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RESEARCH ARTICLE

Drones, communities and nature: pitfalls and possibilities for conservation and territorial rights

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Since the early 2010s, small drones have become key tools for environmental research around the globe. While critical voices have highlighted the threat of 'green securitisation' and surveillance in contexts where drones are deployed for nature conservation, Indigenous peoples and local communities (IPLCs) worldwide have also begun using drones – most often in alliance with non-governmental organisations or researchers – exploring this technology's potential to advance their own territorial, political and socio-ecological goals. Against this backdrop, this paper examines six different experiences in five countries where communities are using small drones in areas of high ecological and cultural diversity with international significance for nature conservation. We highlight the ways that communities deploy drones – both in terms of their motivations and actual use strategies. We also reflect upon the opportunities and barriers that IPLCs and their collaborators encounter in designing and implementing meaningful drone strategies, explicitly considering social, economic and political challenges. Finally, we consider the socio-ecological outcomes that community drone use enables across these sites along with the ways that drones engender more biocultural and territorial approaches to conservation through IPLC-led monitoring and mapping efforts. In conclusion, we suggest that effective, meaningful and appropriate deployment of drones, especially with IPLCs as protagonists in their use, can support nature conservation together with the recognition and protection of biocultural and territorial rights. Given the mounting demands for conservation to counter intertwined global socio-environmental crises, community drones may play a role in amplifying the voices and territorial visions of IPLCs.

Key words community-based monitoring • conservation • Indigenous peoples • Indonesia • Latin America

Key messages

- Community drones represent the adoption of these technologies for community-led priorities.
- Many regions are seeing an increase in community drones in high-value nature conservation zones.
- Conservation outcomes may improve in these areas, depending on a range of contextual factors.
- Community drones allow users to promote biocultural conservation and assert territorial rights.

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Introduction

Efforts to conserve nature have increasingly come to rely on earth observation to identify, plan, monitor and enforce conservation spaces (Adams, 2019; Pritchard et al, 2022). The rapid advances in digital data production, processing and storage have made earth observation technologies, which include satellite remote sensing and more traditional near-earth aerial imagery collection, increasingly powerful as well. In the context of biodiversity conservation and nature-based climate change mitigation efforts (Bayrak and Marafa, 2016; Anguelovski and Corbera, 2023), which have well-documented histories of producing conflict and marginalisation (West et al, 2006; Adams and Hutton, 2007), these powerful technologies have the potential to create new frontiers of exclusion. Drones in particular have provoked calls for caution (Humle et al, 2014; Massé, 2018; Duffy et al, 2019). At the same time, the democratisation of earth observation has highlighted the potential of drones as increasingly accessible tools that may enhance inclusive and transformative governance, especially as Indigenous peoples and local communities (IPLCs)[2] take up these technologies for their own territorial goals, which encompass political, economic, cultural and socio-ecological priorities (López Sandoval et al, 2017; Paneque-Gálvez et al, 2017; Radjawali and Pye, 2017; Millner, 2020).

Even as drones and the data they produce still remain primarily under the control of actors external to IPLCs (Sandbrook et al, 2021; Pritchard et al, 2022), what we term 'community drones' are becoming more common and may suggest another set of outcomes. Community drones involve uses that correspond primarily to the needs and interests of IPLCs themselves, where these communities participate directly in at least some of the steps related to the drone's use, from planning the deploy to flying the drone to processing, analysing and/or using the data generated (Vargas-Ramírez and Paneque-Gálvez, 2019). Although some studies now explicitly consider community drones, understanding how communities engage with this technology and the degree to which it may serve broader community goals remains unclear (Radjawali and Pye, 2017; Millner, 2020; Macdonald et al, 2021).

This article draws on the authors' experiences supporting and studying community drone users by examining six cases across five countries to ask: why do communities engage with drones in spaces of high value for nature conservation? What benefits and drawbacks might drones provide to these users? And what are the potential implications for conservation outcomes and for IPLCs themselves? The cases, from Colombia, Guatemala, Indonesia, Mexico and Peru, highlight the different degrees to which IPLCs engage with drones as well as the importance of their political, economic, cultural and socio-ecological contexts for limiting or enabling bottom-up approaches to drone use.

In the next section, we provide a brief overview of the literature on community drones before outlining our methodological approach. We then provide a brief overview of each case and trace key factors that motivate, enable or constrain community use of drones in these spaces. We then discuss the benefits and drawbacks of drones to produce improved outcomes for nature conservation and IPLCs' territorial projects based on these cases. We close by highlighting the important role that drones may play in conservation spaces vis-à-vis IPLC rights and territorial visions, given that their use can shape the socio-ecological landscapes in question.

Background

Drones have gained growing relevance in a wide range of fields and civil applications (Otto et al, 2018), ranging from agriculture (Rejeb et al, 2022), to archaeology (Risbøl and Gustavsen, 2018), to risk and disaster management (Furutani and Minami, 2021), to nature conservation (Wich and Koh, 2018). The use of drones for this final field has generated some controversy, however, due to its relationship with militarised conservation surveillance and potential for negative social and cultural impacts given high social tensions around many protected areas (Humle et al, 2014; Sandbrook, 2015; Simlai and Sandbrook, 2021). Specific concerns range from unauthorised drone intrusions into culturally sensitive areas to exclusion of local knowledges from decision-making processes based on high-detail, drone-acquired data to the criminalisation of local communities, especially around resource access and use (Reyes-García et al, 2022; Pritchard et al, 2022). These controversies have motivated the exploration of more democratic and collaborative uses of drones for conservation from perspectives such as citizen science (Bunting et al, 2022), community-based monitoring (Paneque-Gálvez et al, 2014; Mena et al, 2020), and participatory mapping (Paneque-Gálvez et al, 2017; Radjawali and Pye, 2017; Colloredo-Mansfeld et al, 2020; Macdonald et al, 2021).

Previous research into community-based management as well as counter- and territorial mapping has indicated that placing people on the map in conservation landscapes can have mixed results – even when local people themselves participate in or lead the process. Earlier research from Central America and the Amazon, both important frontiers for drone usage, suggests that the 'territorial fix' works in part through cartographic objectification of place, which can fragment territories, constrain physical access to places, produce more state-friendly institutional forms, and limit opportunities for meaning-making for IPLCs (Hale, 2006; Bryan, 2011; Reyes-García et al, 2014; Cheyns et al, 2020). Feminist and critical geographers in particular call attention to the ways that mapping practices can function as 'an imposition of fixed limits on local epistemologies of fluid boundaries and tolerant territorialities, forcing local communities to translate their territorial aspirations into maps that Western institutions will accept' (Oslender, 2001: 253). Despite these theoretical drawbacks, many IPLCs have actively pursued mapping as a strategy to claim and gain legal recognition of their territories, especially to counter unfavourable government policies or to indicate the extent and sustainability of their resource use across time and space (Rye and Kurniawan, 2017; Galeana, 2022). As pressure on IPLC lands has mounted in recent decades, mapping has become a key strategy for both counter-claiming and for forging new forms of territorial identity and practice (Chapin et al, 2005; Chambers, 2006; Offen, 2009).

To this end, drones provide IPLCs in conservation-relevant spaces a potentially powerful tool to advance their interests in contested contexts – especially where they receive external support to use these technologies (Radjawali and Pye, 2017; Vargas-Ramírez and Paneque-Gálvez, 2019; Millner, 2020; Macdonald et al, 2021). Increasing attention to nature-based climate solutions has renewed global prioritisation of nature conservation, but also potentially provided a new source of contestation over the use and control of IPLC territories (Bayrak and Marafa, 2016; Townsend et al, 2020; Osaka et al, 2021). Global and national initiatives have received critiques for their failure to view the integral socio-ecological systems that constitute zones of interest for new nature conservation programming (Fougères et al, 2022; Anguelovski and Corbera, 2023), despite long-documented attention to the importance of biocultural conservation to achieving just and effective outcomes (Gavin et al, 2015; Lukawiecki et al, 2022). In the face of traditional threats to maintaining land rights and use, from extractivism to industrial agriculture to exclusionary conservation practices (Bebbington et al, 2018), community drones may be a tool for inserting IPLC concerns directly into this growing demand for nature conservation and restoration in multiple global policy arenas (Fleischman et al, 2022; Pritchard et al, 2022).

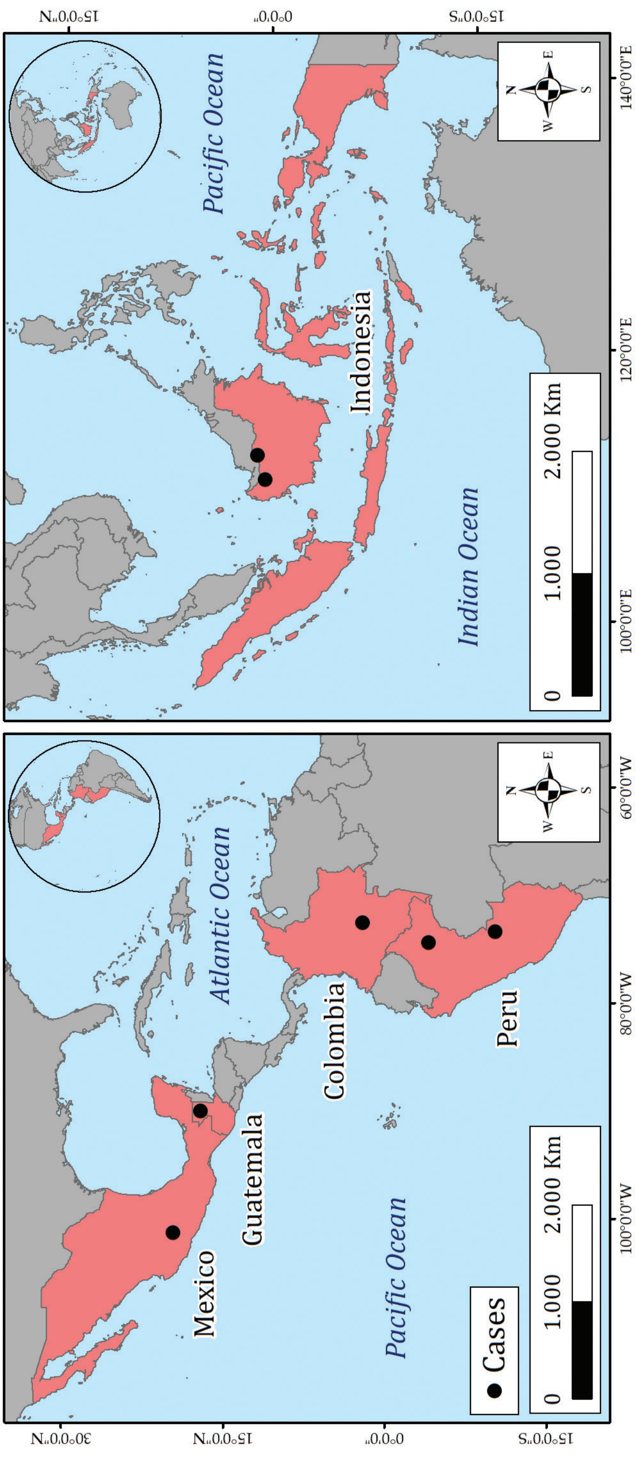
Methodological approach

This article draws on the empirical research experiences of each of its authors, who have worked extensively in disparate sites with community drones in high-priority nature conservation contexts. Though the methods used by each of us varies by disciplinary approach and research questions, from participatory mapping to ethnography, we combined our previous experiences by reflecting on key differences and similarities in our approaches, the contexts in which we have worked, and what role drones play in those contexts in relation to IPLCs and conservation. Informed by the emerging literature on drone usage in conservation and based on our experiences, we explored the political, economic, social, cultural and environmental factors that may explain why IPLCs engage with drones in conservation spaces through a comparative reflection exercise.

To standardise the comparison, we develop six case studies from five countries providing a brief overview of the location, community context and conservation site (Figure 1), based on our previous work and including both published and unpublished data, all of which was collected in keeping with research standards of our respective organisations. To probe the degree to which our defined set of potential factors might play a role in IPLCs engagement with drones and related implications across cases, we explicitly present for each case some background as well as drone-specific analysis. We examine:

1. The location and conservation value of the site as well as threats to ecosystems.
2. The IPLCs in or around the site and the context of their territorial struggles.
3. A brief overview of why drones are used, for what exactly, with whom and for how long.

Figure 1: Geographical location of the covered cases across five countries.



Source: Authors' own elaboration (World Food Programme, 2019).

4. Constraints on drone use (include funding, technical know-how, regulations, safety, environmental or cultural barriers, infrastructural constraints and ethical guidelines).
5. The benefits from drone usage for IPLC land-use and territorial rights as well as for nature conservation, according to community members and from the researchers' perspectives, in addition to secondary sources.

Through consideration of these questions for each case, and collective reflection and comparison, we develop an initial framework for understanding community engagement with drones in nature conservation spaces.

Drones, communities and conservation: six cases

In this section we present the six cases from across five countries, arranged alphabetically by country. For each case, we address the questions outlined in the previous section.

Colombia (Guaviare Department)

The Andean, Orinocense and Amazonian ecosystems converge in the Department of Guaviare, where humid tropical forests give way to savannahs in the north of the Colombian Amazon. This area has long been the target of conservation interventions, given the global importance of the Amazon for biodiversity conservation. Intermittent conflict, land speculation and drug trafficking-related money laundering promote illicit cattle ranching, palm oil monocropping and land grabbing, driving continued deforestation and fires in this region (FCDS and Unidos por los Bosques, 2022).

Drones originally entered Colombia in the context of its long-running internal armed conflict (1958–present). The military began using drones in Colombia in 2002, and deployed this technology to attack guerrilla camps, undertake espionage operations and fumigate illicit crops (Huezo and Bazán Orobio, 2021). The first community drones arrived in Colombia in 2014, as part of an international effort by organisations such as The Nature Conservancy to train representatives from the environmental sector and civil society to monitor natural disasters and conservation agreements in Colombia. The Food and Agriculture Organisation of the United Nations further supported this programme, expanding the network of community-oriented drone use that had previously emerged in Central America (Vargas-Ramírez and Paneque-Gálvez, 2019).

In 2017, the National Amazonian Research Institute (SINCHI), part of the Ministry of Environment, first deployed drones for conservation in Guaviare to monitor the forest conservation agreements it had implemented with 12 peasants' associations. These agreements guarantee that at least 50 per cent of the primary forest area in peasants' farms remains protected over time, equating to nearly 2.4 million ha under agreements in Guaviare (Ministerio de Ambiente y Desarrollo Sostenible, 2021). The conservation monitoring programme between the peasants' communities and SINCHI relies on four key technologies, which together make up an integrated system (called MOSCAL): GIS, low-altitude flyovers and aerial photography, community monitoring and drones.

SINCHI manages the drones under this monitoring programme, and its professionals combine aerial photography and satellite images with peasants' organisations' field-based observations and monitoring data to fulfil its mission. Though its resources come mainly from international cooperation agencies seeking to reduce deforestation, including through the Global Environment Facility, Green Climate Fund and REDD+ projects regulated by the Colombian government, SINCHI manages its programmes to explicitly incorporate community inputs. In field visits the relevant author carried out between 2021 and 2022 in the villages of Guaviare, the community leaders of the Community Action Councils (Juntas de Acción Comunal) together with the local environmental NGO Foundation for Conservation and Sustainable Development (Fundación para la Conservación y el Desarrollo Sostenible, FCDS), they recognised the legitimacy and value of SINCHI because of its dialogue, knowledge transfer and consultation practices, as well as its non-militaristic ethos, neutrality in the face of disputes, and protection of the confidentiality of peasants in the field. These factors are especially significant given that SINCHI operates in a region that experiences armed conflict and drug trafficking, meaning that careless monitoring and data practices could put human lives at risk.

The peasants' associations do not use drones themselves, although legally they could. They have deliberately decided against piloting drones, given that still-powerful illegal armed groups have banned drone use in their areas of influence. By strategically allying with SINCHI in its monitoring efforts, peasants leverage conservation initiatives to achieve territorial defence objectives and to encourage the state, civil society and scientists to recognise their rights and role in conservation. Despite the conflicted environment of Guaviare, and their own deployment of more analogue tools, peasants' associations have found ways to enhance territorial rights through drone-based forest monitoring. They intertwine community expertise, knowledge and practices with those of scientists and conservation professionals to constitute an expanded network for protecting the Amazon Forest and its communities.

Guatemala (Petén Department)

In the north of Guatemala lies the Maya Biosphere Reserve (MBR), which includes strictly conserved national parks as well as community-managed multi-use areas. The tropical lowland forest is home to a variety of endangered species and keystone predators, such as the jaguar (Nature Conservancy, 2022). The MBR is also known for its important Maya archaeological sites, including Mesoamerica's largest pyramid at the remote El Mirador site (Devine, 2018). Established in 1990, towards the end of Guatemala's 36-year civil war, the MBR became part of the country's 1996 peace process when it included measures to grant conditional forest rights to communities, specifically in the form of 25-year forestry concessions.

Concession rights enable community organisations to extract timber and non-timber forest products in a sustainable, certified manner in return for maintaining forest integrity (Elías and Monterroso, 2014). Community concession organisations, organised through the Association of Forest Communities of Petén (ACOFOP), have significantly invested in forest monitoring and protection activities, resulting in less deforestation, fewer fires and a similar or higher level of biodiversity in comparison to state-managed lands (Davis and Sauls, 2017; Stoian et al, 2018); however, communities' rights to the forest remain contested despite these outcomes.

A range of economic interests have invested in rezoning the MBR to enhance access to El Mirador, arguing that doing so will increase tourism and income levels locally and nationally. However, several concession communities overlap with the proposed rezoning, and by the late 2010s, pressure from pro–El Mirador expansion factions presented communities with a major challenge (Rahder, 2020; Devine et al, 2021). As one element of countering narratives arguing that the communities were not appropriate forest stewards, ACOFOP turned to mapping and monitoring with drones as part of a technical, but also a political, strategy (Millner, 2020).

Through support from the Climate and Land Use Alliance / Ford Foundation and in partnership with Rainforest Foundation US (RFUS), forest monitors from MBR communities received drone training between 2015 and 2018 (Millner, 2020). ACOFOP has now adopted drones as a regular tool for monitoring, prevention of and control of forest fires and deforestation, building on previous GIS and mapping efforts. Concession organisations own and maintain their drones and produce standardised information to share with the government, external certifying agencies and donors. The use of drones and other monitoring technologies has also indicated the capacity and investment of communities in forest protection – images of community drone users and ACOFOP-produced maps featured heavily in press conferences and political advocacy around the concession renewal process, which has ultimately succeeded (Davis and Sauls, 2017; Devine et al, 2021).

While there are limits on drone use in certain national parks, and illicit interests along the western fringes of community concessions can stifle their use there, ACOFOP-supported communities face few limits on the use of this technology. In the current, relatively favourable political conditions, where ACOFOP has secured further 25-year concessions and garnered international accolades for their forest protection accomplishments, these communities are in a strong financial and institutional position in terms of forest monitoring, though their reach is limited spatially, and political conditions are subject to change with each set of elections. ACOFOP's communities also increasingly speak of the defence of territory as one of their primary objectives for drone use, linking their political goals to ongoing long-term nature conservation governance.

Indonesia (Kembayan District)

In the middle of large oil palm concessions (Kembayan District, Sanggau, West Kalimantan), lies a remnant forest patch (1,600 ha) and nearby villages and hamlets that constitute a mosaic landscape of biodiversity-rich forest gardens (locally known as *tembawang*) and jungle rubber mixed with fallow forest at various stages of regrowth. While communities generally maintain their traditional *tembawang*, some are starting to convert these gardens into rubber monoculture or oil palm smallholder plantations, as is also the case for many fallow forests on the expanse of paddy fields. This situation means remnant biodiversity in isolated traditional agroforestry systems is at high risk (Simamora et al, 2021).

Part of Kembayan District is under a Community Forest Scheme (*Hutan Kemasyarakatan* – HKm), a component of the Government of Indonesia's Social Forestry programme, which has allocated 12.7 million ha of forest to be managed by communities nationally (Resosudarmo et al, 2019); however, a lack of institutional engagement has generated tensions between the government and communities

(Fisher et al, 2018). In 2012, the Ministry of Environment and Forestry granted the Bokal Kuomo Farmer group in Kembayan the rights to manage 700 ha of former state production forest area through HKm and expected that farmer groups would plant the tree species they recommended (Myers et al, 2016). The communities' preference for planting *tembawang* and rubber, however, led the Ministry to consider revoking those rights.

Drones entered this context in response to the threat to the HKm programme in Kembayan. A local NGO involved in advancing social forestry, Yayasan Perhutanan Sosial Bumi Khatulistiwa, developed a research action project on the use of trees on farms to maintain biodiversity while enhancing livelihoods. This project, funded by the International Climate Initiative of the German Federal Ministry for the Environment, included an international research organisation (CIFOR) and a local university (Tanjungpura University, Pontianak) with the technical capacity to address this issue qualitatively and quantitatively. These partners organised meetings with the local communities, including undertaking several focus group discussions to understand community perceptions of trees on the farm and their strategies on tree planting investments. The local NGO suggested a participatory mapping project with drones to produce a 'modern' map to replace the communities' previous sketch maps of the area, which the group thought would enable better negotiations with the Ministry of Environment and Forests regarding the extension of the management contract. The communities collaboratively agreed to this approach.

Together with drone products, related ground surveys and co-produced knowledge regarding available biological resources, the community demonstrated its ability to collectively plan for developing innovative agroforestry farming systems towards better management of their forests and lands, allowing them to protect remaining biodiversity while enhancing their livelihoods. The detailed map and related agroforestry micro-projects proposed by communities have been submitted to the provincial office of the Ministry of Environment and Forestry, in the hopes of securing the group's HKm programme. At the same time, unresolved land conflicts with nearby oil palm companies, a still-emerging community capacity for using drones autonomously, and variable community expectations for the programme's potential to enhance livelihoods and territorial rights remain challenges.

Indonesia (Batang Lupar District)

In the remote interior region of West Kalimantan, intact forest still covers large areas, and traditional swidden agriculture practices coupled with traditional agroforestry systems prevail (Laumonier et al, 2020). The diversity of ecosystems and their importance for the conservation of Borneo's biodiversity led to the establishment of the Danau Sentarum and Betung Kerihun National Parks, later becoming part of a transnational cooperation under the Heart of Borneo initiative (Wulffraat et al, 2017). This World Wide Fund for Nature initiative has advocated the establishment of a biodiversity corridor between these two parks, where NGOs and academics have highlighted the threat of land-use change due to encroachment of oil palm for years (Yuliani et al, 2010). Any transformation of these landscapes in the upstream part of the corridor may have an impact on the integrity of the wetland ecosystems downstream and on the Malay communities living there, aggravating local farmers and fishers' vulnerability and potential conflicts between communities.

Following participatory research on villagers' perceptions of landscape, biodiversity and ecosystem services, led by CIFOR, local communities expressed a desire for detailed maps for the purpose of negotiating with agroindustry and the government regarding any future land development in their territories. CIFOR joined with a not-for-profit consultancy and research organisation, Swandiri Institute, which had pioneered community drones in West Kalimantan (Radjawali and Pye, 2017; Radjawali et al, 2017), to propose a mapping intervention covering part of the corridor with the aim of empowering communities in defending their ancestral way of managing land.

Following several village meetings to explain the objectives and methodology of the mapping project and an initial scoping survey in the field, the village assembly provided consensus and gave free, prior and informed consent to the process. Swandiri Institute and CIFOR researchers then organised drone missions with community-identified 'village experts', who became key informants for classifying local forest types and land uses. An initial ground-check of the aerial photography was organised with these local informants to create a geolocated database of key biophysical landmarks.

With this sketch map in hand, the researchers organised the remaining villagers into groups, based on gender and age, discussing with each group what more should be mapped, focusing on key socio-ecological landmarks, including sacred sites, restricted access areas and village natural resources. The village experts then compiled all maps drawn during the community meetings into one territorial 'master map', which they put on public display in the village for everyone to review and contribute to. The resulting maps enabled community-based landscape monitoring for REDD+, village boundary conflict resolution, a rejection of companies' plans to convert land to oil palm production in the corridor area, and a proposal for a 'village forest' (a right given to a village government to manage certain area of forest).

Although such detailed, at scale, maps far surpass the previous sketch maps, gaining government recognition of them remains a challenge. The government's Geospatial Information Body has not yet officially accepted or recognised participatory mapping, even though these new maps address previous government critiques about the informality of sketch maps. This lack of state recognition of the maps means that villages in the proposed biodiversity corridor area remain in limbo in terms of territorial and traditional land management rights.

Mexico (Michoacán State)

Since the 1970s, the La Mintzita wetlands of central Mexico have come under increasing threat from industrialisation and under-regulated urban development. Given the hydrological and environmental importance of the springs at La Mintzita, which provide drinking water to nearby communities and the city of Morelia, the government created a Natural Protected Area in 2005, and subsequently designated it a Ramsar Wetland of International Importance, in 2009. However, despite the springs' importance and official protection measures, environmental legislation and urban development planning mechanisms have failed to impede attempts to shift land use towards urbanisation, agriculture and industrialisation.

Inside of one of the irregular settlements established next to the springs lives the Mintsïta Gardens Ecological Community (MGEC). After settling in the area in 2002, a group of families increasingly noted both the socio-ecological importance of the springs and the mounting interest by the government in promoting nature conservation in the zone. In response, they began taking action to mitigate environmental harms, both to offset degradation around the springs and to justify their continued occupation of the newly protected zones (Paneque-Gálvez et al, 2016; Orozco-Meléndez and Paneque-Gálvez, 2022). More than avoiding eviction, MGEC currently seeks collective land ownership over their settlement, which partially overlaps the protected areas. Given what MGEC sees as a lack of adequate government action to protect key hydrological resources, they have been leading the environmental defence of La Mintzita since the 2010s.

In this context, MGEC partnered with the National Autonomous University of Mexico (UNAM) starting in 2016, using university-owned drones to monitor land-use changes through audiovisual and cartographic means and to file the corresponding complaints (Paneque-Gálvez et al, 2016). Through this collaboration, MGEC received training on cartography and GIS, drone safety and operations, and the drone regulatory framework, enabling the community to more easily identify, monitor, document and denounce (potential) environmental crimes in the area as well as to undertake community-based water quality monitoring (Vargas-Ramírez, 2018; Paneque-Gálvez, 2019). Drone-generated data and products have made the community's role as environmental defenders more visible. This collaboration has also enabled the co-production of spatial and territorial knowledge, fostering a better understanding of the environmental and social problems driving land and resource conflicts, including unclear land rights, under-regulated water use permits, water pollution and the absence of state agencies for law enforcement.

Because existing drone regulations in Mexico were designed primarily for urban contexts with significant air traffic, they hinder the use of this technology even in the outskirts of mid-sized cities and in rural settings despite the low or non-existent risks associated with their deployment in such contexts. These regulations can be burdensome for communities and their partners, requiring government permits for mapping flights, as well as the submission of the data obtained to government agencies, which can undermine data sovereignty (Vargas-Ramírez and Paneque-Gálvez, 2020). Furthermore, giving such information poses a threat to territorial rights, given that after 12–18 months the information can be used by government agencies to design or implement projects that could contravene local interests and needs. Finally, quite practically, while some MGEC members can operate the drones themselves, usage depends on the UNAM team's availability: the drones, as public university assets, may not be autonomously administrated by the community. However, MGEC presently is seeking funding from NGOs to acquire its own drone and continue its fight for nature conservation and territorial rights. The authors consulted with MGEC about including their use of drones in this and other academic articles, and community members support sharing their case, in part to raise greater awareness about their political objectives and territorial claims.

Peru (Loreto and Ucayali Departments)

Since 2015, Rainforest Foundation US (RFUS) has developed a collaboration with Indigenous political organisations representing 36 communities along key Peruvian Amazon River basins. The Amazonian ecosystems where RFUS works include very-high biodiversity zones that are subject to many national and international conservation projects, as well as deforestation threats (Vijay et al, 2018; Bebbington et al, 2018) – and where many Indigenous communities hold territorial rights under the main Peruvian land tenure arrangement for Indigenous peoples (Slough et al, 2021). Working with Indigenous organisations like ORPIO (Organización Regional de los Pueblos Indígenas del Oriente) in Loreto and ORAU (Organización Regional AIDESEP Ucayali) in Ucayali, RFUS has co-designed a technology-based territorial monitoring programme called 'Rainforest Alert: Information into Action'. The programme aims to curb climate change and biodiversity loss while enhancing the well-being of Indigenous peoples and protecting their cultural and territorial rights through an approach anchored in the science and practice of biocultural conservation.

Under Rainforest Alert, RFUS first receives near-real time deforestation alerts from the World Resources Institute through its Forest Global Watch platform (globalforestwatch.org). Then, RFUS and its Indigenous organisation allies share the deforestation alerts with relevant participating communities as printed maps and GIS files. Indigenous monitors then use these files and their smartphones to ground-truth whether deforestation has occurred. If they verify the deforestation alert, the monitors investigate and report back on each case. RFUS, ORPIO and ORAU collate these reports monthly and, when appropriate, inform or denounce specific deforestation events to the appropriate environmental authorities. Rainforest Alert has been funded primarily through bilateral donors and WREN (a direct funding carbon offset firm). Further, several local, national and international NGOs have endorsed and supported the programme, as have government institutions that do not have the capacity to realise this type of forest conservation enforcement work themselves.

Where fully implemented, this monitoring system has achieved clear environmental and social gains, as deforestation and territorial threats have significantly decreased (Slough et al, 2021). The programme's peer-to-peer approach enables Indigenous monitors to train new monitors themselves in their own language and without much external assistance, which has been key for scaling up to new communities in a more gender-inclusive way. Rainforest Alert pays participating communities for their monitoring efforts based on the amount of tenured land they hold and monitor, and RFUS helps to supervise the expenditures alongside the leader of each regional Indigenous federation, which in principle prevents corruption. This approach means that at least the largest communities receive enough funding to invest in livelihoods improvements.

These communities do face constraints, however, especially related to funding, logistical challenges and capacity limits. The programme's donor-dependence means that scaling up operations, including recruiting and training permanent staff to run geospatial data hubs, requires additional influxes. That participating communities are relatively remote, and lack reliable and consistent electricity, internet and mobile phone signal, challenges the logistical operations of Rainforest Alert as well. While forest monitors are using drones to detect and denounce deforestation in these remote zones, they operate in the context of very limited enforcement capacity by the state, which has few material resources and almost no budget to respond to most reports of environmental crimes. Although the RFUS staff assigned to this programme remain committed to the project and its goals, they express concern that the specificity of skills required, the harsh nature of the work they do, and the time needed to train new members, severely hinders a much-needed expansion of the programme. RFUS have co-designed specific protocols to appropriately deal with data control, access and use so that they are under a model of Indigenous ownership. At the same time, RFUS have has sought alliances with academia to document and analyse their work with Indigenous communities and organisations in the Peruvian Amazon and has authorisation to publish academic results derive from such academic collaborations.

Discussion

Empirical trends across cases

Across the six cases, drones fit into each conservation space in distinct, yet sometimes concordant, ways. Here we summarise similarities and differences in some of the key socio-ecological and political-economic factors across the cases, responding to the empirical questions outlined in the methodological approach section.

First, each of these community drone sites has high value for nature conservation and faces threats from ongoing industrial or extractive development processes, but the underlying ecosystems and types of protection vary. Some areas are under fairly strict protection, such as in Guatemala, while others are of interest for enhanced intervention but thus far lack significant legal protections, as in Indonesia's cases. While most of the areas we considered are forests protected for their carbon sequestration and biodiversity value, the Mexico case stands out as a site where drones may also be important for protected areas in peri-urban and wetlands zones.

The community drone users also vary, including their relation to nature, land and rights in these key conservation spaces. Many of the aforementioned communities or groups are not explicitly organising as Indigenous groups, for example in Guatemala and Colombia; however, many of them identify as Indigenous and/or depend on traditional land practices for their livelihood strategies, maintaining strong social-ecological and cultural ties to their territories (Devine, 2018; Sauls, 2020; Orozco-Meléndez and Paneque-Gálvez, 2022). In most cases, conservation policy and practice have at times been a threat to community tenure and territorial aspirations, although all groups now express a strong commitment to nature conservation.

In some cases, communities primarily use drones for ecological monitoring – whether of forest fires, illegal deforestation, unregulated urbanisation, or reforestation – although this monitoring clearly ties back into establishing conservationist credentials and supporting territorial rights, as the Guatemala, Peru, Mexico and Colombia cases indicate. In the Indonesian cases, on the other hand, drones have contributed explicitly to establishing the locations of community lands and their uses as well as documenting traditional ecological knowledge through participatory mapping practices. In all cases, community drones have become a tool for claiming land and territorial rights, defending traditional land-use practices, and asserting IPLCs' potential for enacting effective conservation action.

Across these cases, the degree to which community members themselves operate drones varies. Likewise, there is variation from case to case regarding IPLCs' analysis, use and dissemination of drone data (Table 1). These differences are of paramount importance given their potential repercussions on data justice and data sovereignty (for example, IPLCs' ability to maintain control over drone data and subsequent decision-making processes). In each of the cases analysed, IPLCs had different levels of pre-existing technical exposure and capacity upon their introduction to drones. Because of the requirements of the concession system, for example, ACOFOP and its communities have highly developed forest monitoring and vigilance rules, which included some mapping and GIS use prior to their introduction to community drones. On the other hand, communities in Indonesia had limited internal techno-scientific capacity, though the process of community mapping with technical partners enabled them to bring traditional and local knowledge into broader conversations.

These experiences suggest funding and partnership landscapes also matter – areas where communities have claims to land and where conservation priorities are high may find themselves well positioned to take up community-based monitoring (Guatemala, Peru) with strong external support (Millner, 2020; González and Kröger, 2023), while others may find themselves in potential conflict with actors who have greater access to drones, or who can use them in exclusionary ways, as previous literature suggests (Humle et al, 2014). However, conservation partners and donors might be key allies for communities who find themselves unable to use drones, as in the case of Colombia, whether for legal or for safety reasons. On the other hand, while a strong partnership has supported MGEC in Mexico, both a lack of funding and onerous regulations around drone flight may challenge the long-term sustainability of this community's efforts (Vargas-Ramírez and Paneque-Gálvez, 2020). Thus, while we observe clear differences in community capacity to use drones autonomously, ranging from technical challenges to legal limitations to safety concerns, we also see the potential for IPLCs to become adept drone managers over time when presented with the support to do so (Paneque-Gálvez et al, 2017).

From these experiences, no singular or linear narrative of community engagement with drones emerges; however, we do find that a range of social, political, environmental and even cultural factors may influence community uptake of drones, either directly or in cooperation. Across these factors, local socio-ecological conditions and political-economic factors interact with external demands, especially for conservation and climate mitigation, to produce the circumstances enabling this range of possibilities for community drones. Institutional factors – from the designation of protected areas to the legal recognition of territory – can support or constrain levels and types of

Table 1: Summary of degree of community uptake of drones by case

Most autonomous ↑	Guatemala (Petén Department) -Communities own, operate, analyse data, produce data products, disseminate products from drones
	Peru (Loreto and Ucayali Departments) -Communities own, manage, operate, analyse data, produce and report data from drones
	Mexico (Michoacán State) -Community operates, engages in data analysis, engages in data reporting from drones, uses analysis outputs
	Indonesia (Batang Lupar District) -Communities work with partners who use drones, support drone operations, perform ground checking, manually populate data, use analysis for negotiation
	Indonesia (Kembayan District) -Communities work with partners who use drones, participate in data analysis, use analysis outputs for negotiation
↓ Least autonomous	Colombia (Guaviare Department) -Communities work with partners who use drones, seek to gain access to and use analysis outputs

community drone engagement, as can legacies of international concern for a specific site or social movement (Sauls, 2020). The conservation sites in question are also embedded within broader historical processes of conflict and resource use, which influence the social and political possibilities for community drones as well (Devine et al, 2021; González and Kröger, 2023). These factors provide a lens through which to understand the rationales, modes and outcomes in community drone engagement.

Pitfalls and possibilities

Building on these cross-cutting themes, we return to the research questions presented in the Introduction. First, on why communities use or engage with drones in conservation spaces, we find that practically, environmental monitoring and participatory mapping are key activities; however, the underlying rationale of communities for drone usage relates much more clearly to goals of defending territory, protecting biocultural practices and enhancing sociopolitical capital in nature conservation contexts. In the Guatemalan case, for example, the successful use of drones in forest-fire monitoring was the highlight of an ACOFOP campaign ahead of the concession renewal process, demonstrating to the government, conservation NGOs, the press and international donors the communities' technological savvy as well as deep knowledge of the forest (Davis and Sauls, 2017). In Indonesia and Colombia, participation in social forestry and forest conservation agreements is a means to advance claims for more secure land tenure and community-conscious conservation, and drones are a key part of demonstrating the value of community work as well as their active presence in constructing nature conservation landscapes. Ultimately, the goal of community drones across these cases is increasing rights, recognition, autonomy and security.

At the same time, while we observed clear rationales for and benefits from community drone use, there are also potential drawbacks, limitations and ongoing challenges in the context of practical usage and achieving said ultimate goal. Ranging from the strict drone regulations in Mexico, which require onerous bureaucracy that can hinder effective community use (Vargas-Ramírez and Paneque-Gálvez, 2020), to logistical constraints, especially in remote areas of the Peruvian Amazon and Indonesia, to the expense of purchasing and maintaining drones, which even in the most autonomous cases have historically depended on external donor support, there are steep barriers to entry and continued use (Paneque-Gálvez et al, 2014; 2017). While legislation is not a constraint factor in most cases, the Mexican example highlights how important a favourable regulatory framework is for enabling community drones, which can contribute concretely to nature conservation outcomes (Vargas-Ramírez and Paneque-Gálvez, 2020; Slough et al, 2021). Political contexts also matter. The examples of Colombia and Mexico stand out on this point, as overt violence or the threat of it directly challenges community drones, but the degree to which governments recognise IPLCs as valid stakeholders – or rightsholders – in the first place may limit the degree to which drones offer the desired benefits (Vos, 2018; Castillo, 2019; Tebbutt et al, 2021). These barriers to full community control of drones and their data speak to ongoing challenges related to the degree to which such geospatial technologies might support data sovereignty, environmental data justice and, ultimately, territorial goals (Latulippe and Klenk, 2020; Reyes-García et al, 2022; Vurdubakis and Rajão, 2022).

Finally, we asked at the outset: what are the potential implications for nature conservation outcomes and for IPLCs themselves? We have highlighted the direct gains for priority conservation outcomes and, across all the cases, evidence of improved monitoring of ecosystems for their health and integrity, whether directly by IPLCs with drones (Guatemala, Peru, Mexico) or through new networks in which traditional knowledge and community initiative on-the-ground complemented drone-based monitoring (Indonesia, Colombia). The partnerships that drones produced across several of these sites have enhanced community technical capacity vis-à-vis nature conservation goals, but also provided alliances that emphasise IPLCs' legitimacy and agency in conservation processes. This strengthened position in relation to other partners, and at times international donors and government actors, has in some cases already strengthened IPLC rights and territorial governance, while in others it still remains part of achieving that long-term goal (Cheyns et al, 2020; Devine et al, 2021). While we have analysed these partnerships in terms of their implications for communities, we also note that such engagements can influence the capacity, knowledge and skills of researchers and other collaborators in terms of promoting more culturally meaningful and appropriate forms of knowledge co-production with IPLCs.

Despite ongoing, and sometimes steep, challenges to community drone use, IPLCs in spaces targeted for nature conservation are increasingly finding drones a worthwhile tool. Whether for denouncing environmental crimes in Peru and Mexico, documenting territory and land use in Indonesia, monitoring conservation agreements in Colombia, or providing forest-fire early warnings in Guatemala, drones are offering groups new and additional capacities to both actively protect the ecosystems they depend on and to demonstrate their pivotal role in such efforts. In doing so, IPLCs activate a burgeoning set of practices that weave together different data, technologies, actors and discourses to assert IPLCs' rights as well as their own territorial visions (Halvorsen, 2019). Through community drones, these IPLCs are enacting vertical territorial claims that counter the exclusionary power that such techno-scientific mechanisms have long evoked and suggest new sociopolitical configurations and possibilities (Massé, 2018; Millner, 2020).

Conclusion

While Offen (2009) observes that IPLCs in the 21st century seem to face the conundrum of 'map, or be mapped', community drones suggest less of a zero-sum game. Rather, community drones produce space to map differently, both by putting the means of geospatial data production directly into the hands of IPLCs, in some cases, but also by making explicit the contributions of multiple forms of knowledge to effective environmental governance. While the processes are distinct, and sometimes uneven, the six cases illustrate how community drones may be part of shifting on-the-ground understandings of ecological problems and their possible solutions in favour of more responsive and inclusive ones.

Especially in an era of renewed dedication to nature conservation in the face of intersecting socio-environmental crises, additional research and partnerships to explain and support the processes through which community drones might play a role merits greater attention. In particular, where countries have regulations that prohibit or limit community drones, it can hinder implementation of effective, inclusive environmental monitoring for these nature conservation goals (Vargas-Ramírez and Paneque-Gálvez, 2019). This regulatory context may also speak to ongoing challenges for IPLCs to claim and defend their territorial and biocultural rights, including political ones. By outlining some of the pitfalls and possibilities of community drones, this article provides both concrete evidence of their conservation utility, but also potential for transformative socio-ecological, biocultural and territorial practices.

Notes

[1] Corresponding author.

[2] Indigenous peoples and local communities (IPLCs) is currently the accepted umbrella term used in relevant global environmental treaties and frameworks, including the United Nations' Convention on Biodiversity (Parks and Tsioumani, 2023).

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Conflict of interest

The authors declare that there is no conflict of interest.

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