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Justice and ethics in conservation remote sensing: Current discourses and research needs

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ABSTRACT

Advances in remote sensing are transforming research and practice in biodiversity conservation. But the increasing use of these technologies and data also provokes major ethical and social justice questions. In this scoping review, we examine the extent to and ways in which ethics and justice are discussed in relation to uses of remote sensing in conservation. Our literature search identifies only 31 peer-reviewed English language papers containing substantive discussion of justice and/or ethics and conservation remote sensing. Within these papers, emergent themes and tensions include the use of remote sensing technologies for surveillance (and the extent to which this is framed as positive or negative), the militarised associations of remote sensing technologies, the ways that remote sensing technologies can disrupt or harden power asymmetries, and whether the greatest ethical risks or benefits are seen as being for people or other species. Building on recommendations identified in this review, we reflect on how conservation can learn from work on data ethics in other fields, such as the ethics of artificial intelligence. We also discuss the mechanisms (such as formal laws, journal review procedures, and greater individual reflexivity) which could support the use of remote sensing technologies and data to advance socially just conservation. Finally, we highlight research priorities including the need for more comparative case study analyses, greater research efforts on the political economy and geopolitics of conservation remote sensing, and work which situates novel technologies within longer-standing debates about ethics and philosophies of biodiversity conservation.

1. Introduction

Remote sensing data are transforming research and practice in biodiversity conservation (Rose et al., 2015; Bakker and Ritts, 2018). Particularly important are the data derived from satellite remote sensing and from near-earth remote sensing technologies such as drones. Satellite-derived data mean that researchers can monitor the earth's land surface and habitats at scales and resolutions that would have been impossible with traditional in-situ monitoring and surveys. For example, the European Space Agency's Sentinel and NASA Landsat missions provide regular and highly detailed multi-spectral imagery of the Earth's land surface and ecosystems — all free at the point of use. At the same time, the last decade has seen a rapid growth in the commercial satellite industry. Companies such as Planet and SpaceX are creating vast microsatellite constellations with the ability to image the Earth as frequently as every day at as high a resolution as 15 cm. Drones provide data over smaller areas, but offer greater flexibility in the types of data that can be collected, and are increasingly being used by conservation practitioners (Sandbrook, 2015) and by communities living in high-biodiversity areas (Vargas-Ramirez and Paneque-Gálvez, 2019; Sauls et al., 2023). These technological advances are leading to new ways of understanding conservation landscapes, and of planning, monitoring, and enforcing conservation actions.

The 'technological turn' (Parris-Piper et al., 2023) in biodiversity conservation raises major ethical and social justice questions. Remote sensing technologies can enable forms of conservation which also advance social justice, such as when Indigenous peoples and Local Communities (IPLCs) use drones to support their stewardship of highly biodiverse lands. However, new technologies can also enable socially harmful forms of surveillance — such as when drone technology is

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coupled with the use of Google's Facial Recognition AI to 'hunt' poachers (Newton, 2018). Monitoring technologies can be used to legitimise militarised and violent interventions on the ground (Büscher, 2016; Lunstrum and Ybarra, 2018), with IPLCs criminalised without due process (Parris-Piper et al., 2023). The 'panoptic gaze' of satellite remote sensing (Davis et al., 2021) also raises urgent questions about privacy and data sovereignty, given that informed consent to be observed can hardly be obtained at planetary scale.

Alongside direct implications for peoples' rights and wellbeing, there are risks of structural violence – the reinforcement of social structures that perpetuate inequity and cause suffering (Nordstrom, 2004) – arising from increased technological dependence in conservation decision-making. Satellite remote sensing, for example, allows landscapes to be 'known' and represented by people thousands of miles away who have never set foot on the land itself (McCarthy and Thatcher, 2019). This could lead to more autocratic, top-down decision-making, reducing the voice and influence of those living in conserved lands (Adams, 2019; Schultz et al., 2022). Furthermore, although remote sensing data are often treated as apolitical, data generation and analysis are value-laden processes. The aspects of rural environments deemed worthy of being 'seen', and the ways that data are used, depend both on the capabilities of remote sensing technologies and the interests of those with the power to use and make decisions based on remote sensing data (Bennett et al., 2022). The different choices remote sensing users make about and with data will have material and potentially lasting impacts on people and ecologies. This makes attention to data politics and data justice essential for socially-just environmental governance (Nost and Goldstein, 2022; Pritchard et al., 2022).

Exploring the ethical and social justice dimensions of remote sensing technologies is particularly urgent in the case of conservation for three reasons. First, conservation has a complicated relationship with social justice. Key conservation actions, such as the establishment of strictly protected areas, have often been associated with infringements on the rights and wellbeing of local peoples (Mollett and Kepe, 2018; Tauli-Corpuz et al., 2020). Second, conservation in many parts of the world is showing a trend towards more militarised, exclusionary practices (Duffy et al., 2019). New technologies and forms of data have the potential both to reinforce and to countermand this trend. Third, remote sensing technologies and the data they provide will play a central role in efforts to meet the biodiversity targets adopted through the Kunming-Montreal Global Biodiversity Framework in 2022, particularly the goals to protect 30 % of the globe for conservation by 2030 and restore 30 % of degraded lands. These global goals are already shaping international and national policy agendas as well as the conservation funding landscape, and remote sensing data are playing important roles in defining strategies and monitoring progress.

These factors in combination make it fundamentally important to understand the potential ethical and justice implications of remote sensing technologies and data. Our focus in this paper is primarily on social justice, which has received increasing attention in conservation in recent years (Martin et al., 2013). Justice and equity have been framed as important from both moral and instrumental perspectives — current evidence suggests that conservation interventions are more likely to persist if they are perceived as equitable (Schreckenberg et al., 2016; Friedman et al., 2018). Following Sen's (2009) theorisation of justice, a goal of conservation efforts should be to mitigate (or at least not replicate) *manifest injustices*. This means that, while trade-offs are inevitable in any land use choice (Meyfroidt et al., 2022), the greatest losers in these trade-offs should not be people who are already marginalised and disadvantaged. Beyond this harm-avoidance approach, however, lies the bigger question of how remote sensing technologies could help to disrupt environmentally-harmful structures and systems, and foster different kinds of human-environment relations — in other words, how remote sensing technologies could become an enabling factor for just and ethical transformations to sustainability. Understanding how ethics and justice are currently being considered in relation to conservation remote sensing is a first step towards addressing this bigger question. While our core focus is on social justice, we do recognise the bodies of work on more-than-human and multispecies ethics and justice (Celermajer et al., 2022). We highlight emergent points of tension between different conservation worldviews as part of our review.

The explosion of research over recent years focused on developing and applying remote sensing data to monitor changes in the natural environment has significantly expanded our understanding of natural and socio-ecological processes in many conservation landscapes. In this scoping review, we find that there has until very recently been sparse engagement in the literature with the ethical and justice issues accompanying the rise of conservation remote sensing. We begin by systematically reviewing the ways in which issues of justice and ethics are currently discussed in literature specifically focused on conservation remote sensing. We then situate this systematic analysis in the developing literature on the political and justice dimensions of environmental data. We reflect on omissions, disconnects, and research priorities made apparent by current literature, drawing key lessons and recommendations about how to research and practice conservation ethically and equitably as remote sensing data become ubiquitous in decision-making.

2. Methods

This paper is written by a team of scholars with diverse disciplinary backgrounds and who have engaged with remote sensing technologies and data in different ways. The lead authors ([names removed for review]) were both trained in the natural sciences but moved into the environmental social sciences during their postgraduate training and through that transition have come to see remote sensing data through a more critical lens, while working in East Africa and Southern Africa respectively. [Third author] is a human-environment geographer with training in GIS and remote sensing who works on forest rights and land, primarily in Central America. [Fourth author] is a social scientist with an interest in how new technologies are used to manage human and nonhuman life in rural spaces, especially in East Africa. [Fifth author] is a socio-environmental systems researcher whose work develops and critically evaluates remote sensing approaches for managing trade-offs around land and water in rural landscapes, including in the Global North. The shared goal of the authorship team is to look critically at the current conservation remote sensing landscape, in order to build forwards towards more effective and socially just uses of remote sensing data in conservation.

To understand the extent to and ways in which ethics and justice issues have been discussed specifically in English language academic literature on conservation remote sensing, we carried out a scoping review of peer-reviewed literature indexed in Web of Science. Our first search in January 2022 focused on the ethical dimensions of conservation remote sensing from a privacy and surveillance perspective, using the search terms in Table 1. This returned a total of 131 papers. A follow-up search in October 2022 focused specifically on justice and equity implications of remote sensing, after it became clear that these issues had not been captured in the results of our first search. This second search returned a total of 189 papers. Both searches included all papers published from 1990 to 2021 (including early access to papers with an official publication date of 2022).

In our search, we made the decision to use the terminology of both ethics and justice throughout this paper, recognising the entangled usage of these terms in conservation literature. We adopted a systematic approach to identify papers that explicitly address these concepts in relation to conservation and remote sensing, anticipating that this would also highlight the linguistic disconnects that exist across disciplines when discussing issues of ethics and justice. Additional relevant literature that the authorship team are aware of (but were not picked up in the review due to using different terminology) are discussed in the final section of our Results and in our Discussion. We use the Discussion to situate our systematic analysis in the wider literature, and to support

Table 1
Web of Science search terms, for dates 1990–2021 (inclusive). The search required that either the title or abstract of a given article include at least one term from each column to qualify. The italicised terms in the keyword 'Ethics/justice' column indicate those included in a second search, to expand the initial pool of potentially relevant articles to cover justice and equity implications.

Keyword group: Remote sensing/data	Keyword group: Landscape intervention	Keyword group: Ethics/justice
"Remote sensing"	Restoration	Privacy
"Remotely sensed"	Conservation	"Ethic*"
Satellite	"Nature-based"	"Counter-mapping" OR
Drone	"REDD*"	"Countermapping" OR "counter
Landsat	Biodiversity	mapping"
"Earth observation"	"Environmental management"	Surveillance
		Trust
"Digital data"	"Landscape management"	*Just*
Imagery		*Justice*
"*Spatial data"	"Degradation"	*Equity*
"*Spatial technolog*"	"Reducing emissions from deforestation"	*Equitable*

recommendations on advancing more ethical and equitable use of remote sensing data in conservation specifically.

Papers were assessed for inclusion in the full analysis based on whether they met the core criteria for the scoping review, which were: (i) that the paper had a focus on biodiversity, species or habitat conservation; and (ii) some discussion of ethical or justice issues associated specifically with remote sensing technology and/or data. The full texts of the papers from the first search (which included the terms privacy, ethic*, counter-mapping, surveillance, and trust) were reviewed by the first author and coded as 'include', 'exclude', or 'maybe'. All 'maybe' papers were then discussed among the full authorship team to refine the parameters of what counted as conservation and remote sensing, and to ensure consistent application of these parameters. Given that the word 'just' can have multiple meanings, abstracts of papers from the second search (which included the additional terms just, justice, equity, and equitable) were first examined in order to exclude papers using just in a different sense, i.e., not in relation to justice, equity, or fairness. The remaining papers from the second search were then divided in half and coded by two separate authors, who met weekly throughout the whole process to carry out consistency checks.

We identified 31 papers as meeting the parameters for inclusion in the full analysis. Full texts were then reviewed for each paper and summaries provided for the guiding questions outlined in Table 2. The full list of analysed papers is provided in Supporting Information Table 1.

We recognise that the choice to exclude book chapters does mean that we omit some relevant work (e.g., Simlai and Sandbrook, 2021). We are also aware of relevant literature published since first submitting this paper for review, such as a *Global Social Challenges* Special Issue on drone ecologies (Millner et al., 2023). We integrate the relevant points from this additional literature into the Discussion section of our paper.

3. Results

Of the 31 papers identified for inclusion in our full text analysis, the majority are published in journals focused on ecology and conservation, remote sensing, or both (e.g., *Remote Sensing in Ecology and Conservation*, *Biological Conservation*, *Frontiers in Marine Science*, *Methods in Ecology and Evolution*). A smaller number of papers are published in geography journals and in generalist publications such as *PLoS ONE*. All papers identified for inclusion were published from 2015 onwards, with the exception of one paper published in 2010 (which advocated for increasing surveillance in conservation). Notably, 77 % of papers were published in the 5 years prior to this review. Out of 16 papers that identify a geographic focus, studies cover a range of locations globally, including in the Middle East, South-East Asia, Europe, South America, North America, Africa, and Australia (Fig. 1).

Table 2
Guiding questions used to analyse each paper during the full-text analysis.

Code	Description
Reference	Full referencing information for the paper (Chicago author-date)
Journal	Which journal is this article in?
Year	Year of publication
Include? (Y/N/M)	Should this paper be included as a "core" paper for our question? Yes, No, or Maybe
Why	Summarise justification for inclusion or exclusion
Key research question	What is the driving question/problem the article seeks to address?
Key argument/finding	What is the core finding or argument of this article?
Ethics/justice/surveillance/privacy/trust	What element of ethics/justice/surveillance/privacy/trust does this article address, and how/to what degree?
Ethics: Core/peripheral/implicit /throwaway	How significant is the consideration of the "ethics" element to the paper's question/focus?
Technology/data type(s)	What data or technology type(s) does the article examine?
Primary/secondary data	Is the data or technology in question used by the authors (primary) or does the paper focus on secondary data (i.e. Landsat)?
Object of tech/data (surveillance/monitoring/etc.)	What is the data or technology actually examining (what is its use, as in – drone surveillance of wildfire, tree cover loss, etc.)?
Tech/data relation to ethics	Do the data/tech in the paper relate to the "ethics" element discussed? How directly?
Geographic scope	What geographical location does this paper examine, if any specified?
Questions/comments	What questions/comments/reflections do you have about this paper?

Despite satellite data being more widely used for remote sensing applications in conservation policy and practice, the academic literature in our collection focuses primarily on drones. Nearly twice as many papers focused on drones (55 %) compared with satellite technologies (29 %), while the remaining papers (16 %) discuss multiple technologies. Terminology referring to drone technologies varies considerably across papers, with references to unmanned aerial vehicles (UAVs), unmanned or unoccupied aircraft systems (UASs), and remote piloted aircrafts (RPAs). For consistency, in this paper, we group these technologies under the umbrella of 'drones' (Chabot et al., 2022). In this section, we draw out some of the key themes, tensions, and omissions from the papers identified in our review.

3.1. Intentional surveillance and 'bycatch'

One set of concerns apparent in the reviewed papers focuses on how people living in or near conserved areas may find themselves observed. This is often without their knowledge and/or consent, potentially jeopardising privacy and reinforcing exclusionary conservation practices. Sandbrook et al. (2021) frame remote sensing tools as part of a wider set of 'conservation surveillance technologies' that can collect data on people both accidentally and deliberately. We follow their lead by differentiating the ethical concerns raised around intentional surveillance from those associated with 'human bycatch' during conservation monitoring (Sandbrook et al., 2018: p. 493).

For observation through bycatch, the ethical issues discussed include privacy infringements (Linchant et al., 2015; Nowlin et al., 2019) and accidental capture of illegal activity (Piel et al., 2022). The latter often occurs where remotely sensed data are intended to provide information about wildlife numbers, but unintentionally capture potentially sensitive information about people (Sandbrook, 2015; Sandbrook et al., 2021; Tabor and Holland, 2021). For example, remote sensing can document natural resource extraction in contexts where these resources play an important role in local livelihoods, but where such use is illegal or not officially sanctioned. Duffy et al. (2018) highlight the ethical

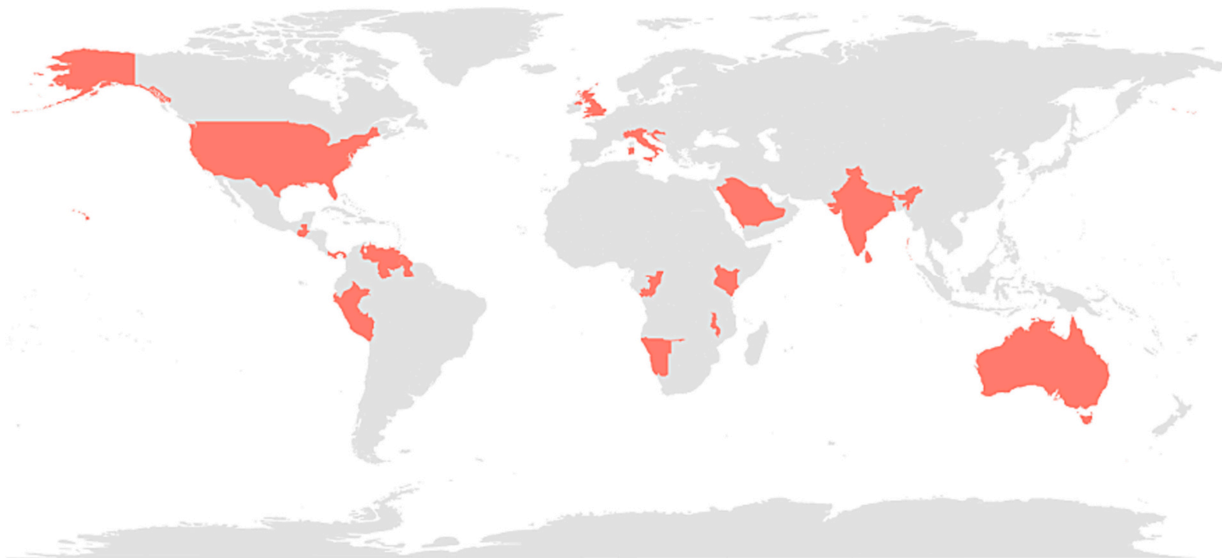

Fig. 1. Geographic distribution of the countries represented in the 16 papers identified in our review that have a specific geographic focus.

challenge of whether or when images that unintentionally capture such illegal behaviour should be shared with law enforcement officials by conservation researchers or practitioners. Such cases may create moral dilemmas for conservationists who could have to make decisions based on little to no ethical training, with potentially severe consequences (e.g., arrest or imprisonment) for those who are captured unawares on remotely sensed images.

On the other hand, remote sensing is also used for intentional surveillance, particularly in the context of regulatory monitoring and control including 'anti-poaching' and environmental compliance strategies. Adams (2019) argues that the application of these kinds of surveillance technologies is playing a central role in the rise of more coercive conservation strategies. Sandbrook (2015) supports this contention, describing how drones have been used deliberately to generate a fear of punishment to deter illegal activities, using 'fear as a tool of conservation (p. S641).' This use of intentional surveillance is worrying, given that marginalised and disempowered groups are more likely to experience negative impacts (Curnick et al., 2022) and may have lower capacity to challenge the assumptions made in assessments based on remote imagery.

Other papers argue for surveillance by conservationists as an ethical imperative, rather than a source of ethical risk. Such papers tend to highlight how remote sensing technologies are used to combat illicit activity, portraying this application as inherently positive because of its perceived power in protecting populations of endangered species (Acevedo et al., 2010; Kiruba-Sankar et al., 2019; Kurekin et al., 2019; Provost et al., 2020). Several papers recommend using remote sensing technology to strengthen conservation surveillance measures, such as monitoring fishing vessels (Elahi et al., 2018; Nowlin et al., 2019) or increasing 'anti-poaching surveillance' (Linchant et al., 2015; Rees et al., 2018; Shaffer and Bishop, 2016). The fear associated with such surveillance technologies is also framed as a positive trait in some papers, as exemplified in Shaffer and Bishop (2016): 'A drone's presence also acts to deter poachers as word spreads that flying machines, which can see at night, are reporting their location to rangers' (p. 527). This points to contention across disciplines in terms of whether surveillance is considered to be a source of (in)justice.

It should also be noted that meanings of the term surveillance vary across disciplines, creating further slippages and disconnects across the literature on conservation remote sensing. In contrast to the surveillance of people as discussed above, surveillance is commonly used in biological and ecological contexts to refer to monitoring nonhuman populations. That the same technologies and practices can be framed so differently, particularly in terms of an ethical imperative versus an ethical risk, hints at profound differences in whose lives and livelihoods are prioritised by different authors. We explore this distinction in greater detail in Section 3.4, where we discuss anthropocentric versus multispecies understandings of justice. Further, we note that the kinds of surveillance practiced using drones are very different to those enabled by satellite remote sensing. The majority of the papers discussed above focus on surveillance using drones. There was little discussion of the use of satellite data to surveil e.g., deforestation or water abstraction, despite the obvious links between these practices and the livelihoods of people living in conserved landscapes.

3.2. Militarisation and militarised associations

There are a number of ways in which authors consider the use of remote sensing technologies for surveillance to intersect with the militarisation of conservation. Drones, in particular, have implicit links to military applications (Duffy et al., 2018). These associations are strengthened by the increasing use of military discourse by conservation organisations in the media (Campbell and Veríssimo, 2015), often called green militarisation (Fish and Richardson, 2022). Campbell and Veríssimo (2015) describe 'drone wars' in the Maltese countryside, where drone use for conservation surveillance and enforcement is inflaming tensions with hunters, leading to retaliatory killings of wild birds and cases of drones being shot down.

In addition to exacerbating conservation conflicts and inequalities, Duffy et al. (2018) reflect on the psychological harms that drones could cause, particularly in areas with active or recent conflict. This suggests context dependencies in the ethical and justice implications of conservation remote sensing that the existing pool of empirical literature is still too shallow to explore.

3.3. Remote sensing and distributions of power

A much smaller number of papers in our review consider how remote sensing technologies and data are changing conservation politics and governance i.e., how remote sensing technologies interact with and alter power relations, and how this in turn impacts who benefits from or is disadvantaged by conservation practices. Three papers explore cases in which local people have used drones as tools of resistance against conservation authorities and other land managers. This is termed 'drone environmental activism' by Fish and Richardson (2022: p. 6). Paneque-Gálvez et al. (2017) describe how drones have been used in mapping efforts by Indigenous communities to reinforce claims to land and to monitor forests for encroachment by external actors. Similarly, while recognising how drones can support militarisation and create 'spaces of fear', Millner (2020) describes how communities in Guatemala have mobilised new monitoring technologies to assert territorial rights and resist new forms of spatial enclosure. Fish and Richardson (2022) stress that while critiques of the use of remote sensing data are important, critics must be careful not to get too lost in identifying vulnerability and overlook instances of drone counter-mapping. They highlight drones' 'dual potential — a capacity for both freedom and oppression' (Fish and Richardson, 2022: p. 12).

Other authors, however, express concerns over how conservation remote sensing can shift influence away from local people and produce or reinforce top-down, unaccountable governance structures. Adams (2019) raises potential ethical issues with the development of 'conservation by algorithm', where remote sensing technology is increasingly used to automate conservation decisions (p. 337). While automation can bring advantages such as continuous data flows and quicker species identification, certain applications raise major ethical questions. One example is the automation of decision-making for dispatching law enforcement, which Adams (2019) sees as propelling 'a biopolitical regime operated remotely and autonomously that subjects both nature and society to discipline', further increasing the distance between the decision-makers and those affected by conservation on the ground (p. 345). Oberhauser (2019) also describes how asymmetries in understanding the algorithms used to analyse remote sensing data could reduce transparency in conservation decision-making.

Although high resolution satellite data is freely available for public use from various online sources, this does not equate to having the resources and technical capacity to process, analyse, and interpret this data. As these are also not evenly distributed, access ultimately remains highly inequitable despite free data availability. Two papers highlight how these inequalities in access and capacity to use remote sensing data could change who has the power to tell stories about conserved lands, with major implications for conservation practice. For example, Sandbrook (2015) proposes that using remote sensing technologies to inform anti-poaching strategies supports harmful narratives about conservation among the wider public, pitting 'good' conservationists against 'poachers'. In addition, Windey and Van Hecken (2021) discuss how geospatial data use can lead to simplified representations of space and people, which in the Democratic Republic of the Congo has resulted in the reinforcement of problematic narratives which frame local people as the primary drivers of deforestation.

3.4. *Justice and ethics for who — or what?*

An additional divide in the reviewed papers is whether they focus on ethical and justice risks for humans, other species, or (rarely) both. Papers focusing primarily on humans often use the language of 'social concerns' or 'social implications', including privacy infringements (Linchant et al., 2015; Alkhelaiwi et al., 2021), inciting fear or hostility (Duffy et al., 2018), safety issues (Sandbrook, 2015; Duffy et al., 2018), the inability of surveilled peoples to give consent (Sandbrook et al., 2021), and data security and equitable data access (Curnick et al., 2022; Madin et al., 2019). These more anthropocentric perspectives also emphasise the ways that remote sensing technologies and data shape and are shaped by the wider politics of conservation, and how this could lead to more serious detrimental impacts on marginalised groups. To give one example, drones can be used to monitor and control activities that are implicated in deforestation yet necessary for peoples' livelihoods, such as hunting and gathering of non-timber forest products (e.g., Ngabinzeke et al., 2016).

Another set of papers focus on ethical responsibilities to other species. This includes ethical concerns about the impacts of remote sensing technologies on animal welfare (Bevan et al., 2018; Duporge et al., 2021; Hartmann et al., 2021; McIntosh et al., 2018). We find that this subset of papers tends to focus on the risks of drones causing disturbance to the animals being monitored, often making recommendations for ethical operating thresholds such as optimal flight altitudes (Bevan et al., 2018; Duporge et al., 2021; McIntosh et al., 2018) and launch distances (Hartmann et al., 2021). This group of papers also includes those discussed in Section 3.1 that treat surveillance as a means to the ethical end of endangered species conservation.

Perhaps more interesting is that most papers do not explicitly detail their assumptions about what a just approach to conservation should be or do, or who justice should be for. This is instead often implicit in the ways that authors choose to frame remote sensing technologies and data, and their impacts on human and non-human lives.

4. Discussion

4.1. *Patterns and omissions in current literature*

Several authors have argued in recent years that research on the ethical and social justice implications of conservation remote sensing has lagged far behind technical methods development (Adams, 2019; Sandbrook et al., 2021; Pritchard et al., 2022). Our review supports this perception, with only 31 papers meeting our inclusion criteria of containing substantive discussion of ethics and justice specifically in relation to the use of remote sensing technologies in conservation. To provide a point of comparison, a search including only the "remote sensing/data" and "landscape intervention" keyword groups listed in Table 1 returns more than 16,000 peer-reviewed papers, of which over 3000 were published before any of the 31 studies in our review that focus on ethical and justice issues. Adding the third group of search terms (those relating to ethics and justice) brings the numbers down into the low hundreds.

We observe several patterns in the existing peer-reviewed literature on this topic. First, while our sample is small, reflecting the nascent stage of research in this area, there are hints of differences in the ways that surveillance through remote sensing technologies is framed in different geographic locations. Those papers that focus on surveillance in locations in the Global North, including Malta and the US, are critical of surveillance using remote sensing technologies (Campbell and Veríssimo, 2015; Nowlin et al., 2019). The sample of papers discussing issues of surveillance in the Global South is more mixed, with several authors framing surveillance through remote sensing as a positive characteristic (Acevedo et al., 2010; Shaffer and Bishop, 2016; Kiruba-Sankar et al., 2019). This pattern may reflect the longer-term relationships between colonial settlement and conservation in countries such as India and Kenya, in which some conservation organisations continue to uphold racial-colonial narratives by presenting non-white populations as the threat to biodiversity, with novel technologies that monitor and surveil as the solution (Kashwan et al., 2021; Van Sant et al., 2021; Bersaglio et al., 2023).

Second, the existing literature (particularly with regards to surveillance) is skewed towards drone rather than satellite data, despite satellite data being far more widely used in conservation research, policy and practice. We suggest that this is because of the immediacy of drones and the clear tangibility of their presence and impact for those being observed, in comparison to a satellite flying hundreds to thousands of kilometres above the land surface. As less expensive forms of drones have come on the market, these technologies have also become more accessible to IPLCs seeking to advance their own conservation narratives, as in the case of indigenous people and subsistence forest communities in Guatemala discussed by Millner (2020). While continued research on drones is undoubtedly important, the use of satellite data in conservation should be seen as a priority for social science research. Drones can undoubtedly have negative impacts on both material and psychological wellbeing. However, the scope of potential harms from satellite remote sensing is far wider ranging. This is due to the global coverage of satellite data and extent to which they are already used in multi-scalar conservation decision-making, their ability to transcend traditional geographic boundaries, and the challenges of controlling what data is being imaged from space and by whom.

Whether papers prioritise ethical and justice risks to people or to other species represents a third pattern of note. The article by Shaffer and Bishop (2016) on the use of drones in elephant conservation particularly embodies this trend, where the fear response provoked by drones among local people is characterised as a positive for elephant conservation. The differences we see in the current literature are symptomatic of much longer-standing debates in conservation, particularly about the extent to which conservation actions should also benefit people (Kareiva, 2014) and the extent to which conservation should seek to advance social justice alongside preserving biodiversity (Brechin, 2003; Chapin, 2004; Shoreman-Ouimet and Kopnina, 2015).

A final noteworthy pattern emerges from examining the wider set of papers identified in our initial search that did not meet the criteria for inclusion in our core review sample. These papers do not discuss the ethical and justice implications of remote sensing data, but instead these data to make visible justice and injustice in conservation governance more broadly (e.g., in REDD+ initiatives; Boissière et al., 2014; Bos et al., 2020). This finding suggests that while many scholars of conservation use remote sensing data to analyse the justice implications of conservation practices, few explicitly examine the justice implications of the data themselves. This may reflect the narrative in conservation and broader natural resource management that you 'can't manage what you don't measure' and, hence, that there is an ethical or justice imperative to use data in ways which make conservation landscapes more visible and therefore governable. The tension, as in the question above as to whether papers focus on ethical risks to people or other species, is that the positionality and values of the authors determine what is worthy of being seen, considered in governance, and conserved. The observation that remote sensing data are often used as a tool in research advocating for a more just conservation also echoes a distinction identified by Vera et al. (2019) between work on environmental justice and on data justice. Environmental justice has often made use of data to make injustice visible, as in the case of the Environmental Justice Atlas (Temper et al., 2015). Data justice research, in contrast, emphasises that being represented through data is not always beneficial, and that there is a need for greater critical attention to who is made (in)visible through data, in what ways, and with what consequences (Taylor, 2017; Dencik et al., 2019).

The biggest notable absence in our reviewed literature is on the political economy of conservation remote sensing. As Alvarez León (2022) highlights in the context of satellites, there are complex geopolitical dynamics and stakes associated with satellite launches. These dynamics are shaped by path dependencies from colonialism and the Cold War, and by the shifting political relationships between emerging economies and established global powers. Powerful governments, such as those of the United States and China, have used the deepening global biodiversity crisis to rationalise the remote monitoring of other states' environmental space, as have international conservation organisations and corporations. This remote monitoring of distant environmental space tends to be presented as a global benefit and necessary for building the scientific knowledge needed to combat biodiversity loss and climate change. Yet, the benefits of this data are more readily available to those who collect, own, and control it. The environmental data collected by foreign states and private, for-profit companies can be readily commodified by those that control it. It may also be used to influence and inform conservation decision-making processes by actors who are distant and detached from the landscapes they seek to influence. This set of concerns links to broader, ongoing conversations around the politics of environmental data, colonial surveillance, and digital capitalism (Gabrys, 2016; Goldstein and Nost, 2022), which warrant further attention by conservation researchers and practitioners. Similarly, the private sector has a growing role in the collection and delivery of satellite remote sensing data products. These data often offer advantages in terms of resolution and imaging capabilities beyond publicly available datasets, meaning that actors who can afford to purchase such data may be able to benefit from privileged monitoring capabilities that could advance their own interests.

4.2. *Learning from other research fields*

Work on the ethical and social justice dimensions of conservation remote sensing technologies and data can learn from recent advances in other research fields. First, work on conservation remote sensing is part of a broader context of research on the social dimensions of environmental data. As with many young and rapidly developing research areas, work on social dimensions of conservation and environmental technologies comes with a diversity of labels, such as political ecologies of data (Nost and Goldstein, 2022), digital environmental politics (Machen and Nost, 2021), Smart Earth (Bakker and Ritts, 2018; Gabrys, 2020), conservation and environmental data justice (Vera et al., 2019; Pritchard et al., 2022), critical remote sensing (Bennett et al., 2022) and emerging technologies (Madin et al., 2019). These bodies of work are often published in different spaces and use different vocabularies, such as discussing 'social implications' (e.g., Sandbrook et al., 2021) vs. 'vertical geographies' (e.g., Massé, 2018; Millner, 2020). This is further complicated by differential understandings of the same terminology between disciplines. For example, discussions of surveillance in remote sensing can have very different meanings, ranging from the monitoring of people to capture instances of illegal activity (Shaffer and Bishop, 2016; Kiruba-Sankar et al., 2019) to the ecological monitoring of nonhuman populations. Determining how these bodies of work and the people who write them can communicate in productive ways will advance efforts to address the social justice and ethical issues that arise in relation to conservation efforts.

These efforts can also learn from wider work on the ethics of data science methods, such as artificial intelligence (AI) and machine learning (ML). What we observe in remotely sensed imagery is the product of both raw signals captured by satellites and drones and the algorithms that are used to extract usable information (e.g., about land cover change, species prevalence, or livelihood activities) from these data. Issues such as algorithmic bias, lack of model transparency, and over-extrapolation of model predictions apply as much to conservation remote sensing as to debates about ethical implications of AI and ML in other facets of society (Crawford and Calo, 2016; Zou and Schiebinger, 2018; Rich and Gureckis, 2019). Wearn et al. (2019), for example, highlight the potential for algorithmic bias leading to local livelihoods being misclassified as illegal activities (e.g., poaching) in AI algorithms and models that lack important contextual knowledge and information. Similarly, Alix-Garcia and Millimet (2023) show how hidden or obscured uncertainties in remote sensing data can result in misestimation of land cover change that could bias design, targeting, and evaluation of conservation policies. A lack of in-situ monitoring is sometimes used as a justification to ignore such uncertainties in these data, under the premise that it is 'better to have something than nothing'. This may, however, create inequities in outcomes where some groups have the capacity to challenge these uncertainties, but others cannot. Given these parallels, we argue that there are large opportunities and benefits for the conservation community to engage with emerging best practice around societal use of AI. This includes a wide range of initiatives (Jobin et al., 2019; Floridi and Cowls, 2022) such as Asilomar AI Principles (https://futureoflife.org/open-letter/ai-principles/) or the Alan Turing Institute's FAST track principles (Leslie, 2019), all of which provide guidance on how conservation researchers and practitioners might seek to minimise or avoid ethical risks associated with AI.

Finally, conservation researchers and practitioners could learn from other fields that have been engaging in discussions about the ethical and social justice considerations of remote sensing for several decades now. For example, 'humanitarian drones' play a key role in relief and reconstruction efforts in situations of conflict, disasters, epidemics, and population displacement. In response to growing concern about the ethical implications of humanitarian drone use and inadequate governance guidance, various guidance documents have been prepared for technology developers and operators, such as the Humanitarian UAV Code of Conduct and Guidelines (2021) and the Handbook on Data Protection in Humanitarian Action (2020) (Wang et al., 2022; Wang et al., 2021). Other fields where remote sensing technologies and techniques provide key data, ranging from archaeology (Cohen et al., 2020) to agriculture (Foster et al., 2020), are also increasingly grappling with the ethics and justice implications of their increasing use. Challenges such as identifying and appropriately engaging affected local peoples, as well as determining the degree to which data transparency may help or hinder a given intervention, echo ethical concerns relevant to conservation.

4.3. Practical steps for conservation researchers and practitioners

As well as the research priorities highlighted above, our review suggests some practical steps conservation researchers and practitioners could take to mitigate ethical and justice risks. The first is to take advantage of tools already developed to guide responsible use of conservation technologies. Most immediately relevant is the recently published 'Responsible Drone Use in Biodiversity Conservation' (Millner et al., 2023), which has been developed specifically for conservation organisations using drones. Other useful resources include: Sharma et al.'s (2020) ethical code of conduct for the use of camera traps in research on wildlife; Sandbrook et al.'s (2021) proposed principles for the socially responsible use of conservation monitoring technology and data; Di Minin et al.'s (2021) guidelines on data privacy when using social media data in conservation science; and Young et al.'s (2022) checklist and considerations' guide for ethical ecosurveillance. These tools provide conservation researchers and practitioners with practical guidance on ensuring due consideration and, where appropriate, mitigation of social concerns when using digital technologies for conservation research (Sandbrook et al., 2023).

Yet, as long as the adoption of these types of tools remains up to individual researchers, issues around justice and ethics in relation to conservation remote sensing will continue to fly under the radar. Instilling greater awareness of the ethical and social justice implications of conservation remote sensing requires broader efforts. For example, funding bodies and institutional ethical review boards could require researchers to demonstrate in their applications consideration for the social implication of their research (Sandbrook et al., 2023). Institutions could require data management plans to explain how a project will protect privacy over its lifespan (Di Minin et al., 2021). Universities could incorporate information about the social consequences and ethical dilemmas of using remote sensing in conservation into their curricula. Relatedly, universities could require researchers using remote sensing to complete short training courses on socially responsible use of conservation technology — a strategy already used by many institutions to mitigate against other ethical quandaries in research.

Journals also have a vital role to play in supporting the socially responsible use of conservation technology and refusing to publish research done using remote sensing technologies in socially irresponsible ways. This could include research that uses digital technologies in ways that go against best practice – for example, by impinging on peoples' privacy – and research done without consideration to relevant international, national and local laws, including biocultural protocols (BCPs). As Sandbrook et al. (2023) have argued, journals should develop guidelines regarding what they will and will not accept for publication based on these types of parameters. *Oryx* put this suggestion into practice in 2021 by adding a statement on socially responsible use of conservation technology in its instructions to authors, and ten other journals have since followed suit (Sandbrook et al., 2023). Combined, these recommendations demonstrate that the various institutions involved in research can encourage researchers to consider the potential consequences of using remote observation during all stages of the research process, from data collection to data management to data sharing and dissemination.

Recognising that not all conservation research is subjected to ethics review or published, and also that not all conservation remote sensing is done for research purposes, there are other means of encouraging greater attention to the ethical and justice dimensions of remote sensing technologies. Existing international, national, and local legal provisions outline the circumstances under which people can be identified, tracked or monitored (Choudry, 2019; Zuboff, 2019; as cited in Sandbrook et al., 2021). However, the applicability of such laws to remote sensing, and particularly to satellites, is ambiguous, and there is a need to consider whether existing privacy laws are fit for purpose in a world where one can now use remote sensing to track movement of individual people and animals. A growing number of IPLCs are also establishing their own frameworks for guiding conduct on their territories. For example, BCPs can be used to establish rules around access, benefit-sharing and 'free prior and informed consent' between IPLCs and any individual gathering information on or about their land (MASTA, 2012). New work on Indigenous data sovereignty (Kukutai and Taylor, 2016) is also developing new models through which IPLCs can claim ownership of data about their lands — although the same question persists over how such models would translate to large-scale satellite data.

Advancing equity and social justice in or through conservation remote sensing will require interventions that extend beyond the way these data are used by researchers and practitioners on the ground. Efforts to promote more socially responsible use of remote sensing must also engage the generators and providers of remote sensing technologies and data, both within the public (e.g., NASA, ESA, etc.) and private (e.g., commercial satellite companies such as Planet and SpaceX) sectors. These organisations shape and determine what we see and do not see in remote sensing imagery and hence have a central role to play in addressing injustices that result from use of these data in conservation policy and practice. For example, there is a need to evaluate how data providers could be encouraged or incentivised to report underlying uncertainties and biases in remotely sensed imagery, and document assumptions made when developing the data products which are ultimately used by conservation researchers and practitioners. This could include greater focus on ethical and justice considerations around data use within companies' codes of practice. It could also include environmental, social, and governance (ESG) strategies that extend beyond the notion that remote sensing is purely a solution, as opposed to a risk, to equity and justice. Greater transparency will not in itself eliminate potential for injustice, but it would provide a basis for improving accountability. This is by enabling affected groups to interrogate which conservation decisions are made, going some way to addressing the false sense of certainty that mapping products and data often convey to decision makers (Specht, 2020).

There is also a need to try and level the playing field in terms of who can access and utilise state-of-the-art remote sensing imagery, often only available at substantial cost through proprietary platforms. Recent examples of attempts to democratise access to remote sensing data include Planet's recent partnership with Norway's International Climate and Forests Initiative (NICFI) to provide free to access to Planet's high resolution pre-processed mosaics of the world's tropics (www.planet.com/nicfi/), and Radiant Earth's efforts to develop open-source datasets that can be used for training remote sensing models of land use change (https://radiant.earth). Indeed, we are seeing increasing trends towards open data initiatives with the satellite imagery sector. In the long run, these are likely to be strengthened further as business models of satellite image providers shift towards provision of data analytics and derived products. This poses the risk that widening access to the data will be accompanied by new power divides in terms of who has access to tools and resources to process and analyse data. This could exacerbate existing inequities rather than closing them. A full treatment of how relationships of power between different actors shape the composition and use of remote sensing data is beyond the scope of this paper but is a central theme in work on the political ecology of data (Nost and Goldstein, 2022) and critical remote sensing (Bennett et al., 2022).

4.4. Priorities for further research

We acknowledge three limitations in our systematic literature review approach. First, we limited our review to peer-reviewed papers. Book chapters (e.g., Simlai and Sandbrook, 2021) and grey literature are not covered in this synthesis, although they are incorporated where relevant into our discussion in Section 4. Second, we included only papers published in English, and our findings should therefore be seen as representative of the current state of these conversations in anglophone literature only. Third, the protocol used in our review means that we mainly captured papers that discuss direct uses of remote sensing data to inform conservation practice. We were less able to identify those papers discussing maps or platforms in which remote sensing data are just one among many data inputs (e.g., Hazen and Harris, 2006). Finding ways to understand how choices made earlier in data supply chains shape the distributive consequences of data use should also be seen as a priority for research. Despite these constraints, this paper presents the most thorough review on the topic to date, and the compiled papers provide valuable insights into current debates around ethics, justice, and conservation remote sensing.

The reviewed papers highlight several priority avenues for future research. The political economy of conservation remote sensing emerges as one of the most prominent research needs. Research needs to move beyond local-scale analyses to consider the diversity of actors and motivations that compose data value chains, and the ways these shape the generation, use, and ultimate impacts of remote sensing data. More in-depth comparative case study research, casting light on how different conservation histories and political dynamics shape the use of remote sensing technologies and data, would also deepen understanding of ethical implications of remote sensing in conservation. Exploring the links between technology and data use and the different philosophies of conservation, and situating these technologies within wider-ranging debates on conservation ethics and goals, would further contribute to a more nuanced literature. This multi-scalar systemic approach is also essential for understanding the roles that remote sensing technologies could play in broader transitions to sustainability.

The findings of our review reinforce ongoing discussions about the need to broaden the scope of conservation research moving forward. There is growing recognition around the importance of interdisciplinarity in conservation research (Bennett et al., 2017a; Bennett et al., 2017b; Brittain et al., 2020; Chua et al., 2020). As Brittain et al. (2020) write, traditionally-trained conservationists are not always well-prepared for the ethical challenges that arise when doing conservation research; the same argument could be made for natural resource managers more broadly. However, collaborating with social science and humanities researchers can help ensure adequate consideration of social impacts and important ethical questions. Relatedly, fully understanding the ethical and justice implications of using remote sensing technologies in different contexts requires meaningful partnerships with IPLCs and other knowledgeable local practitioners living in these contexts.

5. Conclusion

The scoping review presented in this paper serves to reinforce recent calls for more research on the social and ethical dimensions of conservation remote sensing. Bringing thinking on the justice and ethical implications of conservation remote sensing up to speed with the rate of technological development will require a strong interdisciplinary research effort, with an openness on all sides to learning across the usual divisions within and between natural, social, and data sciences. It will also require creative thinking, as many of our existing ethical standards and norms may no longer be effective safeguards in the era of 'big' environmental data. A willingness to engage with these steps, however, will have major rewards by helping to ensure that remote sensing data are harnessed in pursuit of the dual goals of advancing human prosperity and mitigating the biodiversity crisis — especially so in an era of rapid socio-ecological change.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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