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USING TECHNOLOGY TO SERVE THE AGRICULTURAL COMMUNITY IN THE WESTERN CAPE PROVINCE OF SOUTH AFRICA

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Abstract

The Western Cape Department of Agriculture has a team of agricultural experts using novel approaches to address the challenges faced by South African agriculture. The objective of this paper is to describe some of the innovative research and technologies, and methods of technology transfer, used to better serve the agricultural community. The spectrum of technologies implemented includes new research on breeding (biotechnology); new approaches to conservation agriculture; remote sensing satellite and spatial information for improved decision making, such as the spatial intelligence project and FruitLook; Agricultural Integrated Management System; and technology to manage and disseminate information, such as smart (digital) pen and paper technology and Agri-Touch. The paper is an introduction to some of the cutting-edge research and technologies and new methods of communication, information dissemination and decision making support that serves the agricultural community in a tangible way.
Keywords: Technology, Biotechnology, Conservation Agriculture, Remote Sensing, Information Dissemination

Introduction

The South African Government's National Development Plan (NDP) "Our Future - Make it Work" is a long-term strategic plan to be implemented in phases by 2030. It is viewed as a "platform for united action by all South Africans to eradicate poverty, create employment, and reduce inequality as critical building blocks towards a truly united, non-racial, non-sexist, democratic and prosperous society" (National Planning Commission, 2011). Chapter 6, "An integrated and inclusive rural economy", specifically addresses agricultural development in terms of food security and the sector's potential role in job creation. In order of priority, the five key areas of agricultural advancement are: sustainable agriculture; conservation; water use efficiency; adaptive research, and Extension and small-scale agriculture (National Planning Commission, 2011). The Western Cape Department of Agriculture (WCDoA) addresses these areas in its provincial goals which are implemented through relevant projects, examples of which are described in this paper.

"Sustainable agriculture does not mean a return to either the low yields or poor farmers that characterized the 19th Century. Rather, sustainability builds on current agricultural achievements, adopting a sophisticated approach that can maintain high yields and farm profits without undermining the resources on which agriculture depends" (Gold, 2007). In terms of sustainable agriculture, the WCDoA is committed to developing and enhancing the use of natural resources in a sustainable manner within the context of climate change to ensure food security. All of the Department's projects contribute in some way to support the triple bottom-line principle or three pillars of sustainability: people, planet, profit. The WCDoA also aims to increase agricultural production by at least 10% over the next 10 years. This can be realized by both increasing production and/or by decreasing the cost of production by developing more efficient systems. Adaptive research, that uses new technologies to solve challenges in the sector, plays an important role in this respect. The projects described in the following sections contribute to these aims by offering both innovative scientific and practical solutions by using cutting-edge technology.

Biotechnology Projects

The ovine genomic selection project and the ostrich artificial insemination (AI) project are two examples of how scientists at the WCDoA use biotechnology to serve the agricultural community. There are 11 million Merino sheep (Department of Agriculture, Forestry and Fisheries, 2013) farmed by 2,500 farmers under extensive conditions in the arid regions of South Africa not suitable for other agriculture. The industry would benefit significantly from the development of ovine genomic selection for the Merino sheep as a result of more accurate selection at an earlier age. The ostrich industry is worth 2.1 billion rands (US$ 168.7 million) and the 588 registered export farms (453 located in the Western Cape Province) employ 16,000 people (Department of Agriculture, Forestry and Fisheries, 2013). The recent outbreaks of avian influenza have had a detrimental impact on the industry with ostriches culled to prevent the spread of the disease, and a ban on the export of ostrich meat to the European Union have had a negative impact on profitability. The ostrich AI technology is a forward thinking approach to ostrich breeding which can contribute to rebuilding the industry, after the recent population decline, in the near future.

Ovine Genomic Selection

A project to evaluate the SNP50K beadchip genotyping platform is currently underway with the aim to estimate genomic breeding values for at least one South African sheep breed within the next 3 years. The value of this new genomic technology is that DNA markers can provide accurate information on early prediction of an animal's genetic worth and its individual performance; thus, a farmer can select the best animals earlier, efficiently and accurately (Naidoo, 2012). Olivier (1999) identified reproduction as the primary trait of economic interest in the South African sheep industry. However, reproduction is sex-limited, lowly heritable and expressed late in the life of an animal and is, therefore, a complex trait to measure and improve using traditional selection strategies. Genomic selection strategies that enable the selection of young animals by the evaluation of marker as well as pedigree information, provides an ideal system for improving reproduction traits in the context of the South African sheep industry.

Although South Africa has not invested in ovine genomic evaluation yet, molecular genetics (mostly based on microsatellites or other earlier marker systems) have been used in South Africa for studying breed diversity (Soma et al., 2012), the characterization of the Namaqua Afrikaner as an indigenous fat-tailed breed for conservation (Qwabe et al., 2012) and determining the molecular divergence of a South African Merino resource flock selected for and against the ability to rear multiple offspring using random amplified polymorphic DNA (RAPD) (Naidoo et al., 2005; Naidoo et al., 2013). Recently, Sandenbergh et al. (2013) used the commercial ovine SNP50K beadchip to confirm divergence at the molecular level in the South African Merino resource flock divergently selected for the ability of ewes to rear multiple offspring. The genotyping platform was also evaluated for other South African breeds, namely the Namaqua Afrikaner, the Dorper, the South African Mutton Merino as well as commercial fine wool and medium wool Merino studs (Sandenbergh et al., 2014). The ovine 50K beadchip was found to be useful for genotyping large numbers of genetic markers of commercial South African sheep breeds, such as the Merino, South African Mutton Merino and Dorper.

The aforementioned project results paved the way for implementing genomic selection in South African sheep breeds, as is done in the Australian (Rowe et al., 2013; Swan et al., 2014; Van der Werf et al., 2014) and New Zealand (Auvray et al., 2014; Dodds et al., 2014) populations. A framework to allow this has been drawn up by Cloete et al. (2014) and the urgent need for a reference population of at least one South African sheep breed has been identified as a real and present requirement for success. The project team is in the process of acquiring additional project funding for genotyping, negotiating with external overseas collaborators and the compiling of phenotypic data that are all needed. It is foreseen that the basic infrastructure to estimate genomic breeding values for at least one South African sheep breeds will be in place by 2018. The value of this new genomic technology lies in the ability to rapidly increase the genetic merit of a sheep flock and to produce animals that increase the profitability of sheep farming for individual farmers.

Ostrich Artificial Insemination

The commercial ostrich industry produces leather, meat, and feathers as primary products (Cloete et al., 2012). The industry is characterized by challenges resulting from a very narrow male to female ratio compared to other livestock, a communal nesting system that complicates the recording of pedigrees and the confounding of random female, male and paddock effects in pair-breeding systems where pedigree information is routinely obtained (Cloete et al., 2008). A workable artificial insemination system can surmount all these challenges in this species. The ostrich AI project is a novel approach to solving the industry's challenges resulting from the absence of an official recording and evaluation scheme (Cloete et al., 2008). The project aims to provide a viable alternative to the current natural mating systems by developing new techniques to collect and cryo-preserve ostrich semen for AI.

A resource population of ostrich males where semen could be collected routinely was established, while a population of females producing eggs in the absence of males has also been established (Bonato and Cloete, 2013). Key research outputs from the project indicated that ostrich males could be ejaculated up to two times a day without a reduction in semen volume, sperm numbers and sperm viability (Bonato et al., 2011); that semen output, semen quality and male libido followed a distinct seasonal trend but that semen could be collected all-year round from this species (Bonato et al., 2014); and that the viability of ostrich semen can be extended in temporary storage at the correct pH levels and storage temperature conditions (Bonato et al., 2012). The short-term liquid storage and indeterminate cryo-storage conditions of ostrich semen are being refined. All the key prerequisites for a viable ostrich AI protocol have been met. However, repeatable variation among animals in semen traits of males and the reaction of females to insemination still cause insemination outcomes to be unpredictable. The project team is in the process of refining the technique used for semen storage and the dose used for inseminating females. Animals of both sexes showing desirable behavior and good breeding values for traits like egg production is also recruited into the program to better understand the variation between animals. In addition, the imprinting of day-old chicks on humans is currently being investigated in order to facilitate the training of animals for this program, but also to improve human-animal relationships and the welfare of the birds. Ultimately, it is foreseen that the refined protocol can be developed to provide a viable alternative to the natural mating systems being used at present.

Sustainable Crop Production through Conservation Agriculture

Conservation Agriculture (CA), as defined by the Food and Agriculture Organization (FAO), is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits, and food security while preserving and enhancing the natural resource base and the environment. The three main principles of conservation agriculture are: (1) minimal mechanical soil disturbance; (2) permanent organic soil cover; and (3) diversification of crop species grown in sequences/associations i.e., crop rotation. The WCDoA's conservation agriculture experts hosted their 2nd Conservation Agriculture Symposium and Expo that brought together experts in the field. The conference also held webinars, connecting experts from the USA to delegates in South Africa. Pre-harvest "green tours" and post-harvest "brown tours" offered farmers an opportunity to learn about CA practices in a hands-on environment. The long-term trials conducted by the crop research team have yielded informative results applicable to farmers practicing winter-grain cropping in the Western Cape.

Rain-fed agricultural production systems in the Western Cape have been based on winter cereals since the 1700s. In the Swartland, located in the west coast region of the Province, wheat has been the main crop for the past century and was produced in monoculture with an occasional break of bare fallow lands or oats fodder-crops. However, since the mid-1900s and due to the region's inherent production potential for wheat, the advent of commercial fertilizers and improved chemical pest control measures, as well as government subsidies in wheat production the production regime has changed. The aforementioned factors encouraged the expansion of wheat production into marginal areas (Arkcoll, 1998). The establishment of annual legume pastures, that are adapted to the moist cool winters and dry hot summers, was encouraged during the land improvement scheme of the 1970s and 1980s with limited success, despite extensive research showing the benefits of including such pastures (annual *Medicago* and annual clover species) into a farming system in rotation with wheat (Van Heerden, 1998). Percent increase in input costs, competitive world market prices and uncertain production due to decreased soil potential, and variable unpredictable rainfall have greatly reduced the biological and economic sustainability of wheat production in the Western Cape.

Strauss et al. (2014) conducted an economic evaluation of crop and crop/annual legume pasture rotation systems in the Swartland, Western Cape. This was done in an attempt to determine the potential economic implications of including sheep production from annual legume pastures into the rain-fed grain production systems of the Swartland. Given the lower input costs and higher or similar gross margins and, therefore, lower financial risk, the results clearly illustrated the benefits of including annual legume pastures (with sheep production) into the rain-fed farming systems practiced in the Swartland, Western Cape. According to Hoffmann and Laubscher (2002), the Swartland receives more than 80% of its annual rainfall in the winter months. Therefore, the inclusion of medic and medic/clover pastures and alternative cash crops such as canola and lupins into the cropping system provides an improved return on capital investment when compared to wheat monoculture.

Applications and Implications for Conservation Agriculture

One of the main beneficial effects of including legumes in cereal grain rotations is to reduce Nitrogen (N) inputs in the subsequent grain crop (McEwen et al., 1989). N supplied by legumes has been shown in certain circumstances to disperse through the soil profile and is more effectively retrieved by wheat compared with surface applied N fertilizer (Lòpez-Bellido et al., 1996). Medics and clovers have been shown to contribute to soil organic matter and provide 40 to 100 kg Nha-1a-1 to the soil profile, up to 40% of which is available to the subsequent crop (Ladd et al., 1981). Grass weeds may be effectively controlled in broad-leaved crops and legume pastures; thus, reducing costs, grass-weed competition and contamination, while also increasing yields in the subsequent grain crop. The removal of grasses during the pasture phase prevents addition of grass seed to the soil seed bank; thus, limiting the potential for grass contamination and competition, reducing costs, and increasing yields in the subsequent grain crop (Le Roux et al., 1995). Soil health improvement in terms of carbon increases especially in the crop/pasture systems where the soil is only disturbed every second year by a no-till planter was also evident with total soil carbon content increasing from less than 0.5% to nearly 2% from 1996 to 2010.

Remote Sensing Satellite and Spatial Information for Improved Decision Making

The spatial intelligence project and the FruitLook project both use remote sensing satellite and spatial information to support decision making in the agricultural sector. These projects address critical issues with regard to the way information is used to make decisions. The implementation of these decision making tools will facilitate the Department's ability to deliver a high quality of service to stakeholders in line with national priorities for agricultural advancement.

The Spatial Intelligence Project ("Flyover Project")

Land use and infrastructure data were urgently required to support decision-making regarding many strategic objectives and operational issues within the Western Cape, such as land reform projects, conservation planning, catchment management, disaster management, spatial development frameworks, environmental management frameworks and a wide variety of auxiliary research and development projects. The mandatory requirement for spatial planning (Spatial Development Frameworks) processes across all levels of South African government has made these data a critical component in responsible, informed decision-making across many disciplines, towards improved service delivery and sustainable development in the Western Cape.

The "Flyover Project" made use of satellite imagery to accurately map field boundaries and then used light aircraft carrying experienced observers to identify all agricultural cultivation per field, across the entire province. At the same time, agricultural infrastructure such as silos, tunnels, packing sheds and dairies were also mapped. This addressed the urgent and transversal need for a detailed set of farm-scale, land use, and infrastructure data for the entire Western Cape to service internal needs, as well as the needs of a wide variety of stakeholders involved in provincial administration, planning, research and disaster management. Some 250,000 land parcels and thousands of infrastructure sites were identified and mapped, representing a quantum leap in the level of spatial detail, and corresponding crop production statistics that are now available to be analyzed and disseminated. Also, the resulting spatial data will be transferred into the Agricultural Integrated Management Systems (explained in the next section) of the WCDoA and made accessible to all stakeholders via a Web mapping portal, the CapeFarmMapper (http://www.elsenburg.com/gis/apps/cfm/). The new provincial dataset will allow agriculture for the first time to accurately measure, map, monitor, and disseminate information on agricultural production and the operational "footprint" of agriculture in the multidisciplinary, transversal, and increasingly technologically-intensive sphere of regional planning.

FruitLook Project

The FruitLook project, launched in 2011, is a spatial approach to assess and improve water use efficiency of vineyards and deciduous fruit orchards in South Africa. Water is a critical resource, which challenges the irrigated agricultural sector to explore innovative solutions to improve the use thereof. New technologies developed, using satellite data, show the spatial and temporal variations of actual crop water use, growth parameters and N content at the field level, and helps farmers to improve their production and reduce inputs and associated costs.

FruitLook uses this technology to offer weekly updates for grape and deciduous fruit producing areas in the Western Cape through the web-portal www.FruitLook.co.za. The FruitLook web portal provides real-time information to farmers on the actual water use by fruit crops and eight other parameters. It will assist them to optimize their agricultural water use and also result in savings in the use of electricity and fertilizer. Currently, 507 people are registered as users of the data, including farmers, specialists, Extension officers, and researchers. A total of 802 irrigation blocks were registered on the web portal in 2013-2014 representing an area of 12,047 hectares (29,956 acres), with an average irrigation block size of 15 hectares (37 acres).

The FruitLook project is funded by the WCDoA with support from the National Department of Agriculture, Forestry and Fisheries, HortGro and the d Applications Promotion program of the European Space Agency. The project is executed by eLEAF Competence Center from the Netherlands in cooperation with the University of KwaZulu-Natal, South Africa. The aim is to get to the stage where farmers will start to contribute towards the cost of the service for using the information provided, and eventually to the stage where the subscriptions can fund the project.

Agricultural Integrated Management System

The Agricultural Integrated Management System (AIMS) is a spatial intelligence system that will be implemented as a business intelligence tool. It is a complex integrated cross-functional system, which manages data at the municipal, provincial, national, and parliamentary levels. Strategically, AIMS will define the way business is conducted; workflows will detail the processes to be followed for enhanced project management. One of the challenges faced by the WCDoA is collecting useful and relevant data at the farm level and the management of this information. There are currently major limitations on the monitoring and evaluation, reporting and analysis of the current state of agriculture in South Africa.

This notwithstanding, when AIMS is fully established, it will provide an accurate and verifiable baseline of the current state of agriculture in the Western Cape. It is being established through the fly-over project, collection of interview data using digital pen technology (Smart Pen) and the incorporation and comparison of legacy data into the new system throughout the province. AIMS will provide further benefits as access to the level of accurate data and the use of the incorporated management and measurement tools are improved. This will provide transparency and accountability of measures; thus, resulting in lower operating costs through greater budget and personnel management control, faster and more efficient service delivery, and easier tracking and control of departmental budgets. AIMS will support decision making processes by providing access to tailored reports (containing current, accurate, and empirical data) to reflect the specific requirements of stakeholders (e.g., directors and ministers) which will ultimately lead to providing a better service to the agricultural community.

Technology to Manage and Disseminate Information

The Smart (Digital) Pen and Paper technology and the Agri-Touch information kiosks are examples of new technology implemented by the WCDoA to improve the service delivery in terms of Extension services. The smart pen was implemented as a system to facilitate the administration of Extension projects, which involve paperwork and field work. The Agri-Touch information kiosks promote public access to information and it will be a useful tool to help bridge the communication gap.

Smart (Digital) Pen and Paper Technology

Prior to the implementation of the Smart (Digital) Pen and Paper technology, traditional paper reports on project site visits were easily lost or the delivery to the head office was delayed which resulted in poor service delivery to the project beneficiaries. With the introduction of the Smart Pen technology, Extension officers can report from the field, saving valuable time. Information reaches head office in real-time (preventing data loss); thus, enabling officials to respond quickly to the beneficiaries needs, prevent possible failures of projects and to provide the necessary Extension services to emerging farmers more efficiently. The paperless system is also more environmentally sustainable than traditional paper reporting and fits into the greening campaign of the WCDoA. The Smart Pen technology, comprise GPS monitoring, form validation, X-Station handwriting recognition, photos, and real-time submission that creates a much improved Extension service to communities in the Western Cape. In addition, it uses plain paper printed with the specific form design, the pen motion captures the Extension officers handwriting and transmits this in real-time to the database.

Agri-Touch

The Agri-touch is a computer-based platform in the form of a kiosk that is fully touch-screen operated with wireless, General Packet Radio Service (3G) and Local Area Network capabilities. The purpose of the Agri-Touch is dissemination of information to dispersed resource poor communities who ordinarily would not have easy access to a reliable internet service. The Agri-Touch presently provides public access to the departmental website (www.elsenburg.com) and Agri-suite (a subscription based agricultural information system, which includes market and marketing information). Access to this kind of information will contribute to the economic viability of small, medium and micro agricultural enterprises, and contribute to job creation and food security by the sector as enshrined in the National Development Plan.

Conclusion

Agriculture is a vibrant and robust industry in South Africa with diverse challenges. Customized technology that is specifically adapted to the sector plays a vital role in supporting and growing opportunities in agriculture. New technologies that help mitigate the effects of global warming by conserving resources and ways to farm more efficiently by producing more with less will contribute to enhancing food security as well as address the broader issue of climate change. Furthermore, the critical issue of supporting small-scale farmers through providing access to information via the Agri-Touch platform is a promising intervention.

The discussion above relates how WCDoA fulfills its mandate to provide a world-class research and advisory service; to alleviate poverty, grow the economy, and ensure food security for the population in the Province. The Department is committed to providing cutting-edge technology to the Western Cape agricultural community in particular, and the total population of the Province in general. Indeed, these technologies include, but not limited to, biotechnology, conservation agriculture, remote sensing and spatial information, agricultural integrated management system, and dissemination of agricultural information. These technologies when well-implemented or transferred have the potential of significantly increasing agricultural productivity.

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