Feature Article

Training the next generation of animal scientists for South Africa

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Implications

- There is a lack of interest in agriculture among the South African youth and agriculture is usually not considered as a career of first choice.
- An increased proportion of black and female students enter the higher education system in South Africa.
- The majority of students come from a nonfarming background with very limited or no previous exposure to agriculture.
- Training of undergraduate students needs to be adjusted to reflect the future demands of the animal science industry without resulting in "academic drift".
- Future animal sciences programs will see greater incorporation of computer skills and data sciences at an earlier level.

Key words: agriculture, animal science, careers, higher education

Introduction

It is estimated that the world's population could grow to 9.7 billion people by 2050, with the largest population increase expected in Africa (United Nations Department of Economic and Social Affairs, Population Division, 2019). This population growth will go hand in hand with a parallel increase in nutritional demands, specifically for animal protein. The onus will largely rest on agriculture, and especially livestock production, to meet this increased demand. Agriculture is a major contributor to the South African economy, with animal products contributing 49.2% to the total gross value of agricultural production (Department of Agriculture, Forestry and Fisheries [DAFF], 2019).

In South Africa, agriculture is also a significant provider of employment, especially in the rural areas of the country. The agricultural sector delivers more jobs per Rand invested than any other primary production sector (DAFF, 2016) and plays a critical role in rural poverty alleviation and food security. Furthermore, the agricultural industry in South Africa consists of a combination of medium- and large-scale commercial operations, which produces the majority of the country's agricultural produce, and smallholder farmers, which are the main source of livelihoods in remote rural areas.

The National Development Plan of South Africa identified agriculture as one of the main drivers for the economy with the potential for job creation and development of rural communities. To bridge the skills gap in the agricultural sector and to promote rural development, the DAFF introduced the External Bursary Scheme in 2004. The DAFF bursary scheme is further used to contribute toward economic growth and job creation and to increase the number of skilled technicians, professionals, scientists, and researchers in the agricultural sector.

Current Situation in South Africa

There is a lack of interest in agriculture amongst the youth of South Africa and, generally, agriculture is not considered as a career of first choice (Terblanché, 2006; Academy of Science of South Africa [ASSAF], 2017). The perception among youth is that agriculture consists of hard labor with low income and with limited space for career advancement (DAFF, 2015). Within higher education, there are more attractive high-profile study disciplines with ample career options, such as accounting and medicine. There is, however, limited awareness or understanding of the multiple and diverse career opportunities that exist in the agricultural sector, especially alongside the entire market value chain (DAFF, 2015; ASSAF, 2017).

In the past, the majority of students that enrolled for agricultural degrees came from farming backgrounds, with the aim of pursuing a career as a farmer. The majority of these students were also male, while a small number of students were

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female and from urban areas. Since 1994, the demographic profile of students studying agriculture shifted, with increased proportions of black and female students entering tertiary education. An increase in the number of students enrolled in undergraduate and postgraduate degrees at higher education institutions was also seen (Department of Higher Education and Training, 2019). The shift in student demographics and increased enrollments can primarily be attributed to increased access to tertiary education due to government funding, primarily toward the National Student Financial Aid Scheme (NSFAS) and DAFF bursary schemes, as well as the implementation of broad-based black economic empowerment within South Africa, thus creating more job opportunities for black graduates, especially in the public sector.

NSFAS provides loans and bursaries at all public universities to eligible students from poor and working-class families to enable access to higher education and training. The DAFF bursaries enable young people from poverty-stricken rural communities with excellent academic achievement to further their studies in one of the identified scarce skills in agriculture, forestry, and fisheries. Subsequently, the number of students, females included, pursuing agricultural degrees increased. It is, however, debatable if the DAFF bursary scheme initiative is successful in uplifting the candidates from rural communities since the majority of students studying agriculture currently come from an urban, nonfarming background with very limited or no previous exposure to agriculture and farm animals.

Implementation of the Skills Development Act (Act 27/1998) in support of the South African Qualifications Authority Act (SAQA Act 58/1995) provides an institutional framework to devise and implement national, sector, and workplace strategies for learnerships that can lead to recognized occupational qualifications. The purpose of these acts is to provide a platform where the skills of the workforce can be improved and to ensure that critical, scarce skills, especially those needed in the agriculture industry, are addressed in a timely manner. The implementation of AGRI-SETA bursaries whereby agriculture producers (primary and secondary) can be subsidized with funding from the government for the employment and further in-service training of agriculture graduates is one of the results of the Skills Development Act.

In South Africa, the majority of agricultural training is provided by universities of technology, private colleges, and Technikons, who offer degrees in various disciplines related to livestock and crop production. These institutions emphasize vocational training for management, community development, and extension services, which reflects in the degree programs offered. These degree programs are orientated toward Bachelor of Agriculture (BAgric) and Bachelor of Technology (BTech) degrees focusing on animal production, farm management, land reform, and food security. These degree programs are viewed as terminal degrees and will not be discussed further.

In South Africa, there are eight universities offering agricultural degrees specializing in animal science from a first-degree level, with the majority of universities also offering Masters and PhD qualifications (Table 1). The structuring of animal science degree programs in science-focused faculties within universities has resulted in an increased focus on science and research, both during undergraduate and postgraduate training (ASSAF, 2017). Animal science degrees presented at first-degree level include a 3-year Bachelor of Science (BSc) degree and a 4-year Bachelor of Science in Agriculture (BSc Agric) degree, both with specialization in animal science (Table 1). These universities focus primarily on training animal scientists for the commercial livestock industry.

Animal Science Curriculum

The BSc and BSc Agric degrees start to build the scientific knowledge of students at a first-year level and, usually, all BSc students have a similar curriculum based on science-related modules. These modules include physics, chemistry, biochemistry, molecular biology, genetics, and mathematics or statistics. At first-year level, an introductory module to animal science is presented, with more specific subject-related modules only presented from second-year level. At second-year level, students are introduced to animal production systems with specific focus on monogastric and ruminant species. During the third and fourth year of study (BSc Agric degrees), modules are presented to facilitate knowledge and understanding of the scientific principles of animal science. These modules include specialized and applied subject matter related to animal physiology, nutrition, genetics, breeding, and management of livestock species. The curriculum is also structured to incorporate the entire value chain of livestock production systems and to be in line with the demands from the livestock industry. At the undergraduate level, training primarily

Table 1. Animal science degrees offered by public universities in South Africa

University	3-year BSc	4-year BSc Agric	BSc Honors	MSc Animal Science	PhD Animal Science
Fort Hare	X		X	X	X
Free State		X	X	X	X
KwaZulu-Natal		X		X	X
Limpopo	X		X	X	
Pretoria		X		X	X
Stellenbosch		X		X	X
Venda		X		X	
Zululand		X			

BSc, Bachelor of Science; BSc Agric, Bachelor of Science in Agriculture.

focuses on ensuring that students obtain critical thinking skills and practical knowledge that they will be able to apply in the workplace. Practical training sessions involving livestock start at a second-year level and mainly entail species and discipline-specific lectures and sessions (Figure 1).

Universities presenting animal science programs mainly use experimental farms for both practical training and research purposes. The University of Venda, for example, has a feedlot, piggery, and both broiler and layer production units for practical demonstrations and research. Although there has always been cyclic opening and closing of different production units on university experimental farms, there is a general downward trend in the diversity of permanent production units and animal numbers, despite increasing student numbers. Cyclic variation in production units is mainly according to research interests at the time, while the downward trend is the result of excessive running costs and the lack of human capital to manage large production units. Many experimental farms are, therefore, effectively moving away from keeping permanent large herds/flocks on the farm. Instead, animals are often acquired for specific research and training purposes whereupon completion of the project/course the animals are marketed to avoid the costs of maintaining large herds/flocks over time.

Collaboration with industry in research and training is becoming more important and has the advantage of not only limiting the costs of training animal science students but also has the potential of bridging the gap between science and industry. An example of such collaboration that is underway is the joint venture between the University of Pretoria and the Animal Feed Manufacturers Association (AFMA) in building a feed mill for research and training purposes. The day-to-day operations of the feed mill will be run commercially, while training will involve specific courses regarding feed mill management and hosting training sessions for BSc Agric graduates from other universities, as well as a research focus in collaboration with universities and the formal feed industry. Alternative options used to alleviate the costs of experimental farms are the use of well-managed private farms, as well as farms under government control. While the latter is less expensive, it is more limited in availability. The Outeniqua research farm under the management of the Western Cape Government is an important example of a government farm that is often used by universities like Stellenbosch for research and training.

Students benefit by participating in practical training with live animals, especially for anatomy and physiology modules. However, the availability of cows is limited by the large number of students and the number of practical sessions required to master the required skills, as well as ethical and welfare constraints. A recommended alternative to using live animals and slaughtering animals for dissections is to use model animals or organs (Figure 2 and 3). Added advantages from implementing this alternative are increased animal welfare and the health and safety of both animals and students. Different types of animal simulators and models are currently available. "Breed n Betsy" was developed as an education tool for practical teaching of the internal reproduction anatomy of a cow, as well as allowing students to practice skills that are used in pregnancy testing, artificial insemination, and embryo transfer. Some models work on the basis of virtual reality where a student can sense the feel of a rectal palpation. A study by Bossaert et al. (2009) suggested that "Breed n Betsy" cannot fully replace training in live cows but may be valuable to the classical teaching method by accompanying practical training on live cows.

Synthetic organs that are life-like, dry, and durable specimens allow students access to competently prepared and long-lasting study material (Figure 3). These synthetic organs are used to improve the quality of teaching and learning anatomy and are especially useful for anatomical regions or organs that are difficult to dissect and/or visualized. The synthetic specimens can either be used with no wet dissection of a specific organ or it can be used as supplemental study material before dissecting actual organs or animals. Many studies recommend using these organs in conjunction with wet dissections for teaching anatomy (Latorre et al., 2007).

Use of computer software programs to formulate diets and model animal production performance efficiency are some of

Figure 1. Practical training of students at the undergraduate level on (A) pig production systems and (B) wool quality and classification.

Figure 2. "Breed n Betsy" animal models are used for reproduction physiology training of students at most universities.

the most useful tools for training animal science students. While the training of undergraduate students in animal nutrition is less dependent on physical resource capabilities, limitations in the numerical and biochemical skills of students hamper the proper integration of theoretical and practical knowledge in the utilization of these software programs. Furthermore, limitations in terms of laboratory space for chemical analysis training of undergraduate students could be partly overcome by the use of near-infrared spectroscopy (NIRS) as a method of rapid feed analysis. The traditional training method of postgraduate students in animal nutrition has become expensive from a financial and time consuming point of view but is also very challenging from an ethical stance. While the substitution of live animals with alternative in vitro methods for the determination of feed digestibility does have some advantages on hand, the compromises in student training cannot be overlooked. It is evident that the traditional teaching and learning of modern animal science students cannot be fully replaced by alternative methods and/or models. However, the need for students that have the cognitive and mathematical capabilities to work with large data sets and use various software models to accurately predict feed properties and animal production performance will become more critical in the future.

Training students in animal breeding was primarily based on quantitative genetics but, since the development of DNA technology and advancements made in genomics, molecular genetics has also been incorporated in the animal science curriculums. Breeding programs focusing on data-led practices, both from quantitative and a genomics approach, to make well-informed decisions have become the norm. The existing animal science programs in South Africa have limited exposure to data science and much greater focus will have to be placed on mathematics,

Figure 3. At the University of Pretoria synthetic organs are used for animal anatomy and physiology training.

statistics, and computer science skills in the future. Recognizing this need, the University of the Free State started incorporating basic data science concepts in the third- and fourth-year curricula of BSc and BSc Agric students (Figure 4). Introductory courses in R and SAS for data management, mining, and analysis have done much to provide learners with some exposure and experience in these areas. A much more promising observation can be made at the postgraduate level on a national stage with most universities, including bioinformatic analysis of large data sets for Masters and Doctoral studies. However, training opportunities are lacking, and a lot of time is spent teaching students the required techniques. In addition, students spend many hours studying and teaching themselves. Unfortunately, the percentage of students pursuing a postgraduate degree is significantly lower compared to those completing the undergraduate programs (Figure 5).

The BSc Agric degree is equivalent to a 3-year degree plus an honors degree. During the fourth year of the BSc Agric degree, students are enrolled in a research methodology module, where students are specifically introduced to research methods and scientific writing. This module is also employed as preparation for prospective students who might be interested in pursuing a postgraduate qualification (MSc Agric degree). Although, the postgraduate qualifications in animal science offered at traditional universities are primarily research based, the execution and level of scientific interaction of these studies differ widely and contribute toward much skepticism and debate on the application thereof in practice.

The differences in focus areas of undergraduate student training are also reflected in postgraduate research and training, whereby some South African universities will focus more on animal production-related aspects and others more on pure scientific content. In general, postgraduate animal science training is research focused and does not include much course work, while little integration between the various disciplines occurs. A lack of understanding the differences between interdisciplinary versus multidisciplinary research might contribute to the compartmentalization of research outputs experienced in the past and needs to be addressed for future training of postgraduate students.

Professional Career Development

Across the eight public universities that offer animal science degrees, an increasing number of students graduated with an undergraduate degree over time (Figure 5). The total number of students obtaining an MSc degree has remained relatively constant, while the number of PhD students increased slightly since 2013 (Figure 5). The majority of the animal science graduates were from the universities of the Free State, Pretoria, and Stellenbosch (Higher Education Management Information System [HEMIS], 2017). It is important to note that South African universities, in general, have no "active tracking" systems in place to monitor student employment and career development after graduation. Therefore, it is difficult to establish any link between the increases in graduated candidates as illustrated in Figure 5 and the successful placement of candidates within the formal workforce.

To practice as an animal scientist in South Africa, animal science graduates are required by law (Act 27/2003) to register at the national legislated regulatory body of the South African Council for Natural Scientific Professions (SACNASP). According to the SACNASP guidelines, students that obtained a 4-year BSc degree or a BSc Honors degree, together with relevant work experience, qualify to register as a professional natural scientist, whereas a 3-year BSc or BAgric degree allows only registration for candidate and certificated membership. Registration at SACNASP ensures that only registered persons may practice in a consulting and advisory capacity and that persons practice strictly within their area of competence. Both the South African Society for Animal Science and the World's Poultry Science Association are voluntary associations with SACNASP and ensure that registered animal scientists continue to engage in academic activities by means of a continued professional development program. The validity and purpose

Figure 4. A computer lab where students learn to perform data and statistical analysis at the University of the Free State.

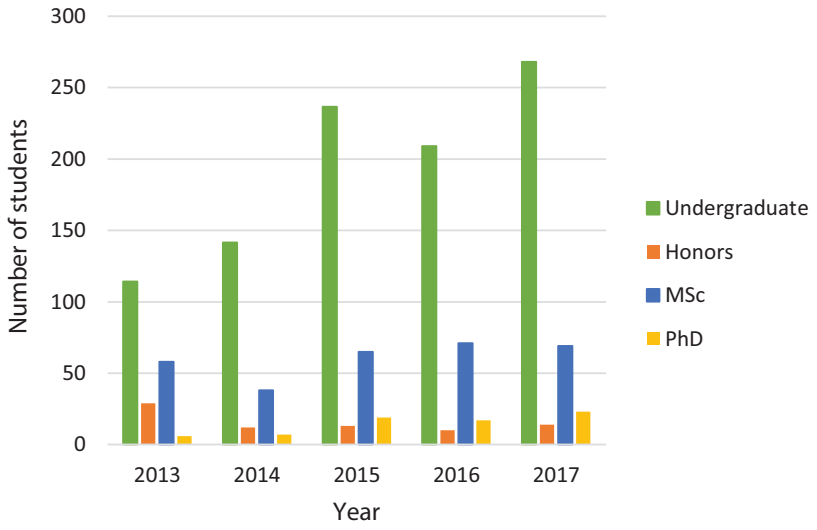

Figure 5. Total number of students that graduated with an animal science degree across the eight public universities in South Africa (Source: based on HEMIS [2017])

of these continued professional development programs are open for debate. However, they serve as a platform to ensure that graduates engage in continuing education with exposure to new developmental changes in practice. Furthermore, due to legislative issues, students seeking employment in the formal animal feed market need to be registered by SACNASP before they are considered.

Future Considerations

As the research demands of the animal science industry continue to change to more sophisticated technology and approaches, individuals filling these positions will increasingly come from nonagricultural backgrounds. The current demographics of the undergraduate population in South African universities reflect this trend. Training of undergraduate students needs to be adjusted to reflect the future demands of the animal science industry, without resulting in "academic drift" influenced by third party stakeholders. Since a large proportion of tertiary education is primarily subsidized by the government in South Africa (i.e., NSFAS bursaries), universities will also need to adhere to the demands of the national government to address the shortages of critical skills within agriculture. While the introduction of more private tertiary training institutions will not be a direct threat for public tertiary institutions, especially at the postgraduate training level, it must be viewed with caution since private and public institutes compete for a similar student pool, while private institutions are less exposed to political interference and instability.

While the formal employment markets will remain relatively constant in terms of the needs for discipline specialists, a wider range of new opportunities will emerge for the creative animal scientist student that is capable of working across discipline fields and capable of adopting new problem-solving techniques in the 21st century. Unfortunately, job opportunities in either the private or public sector will not increase at the same rate as the number of students registering to study Animal Science. It is, therefore, imperative that student training should include entrepreneurial thinking and development, as well as software programming courses to ensure that candidates could be employed beyond the scope of classical animal science in the future. While the role of the "traditional" animal scientist will become less dominant in the future, it will remain critical to ensure that the scientific backbone is indisputable. As animal scientists, we need to be aware of "academic drift" within and between various disciplines and should ensure that stakeholder participation and demands never dominate and overrule pure scientific principles. It is also envisioned that animal scientists will play an even more important role in assisting scientists from other disciplines in addressing global warming challenges in a more holistic and sustainable approach.

The dawn of the fourth industrial revolution and the development of artificial intelligence also influenced the animal science industry. The world of work has fundamentally changed with young career professionals now being faced with a deluge of data to be structured, modeled, and analyzed before making decisions. Modern animal scientists are required to have much broader technical skills than ever before, including a deep knowledge of database usage and being able to program in multiple languages. Traditional disciplines such as breeding, nutrition, genomics, and precision farming, among others, are generating vast amounts of data, and professional animal scientists are now required to be competent in tasks such as the collection of data, storing data, data synchronization, data transformation, data cleansing, data governance, and the development of data models. The development of software agriculture applications ("apps") will enable scientists to "identify," "analyze," "diagnose," and "prescribe" by having a mobile office in hand due to cell phone technology that continually improves and large data sets that will enhance the intelligence that is used in decision-making processes. Future programs in animal science

About the Authors

Rulien Grobler is a lecturer in animal breeding and genetics in the Department of Animal Science at the University of the Free State where she teaches courses in animal breeding and genetics. She was the recipient of a National Research Foundation Scarce Skills Doctoral Scholarship and completed her PhD in animal science at the University of Pretoria. Her PhD research focused on genetics of the polled condition in indigenous South African beef cattle breeds and she has ongoing research interests in beef cattle genomics, livestock genetic diversity, and applied animal breeding.

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Ockert Bernard Einkamerer began his career as junior lecturer in the Department of Animal, Wildlife and Grassland Sciences at the University of the Free State (UFS), South Africa, where he is currently a lecturer. He obtained his PhD in Animal Nutrition from the UFS. Most of his research focuses on diet effects on growth in sheep, fatty acid composition of mutton, and on feed quality. He also manages the Jersey herd at UFS, acts as external assessor for tertiary institutions, actively participates as an Animal Feed Manufacturers Association (AFMA) technical subcommittee member, and was editor of the AFMA Matrix.

Errol Cason was educated at the University of the Free State (UFS), South Africa. Research during his postgraduate studies focused on microbial life in extreme environments, specifically on the taxonomy and functional roles of these microorganisms. During his PhD, he developed an interest in the bioinformatic analysis of bacterial diversity, genomes, metagenomes, and transcriptomes. In 2019, he was appointed senior lecturer at the UFS in the Department of Animal Sciences and shifted his research focus to the adaptation and efficiency of farm animals to mitigate the effect of climate change and lower the carbon footprint of livestock production.

Adri O'Neill graduated at the University of Pretoria, South Africa. Her initial focus was on the use of growth promotants and meat quality. For her PhD, she studied the stress responsiveness of different and meat quality in cattle with catecholamines as indicator. In January 2017, she was appointed as a lecturer at the University of the Free State in the Department of Animal Sciences. Currently, she is involved in evaluating the meat quality of the Tankwa goat; meat quality of different sheep breeds on different production systems, and the effect of heat stress on oocyte development.

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Joseph Jimu Baloyi received his PhD in Animal Nutrition from the University of Zimbabwe. He is currently associate professor, head of the Department of Animal Science, and deputy dean of the School of Agriculture at the University of Venda, South Africa. His research focuses on ruminant nutrition making use of native plant species and agro-industrial byproducts as protein supplements to overcome the undernutrition of livestock that is commonplace for resource-poor farmers and particularly those in harsh environments.

Michael MacNeil received his PhD from South Dakota State University, USA. As a researcher, he has primarily focused on finding genetic solutions to applied problems that compromise efficient beef production, enhancing systems of national cattle evaluation, and using genomic technology to discover quantitative trait loci and assess genetic diversity. He provides statistical consulting to researchers in many disciplines and works internationally to alleviate hunger and poverty. He is an affiliated professor in the Department of Animal, Wildlife and Grassland Sciences at the University of the Free State, South Africa.

will definitely see greater incorporation of computer skills and data sciences at an earlier level to prepare students for the changes in industry. Currently, data scientists are a scarce skill in sub-Saharan Africa; thus, students properly trained in the appropriate skills will be greatly sought after and will likely have a wide range of career options.

Conclusion

Departments of animal science across public universities in South Africa will continue to be important in training animal scientists for the future. The teaching environment will undoubtedly change and evolve on a continual basis due to technological developments. Universities in South Africa need to respond to change and face the challenge of providing quality education to provide excellent animal scientists to meet the industry's future demand for a highly skilled workforce.

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