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RESEARCH ARTICLE

Grounding drones in political ecology: understanding the complexities and power relations of drone use in conservation

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Rapidly evolving drone technologies are taking the conservation sector by storm. Although the technical and applied conservation literature tends to frame drones as autonomous, neutral technologies, we argue that neither drones nor their implications can be adequately understood unless they are grounded, conceptually and methodologically, in the context of broader societal structures that shape how drones and the data they produce are used. This article introduces the value of a political ecology framework to an interdisciplinary audience of biophysical and social scientists interested in the multiple possibilities and complications associated with conservation drones. Political ecology provides the tools for studying and critically engaging with drone use in conversation in ways that are politically engaged and attuned to power relations – historic and present, local and global – in a more-than-human world. In making this argument, we point to four conceptual tools in political ecology that offer a framework for unveiling the power relations and structures that surround drones in different contexts: political economy, territoriality, knowledge and expertise, and more-than-human relations. Using empirics from our work across Latin America (Colombia and Guatemala), Africa (Kenya, Tanzania, South Africa and Mozambique), and North America (the US and Canada), we illustrate the salience of this framework and demonstrate why evaluating what drones do in and for conservation requires first understanding the complex set of power relations that shape their use.

Key words drones • surveillance technologies • biodiversity conservation • political ecology

Key messages

- In recent years, the use of drones in biodiversity conservation has become more common.
- Drones can be used towards different ends, from reinforcing to resisting exclusionary conservation practices.
- Political ecology provides a framework for interrogating what drones do in the hands of different operators.
- Political ecology reveals the deeply political and power-laden nature of conservation drones.

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Introduction

In recent years, the use of unpiloted aerial vehicles (UAVs), or drones, in conservation has skyrocketed. Comprising a range of sensors (optical cameras, GPS sensors, thermal sensors and so on) attached to an aerial device enabled through rotary and/or fixed-wing technologies, drones can be used for a range of conservation purposes, including tracking changes in vegetation, mapping and monitoring wildlife populations, collecting images and videos for conservation research, and monitoring potential threats to conservation areas. Drones can support law enforcement activities, such as searching out and reporting on illegal conservation practices including poaching and illicit resource use. These technologies have also been employed in others creative ways by conservationists, such as dropping seed pucks to support reforestation or steering wandering elephant herds away from danger. Relatively inexpensive, able to surveil large areas, swift in transmitting information and increasingly ubiquitous, drones allow for monitoring and intervention in conservation landscapes at an unprecedented scale with lightning quick pace. Thus, it is unsurprising that drones and other surveillance technologies have been presented as gamechangers that enable more nimble and effective conservation.

Yet, critical conservation social science literature has approached drones with caution, acknowledging the transformative potential of these technologies while also recognising how their misuse may harm human communities within, or dispossessed from, conservation landscapes. Some scholars express concern over how drone technologies are advancing violent, militarised approaches to conservation (Duffy, 2014; Simlai, 2015), while others have shown how drones can invade privacy, harm psychological well-being, and result in hostility towards conservation authorities (Sandbrook, 2015; Simlai, 2022). Scholars and rights groups have also critiqued the inequality around who collects, analyses, stores and controls data gathered by conservation drones, and how this data is sometimes used in ways incompatible with the aspirations of communities on the ground (Sethi et al, 2023). At the same time, there is also a growing awareness of the capacity for drones to empower and support those living within or dependent on protected areas when placed in the hands of communities (Paneque-Gálvez et al, 2017; Radjawali and Pye, 2017). For instance, communities within Guatemala's Maya Biosphere Reserve (MBR) are using drones to secure the right to continue to live within their traditional territories (Millner, 2020; Rahder, 2020).

Given these complexities and contradictions, how might we approach the study of conservation drones and the questions they raise without relying on oversimplified explanations of drones as bad or good or merely complicated? In line with the purpose of this special collection, we answer this question by introducing the value of a political ecology framework to an interdisciplinary audience of biophysical and social scientists interested in the multiple possibilities and complications associated with drones as a conservation tool. At the broadest level, political ecology is an interdisciplinary field of study with methodological and analytical toolkits that help expose the inescapably political nature of all environmental transformations, including biodiversity decline, along with responses to these transformations, such as biodiversity conservation policy and practice. Key themes of political ecology, such as political economy, expertise and knowledge production, territoriality, more-than-human and deeply human relations, are salient to understanding the nuanced workings of drones in conservation and differentiating between uses that ought to be embraced and nurtured from those that ought to be avoided and resisted. A political ecology framework enables us to move beyond oversimplified understandings of drones, instead exploring how drones *are always enmeshed in complex power relationships* that have implications across scales that generate human and non-human winners and losers.

A political ecology framework starts by asking a series of questions to get at these complex relationships and nuanced implications, such as: who owns, controls, operates, and funds drones? Who owns the land and resources involved? Who can access and surveil these spaces, for what purposes and with what effects? Who controls the data produced through conservation drones? Who decides how these data are used, when and by whom? Whose knowledge counts as legitimate in disputes over boundaries and land use? In this paper we show how a political ecology approach adds nuance to applications of drones in conservation, allowing us to grasp, on the one hand, how technologies like drones can reproduce and even deepen existing power inequalities. On the other hand, the same conceptual tools help us appreciate how drones can also upend these same relations; for instance, by empowering communities marginalised by conservation to have a stronger voice or to be better heard. Political ecology, in other words, offers to deepen appreciation of the ways power relations thread through all manner of everyday conservation practices, offering new opportunities to strengthen justice and ethical uses of (aerial) technologies.

Political ecology scholarship and activism is often rooted in case study analyses, understood to be linked to ever widening scales of connections and power relations across time and space. A political ecology approach to drones thus includes outlining general trends in how power plays out across time and space, and in similar ways around the world, while unpacking the specificities of how policies, political-economic rationalities, and technologies become entangled with place-specific power relations. While principally speaking to colleagues interested in drones but new to political ecology, our contribution is also designed to speak to our fellow political ecologists. We share examples from our own fieldwork to illustrate the need for increased attention to the ways that monitoring technologies may facilitate increasing trends towards militarisation and surveillance in conservation, while also showing how drones, as spatial technologies that remake power and knowledge relationships, may be an important tool in social and environmental justice struggles. In turn, a focus on drones can also add to understanding of space, power and knowledge within political ecology; for example, by incorporating the 'volumetric' dimension of space that

drones work across (Jackman and Squire, 2021). In drawing these strands together, we show the importance of *grounding* the study of drones and other aerial technologies conceptually and methodologically, which is to say, recognising and taking seriously the concrete spatial and power dynamics in which they are deployed.

We write collectively as a group of political ecologists and conservation social scientists with decades of experience studying conservation theory and practice across Latin America (Colombia and Guatemala), Africa (Kenya, Tanzania, South Africa and Mozambique), North America (the US and Canada), and Asia (India). While some of us study drones as our central object of analysis (Millner), the rest of us encountered drones and other aerial and surveillance technologies through our broader work, including studies of the politics of conservation knowledge production, policy and practice (Bersaglio, Enns, Goldman, and Lunstrum). Through this work, we have witnessed first-hand how novel surveillance technologies have transformed conservation in different contexts raising unavoidable questions of power, ownership and access. Our expertise is also rooted in our involvement with broader international networks that study drones – including the network behind the 2021 international Drone Ecologies conference – and that make policy recommendations for ethical drone usage (see final paper in this special collection, Millner et al, 2023).

In the remainder of this article, we give an overview of the ways drones have become incorporated into everyday conservation practices, summarising recent currents within critical social science that have addressed these transformations. Building on this foundation, we then structure the main body of the paper around core political ecology concepts that, we argue, can take this analysis further. We focus on aspects of political economy (tied to money, politics and power), territoriality, knowledge production, and more-than-human and deeply human relations, which are all conceptual tools informing fundamental perspectives of political ecology. Cross-cutting many of these themes are concerns for power and resistance, which raise questions about the ethical and justice implications of future drone use in conservation. Grounding our insights in our own empirical work and broader scholarly literature, we show how a political ecology approach reveals the deeply political and power-laden nature of drones. We argue that a focus on power is key, whether drones are being used to control and surveil, resist and empower, or even to achieve objectives that may seem benign or neutral on the surface, but possibly come to appear more troubling as we dig down or, more appropriately, look up.

Critical social science perspectives on conservation surveillance technologies

Advances in digital technologies have given rise to new ways of sensing, measuring, monitoring, representing and visualising nature (Gabrys et al, 2022). Satellites, drones, camera traps, lidar and artificial intelligence (AI) are just some of the tools that have become key to conservation globally. From mobile phone apps for species identification to participatory platforms to crowdsource biodiversity data to the use of drones to gather data on vegetation cover and wildlife populations, digital technologies are changing what we know about nature and how we know it.

As environmental observation has shifted to the skies, scholars of political ecology, human geography, and science and technology studies have begun to write about the

changing spatiality and verticality of environmental governance (Massé, 2018; Millner, 2020; Enns et al, 2022). This body of research has raised important questions about the implications of near constant observation, monitoring and surveillance of conservation landscapes – as well as human and non-human life – from above. In this work, emphasis has been placed on how the use of surveillance technologies to monitor biodiversity could be turned on people with exclusionary effects; for example, sedimenting old stereotypes and legitimising new racist missions against the rights of people who live in conservation spaces (Büscher and Ramutsindela, 2015; Amador-Jiménez and Millner, 2021).

Looking beyond surveillance, a growing body of research also examines how these technologies have enabled a shift towards data-driven environmental governance and decision making (for examples, see: Adams, 2019; Gabrys et al, 2022; Goldstein and Faxon, 2022; Goldstein and Nost, 2022; Nost and Goldstein, 2022). This new approach to environmental governance, which Adams (2019) refers to as 'algorithmic governance', uses data to trigger actions and decisions that are understood to be uncontentious and evidence-led. Yet, as Nost and Goldstein explain, although digital technologies promise to provide more accurate, rapid, and objective information: 'it is increasingly clear that the data produced and circulated through digital technologies does not simply paint a neutral, more comprehensive picture of the planet. That is because approaches to govern nature with and through the digital are inherently entangled with the governance, politics, and materialization of the digital' (2022: 4).

Far from merely 'deciphering' nature, these technologies and models they are guided by always present partial data (Gallagher, 2022). They render certain attributes of the natural environment visible – such as those deemed to have productive potential – to the exclusion of others deemed unimportant or less valuable. Significantly, data-driven environmental governance also tends to render invisible the ways that *people* participate in making and using this data to support decisions. Inevitably this means the values involved in selecting and processing data are kept out of view (Johnson et al, 2022).

Another concern relates to uneven access to and the commodification of environmental data produced using digital technologies. Rather than ubiquitous access for all, these data sit in the hands – or clouds – of powerful actors, such as state agencies, international conservation organisations, intergovernmental bodies and, increasingly, big tech companies, like Google, IBM and Microsoft (Nost and Goldstein, 2022). The corporations that hold these data often mobilise a rhetoric of openness, even technological utopianism, and promise to support evidence-based decision making (Alvarez Léon, 2022). However, in reality, the commodification of this data and profit accumulation by companies is rife.

In this context where there is growing concern about how relationships with nature are becoming ever more digitalised, there is a pressing need to understand and differentiate between specific digital technologies and their uses – including separating uses that ought to be embraced and nurtured out from those that ought to be avoided and resisted. With this in mind, we seek to bring closer attention and greater scrutiny to these digital transformations by engaging with the political ecologies of conservation drones. We believe this focus is useful as drones are somewhat distinct from other geospatial technologies used in conservation.

Although aerial technologies, such as aircraft, have been essential to conservation throughout its history, drones became more pronounced in the sector during the 2010s. The use of drones for conservation has increased dramatically, as they are capable of capturing dynamic visual footage from previously inaccessible vantage

points, mainly in relation to land classification mapping; surveying the distribution and density of wildlife, including monitoring forest cover; and detecting people (Jiménez López and Mulero-Pázmány, 2019). Through the sensors attached to drones and the data they convey to smartphones and tablets, they reveal biodiverse environments in terms of heat and light or collect photos that can be stitched into orthomosaics to map forest cover. Or, through their capacity to film, drones can capture data in terms of illegal activities, including mining activities and poaching.

Yet, it was not the potential to surveil people but the relative affordability, accessibility and adaptability of drones that led to them becoming incorporated into everyday tasks such as monitoring forest cover and vegetation change over the past decade. In contrast with remote sensing and GIS technologies, already used in conservation to produce complex maps of forests since the 1970s, drones enabled a closer view, and could be deployed at a low cost to produce new images at regular intervals. Moreover, drones are relatively easy to fly and, in some cases, the images they take can be downloaded and interpreted with minimal training, unlike many other observation technologies. As such, drones also come with the potential to alter the typical balances of power in terms of who sees what in conservation, enabling new 'subversive' applications (Fish et al, 2017).

A political ecology lens on conservation drones

At the broadest level, political ecology is an interdisciplinary field based primarily in the social sciences that investigates how power shapes ecological processes and vice versa and does so across scale, from the local to the global. Where traditional ecology and conservation biology studies tend to understand biodiversity loss, deforestation, land degradation, and other environmental problems as primarily ecological processes and challenges that require technical solutions (such as data from drones used to monitor biodiversity decline by tracking species abundances, distributions, and interactions; see for example, Besson et al, 2022), political ecology approaches environmental problems as always also social and political issues. So while many political ecology scholars share concerns over ecological transformations related to biodiversity loss, they work to bring to light the complex entanglement of environmental, social, economic and political factors leading to and resulting from such changes.

Like conservation biology, political ecology is defined by an explicitly normative commitment. However, whereas conservation biologists focus their commitment on biodiversity protection, political ecologists strive for positive change in the communities where they work by exposing underlying structural inequalities that negatively impact both humans and non-humans. Furthermore, rather than seeing power as a one-way street that benefits already powerful actors, political ecology has been deeply invested in the question of resistance, or how vulnerable populations push back against environmental changes and initiatives that dispossess or otherwise harm them. In the remainder of this section, we lay out four fundamental conceptual underpinnings of political ecology that shift the study of conservation drones in useful ways, grounding each through specific examples and case studies. These themes include: political economy; territoriality; knowledge and expertise; and more-than-human relations.

Political economy–ecology intersections

A political ecology framework begins with an understanding that ecological processes are always also political, in the sense of being tied to and productive of power relations. Resting at the heart of political ecology is thus a commitment to pulling apart the many ways in which these power–ecology intersections play out in diverse empirical settings and with diverse actors, while working to distil broader trends across these relationships. Practically, this means investigating not only how drones may be useful in conservation monitoring but also how monitoring technologies intersect and interact with social and political relations in conservation spaces, and what the drivers are behind their introduction.

Early political ecology work exposed how economic power structures and economic relations drive environmental change while also shaping responses to various forms of environmental change, including biodiversity protection (Neumann, 2004). In other words, both environmental decline and human responses to it are political and uneven. This can be seen in rising rates of deforestation and the accompanying dispossession of Indigenous Peoples (IPs) and Local Communities (LCs) for forest protection (Bryant, 1998; Kosek, 2006; Hecht and Cockburn, 2011); in species decline and human rights violations associated with militarised forms of species protection (Lunstrum, 2014; Amador-Jiménez and Millner, 2021); and other forms of violence enacted against IPs and LCs through coercive and/or fortress approaches to environmental protection (Brockington, 2002).

This broader backdrop has led some political ecologists to suggest that increased reliance on drones in response to biodiversity decline needs further critical engagement (Sandbrook, 2015; Millner, 2020). Understanding what drones do in and for conservation requires examining how political-economic forces and power relations shape access, use, and data. This includes consideration for who has the power to use drone technology and the data that drones generate as well as who provides permission for drone operators to survey and make decisions about the land, natural resources, and wider spaces through which drones move.

In many cases, already powerful actors in conservation can be observed using drones to dictate responses to biodiversity loss and, in the process, reinforce their power over environments and populations. Across eastern and southern Africa, these actors often include state and military (or military-adjacent) organisations. In South Africa, Denel Aviation – a state-owned aerospace and defence corporation with close ties to the South African National Defence Force – has provided drones with sophisticated detection and tracking equipment to conservancies to assist with tracking poachers (Merron and Lenggenhager, 2021). In 2015, the charitable arm of the Paramount Group, a private South African defence corporation, also gifted South African National Parks a surveillance aeroplane and training for military style anti-poaching operations (Lunstrum, 2018). Although not a drone per se, the gifting of the surveillance aircraft was used to signify and celebrate the corporation's environmental stewardship and commitment to protecting endangered rhinos. These cases illustrate how those with the power to surveil – in this case partnerships between the state and military corporations – can alter and redirect responses to perceived threats against biodiversity and the environment, while also reinforcing existing power dynamics. These cases also underscores the dangers of greenwashing, as one of the most environmentally and socially destructive industries in the world came

to be celebrated for its environmental corporate responsibility (Lunstrum, 2014; see also Biggar and Neimark, 2017).

These 'public–private' partnerships in the name of conservation are neither innocent nor serendipitous. The companies behind drone innovation, manufacturing, and distribution, along with the conservation organisations partnering with them, are all harnessing the power of drones for financial and political power. This includes organisations like Air Shepherd, which has brought together groups of (largely Northern) conservationists, entrepreneurs and researchers to design drones that use AI to search for poachers at night (Worland, 2018). The International Anti-Poaching Foundation, founded by a former Australian military sniper, has experimented with similar technology in Mozambique with mixed success. While not inherently problematic, there is a need to question who benefits from such technology and what power relations and structures this technology risks reproducing. Many conservation organisations involved in developing and using drones for anti-poaching initiatives uphold racial-colonial narratives and politics by presenting non-White populations as *the* threat to biodiversity, and novel technologies that monitor and surveil, such as drones, as *the* solution (see also Kashwan et al, 2021; Van Sant et al, 2021). The data collected by drones also gives these organisations access to new flows of information that enables them to make calculated decisions about animals and people within conservation landscapes – decisions that tend to reinforce stereotypical racial narratives about who belongs within conservation spaces and who does not.

Drone technology is also proving to be an effective way of fundraising and profit-making for the mainstream conservation sector, which further extends the sector's power. By using drones to capture and produce spectacular representations of nature and its threats – such as consumable bird's-eye view images or video clips of poachers being tracked and caught – the conservation sector uses mediating technologies to attract new investment in conservation (see Tsing, 2000; Igoe et al, 2010; Sullivan, 2013).

In other cases, though, less powerful actors have sometimes been able to use drones to secure or advance their community's access to, control over and management of the environment. At the time of writing, Millner (author) was involved in the establishment of a Latin American community drones network involving rural and Indigenous communities from Panama, Guatemala, Bolivia, Peru, El Salvador and Mexico. In each of these contexts, drones and other geospatial technologies are being used as part of community-based monitoring practices, aimed at both improving conservation practices, and community territorial defence. For example, in Madre de Dios, Peru, one participant explained how drones have enabled Indigenous communities to monitor incursions from illegal mining and loggers (see also Tollefson, 2022). While wider land reforms and the protection of communal rights may be needed to address larger systemic injustice, drones are also being harnessed by community groups for change. The proliferation and low cost of drones enables forest-based communities to present their own expertise and knowledge as authoritative (Paneque-Gálvez et al, 2017), which weakens false claims, leveraged by incoming private companies, that rural communities do not / cannot manage biodiverse lands effectively (Millner, 2020).

Political ecology's commitment to grounded research is instructive in unveiling place-specific power relations and political-economic forces that structure what drones do in conservation. For example, where Bersaglio and Enns (authors) work in northern Kenya, sophisticated long-range drones are used to surveil and secure

private wildlife conservancies owned by international conservation organisations. However, in some cases these drones are hired from members of nearby pastoralist communities who have purchased drones for personal use. The owners of the drones have the power to decide when to profit by making their drones available for surveilling conservancies and when not to; for example, perhaps choosing to hire out their drones when there are reports of elephant poachers in the area but not during periods of drought when there is the risk that other community members may be caught unlawfully grazing livestock on conservancy land. Such examples illustrate how the possibilities and problems associated with drones as a conservation tool can only be fully understood by being attentive to the complex and messy political-economic drivers in specific places and moments in time.

Political ecology's analysis of power is needed to respond to important questions regarding who controls surveillance technologies such as drones, who is impacted by them, who can use them, and who benefits from them (financially or otherwise). This includes differentiating between cases where drone use in the conservation sector risks reproducing power asymmetries and structures of inequality and violence; cases where drone use can support efforts of resistance and refusal; and cases where drone use is more ambivalent, achieving something in between. From a political ecology perspective, other important drone-related lines of inquiry include: who owns the technology and data generated by drones? Who else can access the horizontal and vertical spaces drones move through? Who has access to and dominates spaces where decisions are made about how drones are fashioned, equipped, and used? Who makes decisions about what to do with the information captured and reported by drones? Responding to these questions in relation to any specific case of drone use through empirical research is key to understanding the power relations embodied by drones and (re)produced through their use.

Territoriality

Regarding wider questions of conflict and social relations, political ecology foregrounds the theme of *territoriality*. Territoriality refers to the complex ways that different articulations of territory (legal, formal, informal, and so on) become established, contested and defended. Here, territory is understood as space that is owned and controlled by a state or other governing body – territory is, in short, politically invested space. Conservation is relevant to these debates as it is a core practice through which governments and other actors claim and reshape space and related social relations (Neumann, 2004). New kinds of technologies, including drones, are important tools that enable this control over and reworking of conservation-space-as-territory.

Political ecology shows how, in many contexts, conservation as a territory-making practice emerged with colonisation and the expansion of empire (Peluso, 1993; Neumann, 1998; Adams and Hutton, 2007). The field also draws attention to how colonial-era 'fortress conservation' approaches are still used by independent states to uphold or expand the internal territories under their control (Brockington, 2002; Neumann, 2004). For example, maps drawn using geospatial data may be used to redraw boundaries of protected areas based strictly on ecological rather than socio-ecological features, pushing out of view the political interests served by such acts (Rahder, 2020). In this regard, contemporary protected areas are also theatres of conflict where states and local communities often vie for resources. Indeed,

protected areas themselves can be understood as processes of territorialisation that create bounded spaces around concentrations of biodiversity, such that it is easier to control, secure and surveil them (Fairhead et al, 2012; Massé, 2018).

Increasingly, drones and other surveillance technologies are deployed in the practices and processes of state territoriality. In response, political ecologists have started to engage more with how drones are used to further fortify territory in the name of biodiversity protection. A core political ecology concept that names this trend is green militarisation (Lunstrum, 2014; Duffy, 2014). Green militarisation describes 'the use of military and paramilitary (military-like) actors, techniques, technologies, and partnerships in the pursuit of conservation' (Lunstrum, 2014: 816), leading to the surveillance of protected areas not only for the sake of biodiversity but for the (geo)political and territorial interests of states. This is important because while illegal grazing, poaching, and timber-cutting clearly pose important governance issues (and, indeed, may garner considerable emotive interest), conservation agendas may be used as pretexts to enact counter-insurgency interventions and attacks on local racialised populations without losing international legitimacy, with ethnic minorities and migrants being framed as criminals or illegal (Massé and Lunstrum, 2016). Surveillance technologies are integral to these practices, as, for example, they capture images that serve as evidence of people acting inappropriately or illegally. Political ecologists studying these dynamics emphasise the importance of technologies used in everyday conservation as key drivers of green militarisation (Büscher and Ramutsindela, 2015).

For example, the use of 'military and paramilitary actors, techniques, technologies, and partnerships' (Lunstrum, 2014) to defend private wildlife conservancies in central Kenya has become commonplace. These spaces are under constant surveillance by both ground and air to prevent pastoralists from entering to graze their livestock without landowner consent. During periods of drought – when pastoralists may enter conservancies more often or more forcefully out of desperation – or when poaching threats are reported, surveillance intensifies. Rapid response helicopters, AI-powered drones and other military technologies are deployed to watch for (potential) trespassers. An entire assemblage of actors is enrolled in this work, including private armed conservation rangers, public security forces, and even national and foreign military actors, such as the British Army Training Unit in Kenya. Although these actors see themselves as protecting wildlife, they are also securing property claims and extending the dispossession of pastoralists in the area first enacted through colonial settlement. From a political ecology perspective, such examples demonstrate how surveillance technologies, like drones, can strengthen conservationists' claims to space and territory.

A useful concept that informs political–ecological approaches to the study of drones is *vertical territory*. This concept captures the way aerial technologies transform power relations and territorial struggles by illustrating how geopolitical power relations are configured not only through two-dimensional map-making or the management of ground-level flows, but through technologies that make use of height and volume (Massé, 2018; Millner, 2020; Jackman and Squire, 2021). In this sense, vertical territory reveals how aerial navigation, surveillance technologies and relevant legal architectures transform who gets to go where, do what, and how. Technologies that obtain a 'view from above' may exert force, precisely because not everyone has access to aeroplanes or drones, yet very little can hide from the aerial view (Adey, 2010). Territory has, in this sense, a volumetric dimension; a spatial element established

through boundaries in airspace or the use of satellite images (Elden, 2013; Jackman and Squire, 2021).

This volumetric power relation operates not only through the threat of violence but through the creation or intensification of geographies of fear. Using surveillance technologies like drones in conflict-prone areas, alongside planes and observation towers, can generate feelings of spatial insecurity, and even render violence banal (Gordillo, 2018). For Crandall (2015), the sightless gaze of drones reinforces such effects because of their capacity to 'see' without being seen and to translate overview data to far away operators. It is thus important that surveillance technologies can, and are, being co-opted to strengthen geopolitical agendas (for examples, see Adams, 2019; Massé, 2018; Millner, 2020; Simlai, 2022). Over time, the discourse used to justify these interventions leads to blurring between potential 'nature-destroyers' and potential 'terrorists' and configures groups as a natural threat to national sovereignty (Lunstrum, 2014; Ybarra, 2018).

Knowledge and expertise

Central to political ecology is critical engagement with the question of whose knowledge counts when it comes to environmental and natural resource management (Escobar, 1998). This question is tied to a long-standing commitment to challenge dominant narratives that blame ecological decline on poor and marginalised communities and that locate solutions to environmental problems in the knowledge and techniques of powerful economic and political actors, ranging from development organisations and states to corporations. Inspired by the Foucauldian post-structural turn of the 1980s and 1990s, as well as feminist scholarship, political ecology is committed to exposing power–knowledge articulations that benefit elite groups in society at the expense of local land users while also underscoring the situated nature of all knowledge (see Haraway, 2020; Elwood, 2018).

Reflecting this, political ecologists have interrogated the way in which environmental science produces and uses knowledge to ask fundamental questions such as: whose objectives do environmental science and related technologies serve? Whose knowledge is privileged, and whose is hidden or marginalised, when it comes to environmental decline? How does mainstream environmental science demand certain action while foreclosing other potentially more just responses? Here, political ecology is not the same as populist, anti-regulation commitments to 'post-truth' knowledge production, which reject the reality of climate change. Instead, the field recognises both that environmental decline is an empirical reality, and the importance of scientific research to better understand this. Nevertheless, it is important to recognise, as political ecology espouses, that all knowledge production, circulation, and use/application is impacted by and impacts power dynamics (Haraway, 2020; Goldman et al, 2011).

Political ecologists have drawn on Haraway's (2020) critique of the supposed 'view from nowhere' often claimed by science. Drones enable a 'view from above', which could be considered what Haraway calls a 'god-trick' – a sleight of hand that makes knowledge produced through visual technologies such as drones seem authoritative because it presents an overview and seems immune to fallible human perceptions. Rather than offering universally applicable knowledge of ecological processes, political ecology scholarship exposes how drones are shaped by and enable the production of particular types of knowledge that, in turn, can further certain

environmental agendas. Political ecology can be useful in exposing the knowledge politics behind the use of drones in conservation and revealing the 'world-making practices' associated with reliance on drones for knowledge production that can leave out and/or undermine other ways of being in and knowing the world (Goldman et al, 2018; Goldman, 2020).

For example, drones were recently used in national wildlife censuses in Kenya to gather baseline data (WRTI and KWS, 2021). Through these exercises, drones were programmed to fly preset grids across a given area, taking videos *en route*; the videos were then processed by computer software that automatically identifies and counts animals (Adams, 2019). This software was able to differentiate between wildlife and other living beings, such as livestock and humans, and produce detailed data about the number and distribution of animals in a landscape. Guided by algorithms programmed to account for certain types of movement, colours, and animals, and not others, drones count species that the mainstream conservation sector sees as charismatic and worth saving while devaluing others (also see Lorimer, 2007), including those with important socio-ecological function and biocultural meaning, such as livestock. For example, in reports produced following the census, increasing wildlife populations are praised as a sign of conservation success while fears about 'mushrooming human and livestock population' were also propagated (WRTI and KWS, 2021: 75). The information captured in the census has been used to support long-standing narratives in Kenya around the need to secure more land for growing wildlife populations while addressing the 'increasing human foot print of pastoralist communities' (WRTI and KWS, 2021). Ultimately, digital technologies, such as drones, do not provide objective information; rather, these technologies see and count what their programmers tell them to see and count (Nost and Goldstein, 2022) with the aim of producing data that provides legitimacy for the types of environmental narratives that authorities wish to reinforce.

As Adams (2019) has argued, there are real dangers involved in doing conservation by algorithm. Beyond faulty claims about producing a more neutral and comprehensive picture of the environment (Nost and Goldstein, 2022), growing reliance on drone data risks producing a singular and expert-led narrative of how nature should be known and engaged with. This is partly because drones are replacing people, including far more diverse populations that might have previously been involved in exercises such as participatory wildlife counting or community monitoring of illegal activities. This gives remote actors, who often rely on images and AI to understand ecosystems and landscapes, greater power over conservation space. Furthermore, the ability to question this expertise is often suppressed by the scientific power of the drone. As one drone manufacturer in Tanzania insisted, 'drone data will always be correct', even though drone data are of course fallible and limited.

Yet, the power of conservation authorities is never complete: IPs and LCs can (re) assert their own knowledge, supported by technologies, to counter scientific and Western-centric claims to exclusive conservation expertise. This has happened in Guatemala's MBR, where conservation practice historically has enabled the racialised policing of rural populations (Sundberg, 2003; Millner, 2020), contributing to the violent repression of Indigenous groups (Ybarra, 2018) and migrant communities (Devine, 2018). In the early years of the MBR, disciplinary actions were undertaken by governmental authorities against non-compliant communities (Devine, 2018). Mediating institutions have since been established, such as the forest-based association

ACOFOP (Asociación de Comunidades Forestales de Petén), which has accompanied communities since the early 2000s, helping to transform the disciplinary design of forest concessions into a relatively enabling one (Millner, 2020). Even with this change, the use of drones in the area risks amplifying a volumetrics of fear and control. Indeed, the elite Interagency Task Force 'IATF Jaguar' was introduced in 2018 to monitor the Petén using helicopters and infrared cameras, building on previous waves of militarisation (Millner, 2020) and spatial claims that forest-based communities were not managing the biodiverse forests effectively (Rahder, 2020).

However, drone technologies were introduced in 2015 not by state actors, but by ACOFOP, the forest-based association working to accompany forest cooperatives in community-based forestry and to produce information to demonstrate the effectiveness of this local strategy. Specifically, ACOFOP's monitoring network, comprised mostly of young people living in the forest concessions, uses drones to collect data in the form of photographs, video footage and biomass measurements. These are then used to create maps and graphics that tell stories about forest change and protection and ultimately to demonstrate that the communities are managing the forests effectively. The drone images and satellite imagery produced by ACOFOP have been crucial in defending the community forest concessions in the MBR, three of which would have been cancelled by a consortium of archaeological, petrochemical, and state actors who sought to create a new ecotouristic park via a government act proposed for 2005. Central to the argument of this consortium was that the communities were mismanaging the forests, something that ACOFOP was able to disprove via their own use of drones, which produced images of the reduction of fire incidence in community-managed concessions, and forest regeneration. This story illustrates how drones can be used to challenge the outside consolidation of control over conservation areas, contributing to the pursuit of 'data justice' in conservation (Pritchard et al, 2022).

By drawing attention to the types of knowledge that drones produce, political ecology enables us to trace knowledge to concrete conservation policies and practices. As the examples in this section suggest, the types of environmental knowledge that drones produce, the narratives that are built based on this knowledge and the conservation action that these narratives are used to support tend to reinforce existing structures and power relations – namely those that support fortress versions of conservation. However, there is always potential for drone data to be mobilised to refuse and resist the imposition of external and expert-led ways of knowing and managing the environment, as reflected in the opening vignette about the use of drones by communities in the MBR.

More-than-human relations

Recently in political ecology, there has been rising interest in how the field can do better at understanding, representing, and relating to the more-than-human world, which encompasses animals, plants, and other organisms and objects, including spirits, that are entangled within human and social relationships. Rather than seeing these more-than-human actors as passive, or as a mere backdrop for power struggles, scholars have shown how the biophysical properties of nature shape political–ecological encounters and how non-human agency can be better understood and expressed. Political ecologists have also begun to engage more specifically with how non-human life forms have been colonised, disenfranchised, or impoverished because of uneven

power relations between other non-humans and humans (Sundberg, 2003; Srinivasan and Kasturirangan, 2016; Menon and Karthik, 2017; Bersaglio and Margulies, 2022). Although often problematically left unacknowledged, Indigenous epistemologies and ontologies have been particularly influential in thinking about more-than-human political ecologies (Rose, 2011; TallBear, 2011; Todd, 2016).

Adopting a more-than-human perspective involves consideration for how the properties and interests of animals, plants, and even geomorphology may reinforce, disrupt, or otherwise shape drone encounters, along with the power relations in which drones are embedded. For example, there has been recent media and investor hype around several drone start-ups, like DroneSeed in the US, Flash Forest in Canada, and Dronecoria in Spain, which all promise huge advances in ecosystem restoration through rapid reforestation. These start-ups have designed drones that drop pucks of indigenous tree seeds, fertilisers, and fungi to jumpstart natural regeneration. Seed pucks are delivered by drones to degraded, deforested, wildfire-devastated, and hard-to-reach landscapes, and are often coated in prosperity blends of micronutrients that lock in moisture and provide protection against extreme weather and wildlife. Backed by massive investments from financiers, like Airbus and DBL Partners – who were also early investors in Tesla and SpaceX – 'the budding industry of drone forestry has gained notoriety and significant venture capital for formulating a potentially profitable, if largely untested, regenerative geoengineering intervention into the climate crisis' (Fish, 2022: 2).

By focusing on the more-than human, political ecology offers an avenue for investigating the relationality that exists between drones and seeds, in this case, as well as the power dynamics embodied in such relationships.[2] Without drones, seeds alone would not be capable of promising reforestation at a scale grand enough to get the attention of these same investors. Of course, some degree of human engineering is also required to forge a productive connection between drones and seeds, which means human politics and power relationships have also entangled these two entities together. This includes political and economic forces, like patents and flows of finance; but it also extends to the more-than-human forces being assembled to radically transform entire landscapes in line with corporate interests. In trying to understand these entanglements, political ecology forces us to consider the agency and power of non-human actors, from drones to seeds – including constraints on their power – in conservation.

A more-than-human perspective can also help account for how certain non-human lives and more-than-human relations are not only enrolled in conservation but subjected to conservation violence (Margulies and Bersaglio, 2018). In parts of Kenya, drones are already being used to usher charismatic species, like elephants and lions, away from areas where they may experience human–wildlife conflict, and to surveil highly endangered and valuable species, like rhino, 24-7 to prevent poaching. Recent technological advances may soon make it possible for AI-equipped drones to track individual animals at all times – day or night – and to automatically notify conservationists of individual animals at risk or unwell (van Deelen, 2023). Yet, in these same landscapes, pastoralists and their livestock lack the same protection. As an elderly man living in a wildlife conservancy in northern Kenya explained during an interview:

> 'When a human is killed by an animal, like an elephant, [Kenya Wildlife Services] claims not to have transport, so they have no way to help. But if the community reports an animal has been killed or even is suffering a minor injury, KWS already knows before we report. They immediately send

> a helicopter, as well as a number of cars to the site. This shows that animals are regarded with more dignity than human beings! Human beings die, while animals' lives are well secured by rangers. No attention is paid to the security and lives of pastoralists compared to that of wild animals.'

These dynamics point to the politics of life and death at play when conservation actors put drones to work: the operators of conservation drones make calculated decisions about which lives, both human and non-human, are worth saving and which lives, both human and animal, can be forgotten, if not sacrificed (Lunstrum et al, 2021; Enns et al, 2022).

Conclusion

Recent decades have seen a resurgence of interest in advancing conservation agendas and expanding conservation spaces across the Global South, with Northern and international organisations playing a crucial role in the process (Adams and Hutton, 2007). These organisations have devised new public–private partnerships and sources of financing for conservation and facilitated novel environmental policing and security apparatuses. Their efforts have been motivated and emboldened by recognition of the multiple environmental crises threatening the planet, including biodiversity loss, climate change, pandemic risk, and international crime, leading, for example, to the zoning of protected areas without the consent of local populations or consideration for their rights (Sundberg, 2003; Devine, 2018) and the introduction of new borders and control mechanisms around conservation areas (Massé, 2018).

In turn, these trends have been met by calls for more inclusive and just approaches to conservation (Kashwan et al, 2021), along with approaches that seek to decolonise Western sustainability science and conservation (Mistry and Berardi, 2016; Whyte et al, 2016; Goldman, 2020; Mabele et al, 2022). Relatedly, there has been a push to address the digital divide in use and access to conservation technologies and data as a step towards advancing more socially just and effective conservation practices (Pritchard et al, 2022; Sethi et al, 2023). Yet, there remain concerns that global environmental crises will further enshrine conservation expertise and decision making among those who already have power, rather than distribute it more evenly, creating opportunities for further harm to IPs and LCs.

Grounding drone use in relation to these broader trends and processes is essential. Advances in the capabilities of digital technologies, including drones, AI, satellite remote sensing, and camera traps, have played a key role in advancing hegemonic conservation agendas and expanding conservation spaces across the Global South. As many of the examples provided throughout this paper evidence, drone data are used to authorise (geo)political and economic agendas, leading to new forms of dispossession and violence. Drones, developed as technologies of war and surveillance, retain their potential to be used covertly, or even overtly, to surveil rural populations, and to avoid challenge by human rights actors by claiming to do so in the name of biodiversity protection.

Yet, conservation drones are not entirely restricted to reproducing power asymmetries and structures of inequality and violence. Critical work on conservation drones risks overlooking or diminishing the importance of cases where drones are being used to resist, refuse, and transform global conservation politics. As with the case of the MBR,

geospatial technologies can be used to democratise conservation knowledge. When rural communities take drones into their own hands, these technologies can support community-led conservation practices, which in turn strengthens rural autonomy and decision-making capacity (see other article in this special collection, Sauls et al, 2023). Due to the accessibility of some models, drones can also offer new means to hold corporations accountable, counter narratives of minoritised communities, and produce evidence of effective conservation by IPs and LCs.

Political ecology provides the tools for studying and critically engaging with drone use in conversation in ways that are politically engaged and attuned to power relations – historic and present, local and global – in a more-than-human world. Although the technical and applied conservation literature tends to frame drones as autonomous, neutral technology, we argue that neither drones nor their implications can be adequately understood unless they are grounded, conceptually and methodologically, in the context of broader societal structures that shape who can access drones and how and where drones can be used. In making this argument, we point to four conceptual tools in political ecology that offer one framework for engaging with the varied power relations and structures that surround drones in different contexts: political economy, territoriality, knowledge and expertise, and more-than-human relations. Using our own empirics to illustrate the salience of this framework, we further demonstrate why drones can never be severed from a complex set of power relations that shape the implications of their use for humans and non-humans. Wherever there are drones, there are sure to be individuals and populations who benefit from their presence and those who experience some form of harm from their use.

These insights lead to additional, overarching questions that will need to be revisited as drone use in conservation continues and advances in the future. What is the potential of drones for conservation? Under what conditions do drones tend to reinforce exclusionary relationships to land and resources? And, what conditions enable drones to be used to challenge exclusionary, violent processes and bring about more socially just ecological futures? Relying on frameworks from within political ecology when responding to these questions can be fruitful in both academic and practical terms. This is because political ecology demands we take seriously the science and salience of algorithms, ecological processes, and non-human beings and entities; the politics of local communities and global political economies; and the power of military might and regional activism. With this information, we can begin to understand the complexities of drone use in conservation and differentiate between uses that ought to be sought out and embraced from those that ought to be avoided and resisted.

Notes

[1] Corresponding author.

[2] We use the term, relationality, simply in acknowledgement of the varied connections that exist between and co-constitute things. For a more nuanced and politicised understanding of what relationality means within certain Indigenous and other relational ontologies, see: Doucet (2018), Lewis et al (2018) and Byrd (2020).

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References

Adams, W.M. (2019) Geographies of conservation II: technology, surveillance and conservation by algorithm, *Progress in Human Geography*, 43(2): 337–50. doi: 10.1177/0309132517740220

Adams, W.M. and Hutton, J. (2007) People, parks and poverty: political ecology and biodiversity conservation, *Conservation and Society*, 5(2): 147–83.

Adey, P. (2010) Vertical security in the megacity: legibility, mobility and aerial politics, *Theory, Culture & Society*, 27(6): 51–67. doi: 10.1177/0263276410380943

Alvarez León, L.F. (2022) An emerging satellite ecosystem and the changing political economy of remote sensing, in J. Goldstein and E. Nost (eds) *The Nature of Data: Infrastructures, Environments, Politics*, Lincoln: University of Nebraska Press, pp 37–60.

Amador-Jiménez, M. and Millner, N. (2021) Militarisation under COVID-19: understanding the differential impact of lockdown on the forests of Colombia, *Frontiers in Human Dynamics*, 3: art 769365, Available from: doi: 10.3389/fhumd.2021.769365.

Bersaglio, B. and Margulies, J. (2022) Extinctionscapes: spatializing the commodification of animal lives and afterlives in conservation landscapes, *Social & Cultural Geography*, 23(1): 10–28.

Besson, M., Alison, J., Bjerge, K., Gorochowski, T.E., Høye, T.T., Jucker, T., ... and Clements, C.F. (2022) Towards the fully automated monitoring of ecological communities, *Ecology Letters*, 25(12): 2753–75, doi: 10.1111/ele.14123.

Bigger, P. and Neimark, B.D. (2017) Weaponizing nature: the geopolitical ecology of the US Navy's biofuel program, *Political Geography*, 60: 13–22. doi: 10.1016/j.polgeo.2017.03.007

Brockington, D. (2002) *Fortress Conservation: The Preservation of the Mkomazi Game Reserve, Tanzania*, Bloomington: Indiana University Press.

Bryant, R.L. (1998) Power, knowledge and political ecology in the third world: a review, *Progress in Physical Geography*, 22(1): 79–94. doi: 10.1177/030913339802200104

Büscher, B. and Ramutsindela, M. (2015) Green violence: rhino poaching and the war to save Southern Africa's peace parks, *African Affairs*, 115(458): 1–22.

Byrd, J.A. (2020) What's normative got to do with it? Toward Indigenous queer relationality, *Social Text*, 38(4): 105–23. doi: 10.1215/01642472-8680466

Crandall, J. (2015) Unmanned: Embedded reporters, predator drones and armed perception, *CTheory*, https://journals.uvic.ca/index.php/ctheory/article/view/14700/5570.

Devine, J.A. (2018) Community forest concessionaires: resisting green grabs and producing political subjects in Guatemala, *Journal of Peasant Studies*, 45(3): 565–84. doi: 10.1080/03066150.2016.1215305

Doucet, A. (2018) Shorelines, seashells, and seeds: feminist epistemologies, ecological thinking, and relational ontologies, in F. Dépelteau (eds) *The Palgrave Handbook of Relational Sociology*, Cham: Palgrave Macmillan, pp 375–91.

Duffy, R. (2014) Waging a war to save biodiversity: the rise of militarized conservation, *International Affairs*, 90(4): 819–34. doi: 10.1111/1468-2346.12142

Elden, S. (2013) Secure the volume: vertical geopolitics and the depth of power, *Political Geography*, 34: 35–51. doi: 10.1016/j.polgeo.2012.12.009

Elwood, S. and Leszczynski, A. (2018) Feminist digital geographies, *Gender, Place & Culture*, 25(5): 629–44. doi: 10.1080/0966369X.2018.1465396

Enns, C., Bersaglio, B. and Karmushu, R. (2022) Disaster management takes to the skies: how new technologies are reconfiguring spatialities of power in desert locust management, *Political Geography*, 98: art 102732, doi: 10.1016/j.polgeo.2022.102732.

Escobar, A. (1998) Whose knowledge, whose nature? Biodiversity, conservation, and the political ecology of social movements, *Journal of Political Ecology*, 5(1): 53–82.

Fairhead, J., Leach, M. and Scoones, I. (2012) Green grabbing: a new appropriation of nature?, *Journal of Peasant Studies*, 39(2): 237–61. doi: 10.1080/03066150.2012.671770

Fish, A. (2022) Blue governmentality: elemental activism with conservation technologies on plundered seas, *Political Geography*, 93: art 102528, doi: 10.1016/j.polgeo.2021.102528.

Fish, A., Garrett, B. and Case, O. (2017) Drones caught in the net, *Imaginations: Journal of Cross-Cultural Image Studies*, 8(2): 74–79, doi: 10.17742/IMAGE.LD.8.2.8.

Gabrys, J., Westerlaken, M., Urzedo, D., Ritts, M. and Simlai, T. (2022) Reworking the political in digital forests: the cosmopolitics of socio-technical worlds, *Progress in Environmental Geography*, 1(1/4): 58–83. doi: 10.1177/27539687221117836

Gallagher, P. (2022) Digital infrastructure and the affective nature of value in Belize, in J. Goldstein and E. Nost (eds) *The Nature of Data: Infrastructures, Environments, Politics*, Lincoln: University of Nebraska Press, pp 174–90.

Goldman, M.J. (2020) *Narrating Nature: Wildlife Conservation and Maasai Ways of Knowing*, Tucson: University of Arizona Press.

Goldman, M.J., Nadasdy, P. and Turner, M.D. (eds) (2011) *Knowing Nature: Conversations at the Intersection of Political Ecology and Science Studies*, Chicago: University of Chicago Press.

Goldman, M.J., Turner, M.D. and Daly, M. (2018) A critical political ecology of human dimensions of climate change: epistemology, ontology, and ethics, *WIREs: Climate Change*, 9(4): art e526, doi: 10.1002/wcc.526.

Goldstein, J. and Faxon, H.O. (2022) New data infrastructures for environmental monitoring in Myanmar: is digital transparency good for governance?, *Environment and Planning E: Nature and Space*, 5(1): 39–59. doi: 10.1177/2514848620943892

Goldstein, J. and Nost, E. (eds) (2022) *The Nature of Data: Infrastructures, Environments, Politics*, Lincoln: University of Nebraska Press.

Gordillo, G. (2018) Terrain as insurgent weapon: an affective geometry of warfare in the mountains of Afghanistan, *Political Geography*, 64: 53–62, doi: 10.1016/j.polgeo.2018.03.001.

Haraway, D. (2020) Situated knowledges: the science question in feminism and the privilege of partial perspective, in C.R. McCann, S.K. Kim and E. Ergun (eds) *Feminist Theory Reader: Local and Global Perspectives*, New York: Routledge, pp 303–10.

Hecht, S.B. and Cockburn, A. (2011) *The Fate of the Forest: Developers, Destroyers, and Defenders of the Amazon*, updated edn, Chicago: University of Chicago Press.

Igoe, J., Neves, K. and Brockington, D. (2010) A spectacular eco-tour around the historic bloc: theorising the convergence of biodiversity conservation and capitalist expansion, *Antipode*, 42(3): 486–512. doi: 10.1111/j.1467-8330.2010.00761.x

Jackman, A. and Squire, R. (2021) Forging volumetric methods, *Area*, 53(3): 492–500. doi: 10.1111/area.12712

Jiménez López, J. and Mulero-Pázmány, M. (2019) Drones for conservation in protected areas: present and future, *Drones*, 3(1): art 10, doi: 10.3390/drones3010010.

Johnson, N., Strawhacker, C. and Pulsifer, P. (2022) Data infrastructures, Indigenous knowledge, and environmental observing in the Arctic, in J. Goldstein and E. Nost (eds) *The Nature of Data: Infrastructures, Environments, Politics*, Lincoln: University of Nebraska Press, pp 154–73.

Kashwan, P.V., Duffy, R., Massé, F., Asiyanbi, A.P. and Marijnen, E. (2021) From racialized neocolonial global conservation to an inclusive and regenerative conservation, *Environment: Science and Policy for Sustainable Development*, 63(4): 4–19, doi: 10.1080/00139157.2021.1924574.

Kosek, J. (2006) *Understories: The Political Life of Forests in Northern New Mexico*, Durham, NC: Duke University Press.

Lewis, J.E., Arista, N., Pechawis, A. and Kite, S. (2018) Making kin with the machines, *Journal of Design and Science*, doi: 10.21428/bfafd97b.

Lorimer, J. (2007) Nonhuman charisma, *Environment and Planning D: Society and Space*, 25(5): 911–32. doi: 10.1068/d71j

Lunstrum, E. (2014) Green militarization: anti-poaching efforts and the spatial contours of Kruger National Park, *Annals of the Association of American Geographers*, 104(4): 816–32. doi: 10.1080/00045608.2014.912545

Lunstrum, E. (2018) Capitalism, wealth, and conservation in the age of security: the vitalization of the state, *Annals of the American Association of Geographers*, 108(4): 1022–37. doi: 10.1080/24694452.2017.1407629

Lunstrum, E., Ahuja, N., Braun, B., Collard, R., Lopez, P.J. and Wong, R.W. (2021) More-than-human and deeply human perspectives on COVID-19, *Antipode*, 53(5): 1503–25, doi: 10.1111/anti.12730.

Mabele, M.B., Krauss, J.E. and Kiwango, W. (2022) Going back to the roots: *ubuntu* and just conservation in Southern Africa, *Conservation & Society*, 20(2): 92–102.

Mahony, M. (2021) Geographies of science and technology 1: boundaries and crossings, *Progress in Human Geography*, 45(3): 586–95. doi: 10.1177/0309132520969824

Margulies, J.D. and Bersaglio, B. (2018) Furthering post-human political ecologies, *Geoforum*, 94: 103–6. doi: 10.1016/j.geoforum.2018.03.017

Massé, F. (2018) Topographies of security and the multiple spatialities of (conservation) power: verticality, surveillance, and space-time compression in the bush, *Political Geography*, 67: 56–64.

Massé, F. and Lunstrum, E. (2016) Accumulation by securitization: commercial poaching, neoliberal conservation, and the creation of new wildlife frontiers, *Geoforum*, 69: 227–37.

Menon, A. and Karthik, M. (2017) Beyond human exceptionalism: political ecology and the non-human world, *Geoforum*, 79: 90–92, doi: 10.1016/j.geoforum.2016.12.017.

Merron, J.L. and Lenggenhager, L. (2021) Left button picture, right button bomb: nature, warfare and technology in a Southern African border region, *Engaging Science, Technology, and Society*, 7(1): 67–89. doi: 10.17351/ests2021.653

Millner, N. (2020) As the drone flies: configuring a vertical politics of contestation within forest conservation, *Political Geography*, 80: art 102163, doi: 10.1016/j.polgeo.2020.102163.

Millner, N., Cunliffe, A.M., Mulero-Pázmány, M., Newport, B., Sandbrook, C. and Wich, S. (2023) Exploring the opportunities and risks of aerial monitoring for biodiversity conservation, *Global Social Challenges Journal*, 2: 2–23, doi: 10.1332/TIOK6806.

Mistry, J. and Berardi, A. (2016) Bridging indigenous and scientific knowledge, *Science*, 352(6291): 1274–5. doi: 10.1126/science.aaf1160

Neumann, R.P. (1998) *Imposing Wilderness: Struggles Over Livelihood and Nature Preservation in Africa*, Berkeley: University of California Press.

Neumann, R.P. (2004) Nature–state–territory: toward a critical theorization of conservation enclosures, in R. Peet and M. Watts (eds) *Liberation Ecologies: Environment, Development, Social Movements*, 2nd edn, London: Routledge, pp 179–99.

Nost, E. and Goldstein, J.E. (2022) A political ecology of data, *Environment and Planning E: Nature and Space*, 5(1): 3–17. doi: 10.1177/25148486211043503

Paneque-Gálvez, J., Vargas-Ramírez, N., Napoletano, B. and Cummings, A. (2017) Grassroots innovation using drones for indigenous mapping and monitoring, *Land*, 6(4): art 86, doi: 10.3390/land6040086.

Peluso, N.L. (1993) Coercing conservation?: The politics of state resource control, *Global Environmental Change*, 3(2): 199–217. doi: 10.1016/0959-3780(93)90006-7

Peluso, N.L. (1995) Whose woods are these? Counter-mapping forest territories in Kalimantan, Indonesia, *Antipode*, 27(4): 383–406. doi: 10.1111/j.1467-8330.1995.tb00286.x

Pritchard, R., Sauls, L.A., Oldekop, J.A., Kiwango, W.A. and Brockington, D. (2022) Data justice and biodiversity conservation, *Conservation Biology*, 36(5): art e13919, doi: 10.1111/cobi.13919.

Radjawali, I. and Pye, O. (2017) Drones for justice: inclusive technology and river-related action research along the Kapuas, *Geographica Helvetica*, 72(1): 17–27. doi: 10.5194/gh-72-17-2017

Rahder, M. (2020) *An Ecology of Knowledges: Fear, Love, and Technoscience in Guatemalan Forest Conservation*, Durham, NC: Duke University Press.

Robbins, P. (2019) *Political Ecology: A Critical Introduction*, 3rd edn, Hoboken, NJ: Wiley.

Rose, D.B. (2011) *Wild Dog Dreaming: Love and Extinction*, Charlottesville: University of Virginia Press.

Sandbrook, C. (2015) The social implications of using drones for biodiversity conservation, *Ambio*, 44(S4): 636–47. doi: 10.1007/s13280-015-0714-0

Sauls, L., Paneque-Gálvez, J., Amador-Jiménez, M., Vargas-Ramírez, N. and Laumonier, Y. (2023) Drones, communities and nature: pitfalls and possibilities for conservation and territorial rights, *Global Social Challenges Journal*, 2: 24–46, doi: 10.1332/AJHA9183.

Sethi, S., Ewers, R.M. and Balakrishnan, R. (2023) Ecology: correct the digital data divide, *Nature*, 617(7959): art 35, doi: 10.1038/d41586-023-01481-4.

Simlai, T. (2015) Conservation 'wars': global rise of green militarisation, *Economic and Political Weekly*, 50(50): 39–44.

Simlai, T. (2022) *Negotiating the Panoptic Gaze: People, Power and Conservation Surveillance in the Corbett Tiger Reserve*, *PhD dissertation*, Cambridge: University of Cambridge, doi: 10.17863/CAM.84136.

Srinivasan, K. and Kasturirangan, R. (2016) Political ecology, development, and human exceptionalism, *Geoforum*, 75: 125–8. doi: 10.1016/j.geoforum.2016.07.011

Sullivan, S. (2013) Banking nature? The spectacular financialisation of environmental conservation, *Antipode*, 45(1): 198–217. doi: 10.1111/j.1467-8330.2012.00989.x

Sundberg, J (2003) Conservation and democratization: constituting citizenship in the Maya Biosphere Reserve, Guatemala, *Political Geography*, 22(7): 715–40. doi: 10.1016/S0962-6298(03)00076-3

Todd, Z. (2016) An Indigenous feminist's take on the ontological turn: 'ontology' is just another word for colonialism, *Journal of Historical Sociology*, 29(1): 4–22. doi: 10.1111/johs.12124

Tollefson, J. (2022) Saving the Amazon: how science is helping Indigenous people protect their homelands, *Nature*, 610(7930): 22–9. doi: 10.1038/d41586-022-03043-6

Tsing, A.L. (2000) Inside the economy of appearances, *Public Culture*, 12(1): 115–44. doi: 10.1215/08992363-12-1-115

van Deelen, G. (2023) New AI-powered drone technology aids elephant conservation, Phys.Org, 9 March, https://phys.org/news/2023-03-ai-powered-drone-technology-aids-elephant.html.

Van Sant, L., Milligan, R. and Mollett, S. (2021) Political ecologies of race: settler colonialism and environmental racism in the United States and Canada, *Antipode*, 53(3): 629–42, doi: 10.1111/anti.12697.

Whyte, K.P., Brewer, J.P. II and Johnson, J.T. (2016) Weaving Indigenous science, protocols and sustainability science, *Sustainability Science*, 11(1): 25–32. doi: 10.1007/s11625-015-0296-6

Worland, J. (2018) Drones are helping catch poachers operating under cover of darkness, *Time*, 30 May, https://time.com/5279322/drones-poaching-air-shepherd/.

WRTI and KWS (Wildlife Research & Training Insitute and Kenya Wildlife Service) (2021) *National Wildlife Census 2021 Report: Abridged Version*, Nairobi: Ministry of Tourism & Wildlife.

Ybarra, M. (2018) *Green Wars: Conservation and Decolonization in the Maya Forest*, Oakland: University of California Press.