

# ICT Update

a current awareness bulletin for ACP agriculture



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Drone technology has accelerated the planning, design and construction of rice irrigation systems in Nigeria.

Indigenous communities use drones to document illegal occupations on their territories and to safeguard natural resources.

The five steps of making your own digital map for agricultural purposes with small drones.



# Drones for agriculture

## Contents

### Drones for agriculture

- 2** Drones on the horizon: new frontier in agricultural innovation  
*Faine Greenwood*
- 5** Sri Lanka's drone pioneers  
*Salman Siddiqui*
- 6** A bird's eye view on Africa's rice irrigation systems  
*Quan Le*
- 8** Preventing the spread of desert locust swarms  
*Keith Cressman*
- 10** Drones detect crop stresses more effectively  
*William Allen*
- 12** Insuring Indian farmers more effectively  
*Ruchit G Garg*
- 13** INTERVIEW  
'UAV-based remote sensing will be like using a cell phone today'  
*Roberto A. Quiroz*
- 14** The challenge of comparing crop imagery over space and time  
*Ola Hall and Maria Francisca Archila Bustos*
- 16** Documenting illegal land occupancy from the air  
*Nina Kantcheva Tushev, Tom Bewick and Cameron Ellis*
- 18** Transforming smallholder farming through remote sensing  
*Raul Zurita Milla and Rolf A. de By*
- 20** Counting coconuts with drones  
*Ephraim Reynolds and Faumuina Felolini Tafuna'*
- 22** Making sense of drone regulations  
*Cédric Jeanneret*
- 24** BOOKMARK  
Five steps of making a map with small drones  
*Walter Volkmann*
- 26** RESOURCES
- 27** DISPATCHES  
Drones and dogs work together to save avocado crops  
*DeEtta Mills and JoAnn C. Adkins*

### ICT Update



ICT Update issue 82, April 2016.

ICT Update is a bimonthly printed bulletin with an accompanying web magazine (<http://ictupdate.cta.int>) and e-mail newsletter.

The next issue will be available in September 2016.

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Translation: cApStAn

Cover photo: Luke Wijnberg, 3DroneMapping, South Africa

Publisher: Technical Centre for Agricultural and Rural Cooperation ACP-EU (CTA), Wageningen, The Netherlands

Sponsor: Esri, Redlands, USA

With thanks to FAO for distributing ICT Update through e-Agriculture ([www.e-agriculture.org](http://www.e-agriculture.org))

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## Guest editor

# Drones on the horizon: new frontier in agricultural innovation

Drone technology could help farmers around the world monitor their crops, fend off pests, improve land tenure, and more. But to realise its full potential, regulatory regimes are necessary, while keeping citizens' safety and privacy rights secure.

Three years ago, the average person had no idea what a drone was – or associated these flying machines with weapons of warfare. Things have changed. Now, unmanned aerial vehicles, or UAVs (also known as drones) have become one of the world's most publicised and intriguing technologies, used by people in a wide range of professions, from journalism to humanitarian aid work.

Farmers have always needed accurate and up-to-date information on the health of their crops and the environmental condition of the land. Agricultural aircraft have been in use since the 1920s, while agricultural experts increasingly use satellites to assess crop health from the sky. UAVs are a natural progression from macro to micro, from large-scale to small-scale farms.

While UAVs are unlikely to entirely replace manned aircraft or satellites, they have a number of advantages over these more traditional remote-sensing methods. The technology is capable of collecting very high-resolution imagery below the cloud level, with much more detail than the satellite imagery usually available to developing country analysts. They are easy to use: most drone mapping and data-collection missions are now conducted autonomously, meaning that the drone essentially flies itself, while drone data processing tools are becoming less expensive and easier to use.

Perhaps most importantly, drones are inexpensive. In 2016 it is possible to purchase a useful mapping UAV for less than \$1,000. And surprisingly powerful mapping drones can be built at home for even less. While

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*The international drone market has grown considerably in the past few years, building on their demonstrated usefulness to agriculturalists and others.*

processing software can be expensive, open-source and lower cost options exist. Thanks to these low barriers to entry, UAVs are expected to provide significant help to farmers in developing countries, who historically have found it harder to access aerial imagery, either from manned aircraft or from satellites.

### The multiple purposes of UAVs

But what can a farmer actually *do* with a drone? There are many possibilities, some of which are described in this magazine. On the most basic level, drones permit farmers to get a big picture view of their crops, allowing them to detect subtle changes that cannot be readily identified by "crop scouts" at the ground-level. UAVs equipped with special sensors can inexpensively collect multispectral Neutral Density Vegetation Index (NDVI) and infrared (IR) images, permitting farmers to view crop changes that are otherwise invisible to the human eye. This aerial data can also be used to speed up the painstaking process of conducting crop inventories and yield estimates – such as the palm tree counts and coconut oil yield estimates in Western Samoa that are described later in this magazine.

Crop insurers and insurance policy holders also benefit from readily-available and easily repeatable drone imagery: in India, insurers plan to use UAVs to conduct assessment of crop losses after natural disasters, allowing them to more accurately and quickly calculate pay-outs, while large US crop insurers like ADM have begun running their own drone tests.

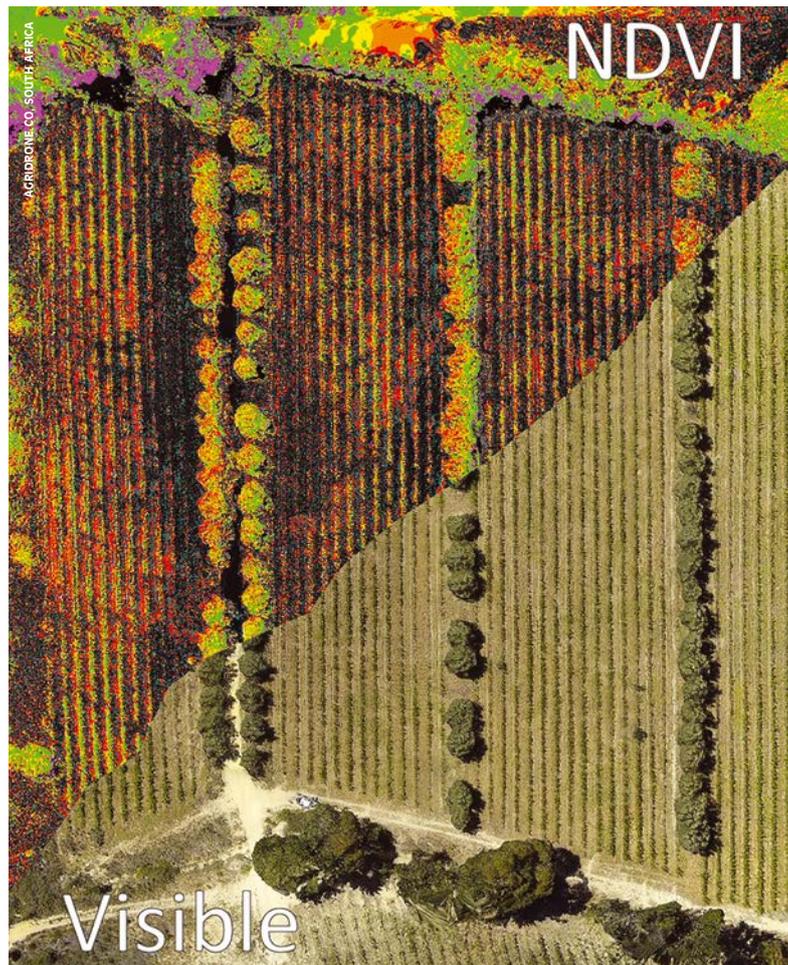
Drones also have proven useful to agricultural planners, greatly reducing the time and cost required to conduct an accurate survey. UAVs can be used to conduct volume estimates, to create irrigation and drainage models, and to collect the data needed to generate high-definition, geographically accurate elevation models and maps. In an example described in this issue, a team tasked with planning a Nigerian rice farm used drone imagery to make decisions on the layout of both rice paddies and irrigation and drainage systems – and, thanks to the drone imagery, were able to quickly determine that their original design was poorly suited to the terrain that was actually available to them.

### Empowering local communities and fighting pests

Ranchers and fishery managers are beginning to experiment with the technology, hoping to take advantage of UAVs' ability to cut down on the time and expense of conducting patrols and reconnaissance work. Cattle ranchers with a lot of land to cover have used drones to determine where their livestock is, and some have found UAVs useful for conducting regular surveys of fencing. Long-range surveillance drones are being experimented with as a method of deterring and apprehending illegal fishing vessels in protected waters.

The technology also has the potential to empower indigenous communities to document illegal occupations of their territories and natural resources – as is described in this magazine. With UAV-gathered imagery of illegal logging and land occupancy government agencies can prioritise and speed up their inspection efforts, ensuring that a week-long field inspection will collect enough evidence to justify government intervention.

UAV technology may even be useful for fighting agricultural pests. The FAO has begun to investigate how drones may be used for detecting and eliminating locusts before they begin their destructive journeys – as can be read in this issue. In the US state of



Split-image from an organic wine vineyard in South Africa. Using NDVI sensors, vegetation shows up in colour from red to green, with green being healthy, red being an indicator of stress.

Florida, researchers are using sniffer dogs and UAVs to detect the redbay ambrosia beetle, an invasive pest that kill avocado trees.

### A growing market

The international UAV market has grown considerably in the past few years, building on their demonstrated usefulness to agriculturalists and others. An August 2015 study from Grand View Research estimated the global commercial drone market size to be \$552 million in 2014 – and its grow to \$2.07 billion by 2022, with agriculture dominating other drone sectors. Other researchers have made similarly optimistic predictions for the growth of the agricultural drone industry.

While North America currently produces the most UAVs in the commercial industry in general and in the agricultural sector in particular, many analysts predict the European market is close behind it in both. Demand (and production) in the rest of

the world, including ACP countries, currently lags behind North America and Europe, but particular growth is expected in Asia-Pacific and the Middle East, per a recent report from research firm Markets and Markets.

Numerous multinational corporations are major players in the commercial UAV industry, including Lockheed Martin, DJI, AeroVironment Inc., General Atomics, Israel Aerospace Industries, Parrot SA, and others. Other companies focus on UAV-specific services, including imagery processing, agricultural analysis, flight planning and drone-to-drone communication, and more. In developing nations, UAV service providers often will purchase a drone from a large manufacturer and then provide different mapping and analysis services as a small business – further decentralising the market. Some budget-minded small drone service providers build UAVs themselves from component parts. While UAVs are indisputably a promising technology, there are still

a number of obstacles to surmount before they become a standard part of the farmer's toolkit.

### Demand for regulations

The largest barrier to drone's wider adoption in the agricultural industry is regulatory, as nations grapple with the problem of keeping UAVs legal while securing air safety and privacy rights. Although some nations, such as South Africa, have already introduced detailed regulatory regimes, many others have no regulations at all. Countries like India, Nepal, and Kenya, have introduced strict restrictions or bans – meant to be lifted at a later, yet-to-be-determined date. In this magazine, after completing on behalf of CTA an ACP-wide study on the subject, Cédric Jeanneret provides a more comprehensive overview of the international state of drone governance and regulations. The rule-making process is ongoing around the world, on the local, national, and international level. One such international effort is represented by JARUS (Joint Authorities for Rulemaking on Unmanned Systems), an experts group whose members include regional aviation safety organisations and various national aviation authorities (NAAs). JARUS works to suggest a single set of operational, safety and technical requirements for certifying UAVs and integrating them into airspace – which can then be used by each participating nation to craft their own UAV regulations.

Some drone-watchers are concerned that regulators will impose restrictions that are too onerous or too expensive for small-scale farmers to meet. Advocacy groups, like AUVSI (Association for Unmanned Vehicle Systems International), work to popularise the technology with the public and with policy-makers, with a goal of keeping the civilian use of UAV technology legal.

### Capacity building

Awareness and education – or a lack thereof – present another barrier to the adoption of UAVs in the developing world. While drones are relatively easy to use, farmers will still need local-language training and technical support before they get started, as well as up-to-date information on the technologies legal status in their country.

Technical challenges present another barrier to the widespread adoption of UAV technology in less-developed

countries. UAV operators need adequate access to electricity (for charging batteries) and the ability to obtain or craft spare parts. Processing drone data is another challenge: producing maps, 3D models, and other useful data outputs requires considerable computing power, or Internet and mobile data that's quick enough to access cloud-computing services.

Drone operators, farm workers, and aid workers alike will need to develop methods of keeping UAVs functional in more remote areas.

## *Drone operators need adequate access to electricity (for charging batteries) and the ability to obtain or craft spare parts.*

### A bright future

It's difficult to predict the future of UAV technology in agriculture, but there are many promising trends and pilot projects. Analysing UAV data is likely to become increasingly automatic, as intelligent computer systems become capable of identifying different crop varieties, automatically categorising and mapping weeds, and swiftly assessing crop damage from pests. Automated analysis may also make wide-scale agricultural mapping a less lengthy process, helping analysts more accurately detect signs of impending famine or crop failure.

More intelligent UAVs can be used for precision crop spraying, enabling farmers to use chemicals in smaller amounts and minimising human contact with dangerous substances. UAVs may also be used for "search and destroy" pest control missions, identifying then wiping out particularly bothersome insects. The technology could be used to quickly determine the distribution of livestock, enabling veterinarians to quickly find animals that may be infected with ailments like foot-and-mouth disease (FMD) – or enabling farmers to swiftly identify the movements of larger crop pests, from wild boar to elephants. Yet more uses for drones are likely to be dreamed up in the near future.

UAVs may have the power to help farmers around the world monitor their crops, plan their farms, fend off pests,

and more. To realise its full potential, actors along the agricultural value chain and lawmakers should work together to come up with ethical – but reasonable – regulatory regimes that keep UAVs legal, while keeping individual citizens' safety and privacy rights secure. At the same time, development agencies should press forward with experimenting with UAV technology, pushing for a world where aerial imagery is available to all farmers. ◀

### Drone Terminology

Unmanned aircraft are referred to in many different ways. The word "drone" originates from the military, but is now widely used to describe civilian technologies. International standards and rules, notably those set by the International Civil Aviation Organization (ICAO) and the European Commission, refer to "unmanned aerial vehicles" (UAVs) as part of a broader category of unmanned aircraft that can be programmed to fly autonomously. The official terminology in civil aviation laws is "remotely piloted aircraft systems" (RPAS). "Unmanned aircraft system" (UAS) is also used by some regulators, such as the US Federal Aviation Administration (FAA).



### About the author

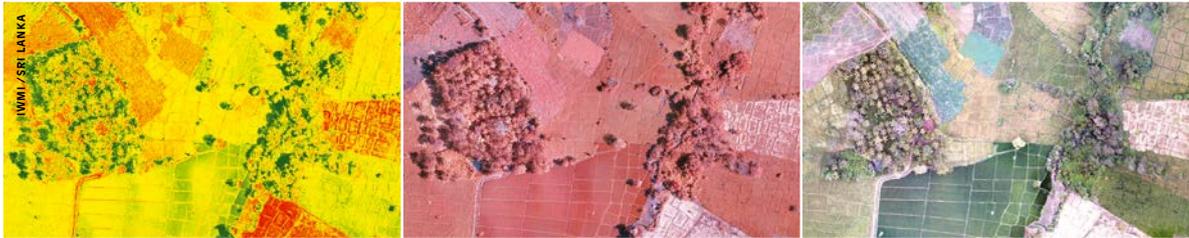
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### Related Links

UAV market information.  
→ <http://goo.gl/6nGR9C>  
Commercial UAV market analysis.  
→ <http://goo.gl/ktJBTe>

# Sri Lanka's drone pioneers

The International Water Management Institute in Sri Lanka has begun to experiment with drone technology to support a wide range of studies like crop monitoring, disaster mitigation and disease prevention.



The image in the middle captured using Near-Infrared (NIR) sensors shows different shades of red, which can be interpreted and represented in the image on the left: 'green' represents crops as being well, 'yellow' as being in stress, and 'red' as being highly stressed.

In recent months, the Colombo based International Water Management Institute (IWMI) has begun to use unmanned aerial vehicles (UAVs) – also known as drones – to monitor rice crops in and around the water scarce area of Anuradhapura. The institute is testing the data-collecting capabilities of UAVs for various purposes. For example, RGB (red, green, blue) colour and near-infrared (NIR) sensors were used to capture images over the paddy fields. These technologies have the potential to help farmers detect fields that are under stress and to help them identify low-laying areas prone to pooling.

IWMI's drone is also regularly used in partnership with local authorities. In December 2015, the Survey Department of Sri Lanka was developing a disaster mitigation plan for Badulla, the capital city of Uva Province. The Survey Department needed a high-resolution Digital Elevation Model (DEM) of the town for the plan, and asked IWMI to use its drone to capture the required aerial imagery.

Using conventional techniques, it might have taken over a year to survey the town. However, the drone used by the IWMI team was able to survey the entire 10 square kilometres area in just three days, by carrying out fourteen UAV flights and shooting 4,600 high-resolution images, with an average spatial resolution of four centimetres.

## Disease prevention

Drone imagery can also be used to better understand the spread of disease, allowing health analysts to create high-quality maps. Chronic Kidney Disease of Uncertain Aetiology (CKDu) is one of the most serious non-communicable diseases presently afflicting Sri Lankans,

and it remains poorly understood. First diagnosed in the mid-1990s, the disease has now been found to occur in six out of the nine Sri Lankan provinces. It is essentially confined to the dry zone and only affects farmers engaged in rice cultivation. CKDu is believed to have resulted in the death of approximately 25 thousand people to date, while over 8 thousand people are currently estimated to be receiving treatment for the condition.

In the CKDu-affected area of Mahiyangana, the disease is believed to be spread via contaminated drinking water, which originates from wells. The UAV has been used to gather geo-referenced data on where households live and where wells are located. The collected data can be used in addition to a digital elevation model to locate the high and low areas of two villages, Sara Bhoomi and Badulupura.

The gathered data has been used in support of a pilot project on prevention of CKDu in the area. According to project leader Ranjith Mulleriyawa, these aerial photos and maps have provided researchers with an improved overall picture of the area, helping them understand how contaminated wells are linked to the spread of CKDu in affected areas.

## High accuracy

IWMI also plans drone initiatives in Nepal to map fresh water springs by using a small thermal sensor. The targeted watersheds in Nepal have dense canopy cover, and it is difficult to use standard optical sensors to identify and locate the springs. The drone-mounted thermal sensor can see through the dense canopy cover to find these springs, as their temperature is

lower than the temperature of the earth surrounding them.

While the use of UAVs in research and other practical applications remains in its infancy, IWMI's initial tests have already demonstrated their usefulness. Drones can be used to carry out surveys over large and hard-to-access areas, in a relatively short timeframe and with high accuracy. For policy experts and decision-makers, these aerial images can provide them with more accurate and up-to-date information than has hitherto been possible. For farmers, high-quality drone images can help them detect potential crop failure early, giving them enough time to respond.

IWMI thinks that UAV based surveys will be especially useful in studies that require highly accurate and repeated monitoring. These include checking for changes in cropping patterns, shifts in the status of important water resources, and documenting the extent of environmental disasters. It doubtless won't be long before farmers routinely use UAVs to monitor their crops, just as they use more conventional machinery to sow and harvest. ◀

## About the author

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## Related links

Website of the International Water Management Institute.  
→ <http://www.iwmi.cgiar.org/>

# A bird's eye view on Africa's rice irrigation systems

Drone technology provides agriculturists with a cost-effective method of infrastructure planning. In Nigeria it has accelerated the planning, design and construction of rice irrigation systems.



## Drones for agriculture

**A**s the drone reappeared in the sky and lowered its altitude in an attempt to land, the research team's driver Richard, who had been volunteering to help out with the mission, ran towards the unpiloted plane in jubilation. 'You're welcome!' he said enthusiastically in both English and Hausa, the language that is spoken in northern Nigeria.

The growmoreX team of the London based company GMX Consultancy, which runs a drone-based farming application service, was in Nigeria to do a preliminary assessment for the development of a 3,000 hectares irrigated rice farm. The farm will be built on land that was acquired in a long term lease from the local government's irrigation authority. The aim of the project was to survey and map a total of 7,500 hectares in preparation of planning and building the irrigation

infrastructure for the rice fields.

Although a manned aircraft could have done the job, it also would have cost a fortune. The alternative is unmanned aerial vehicle (UAV) technology. The project site was in a sparsely populated area, located approximately 75 kilometres from the town New Bussa, some 700 kilometres away from the capital Abuja with limited access to roads, electricity, clean water, and other amenities. Local livelihoods here are mainly based on small-scale agriculture. Crops are grown annually during the rainy season, and include sorghum, rice and beans. Tomatoes are grown during the dry season using pump-fed irrigation.

### First flight

A fixed-wing UAV, which was imported directly from the US with assistance from a local project partner, was used

for the first flight. It took a day to assemble it. That gave the team time to sort out technical hiccups and figure out how to use its automatic mission planning function. The activity attracted attention from local villagers, who had already been informed about the forthcoming agribusiness development.

When all the checks were completed, the team set the UAV's navigation system to 'automatic'. Then the UAV's propeller was turning and it was launched into the air, witnessed by a crowd of people who had gathered to watch the first flight. The mission had begun.

Although the UAV had made it into the air, it suddenly began to fly away instead of starting its pre-programmed mission – likely due to the direction of the wind. The team lost telemetry communication with the drone, and it

was thought that the UAV had crashed.

Suddenly, the radio established a connection with the UAV again, and it finally began its automatic mapping mission. It took the UAV only a few minutes to reach the optimal surveying altitude of 150 metres above ground level. Once at this altitude, it began to fly in a specific pattern, shooting images automatically as it went.

### Advance planning

After the UAV landed safely the camera was checked immediately. The photos looked sharp and beautiful. There were a lot of them: during the 55-minute flight, the drone took overlapping photos of nearly 300 hectares of land.

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*The Emir insisted that we do a flyover of his village, so that his people could see both the drone and the pictures it would take.*

The UAV was able to fly for roughly four hours a day when the sun cast the fewest shadows. This meant that the team was able to map about 1,000 hectares in a single day. That is fast, especially if the harsh terrain and working conditions with high temperatures are considered. Estimations assume that it would have taken a professional surveyor working on foot about twenty days to cover the same area.

To operate an UAV requires advance planning. The researchers made sure no specific regulations barred the team from using the UAV. The local Emir, the village chief and a military airport located about 100 kilometres from the project site were informed of the plans to make use of an UAV. Fortunately, the local authorities welcomed the new technology. There was only one condition: the Emir insisted that we do a flyover of his village, so that his people could see both the drone and the pictures it would take.

The village flyover had an unexpected result. For the first time the team could establish exactly how many houses and dwellings there are in the village, thus enabling researchers to make a much better estimation of its population. This information will be very useful, because the research team is planning

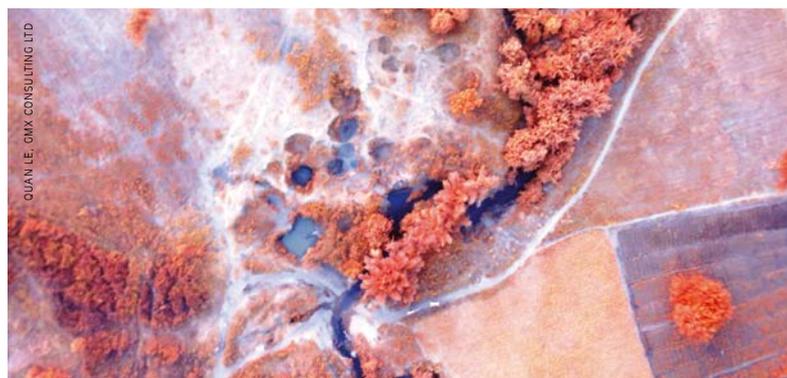


Image of the farm in Nigeria created by using a NDVI sensor – NGB Converted Canon S110 Camera (2015).

to hire local labour to build the rice farm and to run it.

### The hypothesis was proved wrong

Wonderful as the village flyover was, the main objective was to begin planning the rice farm's irrigation infrastructure. For the preliminary investigation, the researchers needed to create a map at a scale of 1:2,000 (1 centimetre on the map represents 20 metres). With such a map the research team could make informed decisions on the best layout of the paddy fields, the irrigation and drainage systems.

Based on the limited information from previous visits to the site, it was hypothesised that it would have been able to lay out the rice fields as large, rectangular basins. Large earth moving and farming machinery would have been needed to build and cultivate those basins. Paddy fields for rice cultivation need careful water management as water levels impact weed and nutrient distribution. This meant that for every 100 metres, half a metre of soil at the top of the field had to be removed to raise its lower end during the levelling process.

However, the drone survey proved the hypothesis wrong. Although it was certainly true that parts of the project site were flat, most of the terrain was an undulating landscape.

The sloping terrain combined with a thin top soil layer led the team of researchers to radically change their designed hypothesis, away from large rectangular basins and towards long, narrow fields that would follow the terrain. But this change also meant that a very different irrigation system design was necessary.

### Avoiding unnecessary costs

By using data required from UAV technology, agricultural planners can

now easier avoid incorrect infra-structural planning. This information also makes it easier to organise the right procurement of machinery, avoiding unnecessary large upfront investments that can break a project if they are improperly planned.

Water is the deciding factor in Africa's rice self-sufficiency. Most rice cultivation is rain-fed in Africa. The lack of irrigation infrastructure is a major obstacle to increase rice production on the continent. Most of the existing systems are poorly designed, built, and maintained.

The good news is that UAV technology can potentially accelerate the planning, design and construction of Africa's irrigation infrastructure. As this project has shown, UAV technology could provide agriculturists with a cost-effective method of irrigation infrastructure planning.

And that is not all. After the farm planning stage, UAVs could be useful for farmers to estimate more accurately how much fertilizer and planting materials they will need during the growing season. Once crops have been planted, UAVs equipped with special sensors can monitor their growth.

With the help of agricultural UAVs, Africa can leapfrog into the quickly-advancing area of precision agriculture – just as African mobile phone companies bypassed traditional fixed line infrastructure to create an innovative mobile finance system. ◀

### About the author

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# Preventing the spread of desert locust swarms

Drones could play an integral role in identifying and preventing desert locust swarms in the fight against this dangerous migratory pest.

## Drones for agriculture

**T**he desert locust is the world's most dangerous migratory pest with a voracious appetite unmatched in the insect world. Within the desert locust's range, which is equivalent to 20% of the earth's land surface, the insects annually reproduce, concentrate and then form swarms that can move up to 150 kilometres per day in search of food. These swarms are able to migrate across long distances, and can even jump from continent to continent. A single desert locust swarm the size of Brussels could consume Belgium's entire food supply in a single day.

While desert locust swarms aren't found in the Americas or in Europe, these insects pose a constant threat to food supplies in some of the world's poorest and driest countries, occupying a huge area that stretches from West Africa to the Indian subcontinent. To control these swarms, vulnerable countries use remote sensing technology and ground surveys to identify and eliminate locust breeding areas. Now, some experts think drone technology could provide survey and control teams

with an inexpensive and efficient method of searching for these destructive insects.

### Early warning system

A global early warning and preventive control system against desert locust has been in place for more than half a century, representing the world's oldest migratory pest warning system. Some two dozen frontline countries have created dedicated national locust centres within their government, consisting of well-trained specialized survey and control teams equipped to scour the desert every day in 4WD vehicles to find and treat infestations.

To find insect infestations, these teams rely on their own knowledge as well as on information from nomads. This knowledge is combined with up-to-date satellite imagery indicating rainfall and green vegetation, allowing the teams to identify potential breeding sites and growing locust infestations. The teams record their observations on a rugged handheld tablet, which transmits the data in real

time via satellite to their national locust centre. This information is then passed on to the Desert Locust Information Service (DLIS), based at the headquarters of the Food and Agriculture Organisation (FAO) of the United Nations in Rome, Italy.

The successful prevention of desert locust plagues relies on regular monitoring in the desert, early warning, and timely response. If a local plague is not detected on time it has devastating effects on local livelihoods. For example, it took more than \$500 million and two years to control the 2003 and 2005 locust crises in northern Africa. Some 13 million hectares were treated with pesticides. Cereal losses reaching 100% were reported in some areas, and in Mauritania alone, 60% of household heads became indebted. Education levels dropped in Mali, as children were withdrawn from school due to economic pressure.

While the early warning and preventive control system to manage locust plagues is well-established and

Farmer in a desert locust swarm in eastern Ethiopia in April 2014.



functions on a daily basis to protect valuable food supplies and livelihoods, it is not perfect. Currently, there are three primary limitations that impact this system: the huge and remote desert areas that must be searched for locust infestations; increasing political insecurity, inaccessibility and dangers within these areas; and the safe use of pesticides during control operations.

*Operating both survey and pest control drones need to be simple and intuitive, as users in the field have limited expertise and computer skills.*

#### High-resolution imagery

The operational use of unmanned aerial vehicles (UAVs) – also known as drones – could potentially overcome these limitations in many affected nations. In the field, UAVs could be used to automatically collect high-resolution imagery of green, vegetated areas potentially affected by locusts. Controlled by a rugged, hand-held tablet, the UAV would follow a pre-programmed flight path, covering a 100 kilometre survey radius.

After the UAV finishes its flight, survey teams would be able to use the data to identify areas that seem most likely to harbour locusts, allowing them to travel directly to suspicious locations. Once the team reaches such an area, the UAV could be launched to hover overhead and identify other, nearby locust infestations that may require treatment. A separate control UAV could then be used to administer pesticides directly onto the locust concentrations. UAVs could also be used to check for locusts in areas that are insecure or cannot be accessed by ground teams.

The above scenario offers a number of advantages, as compared to the survey and control methods currently used in locust-affected countries. Ground surveys would become more efficient, since teams would no longer have to roam the desert in a random manner, hoping to come across suspicious-looking green areas or locust infestations. Instead, UAVs would be able to pinpoint these areas, allowing teams to directly travel to them.

Once in the potentially infested area, the UAV would provide a precise



Desert locust survey in action in northern Sudan.

confirmation of the extent and scale of the infestation at that site, which could be several hectares or square kilometres in size. Control operations would become safer and more effective, as human operators would no longer be exposed to potentially dangerous pesticides while eliminating the insects. Pest control operations would also become more effective, since drones would be able to spray infestations precisely, using the correct pesticide dose and methodology.

#### Remaining challenges

While incorporating UAVs into the existing desert locust early warning and prevention system seems to offer advantages, but several challenges remain. First, an UAV needs to be designed with sufficient endurance to cover at least 100 kilometres in one flight, while carrying optical sensors that can accurately differentiate green annual vegetation from bare ground. The drone system should then be able to process and output these results while in the field. Due to battery and spare parts limitations in developing countries, the UAV should be solar powered, and consist of robust yet simple parts that are easily available in local markets.

The UAV should also be able to accurately detect patches or concentrations of locusts within a single site on a reliable basis. A control UAV will need to be able to balance a potentially bulky pesticide payload with a long flight time, in order to treat the largest number of locust infestations within the greatest amount of area.

Operating both survey and pest control UAVs will have to be simple and intuitive, as users in the field may have only limited expertise and computer skills. Lastly, national governments will need to create legal

frameworks that permit the use of drones for locust control operations.

The FAO is currently working with university researchers and private sector partners in Europe to address challenges concerning design, endurance, power, detection of green vegetation and locusts, and in situ data processing in order to incorporate drone technology into national survey and control operations. Initial field trials are expected to commence later this year in Mauritania to test some potential new technology, and to refine and adopt it for eventual operational use in locust-affected countries.

The FAO remains hopeful that within five years, UAVs will play an integral role in protecting food supplies and livelihoods from the desert locust, as part of the fight against global hunger and poverty. It is hoped that this technology and the lessons learned from the desert locust experience can be further modified and adopted for use in combatting other agricultural pests and diseases throughout the world. ◀

#### About the author

Keith Cressman (Keith.Cressman@fao.org) is senior locust forecasting officer at DLIS, FAO in Rome, Italy. He operates FAO's global desert locust early warning system.

#### Related Links

FAO Locust Watch website.  
→ <http://goo.gl/WFgkc7>  
Nasa Earth Observatory – The Reach of the Desert Locust.  
→ <http://goo.gl/nkLmhd>  
FAO's satellite information for locust forecasting webpage.  
→ <http://goo.gl/SnvMVK>

Multicopter-based remote sensing system over farmers fields in Tanzania.



## Drones detect crop stresses more effectively

Drones can someday serve as a low-cost, effective method of monitoring sweet potato crops, which are becoming increasingly important to smallholder farmers.

### Drones for agriculture

**F**lying a specially equipped unmanned aerial vehicle (UAV) – also known as a drone – a team of International Potato Center (CIP) researchers from South America and Africa used remote-sensing technology to obtain data on orange-fleshed sweet potato fields in Tanzania. The joint study ran for two weeks in the spring of 2015. Roberto Quiroz, project leader at CIP-Lima in Peru, where the image-processing and data analyses were completed, explained the added value of UAV technology. ‘The quality of the data taken by the drones was great, and discrimination of land uses and the estimation of the area for each use were achieved with high accuracy.’

The East Africa study was part of a larger project that focused on the use of UAVs for collecting detailed crop information via high-quality aerial imagery, and built on prior work by CIP researchers in Peru. With funding from the Bill and Melinda Gates Foundation, the researchers plan to develop a remote sensing system for agriculture that is designed to fit the needs of smallholder farmers. By using aerial data these farmers can make more informed decisions about when to plant crops and which varieties they should grow, reducing their risk of crop failure and hunger.

### Local scientists’ involvement

The setting for the field study was the rural landscape of the Mwanza region of northern Tanzania, some 200 kilometres west of Serengeti National Park, along the southern end of Lake Victoria. This is where farmers produce more sweet potatoes than anywhere else in Tanzania.

Lima-based CIP team-members, working with experts from Nairobi, used an Oktokoper XL eight-armed UAV to collect data on several farms during the project period, with advance approval from individual farmers. The team gathered aerial data from many sweet potato fields, as well as fields of sweet pepper, cassava, sorghum, cotton, rice and maize. They also met with government officials, scientists and local farmers to explain the project and its goals.

On their first day in the field, the team met with scientists at the Lake Zone Agricultural Research and Development Institute (LZARDI), in Ukiriguru. Part of Tanzania’s Ministry of Agriculture and Food Security, LZARDI is an agricultural research and promotion agency that focuses on different crops.

Adolfo Posadas, the Nairobi-based leader of the CIP mission, explained to the LZARDI scientists that CIP was

*The spectral signature can reveal whether individual plants are thriving or whether they are stressed by drought, nutritionally deficient, or under attack by insects or a virus.*

developing a wide range of open-source products as part of the project, from software for programming flights and processing post-flight images, to instructions for assembling commercially available drones and sensors. ‘The principal outcome of this project will be to transfer all of this technology so it is freely available to the next user,’ Posadas said. This will reduce costs significantly, although a commercial UAV would still be needed.

### Drone demonstration

In a serendipitous surprise, a LZARDI field just a few meters from the conference room proved an excellent starting place – containing fourteen varieties of orange-fleshed sweet potato growing side-by-side in different sections, allowing CIP researchers to gather a large amount

of data about the varieties they hoped to study in one place.

At the field, the CIP researchers began the multi-step process of collecting drone imagery. First, they used measuring tape to mark rectangular sections of the field. At each corner, they drove markers into the ground, taking specific GPS coordinates for each – creating ground control points that are used during image processing to make aerial images geographically accurate.

At the same time, Luis Silva, a UAV pilot based at CIP-Lima, readied the UAV for flight, adding propellers, sensors and other finishing touches. Pre-flight checks completed, Silva launched the Oktokopter and flew it smoothly over the field, shooting photographs as he went. The first UAV flight used a standard camera, while the second flight used a multispectral camera, which captures and measures light at visible and near-infrared wavelengths.

Making use of different cameras is important because each plant variety has a small but measurable difference in the wavelength of light it reflects when exposed to sunlight – like a distinctive signature. By measuring this spectral signature, users can identify from the air whether a crop is sweet potato, cassava or something else, and may also be able to determine which variety the crop is.

### The signatures of sweet potato varieties

The spectral signature can reveal whether individual plants are thriving or whether they are stressed by drought, nutritionally deficient, or under attack by insects or a virus. Such changes can be detected in aerial, multispectral images before they can be seen by the naked eye. Collecting these signatures is a key part of CIP's project, with the eventual goal of building a spectral library that contains signatures for each sweet potato variety.

During each flight, the drone also took images of the field at different altitudes, ranging from five to hundred metres. This was part of an effort to find the best altitude for shooting photographs for agricultural analysis. Eventually, the researchers hope these aerial images will be superimposed over larger-scale images from satellites to provide better detail on nationwide crop production than is currently possible or affordable.

Everina Lukonge, a plant breeder at

LZARDI and one of the many scientists who helped the CIP team through its work in Tanzania, explained how UAV-based remote-sensing provides an improvement over the current rough estimates made by crop statisticians. 'When the statistics are not known, you cannot estimate production,' she said. 'If you have UAV-gathered data, it means you can estimate the food. Maybe next season there is hunger. Maybe there is a bumper crop, so you can look for a market. It can help in planning and budget allocation.'

### Improving the quality of statistics

Now that the CIP researchers have demonstrated the drone-based system's capability to acquire accurate, high-quality information in the real world, they hope to obtain permission from Kenya and Uganda to fly above other farms. 'We just need a permanent permit to move back in and help the local bureau of statistics and other authorities generate the data they need for improving the quality of agricultural statistics,' project-leader Quiroz said.

CIP's researchers also hope that their remote sensing project will encourage other African nations to begin their own experiments with remote sensing. They captured their work in the field in Tanzania on video with assistance from a graduate student from the University of Missouri-Columbia in the US, and plan to release a film on remote sensing and agriculture in the near future.

'It was important to document the process, because these are new technologies that we want to share with other potential developers and users in Africa,' said Corinne Valdivia, Associate Professor of Agricultural and Applied Economics at the University of Missouri-Columbia, a UAV project participant who studies how new technologies become part of the toolbox for key decision-makers. 'They will be instrumental in finding the pathways for reproducing and adapting the technologies for use in their own countries.' ◀

### About the author

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### Related links

Website of the International Potato Center.

→ <http://cipotato.org>

Three articles from CIP website:

'Creating a Community of Practice'

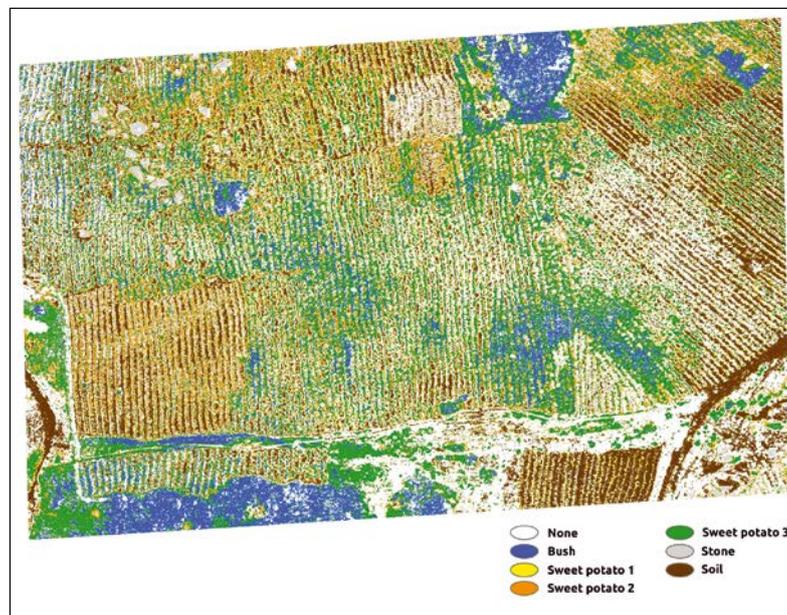
→ (<http://goo.gl/PK8Gh0>);

'Beyond flying UAVs'

→ (<http://goo.gl/vc5muF>);

'Invasion of the Potato Drones'

→ (<http://goo.gl/KdC7V6>).



Sweet potato field captured by UAV-based remote sensing system that shows differentiation of land cover and crop varieties.

# Insuring Indian farmers more effectively

Crop insurance payouts could be sped up with the help of drone technology, preventing financial hardship and potentially helping more small-scale farmers get insured.

Damaged wheat crop in unseasonal rainfall and hailstorm in Rajasthan state, India (2015).



## Drones for agriculture

Thousands of farmers are killing themselves in India every year. They make this ultimate sacrifice not just because the weather gods have been brutal. It is also because they have been failed by crop insurance, their primary protection from climatic flippancy.

Less than 23% of India's millions farmers are covered by crop insurance, and even those who are insured regularly suffer financial hardship from delayed payouts. These payments are often deferred by the slow damage assessment process as land record office personnel travel from village to village to conduct inspections. This means that it takes insurers a long time to receive timely, accurate data.

Indian farmers need to get their insurance payments faster. Therefore, India's central government has launched a technology-focused crop insurance pilot project called "Kisan" to address the problem. It is part of the Indian central government's new crop damage insurance scheme called "Pradhan Mantri Fasal Bima Yojna," which translates as "Prime-Minister's crop insurance scheme."

### Crop insurance system

The Kisan pilot programme combines agricultural data collected by unmanned aerial vehicles (UAVs) – also known as drones – with high-definition satellite imagery, as well as crowd sourced data collected from farmers' smartphones. These data sources can then be used with more traditional estimation methods, potentially helping officials speed

up crop damage assessments and more accurately estimate yield.

While Kisan's use of UAVs is still experimental, the data the devices collect can be used by government agricultural analysts, farmers, and insurance companies to improve the crop insurance system in a number of ways. Aerial imagery can be used to quickly classify surveyed areas into cultivated and non-cultivated land, and to assess how much damage has been caused by natural disasters. Expert analysts can also use UAV-gathered topography and elevation data to monitor soil erosion and to more accurately design water drainage and irrigation systems.

Agricultural analysts could use Normalized Difference Vegetation Index (NDVI) data collected by UAVs to conduct faster and more accurate crop health surveys – allowing insurers to process claims faster. They can use the same data to construct statistical models for risk management, based on historical yield, pest, and weather data. Drone data might also be useful for the early detection and prediction of pest infestations, data that insurance companies could share with farmers. Finally, drone data can be used to detect insurance fraud, preventing fraudsters from insuring the same piece of land multiple times, or claiming damage where there is none.

### A ban on drones

UAVs won't operate alone. In the future, agricultural insurers will likely rely on different combinations of satellite and

UAV data, which can be combined with traditional analysis methods to create a truly comprehensive view of India's farmland. By using these new data-collection methods, insurers would be able to deliver a better, cheaper product. And this would make it possible for more farmers to get insured.

Although UAV technology shows considerable promise for agricultural insurers in India, there are plenty of regulatory and logistical challenges to overcome. Since October 2014, civilians have been banned from using drones in India – a restriction that will likely last until the Indian Directorate General of Civil Aviation (DGCA) comes up with a regulatory system for commercial drones.

While the civilian UAV ban is still in place, some government organisations are beginning to acquire the devices. In January 2016, the Agriculture Ministry announced that it would allow the Mahalanobis National Crop Forecast Centre (MNCFC) to purchase UAVs for assessing crop damage. Eventually, the Agriculture Ministry anticipates buying UAVs for each Indian state to support the crop insurance programme.

India's massive agricultural sector presents another obstacle to the widespread adoption of UAV imagery in crop insurance. While UAVs will help make data collection faster and cheaper, innovative business models will be required to make crop insurance work on such a massive scale.

Therefore, introducing UAV imagery into Indian crop insurance won't always be easy. If the Kisan programme is successful, more Indian farmers will be able to enjoy the peace of mind that good crop insurance brings. And they will have far less to fear from bad weather. ◀

### About the author

Ruchit G Garg (Ruchit@harvesting.co) is founder and CEO of Harvesting (<http://www.harvesting.co>), a Silicon Valley, US based company that provides data driven insights to farmers.

# 'UAV-based remote sensing will be like using a cell phone today'



## **How does UAV technology contribute to agriculture?**

Reliable agricultural statistics are one of the main bottlenecks in today's agriculture. Remote sensing in general can be used for discriminating crops and estimating acreage. The new generation of satellites e.g. Sentinel 1 & 2 and Sentinel 3, which is scheduled to be launched by the European Space Agency in 2022, will provide affordable imageries for agricultural applications. That leaves the clouds as probably the main limiting factor especially under rain-fed conditions. Remote sensing platforms able to register scenes over agricultural fields under the clouds are a must have. With the spatial resolution attained with unmanned aerial vehicles (UAV) based remote sensing, crop discrimination is feasible even with conventional RGB (red, green, blue) cameras. With spatial resolution of less than 10 centimetres, processing imageries to facilitate decisions for precision agriculture is highly feasible. Early warning and yield forecasting systems are no longer science fiction with today's UAV technology.

## **From your answer we understand that the technology can be easily adopted by large scale farmers. How would small scale farmers benefit from it?**

Smallholder farmers are not expected to be direct users of this technology right away but in less than ten years

– my guestimate – farmers will be so permeated by ICT technology that the use of UAV-based remote sensing will be like using a cell phone today. Meanwhile, we need to re-tool government agencies, agriculture-oriented NGOs, and farmers' associations. Moreover, young professionals in physics, electronics and agriculture could become entrepreneurs and provide the service needed in rural areas.

## **Most UAVs used for civil purposes are manufactured in China, the US and Europe. What are your thoughts on producing or assembling UAVs in Africa, as an example?**

First of all, UAV-based remote sensing platforms have at least three key components: the vehicle (the UAV itself); the sensor; and the support interface frame that allows communication with both the radio control and the telemetry from the UAV's control unit. Most people concentrate on the UAV. For an agriculturalist this is probably the least significant component of the platform. One of the reasons is that China, US, and Europe can provide this component at very competitive prices. The problem is when intermediaries in developing countries sell those, otherwise low-cost UAVs, at very high prices. Notwithstanding, UAVs can be locally built. Our partner at University

of Nairobi has built a tetracopter using ardu-pilot technology with great results. The most critical component is the sensor. Most users buy integrated solutions. This is a good starting point but in our experience not always the most convenient. These products, by definition are "black boxes" and thus the user is limited to whatever the vendor defines as the "best" solution for agricultural applications. When you build your own sensors you have total control of the product and have access to the raw data. You can improve your signal to noise ratio and thus generate better imageries. The interface is very important since you want to be able to use the telemetry from the UAV for the processing of the imageries. A must have is open access software for mosaicking, and some of the pre-processing required to generate the data needed for agricultural analyses. CIP has developed open access software that UAV-users are welcomed to download and use.

## **What role could governments and development agencies play in facilitating the adoption of the technology?**

First of all, by making user friendly and forward looking policies e.g. in Peru the proposed legislation pretends to limit flying altitude to 150 metres. Flying fix-wing UAVs at this altitude make no sense for agricultural applications. In the second place, fostering capacity building in developing countries. In third place, modernising the bureaus of statistics and the likes with UAV technologies focusing on open access solutions to guarantee its sustainability. ◀

Roberto A. Quiroz (r.quirroz@cgiar.org) is a biophysical scientist at the International Potato Center (CIP) based in Lima, Peru. There he leads a multidisciplinary team on methods and tools to assess the impact of climate variability and change on agriculture and the feedback of agricultural practices to the environment. He was born in Panama.

# The challenge of comparing crop imagery over space and time

Imagery collected by drones can help agricultural experts identify the causes of low crop productivity. But the technology must be adapted to determine different crop varieties from multispectral images. And problems of image calibration must be resolved.

Near-Infrared (NIR) image of small-scale farms in Ghana. The blue colours represent bare soil or soil covered with debris.



## Drones for agriculture

The University of Lund and Swedish University of Agricultural Sciences initiated research projects in Kenya and Ghana on the use of unmanned aerial vehicles (UAVs) – also known as drones – for agricultural monitoring. The researchers made use of a framework that combines UAV-based observations, biophysical investigations, and conventional infrared spectrometer technology, with existing survey data on village and farm household characteristics that were taken between 2002 and 2014.

Numerous methods exist for estimating crop yields with remote sensing technology. Commonly, researchers compare a vegetation index calculated from remotely-sensed data with ground based yield measures. This allows them to estimate crops yields throughout the study area. Vegetation indices are a measure of plant vigour and health. They build upon the fact that green vegetation strongly absorbs visible light, but strongly reflects near-infrared light

(NIR). While many different vegetation indices have been developed, the most common is the Normalized Difference Vegetation Index (NDVI), which is used in the projects in Kenya and Ghana.

### Different farming practices

A key step in this research project is the use of UAVs for remote sensing instead of satellites to create crop yield maps. The researchers decided that the low spatial resolution of traditional remote sensing and NDVI data was not suitable in the research areas in Kenya and Ghana. This imagery cannot adequately capture the intricate agrarian landscapes and farming systems of sub-Saharan Africa, which are among the most complex in the world.

In fact, most satellite and NDVI technologies are developed with mechanised conventional agriculture in mind – the large rectangular fields and single crops that are common in industrialised nations. Farming practices are considerably different in sub-Saharan Africa, where many

farmers grow multiple crops with similar plant cycles and where intercropping is a common practice. And most sub-Saharan African farming plots are considerably smaller than those found in industrialised areas.

These different farming practices all call for the use of higher-resolution satellite platforms. But unfortunately, these rarely capture imagery of the sub-Saharan regions. Where high-resolution data is available, the satellites revisit these sub-Saharan African regions so rarely that controlled time-series measurements become impossible. Furthermore, due to the study areas' proximity to the equator, the images are often masked by clouds, making them unusable for analysis. Therefore, it is difficult to access satellite imagery to address the specific problems which characterize the complex farming systems of sub-Saharan Africa.

### High spatial resolution images

To address this lack of remote sensed data, the decision was made to use

UAVs to collect high quality aerial data. For this work, autonomous quadcopters have been used and equipped with consumer-grade cameras, which can produce high-resolution NIR and RGB (red, green, blue) images of under-served agricultural areas.

The aerial images that these camera-equipped quadcopters produce have a spatial resolution of three to four centimetres, which is much higher than the spatial resolution that is available from most satellite platforms. These high resolution images are so sharp that they show crop detail even within small fields.

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*Drone image quality is highly dependent on environmental conditions at the time of flight and the camera settings used to address them.*

The drone cameras are able to produce these high spatial resolution images because they fly at 100 metres, which is a relatively low elevation for aerial photography. Since the drone cameras collect both NIR and visible light imagery, they can also be used to develop the vegetation indices mentioned above, which in turn can be used for more detailed analyses.

### Reflectance values

In order to construct robust crop yield maps, at least a couple of observations over the growing season are needed. However, UAV image quality is highly dependent on environmental conditions at the time of flight and the camera settings used to address them. Unless these conditions are controlled for, images cannot be compared over time. Since it is difficult to standardize the environment and settings at the time of each flight (flights take place at different times of year, at different times of day and under varying weather conditions), a calibration method to standardize the images after production has been developed.

This method involves converting the camera's digital number pixel values to what is called "reflectance values". Reflectance values are related to the object itself (such as a specific kind of crop), rather than to the camera model that has been used for the flight.

By using this conversion method, researchers are now able to not only make comparisons between different missions, but also to compare UAV-gathered data with other forms of remote sensed data, when it is available. These reflectance values can also be used as the basis for image classification and change detection, which means observing differences in the state of land features by observing them over time.

The current aim of this research project is two-fold. The first is related to image classification – the process of identifying what agricultural experts are looking at in a remotely-sensed image. The researchers involved in this project hope to classify different types of crops in the aerial imagery and to distinguish these crops from non-vegetation and confounding vegetation such as weeds. The second aim is to develop a calibration method that can be used to derive accurate reflectance values from these remotely sensed images.

### Automatic crop yield estimation

These classification and calibration tests will serve as a jumping-off point for developing a methodology for the automatic or semi-automatic estimation of crop yields in maize. The plan is to use this methodology throughout the study, where researchers expect to conduct a minimum of three to four more flights per field. The methodology that has been developed for classifying maize could then be applied to other crops.

The primary challenge to date has been in processing frameworks for identifying maize plants in an automatic or semi-automatic way. This process involves separating maize from confounding vegetation, such as intercropped beans, weeds or small bushes (see figure 1). Preliminary results indicate that this maize plant classification process is not only possible, but can be done with relatively high accuracy. Based on these results, the research team thinks that UAV technology could potentially be very promising in regions that are currently under-served in terms of high-resolution, remote-sensed image data.

While inexpensive consumer-grade cameras have been used in this project, researchers are still trying to produce robust and relevant measurements by using well-known vegetation indices and calibration techniques, which are



Near-infrared (NIR) image of maize field in Ghana.

often expensive to use. The aim is to reduce the cost of conducting these measurements so that the amount of local data gathered could be increased and thus the number of farmers included in the analyses. Each farmer was provided with copies of the NDVI and yield maps as well as with the drone images. They can use them in understanding their fields and crops and improving their farming practices.

Ultimately, time-series crop yield maps could be created that can be used alongside survey data related to socio-economic conditions and management practices as well as biophysical field data. By combining and comparing these different kinds of data, it would be possible to understand in more detail why yield gaps in sub-Saharan Africa occur. With this new understanding, experts could develop strategies to increase agricultural productivity across this region. ◀

### About the author

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### Related Links

Yieldgap: website of the research project.

→ <http://yieldgap.keg.lu.se/>

Sub-Saharan Africa data from the Global Yield Gap Atlas

→ <http://www.yieldgap.org/sub-saharan-africa>

FAO's information on the unique and complex qualities of sub-Saharan African mixed farming systems.

→ <http://goo.gl/0AhKf>

IFPRI on mapping crops to improve food security.

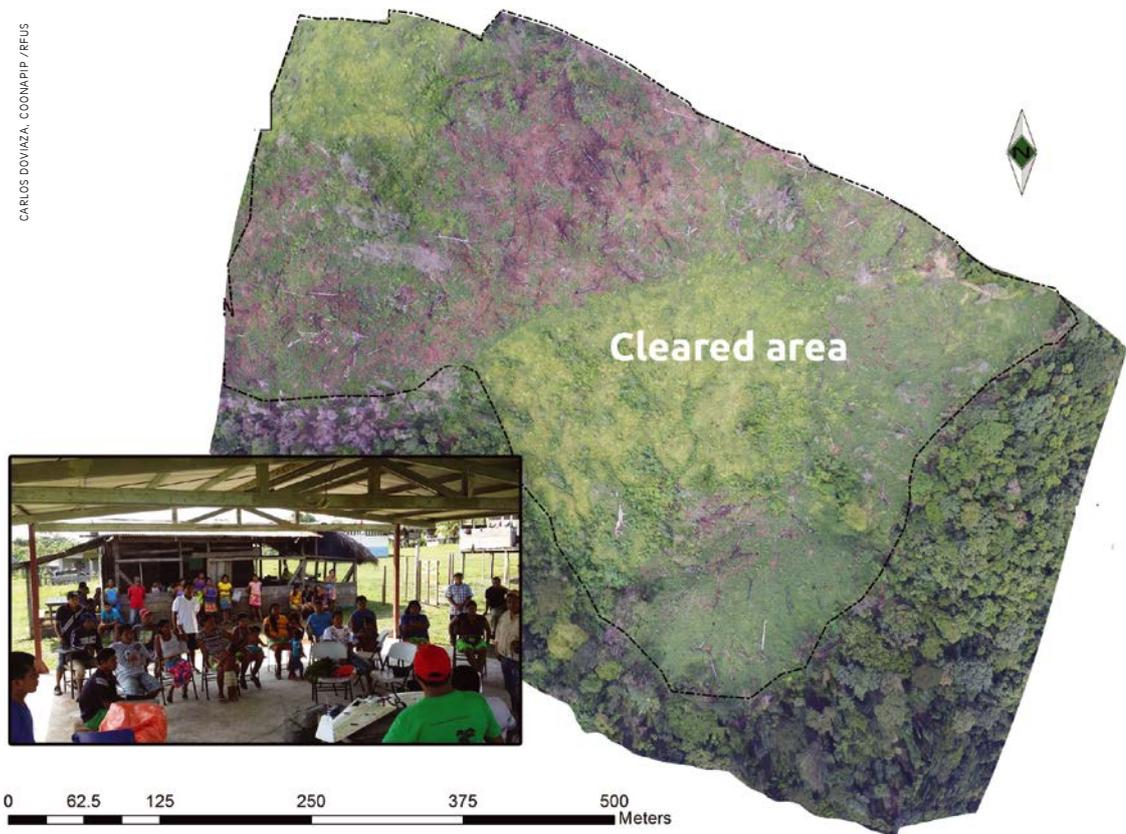
→ <http://goo.gl/oyw0at>

# Documenting illegal land occupancy from the air

Unmanned aerial vehicles have the potential to empower indigenous communities to become equal partners in the efforts to safeguard their territories and natural resources.

Area of illegal deforestation in the territory of the Wounaan Peoples' General Congress as captured by the UAV (Panama, November 2015)

CARLOS DOVIAZA, COONAPIP /REUS



Drones for agriculture

**T**hroughout the Americas, indigenous forest communities' territories face intensifying threats, as global demand increases for land and forest resources. Non-indigenous settlers and loggers illegally enter indigenous territories to poach valuable timber or to burn and clear large swaths of forest. Emerging technologies, such as unmanned aerial vehicles (UAVs) – also known as drones – offer an unprecedented opportunity to empower communities to defend their territories and natural resources. UAV technology allows them to monitor their land in real time, obtain visual evidence of any

trespass, and make claims based on this evidence.

Some of Panama's indigenous communities already make use of UAVs to protect the rainforest. Nearly 70% of Panama's remaining intact rainforest is governed by indigenous peoples. Indigenous communities see the forest as part of their culture and heritage, respecting and understanding its value and safeguarding it for future generations. Newcomers to the area tend to see the rainforest as something to be exploited in the short-term, particularly for felling valuable old-growth hardwoods and clearing forested areas for cattle ranching.

Panama's indigenous communities began using UAVs in 2015 with the support of the Rainforest Foundation US and Tushevs Aerials. Tushevs Aerials is a small organisation that designs and builds UAVs and processes data into maps or digital 3D models. It provides training in any aspect of UAV construction, operation, and data use. Since the beginning of this project UAVs have successfully been used to document illegitimate land occupancy and illegal land logging by non-indigenous groups.

## Armed settlers

The rampant deforestation in the Darien region of Panama perfectly

illustrates this dynamic. Islands of rainforest have managed to resist outside pressure from settlers, thanks to the indigenous communities that inhabit and protect them. With the use of a custom-built fixed wing UAV, the Emberá peoples – near the community of Puerto Indio – could spot and survey over 200 hectares of converted forest that has been illegally occupied by cattle ranchers. The communities' leaders were stunned to witness the extent of the damage. Prior to seeing the aerial imagery, they had thought that there were only about 50 hectares destroyed by illegal ranching.

The occupation and conversion of forested areas occurred several kilometres away from where the indigenous community lives. But because of tensions with the settlers, who are often armed and confrontational, they had not been able to enter the area and document the illegal ranching practices. Using the UAV allowed them to quickly and safely gather data that evidenced the trespass of their territories.

Tino Quintana, the *cacique* or traditional chief of the 440,000 hectares' traditional territory, took the lead on presenting the results of the UAV survey to members of several other Emberá communities. These communities are now working together by using aerial imagery documentation to register official complaints with the regional authorities. The government has promised to remove the settlers, and the Emberá communities plan to reforest the area.

### Documenting evidence

Governments are often faced with resource shortages, and are frequently unable to respond to all requests for intervention. Spatially explicit UAV documentation of illegal logging and land occupancy helps government agencies prioritise their efforts, ensuring that a week-long field inspection will collect enough evidence to justify government intervention.

This experience generated further interest in UAV technology among indigenous communities in eastern Panama, inspiring other leaders to ask for UAV support. The Emberá and Wounaan General Congress, which oversees thousands of hectares of rainforest across 27 distinct territories, was given a DJI Phantom 3 Professional quadcopter by the Rainforest Foundation in November 2015. Wounaan leaders flew this UAV within the district of Platanares on the Pacific coast of Panama. The

geo-referenced images proved that 10 hectares had recently been burned for cattle grazing in the middle of their territory.

Diogracio Puchicama, a Wounaan indigenous leader, who has been threatened by illegal loggers and settlers for several years, because of his efforts to protect 20,000 hectares of rainforest along the Pacific coast, submitted the UAV-generated documentation to the environmental authorities. Impressed by the accurate geo-referencing of the images documenting forest destruction, the Ministry of Environment promised to be more present in the area and enforce the law.

In late January 2016, Diogracio reported that the authorities had been patrolling the district of Platanares constantly, and that most of the settlers had been at least temporarily removed. 'I have been denouncing illegal loggers in Platanares for over five years, and the authorities have done nothing, not moved a finger,' Diogracio Puchicama noted. 'Now, after they have realised that we have the drone, they are doing their job and enforcing the law. It's a good sign.'

### Protection of indigenous rights

Emberá and Wounaan communities are planning in partnership with the Rainforest Foundation US and the Food and Agriculture Organisation (FAO) of the United Nations to fly UAVs in at least six more indigenous communities in Panama. They will use the imagery to raise awareness among local communities of the ongoing illegal and un-monitored forest destruction within their traditional territories and the need to document and denounce this destruction to the authorities. They will also use the aerial photographs to help Panamanians understand how important forests are, and the essential role that indigenous peoples have played in keeping them intact.

The experience from Panama illustrates that UAVs have the potential to alter the power balance in favour of indigenous communities' own ability to protect, monitor, and report on their lands, territories, and natural resources. This technology empowers indigenous people to play an active role in safeguarding their lands and to become equal partners – rather than just beneficiaries – to government and civil society agencies, which are involved

## Using the drone allowed the Emberá and Wounaan communities to quickly and safely gather data that evidenced the trespass of their territories.

in conservation and rights' protection.

Indigenous peoples' communities, organisations, and their civil society partners in the region and beyond are now very interested in adopting UAVs for conservation or for the protection of indigenous rights and territories. There are further discussions with the Mesoamerican Alliance of Peoples and Forests regarding the use of UAVs in Central America and with an indigenous network in Bolivia. Indigenous communities in Guyana and Indonesia are already using UAVs for land mapping. Also in Africa the Shompole Maasai community in Kenya and a forester in the Democratic Republic of the Congo are interested in using the technology. This shows that the interest in UAVs is growing all around the globe for monitoring illegal land use in indigenous territory. ◀

### About the author

Nina Kantcheva Tushev (nina.kant@gmail.com) is co-founder of Tushevs Aerials and indigenous peoples' advisor at the UNDP. Tom Bewick (tombewick@rffny.org) is program manager at the Rainforest Foundation US. And Cameron Ellis (jamescameronellis@gmail.com) is principal at Groundtruth Geographics.

### Related Links

Video on mapping land invasions in the Emberá-Wounaan Comarca with UAVs.

→ <https://goo.gl/EaPwii>

Video that shows a 3D model of the indigenous area surveyed by UAVs in Panama.

→ <https://goo.gl/IWT02G>

Video that demonstrates how Dayaks in Indonesia make use of UAVs.

→ <https://goo.gl/u8Bv2v>

Article and video outlining a training in the use of UAVs with indigenous communities in Peru.

→ <https://goo.gl/jhoMFJ>

# Transforming smallholder farming through remote sensing

The STARS project explores ways to use remote sensing technology to improve agricultural practices of smallholder farmers in sub-Saharan Africa and South Asia with the aim to advance their livelihoods.

“**S**TARS” stands for Spurring a Transformation for Agriculture through Remote Sensing. It is an international project led by the University of Twente in the Netherlands and funded by the Bill and Melinda Gates Foundation. The project investigates how very high spatial resolution satellite images of half a metre to five metres pixels and those derived from unmanned aerial vehicles (UAVs) can be used to monitor and map smallholder farms.

Camera-carrying UAVs were chosen for this project because of their unprecedented centimetre-level spatial resolution and because they can be flown at low altitudes below the cloud level. Using UAV technology, a temporally dense time series of images can be constructed that allow to closely track crop changes over time. Also, on-board cameras can collect images spectrally compatible with those provided by earth observation satellites, making it possible to conduct multi-scale analyses.

The STARS project focuses on three regions: West Africa (Mali and Nigeria), East Africa (Tanzania and Uganda) and Bangladesh in South Asia. These regions present three highly relevant agricultural problems: land tenure and field performance (West Africa), agricultural statistics and food security at regional and national levels (East Africa), and irrigation scheduling (Bangladesh).

## Land tenure registry in West Africa

In West Africa, the team is led by ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). They own two fixed-wing UAVs. These UAVs can be used to obtain both true colour (red, green and blue or RGB) and near-infrared images. These images support the identification and mapping of agricultural plots. More accurate and transparent land tenure information could help West African



*Drones were chosen for this smallholder agricultural project because of their unprecedented centimetre-level spatial resolution.*

smallholder families to secure their land use rights.

In parallel to the collection of UAV images, a field team worked on the ground to measure and map several farm management units. Later, this geographical information was combined with the information gathered by interviewing farmers to create a land tenure registry.

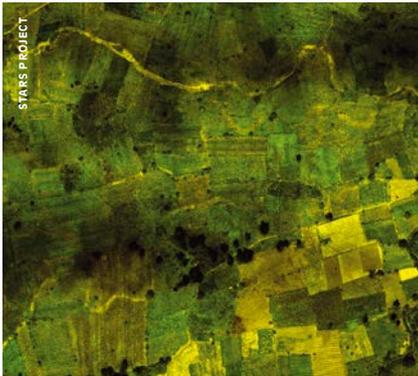
Moreover, by using photogrammetric techniques, the STARS team was able to create precise digital elevation models of the photographed areas.

These elevation models can be used to support land management and to derive crop height – a valuable metric for studying crop status that can be used together with textural and spectral information.

The West African team also owns an eight-armed helicopter model (octocopter) that can carry an RGB and a multispectral (5-bands) camera. This UAV is used in a more experimental fashion, as researchers attempt to determine whether different crop varieties can be identified from multispectral images, or if certain measures of crop health, such as leaf area index or chlorophyll content, can be accurately derived from UAV images.

## Supporting food security policy-making in East Africa

The East African team, led by the University of Maryland in the US, supports the collection of national agricultural statistics and food security policy-making in Tanzania. In this case,



True-colour representation (left) and the respective 3D model visualisation (right) of images acquired from a UAV platform over cropland (Mbuyuni area, Tanzania, June 2015).

the team used two fixed-wing UAVs to map maize-based agricultural systems.

After completing the UAV flights, results were scaled up to the national level, using satellite data and crowd-sourced information from the ground. This resulted in a cropland map that was shared with officials at the Tanzanian Ministry of Agriculture. Maps like these, if created in a timely fashion, can help agricultural experts more accurately forecast yields at a national level, and to make informed decisions about the state of food security.

The East African team, like the West African team, also operates an octocopter. This UAV is used to perform in-farm experiments aimed at better understanding how multispectral UAV images can be used for mapping cropping systems and their condition.

### Optimising irrigation scheduling in Bangladesh

The Bangladeshi team, led by CIMMYT (International Maize and Wheat Improvement Centre), uses two octocopters. One of them is equipped with the same model of RGB and multispectral camera that is used by the African teams. However, the spectral bands chosen by the Bangladeshi team are slightly different so as to allow for a more precise characterization of crop photosynthetic activity. This UAV is also used to map how the fraction of vegetation cover changes over time. This information is key for optimising irrigation scheduling.

The second octocopter is equipped with a thermal camera that was used to assess canopy temperature, which is key for designing an improved irrigation strategy. Although Bangladesh is rich in water, cereal farmers must pump surface water to cultivate their lands during the dry months of winter. The STARS project

hopes to help Bangladeshi farmers to grow an extra crop per year to improve their financial and food security. Remote sensing technology helps farmers to optimise the use of water pumps and it provides valuable information for a sustainable intensification of their lands.

### Challenges

To undertake the agricultural analysis, the STARS team has had to overcome several UAV-related challenges. The team had to secure permission to fly from relevant authorities and had to train various local staff members so that flights could be performed in a safe and timely fashion. Team members also had to inform local people of the activities and engage with farmers in the data collection process.

Operating the UAVs twice per month over each field was challenging. The teams had to arrange complex field visit logistics. They only could fly the UAVs during the relatively brief period of time of the day when environmental conditions are optimal for gathering aerial imagery. Although all regional teams did an excellent job, there were a few crashes. Some of the UAV cameras and batteries overheated and did not function properly.

Another challenge was related to figuring out how to transfer the UAV data from the field to the central offices of the regional teams. This was a necessary task, as high computational power and specialised software is required to process the several gigabytes of information that are collected during a typical UAV flight campaign.

Field data is needed to calibrate the retrieval of crop properties and to classify aerial images collected by UAVs. Hence, the STARS team UAV usage was accompanied by intensive field campaigns, where a wide array of crop-specific information and

measurements were collected, such as leaf area index using smart phones. The teams also collected ground control points, which are accurately surveyed geographic coordinates needed to properly geo-reference UAV imagery. Geo-referenced UAV imagery matches up with other spatial data, and can be combined with other spatial datasets in Geographical Information System (GIS) and remote sensing software.

Finally, there is the challenge of calibrating UAV images. Calibration is needed to ensure that the quality of the images is as high as possible so that multi-temporal and multi-scale analyses can be done. However, image calibration remains challenging and STARS researchers are still investigating ways to operationalise it.

Despite these challenges, the STARS project is steadily progressing towards its goal of determining how remote sensing technology can be used to shed light on the complex agricultural systems in which smallholder farmers operate. As such, STARS is the first stepping stone on a path that leads to more sustainable agricultural production in emerging economies. ◀

### About the author

Raul Zurita Milla (r.zurita-milla@utwente.nl) and Rolf A. de By (r.a.deby@utwente.nl) are with the Department of Geoinformation Processing (GIP) of the Faculty of Geo-information Science & Earth Observation (ITC) of the University of Twente (The Netherlands). Since June 2014, both are involved in the execution and coordination of the STARS project.

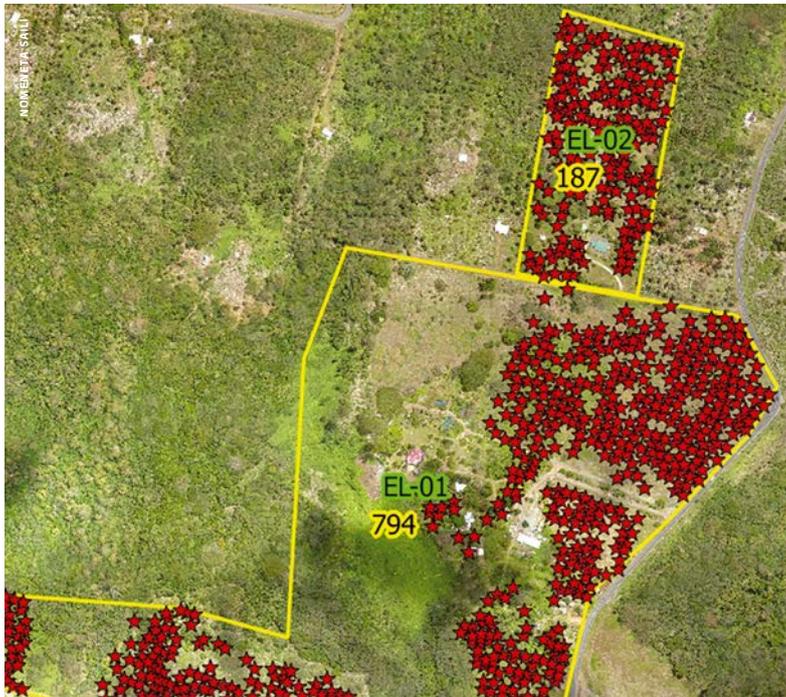
### Related links

The STARS Project web site  
 → [www.stars-project.org](http://www.stars-project.org)

# Counting coconuts with drones

On the Pacific islands of Samoa drone technology is used in a coconut tree survey to forecast more accurately yield and production of virgin coconut oil.

Drone captured image of organic farm with boundary and visual coconut tree count conducted. The yellow number shows the coconut count.



## Drones for agriculture

In 2015 the Samoan agricultural non-governmental organisation (NGO) Women in Business Development Incorporated (WIBDI) realised that it needed a new way to collect and organise comprehensive data from associated farms. The organisation helps local rural families actively engage through fair-trade in the niche market of organic products. They were wondering what would make it easier to carry out organic standards inspections and conduct counts of certain crops, in particular coconut trees.

Coconut is Samoa's most important renewable resource and export product. The country exports copra coconut oil, virgin coconut oil, coconut cream, desiccated coconut, coconut fibre (coir) and shell products mainly to Australia and New Zealand. WIBDI is the largest exporter of virgin coconut oil in Samoa and its main buyer is The Body Shop, which is based in the United Kingdom.

In search for answers to the data collection problem, WIBDI turned to Samoan tech-services company Skyeye

for help. Skyeye's experts explained to them that unmanned aerial vehicles (UAVs) – also known as drones – might be the perfect solution. UAVs are cheaper than manned aircraft, and can collect higher-resolution imagery than civilian satellites.

### Open source server

For its mapping work, Skyeye uses a fixed wing professional mapping UAV, which is capable of covering large areas in a single autonomous flight. 'The drone allows us to capture images of farms that are not easily accessible and it gives us the flexibility to fly whenever we want as long as the weather permits it. Being able to capture up-to-date imagery has been a massive benefit to this digitisation project,' says Skyeye's Geographic Information System (GIS) technician Ephraim Reynolds.

After technicians download images from the UAV, they process them into orthomosaics: stitched-together images that have been digitally corrected for distortion, so that they can be overlaid

*The biggest challenge has been locating suitable landing areas for drones.*

onto a map. They then open these image layers in a free, open source GIS computer programme, known as QGIS. In QGIS, they are able to digitise key farm features – and the high resolution drone imagery clearly shows individual coconut trees, allowing them to conduct a visual count of total tree numbers.

Skyeye uses a GIS feature known as a Web Feature Service (WFS), which allows them to grant users access to its geoserver – an open source server made for sharing geospatial data. With WFS, users are able to download individual layers of information, such as the layer containing information about farm's coconut trees. With this geospatial data farmers then can make their own changes and updates to the digital map. 'In this way, Skyeye is able to divide the labour and make the process of analysing the drone imagery faster and more centralised within one system,' says Reynolds.

### Locating landing areas for drones

To further speed up the process of mapping, Skyeye shows farmers images of their farms from the air so they can draw their property boundaries. By estimating the age of the palm trees on each of the farmer's property, WIBDI is able to forecast the yield and production of virgin coconut oil. These estimates can in turn be used to assess the feasibility of future business ventures, and to make more accurate estimates of expected annual profits.

While the drones have been a boon to WIBDI, they have not been entirely trouble-free. According to Reynolds, Skyeye's biggest challenge has been locating suitable landing areas, as the drone requires an open area free of vegetation to safely land after completing a mission – and



CHRIS SAILI

trees. The drone survey of all 558 farms in WIBDI's network should be completed by April 2016. In the future, Skyeye Samoa hopes to extend the tree-counting process it has developed for WIBDI. 'As Samoa and the Pacific continue to realise how drone technology can be used in various industries, especially in agriculture, the region will become better able to reach large markets and keep up with modern advancements,' says Reynolds. ◀

#### About the author

Ephraim Reynolds (ephrain@skyeye.ws) is GIS technician at Skyeye. Faumuina Felolini Tafuna'i (flyinggeeseepro@gmail.com) is media specialist at Women in Business Development Inc. WIBDI.

#### Related links

Skyeye, Vehicle tracking  
→ [www.skyeye.ws](http://www.skyeye.ws)  
Women in Business  
→ <http://www.womeninbusiness.ws>

such an area can be hard to find on a tropical island. 'Google's satellite imagery in Samoa is outdated. Sometimes, we found that the best solution is to ask the locals in the village where we can find suitably clearing,' he describes.

Maintaining a strong radio link to the drone was another hassle due to tall

coconut trees, which can obstruct the signal and result in the drone not capturing images. 'For this, we shortened the range of the drone's flight path, or found higher ground to launch it from,' explains Reynolds.

By the end of January 2016, Skyeye had mapped 10,480 hectares by drone and counted 138,180 coconut

# Drones for agriculture



## Join the community

# @UAV4Ag

# www.uav4ag.org





## Making sense of drone regulations

Authorities demand regulation for and supervision of the increasing use of drones, because of privacy, safety and security issues. Drone operators must be aware of this.

**W**hile unmanned aerial vehicles (UAV) – also known as drones – are indisputably useful for civilians, the technology has an increasing public relations problem. For example, UK pilots called for research into what would happen if a UAV hit an airliner, after 23 near-misses around UK airports in six months during 2015. In Japan, UAVs equipped with a net have been developed to capture rogue UAVs that might threaten disruptions along flight paths. And the Dutch police are experimenting with trained eagles to take unwanted UAVs out of the sky.

Some people are wary of drones due to the technology's association with lethal military technology. Others have seen recent news reports describing the reckless and indiscreet use of UAVs by

civilians, from paparazzi drones to unauthorized UAVs flights over tourist hot-spots. These incidents have made governments and citizens around the world raise serious concerns about leaving the technology unregulated.

The debate about UAV regulation also concerns developing countries. Some nations, like South Africa, have already implemented regulations on the use of the technology by civilians, while others, like Kenya, have banned the use of UAVs without explicit permission from authorities. Several small island developing states in the Pacific have adopted the regulations formulated by their bigger, more developed neighbours. That is the case for Samoa and Tonga, for example, who follow the UAV laws of New Zealand. Still, many developing

countries have no provision at all when it comes to the use of this technology by civilians.

### Why rules and standards are necessary

One of the fundamental prerequisites for the use of small UAVs in public airspace is the existence of harmonised rules, in particular for UAV operators. These rules should pertain to safety and training, facilitate cross-country recognition of aircraft and pilot certification. Furthermore, such regulations should be combined with appropriate provisions for the protection of public privacy, data protection, liability and insurance. UAV rules also need standards that apply to both private and commercial use, covering issues such as the

identification of types of small UAVs, and development of technologies that can prevent hackers or third parties from taking control of the devices while they are in the air. Clear and concise guidance material, customs procedures, simplified regulations, and readily available online forms and information products, like maps that show where it is allowed or not to use UAVs, could all help to succeed in reducing risks for operators.

The increasing commercial exploitation of smaller drones will require further, specific adjustments, such as limitations on third-party liability, the introduction of UAV weight categories below 500 kilograms, and adjustments to the risk levels that are associated with the flight characteristics of very small UAVs. Some concerns with UAVs are not new: the protection of fundamental civilian rights, such as the privacy of images and data, was already an issue with the use of manned aircraft and helicopters. In this context UAVs represent an increase in the scale of aerial data collection – a new challenge when it comes to strengthening and managing the legal protection of privacy rights and both personal and business data.

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## *UAV rules also need development of technologies that can prevent hackers from taking control of the devices in mid-air.*

The international discussion about regulation of the commercial application of UAVs formally began in 2007 with the creation of an unmanned aerial system study group within the International Civil Aviation Organisation (ICAO). The study group brought to the table several member states and aviation management organizations. In 2011 the study group produced a circular 328, followed in 2015 by a manual on unmanned aircraft systems and proposed amendments to national civil aviation laws.

ICAO's current coordination efforts in the international arena focus almost exclusively on the large remotely-piloted aircrafts used for trans-boundary missions and not on the smaller UAVs.

However, much of the material that was prepared by the study group is useful to develop country-specific and regionally relevant regulations for small UAVs under 500 kilograms and with visual line-of-sight operations, as Leslie Cary, who manages ICAO's programme on drones, said at the Remotely Piloted Aircraft Systems Symposium in March 2015.

The European Aviation Safety Agency (EASA) has been tasked by the European Commission to develop a regulatory framework for drone operations and proposals for the regulation of civil, low-risk drone operations. In achieving this, EASA is working closely with the Joint Authorities for Rulemaking of Unmanned Systems (JARUS), which is producing guidelines that should serve the UAV governance of the national airspaces.

### **Regulations in ACP countries**

Research led by the Technical Centre for Agricultural and Rural Cooperation (CTA) recently examined the current state of drone-related regulations in the African, Caribbean and Pacific (ACP) group of states. It revealed several distinct categories of responses to the drone issue. Indeed, ICAO member states use the organisation's standards and recommended practices and other guidance material to develop their own regulations.

South Africa in particular has implemented and now enforces a comprehensive set of legally-bound rules governing UAVs, placing it among the small group of nations that have working regulations. Others, like Senegal and Kenya, have banned the civilian use of drones or specific airborne tools, such as cameras, although they have amended their aviation laws with drone-related provisions developed by ICAO. Others, like Chad and Gabon, still left notes in their newly updated aviation laws stating that international norms still need to be established on specifics such as certification, licensing and aircraft types. Others have created a variety of forms, guides and information products, and sometimes have simply adopted the UAV rules of another country, without any official amendments to their aviation laws.

In emergency situations, like post cyclone Vanuatu, drones have been used on Efate and Tanna islands for reconnaissance and damage assessment purposes with the endorsement of the government, but in the absence of a legal framework and specific rules. Thus, it appears that the question is no

longer whether, but how and when the integration of UAVs into existing forms of aviation will take place. When rules are unclear, professional small UAV operators working in agriculture or natural resource management should use common sense and follow diligence: have an operator permit, documentation and registration for the aircraft and the instrument used, and seek approval from local authorities. Ideally they also should seek approval from customs and national transport agencies.

### **Emerging UAV expertise**

Tackling safety and privacy issues together with the adoption of harmonised relevant regulation will play a crucial role in the public acceptance of civilian drone technology, and the role of ICAO and JARUS is instrumental in developing the appropriate standards and recommended practices. Regional coordination efforts could spur further harmonisation of national operating rules, licences and certification between neighbouring countries. By doing this they could help the spread of commercial applications and facilitate the growth of regional enterprises and expertise on UAV technology.

ACP countries looking to regulate the technology should consult with professional operators and users of drones to ensure that UAVs' user cases are well defined and their authorisation streamlined for the relevant activities within the individual countries. ◀

### **About the author**

Cédric Jeanneret (cedricj@gmail.com) is a freelance geographer. Cédric is particularly interested in capturing and analysing geographic information to map and learn about the diffusion of innovations and adoption of technology in socio-ecological systems.

### **Related links**

Website of the Joint Authorities for Rulemaking on Unmanned Systems (JARUS).

→ <http://jarus-rpas.org/>

ICAO study of legal issues relating to remotely piloted aircraft (2015):

→ <http://goo.gl/NTZrYj>

Webpage of the South Africa Civil Aviation Authority on UAVs:

→ <http://goo.gl/jeR7ZJ>

# Five steps of making a map with small drones

Flight Planning Parameters (in units of meters)

		Camera Geometry				Overlaps in %	
		f	w	h	Pixel Size	Strip	Photo
		0.016	0.0235	0.0156	3.9E-06	70	80
SONY α6000	Flying Height	Ground Cover				Strip	Photo
		W	H	GSD	Spacing	Spacing	
	25	36.7	24.4	0.006	11.0	4.9	
	50	73.4	48.8	0.012	22.0	9.8	
	75	110.2	73.1	0.018	33.0	14.6	
	100	146.9	97.5	0.024	44.1	19.5	
	125	183.6	121.9	0.030	55.1	24.4	
	150	220.3	146.3	0.037	66.1	29.3	
175	257.0	170.6	0.043	77.1	34.1		
200	293.8	195.0	0.049	88.1	39.0		

## Drones for agriculture

Traditionally all features on a map were represented in the form of symbols whose spatial characteristics, like location, size and shape, could be mathematically defined in a spatial reference system. The underlying spatial information of features depicted in this way is referred to as vector data. Since the arrival of aerial photography, however, maps could also be made with contiguous cells, called pixels, to each of which normalised colour values are attached, just like a digital image. The data used to make a map in this way is referred to as raster data. The maps derived directly from unmanned aerial vehicles (UAV)-carried sensors are in raster form.

In the classical sense, a map has to satisfy at least the following basic

conditions: it has to have a scale, a north arrow and be of uniform accuracy across the mapping domain. The scale on printed maps determined its resolution as well as its accuracy. In the digital age the scale of a map can be changed by simply scrolling the wheel of your mouse. Instead of using scale to achieve desired resolution, analysts nowadays make use of the Ground Sampling Distance (GSD). The GSD represents the width and length of the area covered on the ground by one pixel on the sensor array of the camera. For any given camera, the GSD is thus a function of how high above the ground the camera is located. The accuracy of the map is in turn intrinsically linked to the GSD. For a GSD of 20 centimetres it is not possible to measure distances between

discernible features more accurately than 20 centimetres.

The small drone mapping workflow can be divided into five steps.

### Step 1. Map design and flight planning

To ensure that the map is made "fit for purpose" it is important to decide from the outset which type of sensor(s) (visible light, infrared, multispectral, hyperspectral) will be needed. Once the appropriate sensor has been identified, the appropriate GSD has to be determined. The smaller the GSD, the higher the resolution (and accuracy) of the map will be.

To achieve the desired GSD with a given camera the corresponding flying height has to be computed. This is a function of the sensor

resolution and the focal length of the lens of the camera. Moreover, making maps from images requires the so-called “stereo effect” which is brought about by image overlaps. Overlaps along the flight direction and between adjacent strips are expressed in percentages. Using the footprint dimensions of an image on the ground, the intervals at which the camera must expose and the spacing of adjacent lines which will satisfy the overlap conditions must be computed.

Figure 1 illustrates the relationship between camera sensor size and resolution, focal length and flying height on the one hand and GSD, photo and line spacing on the other.

For example, a GSD of 12 millimetres requires a flying height of 50 metres, the camera must be exposed every 9.8 metres along the flight line and flight lines must have a spacing of 22 metres.

With these parameters a flight plan can be compiled to cover the area of interest. There are many flight planning tools (open source as well as proprietary) available to more or less automatically generate digital flight and task plans which can be uploaded to the drone for automatic execution.

## Step 2. Image acquisition

To provide the resulting map with absolute orientation and location, in other words to geo-reference it, it is necessary to place suitably sized and shaped targets on the terrain. These targets, known as Ground Control Points (GCPs) must be positively identifiable in the aerial imagery and their coordinates in the desired mapping reference system have to be established by survey. Obviously the targets have to be in place during the time of aerial image capture, however, they can be surveyed before or after image acquisition.

Once the GCP targets are in place, the flight plan can be uploaded to the drone for automatic execution. To ensure a safe operation, launching the drone should be preceded with flight checks and terrain evaluation. Upon landing the flight logs of the drone and the aerial images are downloaded to a laptop or storage device for processing.

## Step 3. Image processing

Drone technology is predominantly associated with high resolution mapping, but without the powerful

Structure from Motion (SfM) technique we would not be experiencing the current mapping revolution. The very high degree of automation in this robust mapping technique is key in the democratization of map making.

The first step in the SfM workflow is the alignment of the cameras. This process can be accelerated by introducing the approximate camera exposure positions as recorded by the flight controller of the drone. These approximate camera positions are also used to approximately geo-reference the positions of the camera positions as well as all subsequent products generated by the SfM process. When GCPs (with their terrestrially determined coordinates) are needed for more precise geo-referencing, their image coordinates have to be observed in each image on which they appear. This is commonly the only manual intervention in the SfM process. Once a terrain model and a texture atlas have been derived, various geo-spatial products can be generated. As a rough rule of thumb some 500 20MP images (covering some 5 to 10 hectares at 10 to 20 millimetres GSD) can be processed at high quality in a matter of 24 hours or less on a gaming laptop.

## Step 4. Preparation and visualisation of geo-spatial products

Once the SfM process has been completed various geo-spatial products can be extracted. For a two-dimensional depiction of the terrain an ortho photo is generated on a desired mapping datum and projection. This is a geo-referenced, distortion free raster map (as opposed to a distorted mosaic of “stitched” images). To add the third dimension a digital elevation model (DEM) either in raster or in vector form can be generated. Combining the above products allows for highly realistic 3D visualisations as well as more or less automated analyses such as vegetation health, building detections, terrain evaluations with regard to drainage and irrigation, volume calculations and crop heights, to mention a few.

## Step 5. The extraction of essential information

While raster maps such as high resolution ortho photos with underlying DEMs can convey a tremendous amount

of information, they do so at the expense of very large data volumes which require considerable bandwidth for dissemination. Many graphic information systems, such as Computer Aided Drafting (CAD) programmes simply cannot handle these volumes. It is thus necessary to extract from the mass data volumes those elements that are essential for a specific analysis.

This is done by means of virtual surveying, a process which enables the “surveyor” to effortlessly navigate on and over the virtual terrain while performing measurements as if he were in the field. All data captured by the “virtual surveyor” in this fashion is saved in the much more efficient vector format and subsequently exported to CAD or Geographic Information Systems (GIS). The ability to do surveys virtually brings about enormous performance improvements and cost savings to mapping and surveying, typically reducing field work from weeks or months to a few hours.

## Other developments related to drone mapping

It should be mentioned that SfM mapping without the use of GCP is also possible. This is accomplished by connecting a miniaturised dual frequency global navigation satellite system (GNSS) receiver to the camera to record the exact time of each exposure. In this way the camera exposure positions can be determined accurately to a few centimetres, thus it is argued, obviating the need for GCP. More research is needed before this approach can overcome the scepticism of many mapping professionals.

Finally, the emergence of ever lighter Lidar scanners is another important development. Lidar has the distinct advantage of penetrating vegetation, something which SfM fails to do.

With these steps and developments in mind digital maps can be created and analysed. ◀

### About the author

Walter Volkmann (walter@unirove.com) is president of Micro Aerial Projects L.L.C., a geodetic and cadastral Surveyor, and geo-spatial solutions specialist.

## UAV4Ag community

Members of this community share their experiences in developing UAV technologies and related software applications. More importantly they share information on how to make use of small UAVs to improve the management of crops, fishing grounds and other resource-based activities. Relevant events, capacity building opportunities and publications are signalled as soon as these are known by members of the community.

→ [www.uav4ag.org](http://www.uav4ag.org)



Drones for agriculture

## Drones and aerial observation

This book with the full title “Drones and Aerial Observation: New Technologies for Property Rights, Human Rights, and Global Development. A Primer” is a comprehensive introduction to civilian UAV technology, focusing on how these devices can be used to secure property rights, document environmental destruction, and gather post-disaster data. The free-to-download primer covers many basic aspects of UAV technology, such as the regulatory environment surrounding their use, nuts-and-bolts aspects of mapmaking and photography with UAVs.

→ <http://drones.newamerica.org/primer/>

## Drone2Map for ArcGIS

Drone2Map is a new stand-alone desktop app by Esri that turns drone-captured still imagery into 2D and 3D information products. These images can be used to monitor environmental changes, the impact of natural disasters, to better inspect hard to access assets and critical infrastructure, and to analyse natural and man-made land-based features. The Drone2Map complements workflows in ArcGIS to enable change detection, asset monitoring, and the creation of high resolution base maps.

→ <http://go.esri.com/drone2map>



## “Manual on Remotely Piloted Aircraft Systems”

This document of the International Civil Aviation Organization’s (ICAO) shows how the existing regulatory framework that was developed for manned aviation applies to unmanned aircraft. It gives insight into the changes that will be coming for Remotely Piloted Aircraft Systems (RPAS). It also gives an outline of ICAO’s Standards and Recommended Practices (SARPs) and guidance material, so helping other standardisation organisations to harmonise their activities.

→ <https://goo.gl/oal41V>

## News about UAVs

With UAV technology being adopted for civilian research and surveys around the world, specific news websites are popping up to keep a track on legislation and product developments. For example, sUAS News (→ <http://www.suasnews.com>) is an online news provider for small Unmanned Aerial Systems. Another news website called DroneLife (→ <http://dronelife.com>) has a special section focusing on agricultural UAV developments.

## Flight Riot

This website is devoted to free and open-source drone technology, including building instructions, navigation software, mapping and photogrammetry software, and more. → <http://flightriot.com>

## RPAS regulations

This website has been designed to create a single point of reference where international Remotely Piloted Aircraft Systems (RPAS)-related regulatory information, as well as aviation terminology and recommended RPAS terminology are made available. The website offers free access to a large online library of relevant reference and

guidance documents, and information that promotes awareness of country by country RPAS-related regulatory developments.

→ <http://rpas-regulations.com/>

## Civil drones educational video

This is a video animation made for the European Aviation Safety Agency (EASA) introducing the concept of operations in relation to the use of civil drones. It shows the do’s and don’ts of civilian use of this technology. EASA is working in providing a new set of rules for operating civil drones.

→ <https://goo.gl/C25xvx>

## Understanding the legal environment

Funded by the European Commission, the Drones-Rules.eu project aims at building a comprehensive and high quality online presence with the purpose of increasing awareness and facilitating understanding of the legal environment and constraints in relation with light UAV operations with a focus on non-commercial operators. It also sheds light on the opportunities for economic and job market growth that UAVs represent for entrepreneurs and small and medium-sized enterprises. The portal is due to be launched in June 2016.

→ [www.drones-rules.eu](http://www.drones-rules.eu)

## Humanitarian UAV network

The goal of this network is to promote the safe, coordinated and effective use of UAVs for data collection, payload delivery and communication services in a wide range of humanitarian and development settings. The network is actively developing international guidelines for the responsible use of UAVs and maintaining a wiki to document lessons learned, best practices and existing regulations in countries around the world.

→ <http://uaviators.org/>

## Civil drones educational video

This is a video animation made for the European Aviation Safety Agency (EASA) introducing the concept of operations in relation to the use of civil drones. It shows the do’s and don’ts of civilian use of this technology. EASA is working in providing a new set of rules for operating civil drones.

→ <https://goo.gl/C25xvx>

# Drones and dogs work together to save avocado crops

Florida's multimillion dollar avocado industry is under threat of a deadly fungus that is spread by beetles. But a combination of drones and dogs could be a game-changer.

Invasive redbay ambrosia beetle, which first appeared in the United States in 2000, is native to India, Japan, Myanmar, and Taiwan. Although the beetles are not considered to be major pests in their native range, that is not the case in the US. There, the beetles are feared, because they transmit the *raffaelea lauricola* fungus, which causes a vascular disease in trees called laurel wilt.

This plant disease has already killed approximately 500 million wild laurel trees across coastal forests in south-eastern US. More than 90% of trees die within six weeks of infection, and the disease has a particularly devastating effect on avocado groves. That is a particular concern in South Florida, where commercial avocado crops bring in \$55 million a year, and where the loss of avocado groves to laurel wilt disease could potentially invite replacement costs in excess of \$400 million.

Detecting laurel wilt is a major challenge. Diseased trees can begin to wilt within two weeks, and by the time symptoms are visible, the fungus has likely spread to nearby trees via root grafting. This is a particular problem in commercial groves, where trees are planted close together.

## Spotting infected trees

To contain the spread of the fungus a detection programme was developed by provost and executive vice-president Kenneth G. Furton and Professor of biological sciences DeEtta Mills from the Florida International University (FIU). The programme couples drone surveillance with canine scent detection. 'This is not just a Florida problem,' Furton says. 'From California to Latin America, there are growing concerns about how to respond to this aggressive disease.'

FIU's hunt for infected trees begins with unmanned aerial vehicles (UAVs), which are far less expensive for fungus-hunters to use than manned



helicopters. The UAVs carry thermal digital imaging instruments that are able to search for stressed trees from the sky. UAV-mounted spectral cameras are able to identify the unique spectral signature of laurel wilt and other stressors, allowing analysts to detect affected trees before symptoms are visible to the naked eye.

However, the deployed technology itself cannot identify the cause of the stress. That is where the dogs come in. Dogs have up to fifty times more olfactory receptors than humans, and can be hundreds to thousands of times more sensitive to odour. While drug-sniffing dogs may be better-known, dogs can be trained to detect a wide array of different odours for their handlers. FIU's trained scent-detection dogs are able to detect impacted trees. By using drones to identify particular areas of concern in avocado groves, the dogs are able to search for affected trees in smaller, more manageable areas.

## Removing diseased trees

After a dog alerts on a particular tree, researchers from DeEtta Mills' lab carry out DNA analysis of samples collected from its main trunk or branches, allowing them to confirm that the tree is affected by laurel wilt. As of January 2016, the dogs with the help of UAVs have identified approximately 200 pre-symptomatic trees, all of which were later confirmed to harbour the fungus after lab testing. Currently, diseased avocado trees must be removed, along

with those surrounding them. Already, more than 6,000 of Miami's 74,000 avocado trees have had to be destroyed to contain the spread of the fungus.

FIU's research into laurel wilt detection is funded by the Florida Department of Agriculture and Consumer Services, but the techniques FIU's researchers are experimenting with, could be useful far beyond Miami. The unique detection programme could have far-reaching applications for the entire agricultural industry, including for the much-larger avocado industries in California and in many developing countries. The combination of research, technology, and the assistance from dogs could be the game-changer for the fight against this deadly fungus. ◀

*This article is adapted from other articles written by the authors, like the article 'Dogs, drones battle deadly avocado fungus'. Original link: <https://goo.gl/b1wNPW>*

## About the author

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