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



## LITERATURE REVIEW V2.0:
## UAV technologies

USB
University of Stellenbosch Business School

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# 1. Technology Overview and Detailed Description

Unmanned aerial vehicles (UAV's), sometimes termed drones, are part of unmanned aerial systems (UAS) with the latter referring also to the ground control and communication units, launching systems, software, apart from only the aircraft[1]. A UAV is an aircraft without an on-board human pilot, controlled either autonomously or by remote control. However, all remote control aircrafts are not drones/UAV's – and some writers define the former as a toy and the latter as a tool[1].

The Civil Aviation Authority of South Africa (SACAA) goes further to also define the difference between remotely piloted aircrafts (RPAS), toy aircrafts and model aircrafts: RPA means an unmanned aircraft which is piloted from a remote pilot station, excluding model aircraft and toy aircraft. "Toy aircraft" means a product falling under the definition of aircraft which is designed or intended for use in play by children and "Model aircraft" means a non-human-carrying aircraft capable of sustained flight in the atmosphere and used exclusively for air display, recreational use, sport or competitions[2]. While private use ("hobby laws") have less rules to follow, the process for commercial operations is much more complicated. SACAA views any drone/UAV flying in the sky as an aircraft, which need to abide by the same law as manned aircraft.

As a commercial pilot, a commercial drone pilot must go through certification and exams. Firstly, a Remote Pilot License (RPL) have to be acquired, secondly an Air Service License (ASL) from the department of transport and then a Remote Operators Certificate (ROC) from the SACAA[3].

Although the concept of drones is nearly a century old, with the history of drones beginning as early as World War I, they weren't developed in earnest until the 1970's, when western militaries began to look for new ways to keep their human pilots from harm[4]. According to the Association for Unmanned Vehicle Systems International (AUVSI), a non-profit group that advocates the expanded use of drones in a variety of industries, "UAV's can fly over fields to perform crop-dusting duties, and also take pictures or video to track plant growth. Robots can also perform more delicate procedures, such as picking fruit or harvesting." They point out that aerial drones are not only able to cover six to seven times more area than a tractor in the same amount of time, but they can avoid challenges like soil compaction, erosion, and crop damage that comes with conventional mechanisation[4].

A very detailed description of UAV's as part of UAS, with details on the origin of terms, as well as an exhaustive history can be found in the Wikipedia UAV reference[5]. Furthermore there are some very detailed reviews on the use of UAS in Agriculture such as by Zhang and Kovacs[6].

Reports such as the Goldman Sachs profiles in innovation (Drones flying into the mainstream)[7] outline the general use cases of UAV's in commercial, civil, consumer and military applications as well as some perspectives on areas of growth of markets related to UAV's.

## UAV's in Agriculture

According to Mr Alan Winde, Western Cape MEC for economic opportunities, Elsenburg farmers in the Western Cape have found valuable ways to use drone technology in their farming efforts, and the technology can accelerate change in the agriculture sector[8]. At Elsenburg drones are used to conduct general monitoring flyovers, assess vegetation health, track animals and assess stress in crops. This has led to an upskilled workforce and savings in business costs. Elsenburg drone expert, Arie van Ravenswaay said that drone technology was leading to efficiency gains. "By giving farmers overview imagery in a very short space of time, and by allowing them to become more targeted, they're using less chemical fertilisers, resulting in reduced input costs and better margins. We have also seen farmers upskilling their employees into agri-technicians. A farmer from Laingsburg told me that he has already saved R20 000 in diesel by using his drone to check his water point, instead of using his vehicle."

Many large agribusiness firms have already linked themselves to UAV manufacturers through acquisitions or partnerships, and will promote business for those manufacturers. Drones have many advantages over piloted/satellite surveys, such as improved accuracy/resolution, frequency, and turnaround time. The latter is important as acute crop pressures differ at different stages in the growing season. While drones can provide spraying services, we expect this to be a more niche application, as the weight required to support pesticide tanks would likely put drones over the weight limit as i.e. currently enforced for unmanned flight in the US. Furthermore this puts a lot of extra demand to the battery systems, which at this stage prohibits effective and practical use in spraying, as it also makes the equipment much more expensive.

In terms of drones in a service model versus individual farm ownership, it is likely that these will co-exist for some time, however the current trends in precision agriculture suggest that drones-as-a-service will be more prevalent[7]. In terms of farm-level ownership the mapping/scouting services are typically needed only during the growing season and are most effective when land is surveyed on a weekly basis. Larger farmers may therefore decide to buy UAVs for their farm to survey as often as needed. A service model where UAVs are rented out and operated by third-party service providers may be more viable for smaller farms.

Goldman Sachs estimate the global agricultural drone market to be worth $5.9 bn[7].

## Types of UAV's

Although UAV platforms are classified by either functional categories related more to military use, functional range or size[5], the most common type classifications include fixed wing systems, multirotor systems and single rotor systems (helicopters). Power sources include batteries for smaller systems, petrol or even jet-fuel engines, as well as more recently hydrogen fuel cells[9]. UAV's also differ in terms of its software, position systems as well as type of autonomy[5].

## Surveying, digital elevation map (DEM) creation for farm planning applications

Drones can be useful at the start of the crop cycle to produce 3D maps for early soil or terrain analysis, which is useful in planning of fields in terms of planting and seeding patterns. After planting, drone-driven soil analysis can provide data for irrigation and nitrogen level management[10]. High resolution DEM's are very useful in farm planning, erosion monitoring, and further analysis in geographical information systems (GIS), and this can be achieved with relatively inexpensive drones[11].

## Remote sensing of soil, plants, animal behaviour

Apart from the obvious cost and availability considerations setting it apart from conventional aerial surveys, drones also enable imaging below cloud cover as well as higher capturing resolution, at an "on-demand" frequency.

*Crop vigour monitoring*

Especially on large farms, crop monitoring poses significant challenges for the farmer. These challenges are exacerbated by increasingly unpredictable weather conditions, which drive risk and field maintenance costs. Previously, satellite imagery offered the most advanced form of monitoring, but with the drawbacks of advanced image ordering, limited turn-around (revisit) times, and low resolution. Further, services were extremely costly and image quality were reduced on cloudy/foggy days. Today, time-series animations can show the precise development of a crop and reveal production inefficiencies, enabling better crop management[10].

*Irrigation*

Drones with hyperspectral, multispectral, or thermal sensors can identify which parts of a field are dry or need improvements. When the crop is growing, drones allow the calculation of vegetation indices, which describes the relative density and health of the crop, and show the heat signature, the amount of energy or heat the crop emits[10].

*Crop health assessment*

Different applications of crop health assessment are possible with drones. Apart from spotting bacterial or fungal infections, plant health (see the section on crop vigour monitoring) can be assessed which may also point to root problems or even virus infection. Speedy response can save an entire orchard, and precise detection can also lead to less chemical inputs if a farmer need to intervene. In the unfortunate case of crop failure or damage (also with incidence of hail or frost), another benefit is that the farmer can document losses more efficiently for insurance claims[10].

*Livestock/wildlife management*

Apart from counting and monitoring of animals[12], UAV's can be extremely important measures in anti-poaching campaigns, especially where they can be equipped with night vision video cameras. In larger wildlife management areas, UAV's are also used with wireless sensor networks to monitor animal movement and behaviour[13]. Distant water points and livestock that require checking up on can be handled by sending a UAV (during the day or night) to check all is in order[14].

## Mechanisation considerations for UAV's

*Crop seeding/planting*

Start-ups have created drone-planting systems that achieve an uptake rate of 75 percent and decrease planting costs by 85 percent. These systems shoot pods with seeds and plant nutrients into the soil, providing the plant all the nutrients necessary to sustain life[10].

*Crop spraying*

Japanese farmers have been using Yamaha's R-50 and RMAX unmanned (petrol) helicopters to dust their crops since 1987, and some farming initiatives in the USA use UAV's for crop spraying, as they are often cheaper than a full-sized helicopter[5]. Distance-measuring equipment, ultrasonic echoing and lasers such as those used in the light-detection and ranging, or LiDAR, methods enables a drone to adjust altitude as the topography and geography vary, and thus avoid collisions. Consequently, drones can scan the ground and spray the correct amount of liquid, modulating distance from the ground and spraying in real time for even coverage. The result: increased efficiency with a reduction of in the amount of chemicals penetrating into groundwater. In fact, experts estimate that aerial spraying can be completed up to five times faster with drones than with traditional machinery[10].

## Other applications

UAV's are also becoming invaluable tools for farmers in other applications, such as monitoring livestock (along with for instance RFID sensors/collars), dam water levels[5] as well as in farm security, which is an extremely important and sensitive issue in South Africa[15].

# 2. Application Examples and Case Studies

A range of general applications of drones can be found in the Goldman's Sachs report – the agricultural applications have already been discussed mostly in the previous section.

# 3. Technology or Application Life Cycle: Current Status and Expected Development in 2020 and 2025

Depending on the country of application, UAV technologies are currently in the early adoption phase for agriculture, perhaps early majority in some countries (i.e. US). The technology may now be nearing the state of the art phase, but in some use cases (i.e. soil remote sensing) it is still in R&D phase. It is therefore clear that the technology phase is determined by the context (country of application, legal framework etc.), but also by the type of application. With regards to general surveys with RGB and IR imaging, the technology is already very advanced.

Perhaps considerations in the distant future could include viability of large-scale spraying technologies, with soil scanning as well as yield detection using other sensing systems (i.e. low energy microwave or millimetre wave technology). Agri-tourism may also enter a revolution where the consumer can visit a farm where their food is produced through virtual reality. Perhaps the digital marking of crops or livestock could enable a consumer to trace a product right back to its origins . . .

Drones may also change the way weather sensors are operated if superlight drones can be made to stay in the atmosphere for long (even unlimited) times powered by fuel cells and solar energy. This may enable localised and real-time weather data on farm level.

**Table 1: Heading**

| Technology Area | Current application in agriculture | Expected applications in agriculture by 2020 | Expected applications in agriculture by 2025 |
|---|---|---|---|
| UAV's | Handled in text | Handled in text above | In text above. |

## Business Eco-system View

UAV's require sensors for operation, and provide important outputs for precision farming/smart farming systems. Refer to Figure 2 in the sensors literature review for a view on how sensors slot in with drone functioning, as well as Figure 1 below, where the positioning of robotics/autonomous vehicles are shown in the context of smart farming/precision agriculture.

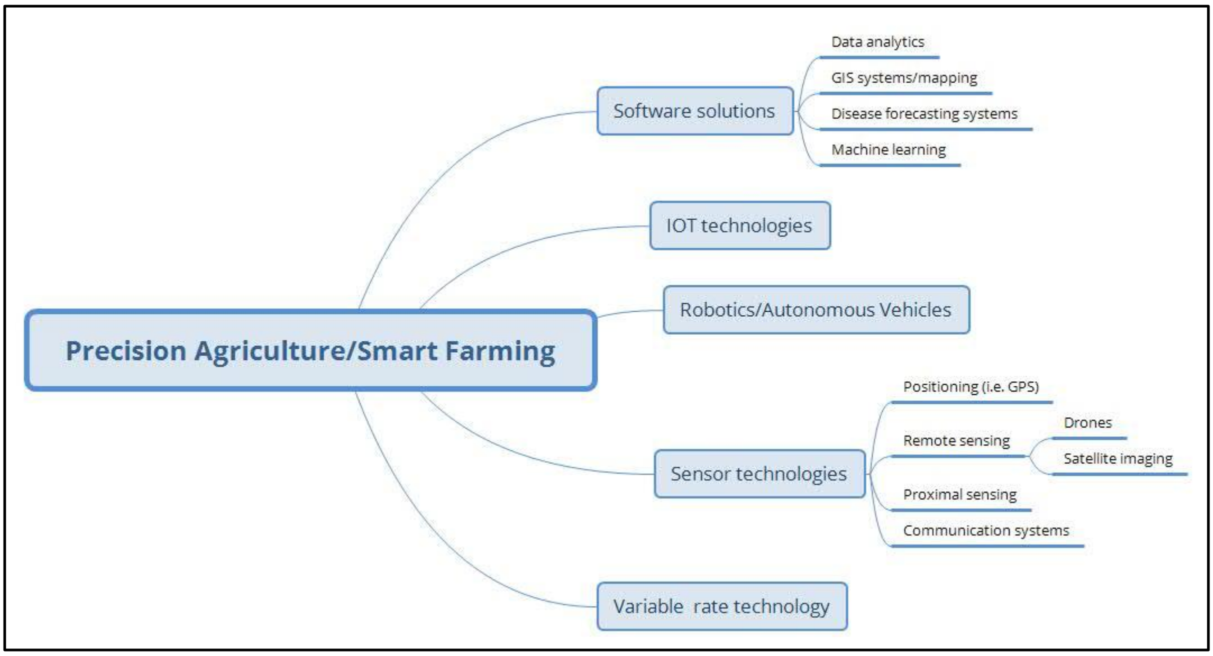


**Figure 1: Some key components of precision agriculture/smart farming**

Drones are the latest addition to precision agriculture technologies, which historically relied on satellites or airplanes for imaging, but those methods were expensive and often unreliable due to cloud cover at time of surveying.

3D Printing can be used to print components of UAV's which is particularly useful in South Africa, where the alternative could be relatively expensive part imports.

## Benefits and Risks

*Benefits*

Drones have many advantages over piloted/satellite surveys, such as:

- improved accuracy/resolution
- improved frequency and turnaround time due to easier/quicker deployment in some cases
- costs can be more than half that of an equivalent aerial survey
- in some cases (i.e. sterile moth dispersal where aeroplanes need to fly very low to be effective) it can have safety benefits.
- Compaction is minimised compared to using a tractor/quad for surveys

Apart from the many possible benefits of, there are also issues that slows its uptake in precision agriculture.

*Risks/issues*

- The obvious risks link to safety/legal barrier issues, which in turn brings business risks related to the cost of operation/licensing, insurance coverage issues, etc. Many safety risks can be associated with drone applications, including air traffic issues, malicious use (i.e. terrorism or privacy invasion), wildfire fighting obstruction and others[5]. Although many countries including Ireland, the Netherlands, Canada, Italy, France etc. has implemented UAV regulations, the USA is often considered one of the most restrictive countries when it comes to the use of UAV's[5]. From 2014, the South African Civil Aviation Authority also introduced strict requirements for the commercial operation of UAV's in the country. Although this authority says that obtaining a drone license is not onerous, an article published by the Mail & Guardian in August 2016[16], outlined the very restrictive bureaucracy, paperwork and costs involved when these licenses are needed, pointing out that it can cost up to R65 000 if a consultant prepares an application pack, and over R30 000 for a remote pilot's license. In Africa, the major challenge to using drones in agriculture are the regulations governing their usage. These regulations are generally controlled by military and civil aviation authorities due to the sensitive nature of airspaces where UAVs operate. Currently only seven countries in Africa have regulations regarding drones. These include Cote d' Ivoire, Kenya, Botswana, South Africa, Nigeria, Rwanda and Ghana. In fact, the regulations in Kenya prohibit the use of the UAVs[17].
- Privacy and data ownership issues
- The type and quality of data that can be captured - to address this, the industry will push for more sophisticated sensors and cameras, as well as look to develop drones that require minimal training and are highly automated[10]. To provide a reliable end product to farmers, advances in platform design, production, standardisation of image georeferencing and mosaicing, and information extraction workflow as well as an effective and user friendly front-end are all crucial elements[6]. It has been suggested that such endeavours should involve the farmer (or we could argue at least the agricultural consultant), particularly in the process of field design, image acquisition, image interpretation and analysis[6].

# 4. Potential Economic, Social, Ecological and Political Developments and Impacts

# 5. Evaluation Matrices

Separate document

# 6. Synthesis, Conclusions and Key Trends from the Literature

Except for UAV’s disrupting industries the commercial (construction, insurance, journalism, real estate, utilities, mining, clean energy, cinematography etc.), consumer (racing, recreation etc.), civil (police, fire, coast guard etc.) and military areas, agricultural UAV applications may be the largest US drone growth area and second largest globally.

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