2014). Therefore, this review focuses on Southern African countries to provide a perspective on the alternative approaches for application of genomic tools. In the process, attention is given to indigenous resources, livestock recording and structures already in place as well as advances in developed countries and the feasibility of applying these advances locally. Finally, the review suggests a few ideas on the research and development required to ensure the future sustainability of ruminant livestock production in the SADC region.

2. The SADC region

2.1. Member states, demographics and economics

The SADC is an inter-governmental organisation that consists of 15 member states (Fig. 1).

The region had approximately 281 million inhabitants in 2011 (SADC, 2013), with more than 60% of the total population resident in the Democratic Republic of the Congo (DRC — 27%), South Africa (18%) and Tanzania (16%). The gross regional product of SADC amounted to 650,935 million US$ in 2011 (SADC, 2013). The bulk of this regional product (63%) was generated in South Africa, followed by Angola at 15%. Agricultural activities contributed between 4% and 27% of national GDP of the individual member states (Directorate of Food, Agriculture and Natural Resources, 2011). According to this source, agricultural products are also important for earning foreign revenue, averaging 13% of export earnings across the region. Agricultural products furthermore contribute 66% to inter-regional trade.

The various countries within the SADC region are in several stages of development with regard to agriculture and infrastructural development (SADC, 2013). Despite these differences, the member states aim to further socio-economic cooperation and integration as well as political and security cooperation among them. The Livestock Unit (LU) within the Food, Agriculture and Natural Resource Directorate aims to address common challenges and to coordinate livestock development activities. The identification, diagnosis and control of trans-boundary diseases (such as foot and mouth disease and Rift Valley Fever) are areas that receive special attention (SADC, 2013).

2.2. Topography, climate and environment

In total, the size of the SADC region comprises nearly 10 million km^2, with approximately 25% arable land (SADC, 2010). The size of the individual countries making up the SADC region range from more than 1 million km^2 in the DRC (2.3 million km^2), Angola (1.2 million km^2) and South Africa (1.2 million km^2) to below 0.1 million km^2 in Lesotho, Mauritius and Swaziland (Directorate of Food, Agriculture and Natural Resources, 2011). Seven terrestrial ecological zones include highly variable habitat types, from mangroves in Mozambique and Tanzania to desert and xeric shrub lands in Angola, Namibia and South Africa (SADC, 2010). Average annual precipitation in the region is highly variable, ranging from below 100 to 300 mm in the arid parts of Namibia and South Africa to an excess of 2000 mm and above in parts of the DRC, Madagascar, Mauritius and the Seychelles (Directorate of Food, Agriculture and Natural Resources, 2011).

2.3. Livestock species and diversity

Despite the huge diversity between these countries, some unique aspects are shared with regard to the availability of livestock genetic resources and their development. Cattle, sheep and goats play a major role in the livelihood of the population in all these countries. According

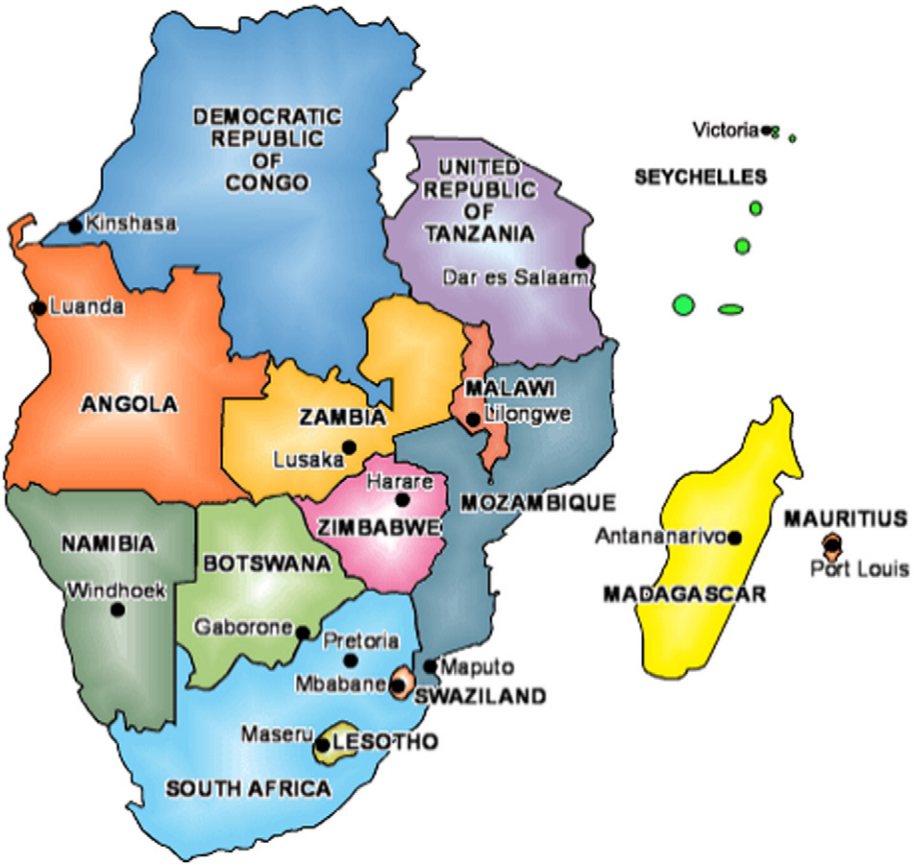

Fig. 1. Countries forming part of the Southern African Development Community (SADC) region.