THE FUTURE OF THE WESTERN CAPE AGRICULTURAL SECTOR IN THE CONTEXT OF THE 4TH INDUSTRIAL REVOLUTION

Review: Smart Water Technology in Agriculture

November 2017

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University of Stellenbosch Business School

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1. Why Smart Water Technology Now?

Population growth coupled with climate change, is increasing pressure on the available water resources for agriculture[1]. It is feared that we will not be able to grow sufficient food for the world's increasing number of people without improved access to water. Sub-Saharan Africa has grown from 180 million to 962 million people from 1950 to 2015. This is about 12 million people a year for the past 65 years. It is predicted that countries will have to double their water productivity to meet expected demand[2].

In the last two decades, South Africa has lost close to 30% of its farmlands due to water scarcity[3]. In 2015/16, South Africa recorded its worst drought since 1904. Agriculture contracted by almost 15% from R78 billion in the fourth quarter of 2014 to R66 billion in the second quarter of 2016[4]. While South Africa has always had seasonal rainfall and been impacted by the cyclical El Niño weather pattern, the effects of climate change mean water scarcity and rainfall variability are set to increase.

The Western Cape Province (WC), currently South Africa's leading agricultural export region, is at present (2014 to 2017 hydrological years) experiencing the worst water shortage in 113 years[5]. It has been declared a disaster region. Major dams in the province have at points in the drought effectively had only 12.3% of usable water in them. The WC contributes 24% to total GDP in South Africa. Agriculture has a total contribution to the GDP of the WC of roughly 4%. Agriculture and agro-processing are responsible for 18% of employment opportunities in the province. The WC has the biggest agricultural workforce in South Africa at 24.5%. The drought will, therefore, have the biggest impact on seasonal employment in the fruit industry[6]

Water technology has a significant role to play in alleviating some of the impacts of the drought in agriculture. The 4th revolution could potentially greatly increase water efficiency and productivity, and alleviate some of the impacts of the current drought. This chapter identifies available climate-smart agricultural technological innovations in the Western Cape, evaluates their potential for addressing the ensuing water crisis and explores how they might affect water use in agriculture in the future.

2. Top Nine Smart Water Technologies for Western Cape Agriculture

Item	Rank	Comment
Remote Sensing	1	Access to information
Smart monitoring of water	2	Reduces waste
Cell phones for weather forecasts	3	Provide useful information to even small holders
Seasonal hydrological forecasting	4	Very important for water budgeting
Unmanned aerial vehicles (UAVs)	5	Detects problems normally not visible
Intelligent irrigation	6	Reduce water use and management costs
Solar power for irrigation	7	Reduces cost of irrigation significantly
Aquifer recharging	8	Vulnerable to contamination
Waste water treatment technologies	9	Still too expensive

Remote Sensing

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. It uses satellite data to show the spatial and temporal variations of actual crop water use, growth parameters and nitrogen content at the field level. This helps farmers to improve their production and reduce inputs and associated costs.

It provides farmers with weekly updates for grape and deciduous fruit producing areas in the Western Cape through its web-portal, www.FruitLook.co.za. It is real-time information on the actual water use by fruit crops and eight other parameters. The system has 507 people that 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)[7]

This system is of great help to farmers in that it helps them to decide when to irrigate and how much electricity and fertiliser they need to use. It has the potential to bring about great savings in water, time and money. Almost half of the producers using FruitLook have indicated they have cut their water use with a tenth. One in every ten says they are now using almost a third (30%) less water than before. The majority have also indicated it is very useful in the detection of over- or underirrigation, with over half of them highlighting that it could be used to detect irrigation problems (for example pipe leaks)[8].

Smart Water Monitoring

Water is lost every day in developing countries through aging infrastructure in agriculture. Leaks not only cause water loss but also increase the likelihood of pollutants contaminating the water. Existing water meter solutions are often manually read by officials, and the information takes long to be recorded. There are feedback delays by several weeks. Smart meters address these challenges by allowing for electronic and real-time metering[9].

Monitoring technologies can go a long way to improve the integrity of water supply networks. Electronic instruments, such as pressure and acoustic sensors, connected wirelessly in real time to centralised and cloud-based monitoring systems can detect and pinpoint leaks quickly Many water meters are now able to communicate with the municipality or user, monitor consumption patterns, dispense prepaid water and provide leakage alerts[10].

Some of the drawbacks of implementing this technology are the costs of importing the technology. Cellular meters are seen as the most viable in Africa because it is able to meter without traditional network infrastructure or traditional manual reading. GreenCape also argues that there is a strong case for developing water companies with business models that incorporate audits and monitoring, shared savings, capital investment solutions for technology and smarter utility management[11].

A different type of smart metering technology in the South African agricultural water sector is the Water Administration System (WAS, https://www.wateradmin.co.za/). This system, which has been developed over nearly two decades, simplifies water release calculations with the use of smart loggers, connected to an internet platform. This reduces water losses and the overall demand of the irrigation scheme, which improves water availability at catchment level. It also as a result improves financial management of the scheme.[12]

Cellphones for Weather Forecasting

Information Communication Technology can alleviate some of the costs of supplying water infrastructure in Africa. Basic mobile phones have been used provide farmers in Africa with daily information on effective agricultural practices, market prices and weather forecasts using text and voice messages[13]. In semi-arid areas, small farmers especially are confronted with difficulties in selecting crops in response to different weather conditions. Total crop failure can have devastating consequences for their futures. Having information about the expected weather conditions, helps them to be better informed about the upcoming season and plan what crops they want to grow[14].

More advanced phone-based information systems have also been developed in South Africa to give farmers access to everything from weather forecasts, to advice about seeds, fertilisers, crop information etc, at the touch of their fingertips (see for example http://www.manstratais.co.za). This type of technology is useful for extension officers, but is generally either still too expensive, or not refined enough for farm-level use[15].

Unmanned Aerial Vehicles (UAVs)

UAVs can greatly improve water monitoring and water stress management in agriculture. Increasingly sophisticated sensors and cameras are developing at a rapid rate. Their application varies from routine checks of dam levels and suspected water leaks, to the monitoring of crop fields with high spatial and temporal resolution remote sensing. UAVs fitted with remote sensing technology that measure thermal energy can be used to assess water stress in plants, via thermal indices (calculated using artificial surfaces as references), estimates of the difference between canopy and air temperature, and even canopy conductance estimates derived from leaf energy balance models. UAVs fitted with remote sensing technologies that measures fluorescence is another possibility. It has also been proposed that chlorophyll fluorescence could be an even better indicator of plant photosynthesis and water-use efficiency under water stress[16].

The monitoring of fruit development at different stages of development is one of the top applications of this technology in the Western Cape. Some of the drawbacks of using drones, is that the climatic conditions have to be optimal, as remote sensing cannot be undertaken in overcast weather and drone readings are influenced by windy conditions. Key to using UAVs remote sensing data for effective water management, is the correct interpretation of data. For example, when comparing data, readings for both technologies should be taken at the same time of day, as plant stress levels vary throughout the day according to climatic conditions[17].

Intelligent Irrigation

Many intelligent irrigation systems have been developed with Water Research Commission funding over the past 4 decades in South Africa. There are soil-based approaches, atmospheric-based approaches through biophysical modelling of the soil-crop-atmosphere system, thermodynamic limits to the amount of water that can evaporate from a cropped surface under particular environmental conditions and modelling approaches that are more mechanistic, generic or crop specific, with pre-programmed (e.g. irrigation calendars) or real-time output[18].

Drip Irrigation is one that has taken off in the Western Cape. It works from the philosophy that plants only need a few regular drips direct to the root system. Each plant gets exactly the right amount of water that it needs in the right location. The savings on water, costs and on the devastating effects of drought, is potentially large[19].

The Chameleon soil moisture sensor and the FullStop wetting front detector are two other intelligent irrigation tools that are being explored in Sub-Saharan Africa. The first represent soil water, nitrate and salt levels in the soil by displaying different colours. The second provides an indication of over irrigation and an opportunity to assess the water quality leaving the root zone.

These tools form the basis of an experiential learning system for small-scale irrigators. Manufactures said farmers quickly learned from the tools and changed their management within a short time. The cost of implementing a learning system was expected to be small fraction of building or revitalising irrigation schemes[20].

Seasonal Hydrological Forecasting

South Africa's dependence on dam-based storage of water, coupled with its variable climate, underlines the importance for seasonal forecasts of water resources (predictions of climate and water resources issued three to six months into the future), and the mainstreaming of these forecasts into water resources management.

Ensemble hydrological predictions are normally obtained by combining hydrological models with ensembles of atmospheric forecasts produced by numerical weather prediction models. To be of practical value to water users, such forecasts should not only be sufficiently skillful, they should also provide information that is relevant to the decisions end users make [21].

The cosmic ray probe, an above-ground sensor, uses the low-energy cosmic-ray neutrons above soil level to detect moisture as deep as 0,5m over a 34ha footprint. It is understood that soil moisture estimates are useful for predicting weather, modelling climate and mitigating disaster. The development of the probe has enabled the measurement of soil water at big enough scales to validate weather modelling. A cosmic array network is expected to improve the quality of soil moisture data used by the SA Weather Service in its national Flash Flood Guidance (FFG) system[22].

Solar Power for Irrigation

The use of renewable energy sources has the potential to decrease the cost of irrigation. A recent study looked at maize production from cultivation and concluded that replacing grid electricity with renewable energy in irrigation significantly reduced costs and environmental impacts of South African maize production[23].

PV-powered water pumping technologies are useful because they require almost no maintenance over the course of the lifetime of the technology. One of the drawbacks of the technology are, however, that initial investment costs are high and sometimes too much to bear for small-scale farmers. If the requirements of the crop are understood and an extensive site survey is done to analyse the working conditions of the system, then cost savings are said to be easier to achieve. The high cost and imported nature of PV technology are thought to be overcome by solar thermal water pumping technologies that have greater possibility of local production, low investment cost, easy maintenance and lower carbon footprint[24].

Aquifer Recharge

Managed aquifer recharge as a water management technology for agriculture has some key advantages, i.e. it reduces evaporation. Managed aquifer recharge is the prime use of water quality management in Atlantis, on the West Coast of the Western Province. The layout of the town allows for the separation of storm water from the residential and industrial areas as well as separate treatment of domestic and industrial wastewater. This permits safe artificial recharge of the various water quality portions at different points in the aquifer, either for recycling or for preventing seawater intrusion[25]. However, aquifers in South Africa are vulnerable to pollution because most usable groundwater is found within 60 metres below the surface and 80 percent of South Africa's aquifers are fractured, making them porous[26]

Waste Water Treatment Technologies

Waste water treatment technologies are an important source of additional water in times of drought. However, in agriculture, due to the volumes of water and the distance from sources of contaminated water required, they are often prohibitively expensive.

a. Desalination

Desalinating water for agriculture is energy intensive and therefore an expensive process. While solar energy can make it less expensive, most solar desalination systems are two independent systems – solar and desalination combined together. These remain still relatively expensive and depend on location, weather and season. Solar/fossil/desalination hybrid systems are more economical and could overcome the intermittence of solar energy. However, additional research is needed on solar/fossil fuel hybrid systems, especially waste heat from decentralised thermal power systems for water and power cogeneration. With the costs being reduced of future solar systems and the development of novel solar technologies solar desalination could be a valid option for future desalination plants[27]

b. Nanotechnology

Nanotechnology is being used as a way to improve membrane technologies in water treatment. The catalytic properties of some nanomaterials have the potential to neutralise chemicals and micro-organisms, making them useful for water resource management in agriculture. Sensors are being developed that use nanotechnology to provide good accuracy and rapid response rates as well as robustness and small size. Nanotechnology also offers the possibility of combining sensing and feedback for example in measuring levels of contamination and treating them.[28]

The adoption of nanotechnology in waste water treatment is costly and the availability of supply is limited. Moreover, the technical and local management of the technology is hard to come by. The environmental, health and safety risks that might arise from the presence of nanoparticles being released into the environment from agriculture are other causes for concern that are raised by researchers.

c. Phycoremediation and Phytoremediation

Phycoremediation is a technology that makes use of algae to remove organic compounds, inorganic nutrients, metals, pathogens, and emerging contaminants from water. Algal species that possesses high photosynthetic growth rates and potential for scavenging various types of contaminants are used[29]. Apart from the expense, the amount of nutrients required to produce sufficient algae in agricultural water are often not present.

Phytoremediation, a technology that takes advantage of rhizospheric micro-organism's of some plants natural abilities to take up, accumulate and/or degrade contaminants from the environment, is seen as a more promising technology, particularly for soil and wastewater clean-up in agriculture. It is aesthetically pleasing, cost-effective and ecologically sound but there is some concern about the contaminants leaking into to the (Barboza, 2015).[30]

3. The Future of Smart Water Agriculture in the Western Cape

All of the smart water technologies discussed in this chapter are theoretically useful to reduce water stress in agriculture in the Western Cape within the next decade. Their overall impact in the end, however, will be largely qualified by four key factors, the affordability of the technology, its geographical viability, how complicated the technology is for farmers to use and the perceived risks that it presents to society at large.

Remote sensing technology in the Western Cape that is available for free for fruit-farmers is a highly effective technology because it is cost effective and easy to use. It provides farmers with free access to satellite information about how well their crops are growing and how much water they are using. Cellular technology, in terms of its application in smart water monitoring and weather forecasting, has the potential to go the same way by providing both large and small farmers with early warning systems to adapt to unforeseen events.

Drones or Unmanned Aerial Devices, on the other hand are a more expensive technology that requires a high level of discernment and training to interpret the data at a farm level. If this can be simplified and made more accessible, it could vastly extended the management capabilities of farmers, enabling them to detect problems not normally visible to the human eye.

A number of intelligent irrigation systems have been devised ranging from the drip system to the soil water sensors, that if implemented can potentially reduce water use significantly in agriculture. Researchers, however, emphasis the need to improve the user-friendliness of these various systems to ensure take up by farmers.

Water treatment technologies in agriculture have not yet taken off, for various reasons. With regards to desalination, the cost of the electricity required to run such plants is prohibitive. The introduction of solar energy desalination has the potential to make this technology much more cost effective within an agricultural context.

Nanotechnology is still perceived as high risk to the possibilities of nanoparticles escaping and contaminating water in farming. The relatively high cost of implementing the technology is another barrier. Similarly, managed aquifer recharge is seen as high risk in South Africa because most are just 60 metres below the surface and are located in fractured porous rock.

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