

# THE DRONE



# REVOLUTION

## UAV-Generated Geodata Drives Policy Innovation

In Brazil alone, officials estimate that 20,000 drones were in operation in 2015, with applications mainly in agriculture, mining, infrastructure inspections, security and border control, and the mapping of environmental areas and cities. Credit: iStock.com/dabidy

*By John Wihbey*

**DRONES ARE REVOLUTIONIZING DATA COLLECTION AND MAPPING, USHERING IN MAJOR SHIFTS AND NEW OPPORTUNITIES IN THE DOMAINS OF LAND MANAGEMENT, POLICY, AND ADVOCACY.**

Unmanned aerial vehicles (UAVs) came into wide use globally about a decade ago, as their cost fell rapidly in the consumer market. In the developing world and in rapidly urbanizing areas, drones are quickly becoming an essential tool for securing land rights, updating maps in virtual real-time, and understanding unplanned settlement patterns. From Latin America to South Asia, the drone is being deployed across the geospatial information and land management sectors, by surveyors defining specific urban parcels, appraisers determining land value over a peri-urban field, and corporate and government employees updating territorial information.

The technical capacity of drones—which can carry multispectral small-format aerial cameras and produce images of both the visible environment and the infrared spectrum—provides a substantial complement to traditional aerial photography and even high-resolution satellite imagery. Because UAVs can fly at very low altitude and execute tight, repeating patterns, they can produce fine-grained images of one centimeter resolution or better, enabling production of three-dimensional images.

Their democratic potential is also stirring excitement, as they empower citizens, nongovernment organizations, and other smaller, more informal networks. “Drones are going to make the difference for policy and decision-making processes, as citizens participate in data creation at critical moments,” notes Diego Alfonso Erba, a land surveyor engineer and expert in Latin American land management systems. “Citizens can fly them, take photos of a situation, and share the results with authorities. In rapidly evolving

situations where informal settlement, unsanctioned resource extraction, or conflict is occurring, drones can furnish proof to legal systems.

Latin America’s pioneering use of drones to enrich and improve land policy and management is echoing across the globe. “We are doing the same thing in China,” says Zhi Liu, China program director at the Lincoln Institute and director of Peking University–Lincoln Institute Center for Urban Development and Land Policy (PLC) in Beijing. In East Asia, drones are aiding new high-tech research and experiments to modernize land registries for contemporary uses and to help address other large-scale challenges, including potential implementation of property tax.

## Cadastral: Public Land Registries in Latin America

In Latin America and Asia, drones are proving especially useful in the evolution of territorial “cadastral”—public registries that manage information relating to land parcels and that play a critical role in land use decision-making throughout Latin America.

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model imported centuries ago from colonial Europe, says Erba, who coauthored *Making Land Legible: Cadastres for Urban Planning and Development in Latin America*, published by the Lincoln Institute in 2016. He is working at the forefront of an effort to upgrade these land registry systems to what are known as “multipurpose cadastres (MPCs),” and drones are playing a key role in this evolution.

Traditional, or “orthodox,” cadastres are maintained as public registries by governmental institutions. They’re inadequate for contemporary urban policy-making because they cover only private parcels and account for limited physical, legal, and economic attributes. Multipurpose cadastres, by contrast, are maintained by volunteer stakeholders in a jurisdiction who commit to providing richer, more inclusive information about a city. MPCs may include alphanumeric data and thematic or domain-specific cadastres pertaining to the environment,

transportation systems, or utility networks, and they may be organized by government and private organizations. The benefits can include better urban planning as well as more equitable taxation, increasing revenues, and a broader tax base.

“The data integration provided by the MPC model is the most direct way to identify and monitor the economic, physical, legal, environmental, and social characteristics of parcels and their occupants,” observe Erba and coauthor Mario Piumetto, a land surveyor who specializes in geographic information systems. “Planners need this information to manage the growth of cities, define strategies for urban financing, reduce informality, and analyze the impact of government interventions” (Erba and Piumetto 2016). By democratizing the tools of geospatial monitoring, drone technology is helping to facilitate this movement toward multi-stakeholder MPCs.

Established Latin American cities with existing cadastres are using drones to tackle challenges associated with informal construction. For example, in Villa 31, one of the most valuable areas of Buenos Aires, some 40,000 people have built informal constructions up to five stories high within a 100-block area, note Erba and Piumetto.

In Villa 31 in Buenos Aires, a government-launched drone survey, in tandem with a street-level laser scanner, created a 3-D model and generated statistics on the occupation of dwellings, streets, and public spaces, creating a more accurate picture of residential development. Credit: Javier Palmieri/Alamy Stock Photo



In 2016, the government launched a drone survey, in tandem with a street-level laser scanner, that created a 3-D model and generated statistics on the occupation of dwellings, streets, and public spaces. With this more accurate picture of residential development, agencies and stakeholders are in a better position to transition informal settlers toward formal property ownership and participation in planning processes.

Ecuador demonstrates how drone-enhanced cadastres can promote resiliency as well. The city of Portoviejo has been using drones to enforce rules against unpermitted occupation of public spaces. By comparing 2010 records with recent drone-produced monitoring imagery, authorities determined that more than 7,000 instances of new construction violated permitting rules. In April 2016, this more accurate real-time record of settlement proved vital when a 7.8-magnitude earthquake wreaked havoc on structures throughout Portoviejo, killing more than 200 people. Photos after the earthquake were compared to recent drone footage, aiding rescue and rebuilding efforts.

## GIS-Assisted Mass Appraisal in China

In China, drones may prove most useful in current efforts underway to assess property value (see p. 8). Since 2003, China has been contemplating introduction of a municipal property tax on the private ownership of residential properties—a power that municipal governments have not had for several decades. However, most cities face a huge technical barrier: There is no system of property assessment or database. Researchers hope drones can help facilitate the underlying basis for assessment.

“The question is how we can help so many Chinese cities to quickly develop a cadastre system, which is the basis of a property tax system,” says Liu, noting that the PLC is funding a research project in China to provide innovations in this area. The next stage is for researchers in China to merge property rights data with 3-D representations of parcels produced by drone

technologies. Crucially, researchers must get the full property rights data from the government—such as formal ownership information and the dimensions of units, parcels, and buildings—in order to match up the 3-D imagery in accurate fashion. It is unclear whether these records are fully digitized in many cities, Liu notes. Although drone-generated data cannot provide missing ownership documentation, better parcel data will ultimately accelerate the process of generating an accurate cadastre system.

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Chun Zhang, a professor of city planning from the Beijing Jiaotong University and a leader of the project funded by PLC, says drones are currently using tilt-shift photography—which can make the features below a drone look like a miniature representation—and creating 3-D models through the imagery captured. The project will then provide basic spatial information. Currently, the drone techniques are being applied in small towns such as Jimingyi, Shexian, and Gubeikou. But as the researchers experiment with drones, they are bumping up against technical and regulatory limits. “The survey area cannot be too large,” notes Zhang, given the limits of the drone’s battery. “The biggest difficulty for researchers is flight control in certain [limited] areas—within the 6th ring of Beijing, for example.” But this should not be a problem if the municipal governments decide to use drones to develop a 3-D property database.

Property valuation is beyond the scope of Zhang’s current research project, but it will be a challenge of massive scale in China. Ultimately the work-intensive process might be solved by computational methods aided by drone-generated

data. In the United States, Liu notes, local governments have long used computer-aided mass appraisal (CAMA) techniques to appraise all properties in a certain area. “In China, we work with a few cities that are refining the computer-aided mass appraisal model to incorporate big data, so they can assess property value more accurately,” Liu says. That sort of work might constitute the next phase of research. But the current phase remains focused on seeing how well existing property records can be matched with the drone data.

In the context of land registries, the use of drones is proving crucial in the initial and provisional identification of physical property limits in cities and jurisdictions where there is still no formal land administration system and the land structure is unknown.

## Pathways to the Drone Revolution

Drones are now functioning in a crucial capacity across a variety of land policy use cases, fulfilling cultural and legal needs, but their development and use obviously have a wider story. Their evolution toward wider commercial and recreational use—including sharper definition of land policy—is in some ways a classic story of second-order effects of technological innovation. The original development and prototyping of the flight technologies took place largely in the context of military research. But some of the key technical breakthroughs required to make flight-relevant instrumentation available at a reasonable price point resulted from the “smart-phone wars,” wherein various communications technology companies raced to perfect efficient hardware and software for compasses, gyroscopes, altimeters, and more (Anderson 2017).

Still, even as the technology has been ready and the economics right for wide public use, the policy environment for drone use has needed to mature. In the United States, for example, the Federal Aviation Administration has tried to grapple with commercial and consumer demand

while balancing concerns over conflicts with manned aircraft flight paths and potential invasion of privacy and land rights. These types of policy debates have been playing out across the globe, as noted above.

Yet many of the technologies under development are focused on agricultural lands, where competing interests and conflict are minimal. Farming is expected to be the primary zone for commercial use of drone technologies. Because drone instrumentation can be used to measure radiation signatures and the infrared spectrum, drones hold massive potential for improvements in crop yields and farming in general (Wihbey 2015). But the benefits have been unevenly distributed over the past decade, as countries such as Japan and Canada have opened up farming airspace, even as the United States is debating where to open up air space policies for agriculture (Lewis 2017). To scale the technology for farming, much greater latitude will be required for drones flying beyond the sight of ground operators. In any case, the idea of “precision farming” has caught on globally, with potential environmental benefits, such as reduced and more targeted use of pesticides and other chemicals. And surely the advancements achieved for rural farm settings will have applications for monitoring, for example, forest reserves and wildlife populations, and for global efforts to limit sprawling unplanned settlements and ensure ecological sustainability (Paneque-Gálvez et al. 2014).

Policies related to the training, licensing, and certification required for drone operators continue to evolve in many countries, and of course formal land surveying itself has its own professional standards that are integrating these new technologies. Citizen or recreational use and informal monitoring of land and urban space is bound to grow only more complicated, as new observational possibilities and challenges emerge from the use of multiple drones simultaneously and “swarming” techniques, as well as the potential for both greater autonomy, as drones become smarter through software, independent of human operators (*The Economist* 2017).



A drone photographed the Mutianyu section of the Great Wall in Huairou, north of Beijing. Credit: Xinhua/Alamy Stock Photo

## Challenges

Drones could prove a crucial tool for managing extensive land use problems expected to emerge over the coming decades as the world rapidly urbanizes, from housing inaffordability to shortages of land for open space (Wihbey 2016). Indeed, drones might facilitate a form of technological “leapfrogging,” similar to that of mobile phone Internet connectivity, which has allowed many individuals and societies across the developing world to connect to the Web without dedicated broadband lines to households.

PLC Director Zhi Liu thinks that multipurpose cadastres would enable solutions, but many Asian cities would need technical advancement, as well as political willingness and public support, to improve and update the cadastres of their rapidly growing cities. Experiments in small cities and towns in China might prove useful to other bigger cities in the region, if not countries around the world.

Regulations throughout South and Central

America are evolving to keep up with the proliferating use of drones as tools to upgrade land policy in the region. In Brazil alone, officials estimate that 20,000 drones were in operation in 2015, with applications mainly in agriculture, mining, infrastructure inspections, security and border control, and the mapping of environmental areas and cities, according to Erba and Piumetto. In May 2017, this growth prompted the Brazilian National Civil Aviation Agency (Agência Nacional de Aviação Civil or ANAC) to issue new safety and operating rules, which cite and specifically follow definitions of other civil aviation authorities such as those found in the United States and the European Union (ANAC 2017).

In Mexico, the Civil Aeronautics General Directorate in Mexico has issued a similar set of rules that aims to prevent accidents and protect third persons and property on land and in flight. In Argentina, flights above 400 feet (122 meters) require authorization, and there are also limitations depending on the weight of the equipment, the areas overflown, and the information collected.





In April 2016 in Portoviejo, Ecuador, drone footage aided rescue and rebuilding efforts after a 7.8-magnitude earthquake wreaked havoc on structures throughout the city. Credit: Andes/César Muñoz/Flickr

## New Frontiers for Drones

Many institutions across the world have become interested in leveraging drone technologies to help solve age-old administrative problems, particularly in areas of the world that have suffered under adverse conditions caused by conflict or difficult economic conditions. The World Bank, for example, has highlighted efforts in the post-conflict Balkans, where areas in Kosovo have been left with lingering problems after property owners, mostly male, were killed in the 1990s regional war. The women left in these areas have struggled to reestablish order with regard to property and land policy, given the lack of formal records. The World Bank has noted: “The time, cost, and complexity of conventional land surveying and registration . . . is an obstacle for these women. It often takes years and is too expensive to complete, leaving these women with no information or legal protection of their rights” (World Bank 2016). In partnership with the Kosovo Mapping Authority, drones are therefore being used to execute cadastral mapping activities.

World Bank experts have also noted that drones are proving to be effective weapons in the fight for land rights in underdeveloped areas on the African continent (Totaro 2017). Although nearly 90 percent of Europe is mapped at a local

level, only 3 percent of the African continent has maps at such resolution. As coastal zones are rapidly developed for hotels and commercial/residential use, drones could help communities keep up with development and garner appropriate tax revenue.

Overall, the strength of drones comes from the richly detailed information they can collect at relatively low cost; they can even produce quality 3-D models of streets and properties and expedite data collection. But certain weaknesses must be taken into account. UAVs can only provide limited territorial coverage, given limited speed and autonomy of flight. Adverse weather conditions are also a significant issue.

Drones have so far proven most effective in urban operations, which often require great detail and richness of data. Any decision to deploy drones has to weigh costs and benefits for a given task. High-resolution satellite images (currently down to 30 centimeters, or 1.8 inches, in resolution) may suffice; if the area to be surveyed extends beyond 25 kilometers (about 15.5 miles), satellite image files may be more appropriate and efficient.

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Yet drones furnish possibilities that no other aerial surveying technology provides given their mass market deployment. “Drones will democratize geospatial information gathering and analysis,” Erba says. “Everybody will soon have access to the tools that only satellite owners had just a few years ago. Photos could be sent all the time to the cloud.” And this new capability, he notes, could strengthen transparency and accountability of many kinds, and bring efficiencies to government: “Aerial photos of areas being invaded or deforested in real-time could be sent directly to the officer responsible for urban monitoring. This extremely relevant information can be provided at no cost to the state, and it can be used immediately for action.”

Whether such action involves more uniform regulatory enforcement, better tax collection, or richer, more dynamic data for land registries, these new technologies are poised to bring major shifts across numerous aspects of land policy worldwide. □

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