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A new eye in the sky: Eco-drones

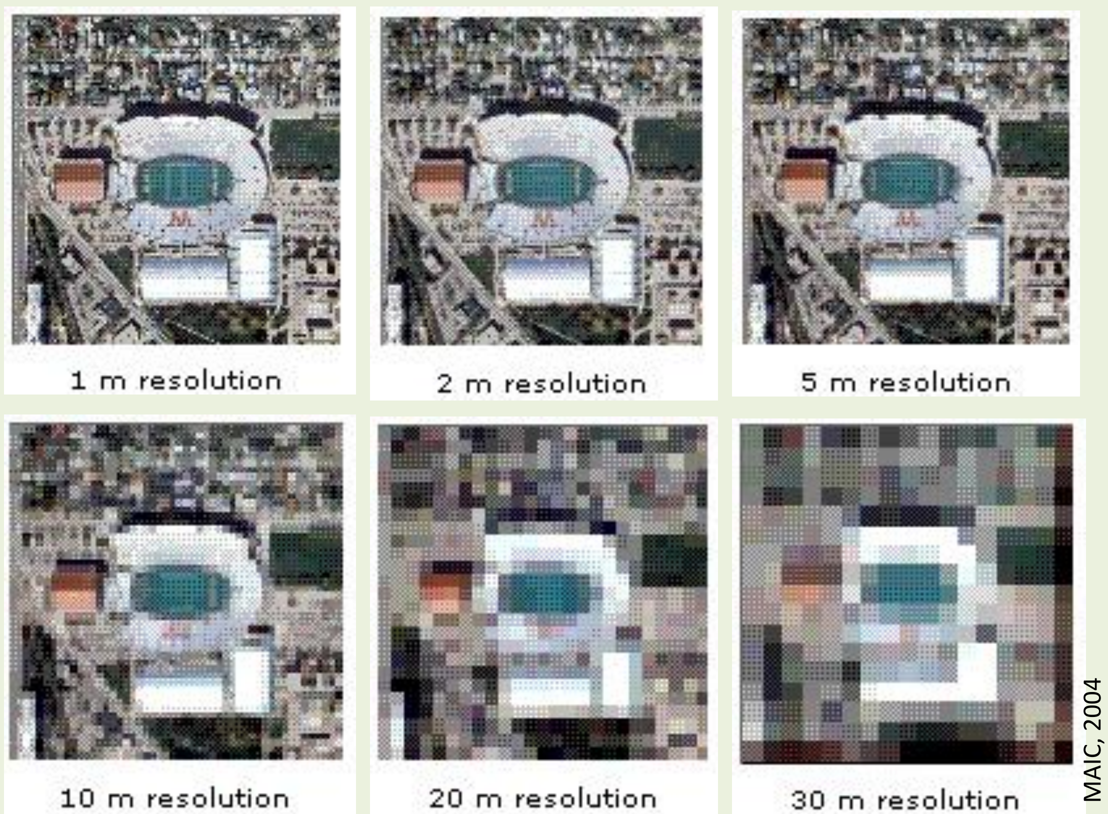
A drone is generally thought of as a military weapon or surveillance tool. Commonly referred to as an unmanned aerial vehicle (UAV), unmanned aerial system (UAS) or remotely piloted aircraft (RPA), a drone can also provide a low-cost and low-impact solution to environmental managers working in a variety of ecosystems. Drones used for these purposes are referred to as 'eco-drones' or 'conservation drones.' Their agility and quality imaging abilities make them advantageous as a mapping tool for environmental monitoring, but there are still several challenges and concerns to be surmounted.

Why is this issue important?

Although many types of satellite imagery are readily available – low resolution for free online (Landsat, MODIS) and high resolution for purchase (WorldView, Quickbird) – they sometimes cannot offer sufficiently high resolution, cover the specific area of study, or capture the time series necessary to fulfill the entire purpose of a project. For several types of situations, satellite imagery and remote sensing analysis are the only way to see what has occurred on the ground, but sometimes the information collected may not be adequate enough. If the image resolution is not high enough to see exact areas of devastation or change, coverage of an entire affected area is not available, or imagery is simply too expensive to acquire, then an analysis will be difficult to complete. The generally low-cost high resolution image capture capability of eco-drones creates the potential for them to fill the data gap between satellites and ground surveying in the aforementioned cases. In addition, eco-drones can do much more than image acquisition, occasionally making them advantageous over typical satellite or aircraft image acquisition.

In addition to image capture, eco-drones can function as a real-time monitoring mechanism for disaster events or illegal resource extraction, distribute broadcast messages and collect and transmit meteorological data (CielMap, 2012). Drones can also fly in riskier and more treacherous areas than humans or manned aircraft can traverse, such as inaccessible shorelines or hurricanes (Nagai et al., 2008; Watts et al., 2012; NOAA, 2012). Due to the size and aerodynamics of drones, they are able to fly at lower altitudes, collecting more precise information than manned aircraft or satellites. This also means that they can fly below clouds making them advantageous in tropical areas where clouds can often impede satellite image collection. A typical UAS can capture images at about 6 cm spatial resolution when flying at an altitude slightly over 200 m (Rango and Laliberte, 2010). With changing ecosystems and disaster dynamics caused by climate change and urbanisation, as well as the elusive presence of environmental crime, on-demand aerial data collection and real-time environmental monitoring will become increasingly important.

Box 1. Variations in detail based upon image resolution.



Pictured above are several images of the same scene, but with varying spatial resolution. Notice the difference in the amount of detail that an image has as the resolution gets smaller (from 30 m to 1 m). Landsat imagery, commonly used for land cover monitoring, has 30 m resolution. Other imagery such as MODIS, which is advantageous for climate monitoring, has resolution much lower than Landsat, ranging from 250 km to 500 km. Cameras on drones can use cameras that capture images with resolution of 1 m or less (Figure 2, see *Benefits of high resolution images captured by an eco-drone* below), as can high resolution imagery such as WorldView, but imagery captured by drones can be a lower-cost option that is able to fly as the event occurs and below clouds.

What are the findings?

A drone can be defined as a system with 'an aircraft with the capacity to fly semi or fully autonomously thanks to an onboard computer and sensors' (CielMap, 2012). Interest in using drones for scientific investigations dates back to the 1970s in which developments during the Cold War created advantageous uses for drones in the research community (Watts et al., 2012). Since then, billions of dollars have been poured into research and development of military and experimental drones, alleviating the commercial market of much of these development costs and enabling the production of a low-cost product that soon will be more widely available and lucrative to the civil and commercial markets (CielMap, 2012). Projections for worldwide spending on unmanned aircraft, in all sectors, exceed US$89 billion over the next ten years (Teal Group, 2012). Technology has improved tremendously over time, but still has far to go.

There are a few challenges associated with using drones, such as smaller image footprint (image area), but with further technological exploration and field testing, solutions can be created. Table 1 describes the advantages of using a drone as well as the challenges users and operators currently face.

Advantages	**Challenges**
Lightweight and easy to transport	Limited flight time depending on model
Low-cost high resolution images	Limited by camera weight
Low-cost operations	Air space limitations and restrictions
Can fly at variety of altitudes depending on data collection needs	Can be limited by wind speed and gusts
Can map areas not accessible by car, boat, etc. on an on-demand time schedule	Limited amount of appropriate software MAIC, 2004
Video recording capabilities	Time intensive to create ortho-mosaics with minimal geographic reference errors
Quick availability of raw data	Due to small image footprint, numerous images must be captured

Table 1. Advantages and challenges associated with drones (Sources: Hardin and Hardin, 2010; Niethammer et al., 2012; CielMap, 2012; Rango and Laliberte, 2010).

Components of the technology

There are three general classes of drones, the most cost effective being close range, and several different models of drones that vary in size, flight time, camera capability, takeoff and landing needs and altitude flight level (Table 2). Drones can vary in wingspan from about 0.5 m to more than 35 m. Altitude is often restricted by government regulations, but some small drones can fly as low as a few hundred metres and some as high as 6,000 m. Large scale drones built for extreme endurance can fly as high as 20 km.

Characteristic	Close Range	Short Range	Endurance
Range	~50 km	~200 km	> 200 km
Flight time	30 min – 2 hrs	8 hrs – 10 hrs	> 24 hrs
Weight	< 5 kg	< 5,000 kg	< 105 t
Speed	~60 kmph	< 485 kmph	< 730 kmph
Altitude	< 6 km	< 16 km	< 20 km
Cost (USD)	$500 - $70,000	< $8 mil	< $123 mil

Table 2. Characteristics of the three general classes of drones: close range, short range and endurance. (Sources: Lucintel 2011, Koh and Wich 2012; CielMap 2012); t = metric tonnes).

Different models of drones are advantageous for different applications. For example, a fixed wing unmanned aircraft (Figure 1A) is best when an extended flight time is required over a long distance. If a small area is being mapped, a multicopter (Figure 1B), which can remain stationary, is best to use. Multicopters such as quad-rotors are also useful in areas of rugged terrain (Niethammer et al., 2012).

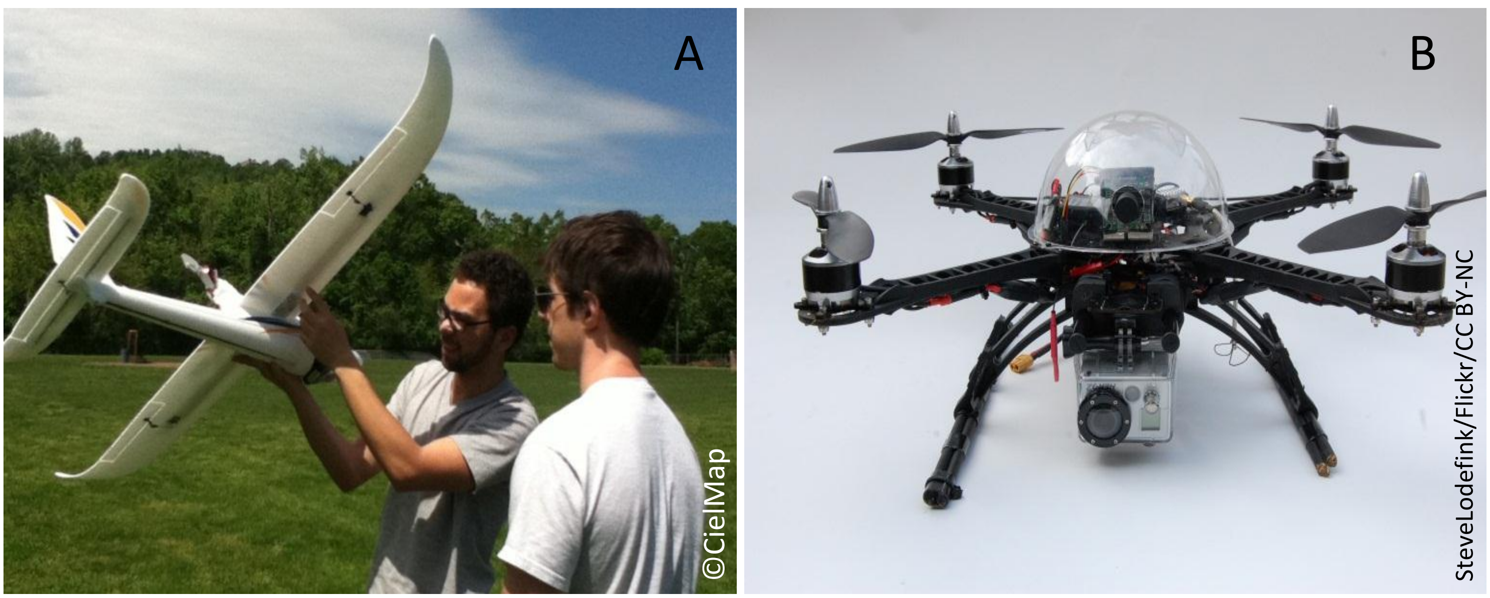


Figure 1. Types of unmanned aircrafts (drones). A. Fixed wing; B. Multicopter

In addition to the drone itself, a complete unmanned aircraft system also refers to the ground control station and the sensors on board (Watts et al., 2012). The complexity of the ground station varies depending on the size of the drone (NOAA, n.d.). A small drone may only require a few laptops and an operator on the ground, while a larger drone involves more equipment that may be mounted in vehicles or trailers in the study area (Watts et al., 2012).

As the model of a drone varies, so does the type of camera or sensor used for image and information collection. Standard imaging equipment on board consists of a digital camera and a multispectral sensor. Depending on how much weight the drone can manage, additional types of sensors can also be carried onboard. Thermal infrared radiometres, hyperspectral radiometres, Light Detecting and Ranging (LIDAR) instruments and Synthetic Aperture Radars (SAR) can also be carried by drones (Rango and Laliberte, 2010).

Images captured from a drone using these cameras and sensors can be stitched together and given a geographical reference much like images from a satellite or a manned plane can be (Hardin and Hardin, 2010).

As previously discussed, some types of drones are capable of carrying video cameras, meteorological sensors, communication transmitters, or a combination of the three (CielMap, 2012). Drones equipped with video cameras allow scientists to monitor disaster situations or biological phenomena such as migration patterns in real time. Law enforcement officials monitoring remote sections of coastline or off-coast areas for illegal fishing can also benefit from a drone with video capability. Meteorological sensors can capture information such as wind, temperature, humidity and pressure (NOAA, 2012). There are many dynamic uses for drones.

Benefits of high resolution images captured by an eco-drone

Niethammer et al. (2012) used drones with a high resolution camera to map fissures on the Super-Sauze landslide in France that had never been mapped before with such detail. Each fissure is approximately 0.1 m in width, making them impossible to detect or measure using satellite data. Using drones enabled the researchers to detect changes in the fissures and draw conclusions they would have had difficulty reaching from the use of satellite imagery. Figure 2 shows a drone prototype and an image it took with a 12 megapixel (MP) camera. Future prototypes from CielMap will test 16 MP cameras as well as a three band (RGB) sensor.

Figure 2. A prototype of a CielMap drone (left image) and a sample high resolution image (right image) taken with the 12 MP camera on board.


USGS-UAS Project Office

Innovative Field Applications

Eco-drones have the potential to supplement data collection efforts and contribute to ecosystem inventory and accounting. Specific environmental and ecosystem applications suitable for the use of a drone can range from precision agriculture, to mapping coastline or soil erosion, to species and habitat monitoring. Drones can be launched into the eye of a hurricane to measure windspeed at altitudes and conditions in which a manned aircraft could not and they can fly over the Artic to observe sea ice conditions and track seal populations (NOAA, 2008). One of the most common civil applications is rangeland management (Rango and Laliberte, 2010). Other environmental applications are described in Table 3.

Change Mapping	Disaster Risk Management	Disaster Risk Mitigation	Illegal Activity	Monitoring
River erosion	Flooding risk	Map impacted areas	Poaching	Migration patterns
Deforestation	Landslide risk	Broadcast messages	Illegal fishing	Endangered species status
Urban expansion	Volcano eruption risk	Monitor forest fire spread	Illegal trade	Agriculture

Table 3. Various environmental applications suitable for the use of a drone.

Use of drones for monitoring destructive activities such as poaching and illegal logging have been notably applied in Africa, Asia and South America. At the end of 2012, Google awarded a US$5 million grant to the World Wildlife Fund (WWF) to use drones, alongside other technologies, to monitor illicit trade in Africa by tracking poachers and the wildlife they are pursuing. Referring to the technology as 'remote aerial survey systems,' surveys will be taken of susceptible areas in Africa and Asia where illegal trade is a US$7 - $10 billion industry (WWF, 2012). Brazil has purchased 14 drones for US$350 million for the Sao Paul Environmental Police to monitor deforestation in the Amazon, track poachers and seek out illegal mining operations. (Cohen, 2011)

The growing occurrences of deforestation and forest degradation worldwide could be more precisely monitored and measured with the use of drones. Member countries of programmes such as the United Nations collaborative initiative on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD+) could benefit from the monitoring capabilities of drones to measure and report deforestation, using the data to calculate forest carbon emissions more accurately. The option of a low-cost drone would be extremely beneficial to governments or organisations with small budgets seeking to fulfill REDD+ requirements.

Early warning applications

Quick, easy deployment and ability to enter hazardous areas make drones a beneficial tool for collecting real-time data about atmospheric conditions, mapping disaster impacts as they occur and their aftermath. This information can be incorporated into current and future early warning systems. Drones can provide information to emergency planners by monitoring evacuation, identifying where environmental conditions are worsening (i.e. flood spreading) and contribute to rescue efforts serving as an emergency response mechanism.

Rapid urbanisation and road construction in China have led to increased frequency and intensity of landslides along highways and roadways (Huang et al., 2011). With more social and economic growth anticipated in China, more roads will be built. Therefore, it is necessary for China to work towards mitigating disasters induced by road construction. Drones can be used to monitor highways vulnerable to landslides, using high resolution cameras to detect cracks that may indicate the onset of a landslide and sensors to detect changes in stress. Once detected, data collected from the drone can be used by authorities to initiate early warning allowing people currently in the area to escape and those travelling to the area to avoid the disaster event before it occurs.

The National Aeronautics and Space Administration (NASA) recently flew a drone into the sulfur dioxide plume and over the vent of the Turrialba Volcano in San Jose, Costa Rica (pictured to the left) to collect data about its volcanic emissions (NASA, 2013). Determining temperature, ash height and gas concentrations (such as sulfur dioxide) over the vent can help scientists predict the direction of the volcanic plume. Manned aircraft would not be able to collect this type of data because the engines would ingest the ash emitted from the volcano, ruining the engines and proving the effort obsolete.

Turrialba Volcano, Costa Rica

Information collected from these missions helps to reduce the impact of potential environmental hazards such as volcanic smog (sulfur dioxide), which can be harmful to people living near the volcano and can eventually be used for early warning.

NASA's Ikhana drone

NASA

The use of drones for early warning of forest fires has been tested by several federal agencies in the USA. By collecting data about forest fires, the public can be alerted of impending danger and firefighters can better plan for how to attack the fires. While helicopters and manned planes could collect similar information, pilot projects conducted by the United States Forest Service (USFS) have proven that UAS technology has a place in wildland fire-fighting especially when considering flight costs, contract requirements, regulations and operations (Hinkley and Zajkowski, 2011). The United States Department of Agriculture (USDA) and NASA have used a drone named Ikhana to gather information that helps fight raging forest fires in California, USA (NASA, 2010). Ikhana has a wingspan of about 20 m, is 11 m in length and can carry more than 180 kg of sensors internally and over 900 kg in pods under its wings. It is designed for long endurance flights at higher altitudes, typically flying at an altitude of 12 km, allowing it to gather a significant amount of data over a long period of time and at an altitude high enough to stay out of the heat of the fires (NASA, 2007). Ikhana is also being used to test new capabilities and advance its technological capabilities to improve the design and function of drones.

What are the implications for policy?

As UAVs become more prevalent in the public and private sectors for research and non-military surveillance, many policy considerations will need to be made. According to a 2012 United States Government Accountability Office (GAO) report, the number of countries with a UAV system for military, commercial, or civil use grew from 41 countries in 2004 to 76 countries by 2011 (GAO, 2012). Tremendous cooperation between nations in regards to airspace jurisdiction will be necessary in the future as eco-drones, and other research drones, become more commonplace. Policy creation and enforcement for demarcation of eco-drones is necessary for communicating to people on the ground that the drones are safe, only for research and to be clearly visible to other air traffic. Future regulations will need to address weight and size of the drones. Data sharing standards will need to be created if data is collected in airspace not native to the research team. Regulations specific to drones used for environmental modeling or research will need to be developed, implemented and enforced with heavy regard to public safety and privacy (Rango and Laliberte, 2010).

Currently, within American airspace, some universities and research establishments in the public and private sector are able to fly drones for purposes that appeal to public interests, such as disaster relief, search and rescue and border patrol (FAA, 2013). To fly a drone, the public sector must obtain a Certificate of Waiver or Authorisation (COA) and the private sector must obtain an experimental airworthiness certificate in addition to following many regulations (FAA, 2013). For both sectors, drones may not be flown over densely populated areas to ensure public safety. For the USA, a better understanding of the systems, operations and technology will be gained over the next few years as the Federal Aviation Administration (FAA) works towards fully integrating UASs into the National Airspace System (NAS) by 2015 (FAA, 2012).

On a global scale, UAV manufacturing and export as well as licensing will need to be regulated to ensure that purpose remains ethical and legitimate and does not violate public safety and privacy (GAO, 2012). European regulations generally coincide with those of the USA, but requirements among most other countries vary considerably (Watts et al., 2012).

To the left are images captured by a drone used in this study:

a) Young palm plantation
b) Maize field
c) Elephant Patrol Unit camp
d) Forest
e) Recently logged forest
f) Forest trail

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