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Rethinking biopiracy through relational criminology in the age of data-driven biology

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Biopiracy is a colonial legacy of misappropriating biological resources and Indigenous knowledge. Despite growing criminalization, especially in the Global South, governance remains anchored in intellectual property law and state-centred biosovereignty, often deepening epistemic injustice and socio-economic inequality. These limitations are magnified in the age of data-driven biology, where genomic databases, artificial intelligence and gene-editing technologies reshape how biological value is extracted and governed. Drawing on green criminology, zemiology and critical theory, the article advances a relational criminology of biopiracy. It advances an ontological shift towards the relational, enabling biopiracy to be understood primarily as a layered regime of misrecognition and exclusion of social relations and positioning critical criminology to inform more just bio-governance.

Keywords biopiracy, relational criminology, critical criminology, Global South, biosovereignty

Introduction

Biopiracy is a colonial legacy with a long history of appropriating biological resources and associated knowledge from Indigenous and local communities. In recent decades, it has increasingly been subject to criminalization, particularly in the Global South (Stone 2008). Yet despite its historical depth and contemporary salience, biopiracy remains unevenly conceptualized and inadequately governed. Existing accounts tend to focus on legality, ownership or regulatory compliance, leaving the relational processes through which harm is produced, normalized and sustained largely unexamined. Rather than treating biopiracy as a discrete illegal act or a quantifiable harm, the article conceptualizes it as a form of relational harm, distributed across time, space and social relations. In particular, it foregrounds

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two under-examined dimensions: relations of definition, through which certain practices are rendered criminal while others remain normalized or invisible; and relations of recognition, through which Indigenous knowledge, agency and interests are selectively acknowledged or marginalized. From this perspective, the persistence of biopiracy reflects not simply failures of legal definition or ownership allocation, but misaligned relational configurations within expert, regulatory and commercial fields.

As this article demonstrates, most regulatory and criminological responses continue to frame biopiracy narrowly through intellectual property law (Jefferson and Robinson 2025)—itself a Western legal construct—and through state-centred assertions of biosovereignty, understood as the claim that states exercise sovereign control over biological resources and genetic data within their territories, with limited attention to the power relations, economic asymmetries and geopolitical inequalities that structure access to biological resources and knowledge (Wynberg 2023; Zhang 2023a). These limitations are further amplified in the context of data-driven biology, that is, contemporary life science research increasingly organized around large-scale genomic datasets, digital infrastructures and computational tools. On the one hand, the increasing strategic value of genetic data has generated new geopolitical tensions and competitive dynamics, described as a contemporary 'gene rush' reminiscent of earlier resource extractivism (Imran *et al.* 2021). On the other hand, the digitalization of genomic data, combined with advances in genetic engineering and artificial intelligence, has enabled forms of automated and remote biopiracy that require little or no direct contact with biological material or local knowledge holders. As a result, traditional event-based and territorially bounded models of regulation have become increasingly inadequate (Elbe 2021: 664; Aubry 2023).

Existing legislative frameworks and dominant IP- and territory-based approaches, at best, prioritize expedience over inclusivity (Wynberg 2023: 11) or what Robertson (2005: 133–135) characterizes as 'conquest by law', whereby legal mechanisms of private property and dispossession—rooted in doctrines of discovery (i.e., legal and religious frameworks dating back to the fifteenth century that authorized European Christian powers to claim Indigenous lands, resources and sovereignty by construing 'discovered' territories as vacant or open for appropriation)—are imposed as the conditions under which Indigenous communities must engage with benefit-sharing regimes (Brush 2007; Wynberg 2023). At worst, such approaches risk producing an 'inversion of justice' (Goyes and South 2016): while strengthening formal legal control over biological resources, they fail to protect Indigenous welfare and may deepen socio-economic inequality and epistemic injustice in which marginalized groups' knowledge, experiences or testimony are systematically silenced, dismissed or distorted, including by deterring much-needed North–South scientific collaboration (Giladi 2018; Heffernan 2020). Relatedly, concerns have been raised that formal legal frameworks governing benefit allocation arising from access to and use of biological resources, known as benefit-sharing regimes, may disproportionately burden noncommercial research, rendering essential work on food security and public health, often producing nonmonetary or collective benefits, impractical or legally precarious (Cock 2010; Prathapan *et al.* 2018).

In response to these limitations, this article argues for a relational turn in the criminological understanding of biopiracy, drawing on critical criminology, an approach that interrogates how power, inequality and social structures shape definitions of crime and harm (Yar 2012; Wyatt and Brisman 2017), alongside critical social theory, a body of scholarship that examines how social norms and risk are produced and contested through institutional and political relations (Beck 1992; Honneth 1995). More specifically, it builds on insights from zemiology, the study of social harms that may fall outside formal

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legal categories of crime (Garland 2001; Tombs 2018) and green criminology, which foregrounds environmental harm, ecological justice and human–nonhuman relations (South 2014; Lynch 2020).

The article repositions biopiracy as a paradigmatic case of legally sanctioned yet socially injurious harm, a growing concern across green criminology and zemiology. The article advances a relational criminological framework that shifts attention from individual acts or regulatory failures to the social relations through which harm is produced, legitimized and unevenly distributed. By bringing together Ulrich Beck's notion of *relations of definition* and Axel Honneth's theory of *recognition*, the article shows how biopiracy can persist under conditions of formal legality through processes of misrecognition that normalize extraction while rendering alternative claims to value and justice socially invisible. More broadly, by foregrounding relations rather than offences, actors or outcomes as the primary unit of analysis, the article offers an analytical framework with wider applicability for criminology research, capable of not only diagnosing persistent governance failures but also opening up the space for the re-imagination of justice across complex, transnational harm contexts beyond biopiracy, thereby informing alternative modes of criminalization and regulatory pathways.

The article is structured as follows. The first section critically examines dominant regulatory discourses and criminological approaches to biopiracy, establishing the need for a relational analytical framework. The second section develops this relational lens further by analyzing emerging biopiracy challenges specific to the age of data-driven biology, including the implications of digitalization, automation and transnational data flows. The final section synthesizes these insights and illustrates how a relational criminological approach can inform more just and effective governance pathways.

Discourses on biopiracy and the case for relational criminology

At first glance, biopiracy appears conceptually straightforward. It is commonly framed as a form of knowledge theft: the misappropriation of genetic resources or associated knowledge without prior informed consent and without fair compensation to the people of the territory from which those resources originate—an extractive practice that disproportionately occurs between techno-economically powerful actors and less powerful communities, including Indigenous peoples (Kim 2020; Rotzin 2024; Jefferson and Robinson 2025).

At a deeper level, however, the identification and appropriation of valuable biomaterials, biodata and associated knowledge and their transformation into proprietary bioproducts or innovations occupy a far more ambiguous legal and moral terrain. This ambiguity is captured in the uneasy duality between bioprospecting and biopiracy (Goyes and South 2016; Wyatt and Brisman 2017). Proponents of bioprospecting argue that the global search for biological resources fuels innovation, particularly in agriculture and medicine, and should be protected as a public good. Critics counter that the primary beneficiaries are rarely source communities: value is instead captured by intellectual property holders, while local populations are excluded from meaningful benefit-sharing. Contemporary IP regimes nonetheless confer legal legitimacy on these arrangements, often under the moral banner of 'progress' (Wyatt 2014). The monopolization of seed DNA by commercial actors such as Monsanto exemplifies this reversal of justice. As Vandana Shiva (2000: 6) observed, it produces 'a new and clever system' that 'mak[es] the theft of the harvest a right and the keeping of the harvest a crime'.

To unpack how criminological inquiry can illuminate these tensions, this section undertakes a dual literature review. The first subsection examines dominant and contested academic and policy discourses on biopiracy, identifying IP-centred and nation-state-centred

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approaches as defining features of existing debates (Nehring 2022). While extensively critiqued, these frameworks offer limited resources for moving beyond persistent impasses in governance and enforcement.

The second subsection advances an ontological shift by engaging criminological debates on invisible harm, social relations and power (Garland and Sparks 2000; Hillyard *et al.* 2004; Tombs 2018). Rather than treating biopiracy as a discrete act of illegal access or misappropriation, it develops a relational criminological perspective that conceptualizes biopiracy as a form of relational harm produced through asymmetrical social configurations. From this perspective, biopiracy operates through what Ulrich Beck (1992) conceptualizes as relations of definition: the capacity to define legitimate knowledge, lawful innovation and acceptable risk is structurally concentrated in techno-economic centers, while source communities are positioned as objects rather than subjects of regulation. This asymmetry helps explain the persistence of governance failure. Even where formal benefit-sharing mechanisms exist, the social relations through which value is defined, extracted and authorized remain intact. Biopiracy governance is, therefore, marked by a deeper problem of relations of recognition (Honneth 1995; 2001; Wyatt and Brisman 2017).

Seen in this light, biopiracy poses a distinctly criminological problem: not only the under-criminalization of harm but also the active misrecognition through which harmful relations are rendered lawful. The contribution here is to integrate relations of definition and relations of recognition into a single relational criminological framework capable of explaining why biopiracy persists even under conditions of formal legality.

Biopiracy governance: intellectual property, sovereignty and critique

Practices now described as biopiracy long predate the term itself. One of the earliest documented cases can be traced to Spanish colonial expansion in the sixteenth century, when medicinal plants from Mexico and Central America were systematically extracted and transported to Europe for commercial and therapeutic use (Rotzin 2024). Similar patterns followed with coffee, cotton, spices and other biologically valuable resources. These practices were not framed as theft at the time but as legitimate imperial extraction embedded in asymmetrical relations of power, knowledge and value.

Only in the past three decades has biopiracy become widely recognized as a governance problem. Yet this recognition has unfolded unevenly and largely through legal and policy frameworks that remain anchored in intellectual property and state sovereignty.

Biopiracy entered sustained academic debate in the 1990s, initially through activist and political-ecological scholarship. Most prominently, Shiva framed biopiracy as a form of neo-colonial appropriation, exposing how intellectual property regimes convert collective, historically embedded knowledge into exclusive private rights (Shiva 1997; 2000; 2001). These interventions were pivotal in politicizing biopiracy and linking it to global inequalities. At the same time, they developed alongside—and increasingly in tension with—regulatory efforts that sought to manage biopiracy primarily through enhanced IP protection.

Regulatory discourse developed in parallel. The cornerstone of global governance against biopiracy is widely considered to be the Convention on Biological Diversity (CBD), adopted at the 1992 Rio Earth Summit. The CBD's preamble affirms that states have sovereign rights over their biological resources, marking a departure from earlier notions of biological materials as the common heritage of humankind. Although initially focused on plants, this principle was soon extended to animals and, effectively, to human genetic materials (Hong 2018; Zhang 2023a). The CBD also introduced the concept of access and benefit-sharing

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(ABS), but it was not until the Bonn Guidelines (Convention on Biological Diversity (CBD) 2002) that procedural requirements such as prior informed consent were articulated. Even then, many states found the framework inadequate in practice: legislative and administrative mechanisms were weak, and the principles of fair and equitable benefit-sharing remained difficult to operationalize (Jefferson and Robinson 2025).

At the same time, the global intellectual property regime was consolidated through the WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), adopted in 1994 and entering into force in 1995. While TRIPS allows states to exclude plants and animals from patentability, it requires protection of plant varieties through patents or effective sui generis systems. Crucially, TRIPS does not explicitly address biopiracy or the misappropriation of traditional knowledge, thereby reinforcing an IP-centred architecture that prioritizes innovation, ownership and commercialization over justice, consent and recognition.

In parallel with these regulatory developments, biopiracy became established as a systematic object of academic analysis, particularly through the work of Bronwyn Parry. Parry reframed biopiracy as a problem of political economy, legal infrastructure and value production, rather than theft alone (Parry 2004a; 2004b). Her analysis demonstrated how biological materials and associated knowledge are transformed into commodities through global regimes of intellectual property, scientific practice and market exchange. Subsequent scholarship consolidated this governance focus by examining ABS regimes, state sovereignty over genetic resources and treaty implementation (Robinson 2010; Goyes and South 2016). Critical and green criminology further reframed biopiracy as a form of harm embedded in global inequalities rather than a marginal or exceptional crime.

Another major legal intervention was the Nagoya Protocol (United Nations 2010), which requires signatory parties to establish domestic frameworks for fair and equitable benefit-sharing. Yet key relational questions, such as asymmetries in land ownership, scientific authority and intellectual property control, remain largely unaddressed (Robinson and Raven 2017). More recently, the WIPO Treaty on Intellectual Property, Genetic Resources and Associated Traditional Knowledge introduced mandatory disclosure of countries of origin in patent applications. While symbolically significant, such measures rely heavily on national patent offices that often lack the expertise and institutional capacity to assess compliance meaningfully.

As Goel *et al.* (2025) show, many national patent offices are poorly equipped to scrutinize disclosure statements or evaluate whether benefit-sharing arrangements are adequate or enforceable. This institutional weakness does not merely generate regulatory inefficiency; it actively shapes what counts as harm, responsibility and legality. As elaborated below, the persistent relational gap between patent offices, Indigenous communities and commercial actors reflects a neglect of what Ulrich Beck (1992) terms relations of definition—that is, who has the authority to define risk and its legitimate responses in the governance of science—carrying clear criminological implications.

At its most acute, this inattentiveness to relations of definition produces what Shiva (2001) describes as wrong criminalization, whereby relational harms experienced by Indigenous and local communities are normalized or rendered invisible through legal and regulatory processes that reallocate legitimacy. Biopiracy is thus better understood not simply as unauthorized extraction but as a structural process through which intellectual property systems legitimize exclusive ownership and control over biological resources and associated knowledge developed collectively over centuries (Shiva 2001: 49).

Frustrated with the limits of international regimes, many non-Western states have pursued more assertive national responses. India's Biological Diversity Act 2002 criminalizes

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unauthorized access, knowledge transfer and patenting of biological resources, backed by imprisonment and fines (India 2003). Brazil's Law No. 13.123/2015 relies primarily on administrative and regulatory sanctions to penalize unauthorized exploitation (Silva and Oliveira 2018). China has established particularly stringent controls over human genetic material: cross-border transfer requires dual approval, and unauthorized export of human genetic data is now a criminal offence punishable by up to seven years' imprisonment (National People's Congress of China 2020; Chen and Li 2025). These measures reflect a growing willingness to criminalize biopiracy-type conduct, yet they remain anchored in state sovereignty and IP-centred logics, leaving deeper relational harms intact. As discussed in the next section, in some cases such sovereignty-focused approaches have perversely worsened conditions for Indigenous and local communities.

Alongside state-led criminalization, institutional efforts in the Global South have also sought to protect traditional knowledge by translating it into formats compatible with modern IP regimes. India's Traditional Knowledge Digital Library (TKDL), established in 2001, was designed to prevent wrongful patents by making traditional medicinal knowledge accessible to patent examiners. While described by its architects as a 'silver bullet' against biopiracy (Sharma 2017), TKDL remains embedded in an IP framework that privileges individualized ownership and fails to account for the collective and relational nature of traditional knowledge. Similar dynamics are evident in China's Guizhou Province, where local governments have codified traditional knowledge into legally protected forms through patent-like mechanisms (Stone 2008). These initiatives seek protection through visibility, yet they reproduce the same epistemic logic that underpins biopiracy itself.

The problem, then, is not that such initiatives are ineffective in all respects, but that they follow the same underlying logic. As critics have noted, they misrecognize what scholars such as Arun Agrawal identify as the foundational epistemological contradictions at the heart of TKDL (Reddy 2006: 175; Wyatt 2014; Efferth *et al.* 2019). Indigenous knowledge systems are relational, contextual and lived, whereas IP-based databases require knowledge to be abstracted, standardized and decontextualized. The point is not to deny that IP-based mechanisms can address certain forms of biopiracy within existing legal frameworks but to argue that they cannot rectify the more deeply embedded systemic problem: a utilitarian valuation of biological and genomic materials that renders biopiracy both profitable and legally defensible (Jacoby and Weiss 1997; Shiva 1997; Sharma 2017; Rotzin 2024). Criminalization and protection thus continue to be framed through IP-centred and nation-state-centred logics, reproducing governance approaches that leave relational and distributive harms fundamentally unaddressed.

Towards a relational criminological approach to biopiracy

While the evolution of both policy and academic discourse around biopiracy, as demonstrated in the previous subsection, has largely revolved around intellectual property, what is pirated in biopiracy is not merely 'property'—whether material or immaterial—in and of itself. Rather, biopiracy entails the appropriation of productive and generative social relations: the local, communal relations through which knowledge is developed, plants are cultivated, ecosystems are sustained and meanings are transmitted across generations. In this sense, biopiracy is less a matter of stolen things than of disrupted relations—a process through which collective forms of production and reproduction are rendered invisible, while value is re-authorized elsewhere through legal and scientific infrastructures.

It is in this context that this article argues that a relational criminological perspective offers a particularly fruitful avenue for analysis. Grounded in critical criminology, this

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perspective extends existing approaches by advancing an explicit ontological shift: it foregrounds social relations, rather than discrete acts, outcomes or objects, as the primary unit of analysis.

This orientation draws on zemiology's and green criminology's turn towards relational sociology and is further informed by critical social theory. It also aligns with wider relational reorientations within criminology that have questioned the adequacy of act- or offence-based frameworks for understanding structurally produced harm. A prime example is Garland's work, which, drawing on Bourdieu, analyses how 'distinctive patterns of social, economic and cultural relations'—or *criminogenic situations*—in the United Kingdom and the United States shape changing ideas about and responses to crime (Garland 2001: ix). More substantively, the perspective developed here identifies two relational dimensions that are especially salient for understanding biopiracy—relations of definition (Beck) and relations of recognition (Honneth)—through which harms are constituted, legitimized and unevenly distributed.

Historically, criminology has tended to conceptualize crime as 'a social problem that presents itself in the form of individual, criminal acts' (Garland and Sparks 2000: 194). However, this framing has increasingly been challenged by efforts to enhance criminology's explanatory power in relation to restructuring power dynamics, structural inequalities, sociological processes and technological change (Garland and Sparks 2000). These critiques have prompted a shift within critical criminology towards social harm as an alternative analytical focus (Hillyard *et al.* 2004; White 2013; 2018). This development later crystallized into zemiology, defined as 'the study of social harm per se' (Tombs 2018: 18). Zemiological approaches broaden the analytical lens to include physical, financial, emotional and psychological harms (Hillyard and Tombs 2004), rendering visible forms of harm that are self-evident yet remain noncriminal or weakly regulated in law (Davies *et al.* 2014; Monaghan and Prideaux 2016), including violations of soft law and institutional norms.

Building on the harm-based turn in criminology, this article argues for analyzing not only harms as outcomes but also the social relations and causal processes through which harm is produced, normalized and rendered legitimate. While this orientation resonates with criminological scholarship that has sought to connect critical criminology with critical social theory, such as Majid Yar's (2012) engagement with Axel Honneth's concept of recognition, this article develops an original analytical extension by treating recognition not as a central relational mechanism through which biopiracy is constituted as harm and by further integrating Ulrich Beck's account of relations of definition to complete the analytical framework.

Drawing on Honneth's theory of recognition, biopiracy can be understood as a layered regime of misrecognition, rather than merely an unlawful transfer of biological resources or benefits. At the level of care and embodied relations, biopiracy entails the detachment of biological materials and associated knowledge from the lived social, ecological and cultural relations through which they are sustained, constituting a violation of bodily and collective integrity (Jardine 2015). At the juridical level, it operates through the denial of epistemic justice, as Indigenous peoples, farmers and local communities are excluded from inventorship, authorship and meaningful participation in governance and are positioned as objects rather than subjects of rights (Giladi 2018). At the level of social esteem, biopiracy systematically devalues nonscientific ways of knowing, recognizing local and Indigenous knowledge only insofar as it can be translated into laboratory science, databases or patents.

These interlocking forms of misrecognition are enabled and stabilized through what Ulrich Beck terms relations of definition. For Beck, risk is relationally produced, and

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power lies not merely in causing harm but in the capacity to define risk and its legitimate responses. Beck's concept of relations of definition thus provides a critical bridge between relational sociology and harm-based criminology, particularly in contexts, such as biopiracy, where injury is produced through diffuse, institutionalized relations rather than discrete acts (Beck 2009; Beck *et al.* 2013). Harm, in this account, arises not simply from unequal distributions of benefits but from the prior erosion and reconfiguration of social relations that determine whose knowledge, bodies and contributions are recognized in the first place.

From this perspective, the chronic difficulties surrounding biopiracy are not primarily questions of how best to define intellectual property or ownership of genetic data. Rather, they reflect the fact that expert institutions, corporations, regulators and publics are locked into contested relational fields. Recognition, as Honneth (2001) argues, precedes cognition: it is not simply that we perceive harm and then evaluate it, but that our relational modes of recognition determine what is rendered visible as harm in the first place. For criminology, this insight is crucial. A narrow focus on outcomes or harms alone risks obscuring the deeper problem of social invisibility and misrecognition through which biopiracy is normalized and legitimized.

The limitations of IP-centred and nation-state-centred approaches that have dominated biopiracy governance over the past three decades become particularly evident in the context of data-driven biology and growing global awareness of social justice inequalities. The remainder of the article, therefore, examines emerging challenges of biopiracy in data-intensive life sciences before demonstrating how a relational criminological approach offers analytical leverage for understanding these developments.

Biopiracy 2.0? New challenges in the age of data-driven biology

Over the past three decades, advances in molecular biology and digital technologies have transformed how life itself is understood and governed. Where biological life was once primarily encountered as embodied, localized and material, it is now increasingly apprehended as a flow of data and information: sequences of DNA that can be extracted, digitized, stored, analyzed and recombined across borders. Life, in this sense, has become partially de-materialized and de-corporalized, reconceived as a complex circulation of molecular information—what has been aptly described as 'sequential life'—that can be processed *in silico* rather than handled *in vivo* (Elbe 2021: 664; Aubry 2023).

This section identifies two developments in contemporary life sciences that intensify the tensions and contradictions inherent in existing regulatory regimes. The first is the proliferation of digital sequencing technologies and genetic engineering tools, such as CRISPR–Cas9, which accelerate the dematerialization and deterritorialization of biosciences. These developments render IP-centred counter-biopiracy regimes increasingly difficult to enforce, as they complicate the identification of origin and blur the boundaries of when harm occurs and what constitutes a criminal act. The second development is a widening global reckoning with social justice and sustainability in the life sciences, shaped by postcolonial critique, Indigenous rights claims and uneven patterns of technological accumulation. Although this has sharpened international attention to biopiracy and its distributive injustices, it has also unfolded within a context of geopolitical rivalry, resulting in fractured and sometimes conflicting regulatory approaches. The issue, therefore, is not simply whether biosovereignty is the right question to ask, but whether sovereignty can continue to be conceived exclusively through the state.

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Addressing biopiracy in an era of data-driven biology requires more plural and relational understandings of bio-resources, sovereignty, recognition and value. Seen in this light, countering biopiracy is not merely a matter of protection or enforcement but of cultivating and safeguarding what may be understood as relational goods.

Dematerialized and deterritorialized biopiracy: new criminogenic situations?

The digitization of genetic sequences is often traced to the Human Genome Project, launched in 1990, and to the Bermuda Principles, agreed upon in 1996, which helped establish the rapid public release of large-scale DNA sequence data as a norm for publicly funded genomics (Marshall 2001; Collins, Morgan and Patrinos 2003). For much of the following two decades, however, the digitization of sequence data was not treated as a distinct regulatory problem, as governance frameworks continued to presume that access to genetic resources primarily involved the physical transfer of biological material.

It was in the mid-2010s that 'digital sequence information' (DSI) crystallized as a governance object. This shift coincided with advances in next-generation sequencing, which dramatically increased sequencing speed while reducing costs (Metzker 2010), and with the maturation of synthetic biology, which expanded the capacity to design, modify and recreate biological functions using sequence data alone. In its narrow definition, DSI refers to nucleotide sequence data, including DNA and RNA sequences and associated epigenetic information. In broader usage, the term is sometimes extended to encompass other biologically derived data, such as metabolomic data, behavioural data, traditional knowledge and information on ecological interactions. Together, these developments have vastly expanded the scope and pace of biological innovation, enabling research on infectious disease pathogens, animals and plants, as well as the design of biomaterials such as nanofibres and bioethanol (Qin *et al.* 2023).

These transformations have not only dematerialized genetic resources but have also deterritorialized biopiracy. Researchers and corporations can now extract, modify and recombine genetic codes without direct engagement with—let alone accountability to—the marginalized communities from which those resources and associated knowledges originate (Bond and Scott 2020; Jefferson 2023).

As a result, DSI has exposed a structural mismatch between data-driven bioscience and international regulatory frameworks premised on material access, bringing questions of fairness, biopiracy and security-sensitive data circulation to the centre of global governance debates (Bond and Scott 2020; Elbe 2021). For example, the CBD's Kunming–Montreal Global Biodiversity Framework, adopted in 2022, calls for the establishment of a multilateral benefit-sharing mechanism for DSI, yet the scope, design and implementation of this mechanism remain under negotiation (Convention on Biological Diversity 2022). Similarly, the WIPO Treaty on Intellectual Property, Genetic Resources and Associated Traditional Knowledge (2024) represents the outcome of more than 25 years of diplomacy between the Global South and Global North aimed at curbing biopiracy. Nevertheless, its regulatory reach remains narrowly focused on patent disclosure requirements. As some scholars observe, meaningful regulatory responses to these digital and data-driven forms of biopiracy may not materialize 'until 2050, if at all' (Jefferson and Robinson 2025: 659).

Focusing on objects or discrete conducts, rather than on the social relations that are reinforced or disrupted through those conducts, risks obscuring how ostensibly well-intentioned regulatory and scientific practices generate new 'criminogenic situations' (Garland 2001). In the context of data-driven biology, digital infrastructures and analytic tools have not

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merely transformed research practices; they have also reconfigured the relational conditions under which biopiracy occurs (Aubry 2023; Heatherington 2024; Lenarczyk *et al.* 2025: 55).

First, DSI has enabled biopiracy to operate as a 'silent disease' (Imran *et al.* 2021: 2), as knowledge can be appropriated virtually and is often extremely difficult to trace. One of the world's most significant open-access DSI infrastructures, the International Nucleotide Sequence Database Collaboration (INSDC), which integrates DNA data banks in the United States, United Kingdom and Japan, is explicitly designed to maximize data circulation in the name of the global public good. However, as the INSDC positions itself as a data host rather than a data owner, it does not mandate provenance metadata, and data submissions are largely anonymous. As a result, only around 16% of entries include information on country of origin. This substantially undermines traceability and effectively creates a regulatory 'loophole' in global efforts to address biopiracy (Nehring 2022: 1977–9).

Second, artificial intelligence has further intensified these dynamics. AI systems can systematically mine digital repositories to identify commercially valuable applications of traditional knowledge and genomic data, enabling what some have described as 'automated biopiracy' (Goel *et al.* 2025: 709). In such cases, extraction is no longer episodic or actor-specific but continuous, algorithmic and difficult to attribute.

Third, the data-driven nature of contemporary biology is also facilitated by advanced gene-editing technologies such as CRISPR-Cas9, a technique adapted from bacterial immune systems that functions as 'molecular scissors' capable of precisely cutting, removing, adding or altering DNA sequences. While CRISPR enables therapeutic interventions, it also allows researchers to generate 'improved' genetic material without direct contact with the original biological resource, drawing instead on digitally mediated knowledge and subsequently claiming ownership over newly created cells (Jaiswal 2025).

Fourth, and most fundamentally, the emergence of DSI and gene-editing tools underscores that the primary enabler of biopiracy is not the biological resource or data itself but profound disparities in technical, institutional and infrastructural capacity to exploit those resources. This asymmetry is reflected in both market concentration and intellectual property ownership. The global CRISPR technologies market was valued at USD 4.59 billion in 2025 and is projected to reach USD 20.42 billion by 2035 (Expert Market Research 2026). Patent landscapes are even more skewed. Analyses show that inventors from the United States, China and Europe account for the vast majority of CRISPR-Cas9 patent filings. One bibliometric study reports that US inventors held approximately 47.8% of CRISPR patents, China 34% and Europe 10.4% (Martin-Laffon *et al.* 2019). In agricultural applications, China accounted for roughly 60% of patents, the United States 26% and Europe around 8%, while the United States dominates human-related CRISPR patents (Hjort *et al.* 2021; Expert Market Research 2026).

These developments matter for biopiracy not because all data use is exploitative, but because they systematically disconnect value extraction from relations of consent, recognition and accountability. While digital sequence information (DSI) is often framed as contributing to a 'global commons' of genetic resources (Bruynseels 2020), this characterization risks obscuring the fact that commons are not given but actively constituted. Commons depend on ongoing processes of 'commoning', understood as the relational work through which responsibilities, rights and obligations are established, sustained and negotiated among diverse actors (Ostrom 1990). In the context of the dematerialization and deterritorialization of the life sciences, this insight has prompted scholars to argue—rightly—that governing biotechnology requires us to 'broadly re-think international relations also as informational relations' (Elbe 2021: 673, original emphasis).

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Taken together, these dynamics suggest that biopiracy cannot be addressed through ownership or enforcement alone but requires a different conception of what is at stake. Rather than concentrating primarily on fortifying intellectual property systems and access-and-benefit-sharing regimes to secure discrete 'goods' such as innovations or outcomes, whose boundaries data-driven biology increasingly blurs or evades, a more promising path lies in cultivating what philosopher Martha Nussbaum terms 'relational goods' (Nussbaum 1986). Building on Nussbaum, Pierpaolo Donati extends relational analysis through the distinction between 'relational goods' and 'relational evils'. These refer to immaterial, *sui generis* realities that emerge from the particularity of relational configurations (Donati 2014: 24–32). From this perspective, harm and crime are not primary phenomena but emergent effects of 'relational evil': they arise when social relations are organized in ways that systematically erode reciprocity, recognition and mutual responsibility. Conversely, relational goods generate benefits that extend beyond direct participants, 'rebounding' to others affected by their wider repercussions, without being appropriable by any single actor (Donati 2014: 21).

Viewed through a relational paradigm, the challenge of biopiracy lies not only in protecting resources or enforcing ownership but also in recreating and sustaining the social relations, capacities and reciprocal forms of recognition through which biological knowledge is generated, shared and valued. This perspective becomes particularly salient when examining the growing appeal and accompanying controversies of biosovereignty as a strategy for countering biopiracy.

Biosovereignty and the 'inversion of justice': governance relations and the limits of the state

The increasing use of digitalization, artificial intelligence and novel gene-engineering tools has further underscored the extent to which biopiracy and its ecological and societal harms exceed the territorial boundaries of nation-states. Green criminology has long highlighted how corporate practices and flexible, modular forms of organizing biotechnology have enabled new phases of extractive and transnational environmental harm, exposing the limits of state-centred legislative approaches to biopiracy governance (South 2007; 2014; Brody 2010; Wyatt and Brisman 2017; Lynch 2020).

This section extends that critique by foregrounding two under-discussed yet consequential effects of contemporary biosovereignty frameworks. While often framed as corrective responses to extractive bioeconomies, such frameworks have proven insufficient in curbing biopiracy and, in some cases, have done so at the expense of domestic scientific development and epistemic justice. In more extreme instances, they have enabled what Goyes and South (2016) describe as an 'inversion of justice', whereby the state acts to protect corporate power while facilitating the exploitation of its own populations. The aim here is not to dismiss biosovereignty as such, but to question the continued reliance on the nation-state as the primary unit for defining, regulating and enforcing biopiracy governance.

The concept of biosovereignty emerged from global struggles against biopiracy and was first articulated through the Convention on Biological Diversity (CBD) in the 1990s, which affirms states' sovereign rights over genetic resources alongside responsibilities to prevent transboundary environmental harm. Initially grounded in the governance of nonhuman biological materials, biosovereignty expanded over the following two decades to encompass human genomic resources. A key moment was Mexico's 2008 amendment of its General Health Act—often referred to as the Genomic Sovereignty Act—which restricted the export of DNA samples and asserted that the Mexican genome should be studied primarily 'by

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and for Mexicans' (Siqueiros-García *et al.* 2013; Rojas-Martínez 2015). Similar assertions of stringent control over both human and nonhuman genomic resources, framed in terms of national sovereignty and security, have since been adopted in countries with historical and ongoing experiences of biopiracy, including Brazil, India and China (Rull and Vegas-Vilarrúbia 2008; Zhang 2023b; Chen and Li 2025).

However, these ostensibly 'new' biosovereignty responses largely reproduce older logics of biopiracy governance—namely neoliberal market rationality, the commodification of knowledge and life and linear assumptions of progress. As a result, they struggle to address the relational and temporal harms generated by data reuse, misinterpretation and commercialization in data-driven biology (Spector-Bagdady *et al.* 2024). When biopiracy is framed primarily as the misappropriation of discrete 'things', a common policy response has been to prioritize the restriction of data flows.

In practice, biosovereignty under these arrangements often consolidates into a state monopoly over access to and use of national bioresources, producing at least two perverse effects that have attracted sustained criticism from both scientific and civil society actors. The first concerns the intensification of epistemic injustice in global science, particularly through the further marginalization of Global South knowledge and scientific communities. To understand this, it is necessary to recognize the assetisation of bioresources (Birch 2017). The transformation of biological materials and technoscientific knowledge into assets capable of generating recurring value depends not on ownership alone but on the ability to mobilize networks of actors who can analyze, adapt and embed these resources into wider societal needs. As Peter Wenzl, manager of the Future Seeds genebank in Colombia, has observed, 'genetic resources are a perfect example where … value is generated by bringing things together, but the value itself does not necessarily exist in each accession in isolation' (Wenzl in Heatherington 2024: 108). Mere possession of biomaterial, by contrast, generates neither durable scientific advantage nor significant sovereign value; indeed, the costs of maintaining gene banks are notoriously high.

Yet contemporary asset thinking has frequently led states to erect additional layers of strategically ambiguous bureaucracy that impede research directed towards public health and ecological benefit (Rull and Vegas-Vilarrúbia 2008). Brazilian scientists, for example, have raised sustained concerns that Law No. 13.123/2015 undermines basic research and international collaboration, acting as a barrier to scientific innovation and global engagement (Editorial 2018). Similarly, India's Traditional Knowledge Digital Library (TKDL) has been criticized as a closed-access model in which both entry creation and access are restricted to a select group of actors, limiting domestic knowledge circulation while discouraging third-party scrutiny and administrative transparency (Sharma 2017).

In short, precisely because value in data-driven biology emerges through productive relational webs that enable genetic materials, data and knowledge to circulate, be recombined and acquire meaning, policies that prioritize the restriction of data flows rather than the reconstitution of relational obligations risk undermining both domestic scientific capacity and public benefit.

The second perverse effect concerns how state-centred biosovereignty, when coupled with an IP-dominated economic logic, incentivises forms of gene hoarding that reproduce a 'business as usual' approach—one that 'neither transfers power nor enables a community-based or community-owned approach to commercialization' (Wynberg 2023: 10; Rotzin 2024).

Criminological studies of biopiracy in Colombia illustrate how, when biological resources and associated local and Indigenous knowledge are appropriated through formally legal mechanisms such as patents, land titling and investment agreements, environmental

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destruction, loss of livelihoods and cultural erosion are treated as acceptable collateral costs of development. Rather than being recognized as victims, rural and Indigenous populations are frequently criminalized, displaced or rendered administratively illegible, while corporate actors are framed as legitimate innovators or investors (Goyes and South 2016). These dynamics exemplify the risk of 'wrong criminalization' identified by Shiva (2001), whereby harm is reframed as legality and resistance as deviance.

There have been modest efforts to expand the role of communities within biopiracy governance by recognizing Indigenous actors as relevant definers of risk and harm, rather than merely as 'stakeholders'. Such initiatives speak directly to both Beck's 'relations of definition' (Beck 1992) and Honneth's concern with relations of recognition. One such example is found in Aotearoa New Zealand, where Māori-led advisory and scrutiny mechanisms have been introduced within the intellectual property system in response to the misappropriation of *mātauranga Māori* (Māori knowledge) (Lai *et al.* 2019). While these committees provide culturally informed assessments to intellectual property offices, their advisory status highlights the limits of procedural inclusion, leaving deeper relational and distributive harms embedded in IP regimes largely unresolved.

More fundamentally, dominant forms of biosovereignty often fail to generate meaningful political and cultural recognition. Rather than redistributing power, biosovereignty frequently functions as a mechanism for conserving state authority by containing Indigenous claims within state-sanctioned categories, a process Espinosa (2025) terms 'patrimonialization', in which Indigenous sovereignty is reframed as cultural property or heritage rather than recognized as an autonomous political and legal order.

As Aliverti (2023) argues, these dynamics call for moving beyond assumptions about the legal purity or coherence of the state. At the margins of state power, legality and illegality are co-produced through contested claims to sovereignty, particularly where normative orders—or 'legal fictions'—are shaped by economic liberalization and globalized capitalism. Under such conditions, law operates as the implicit scaffolding of state sovereignty, legitimizing harm while imposing disproportionate burdens on marginalized communities.

This ongoing contestation between social relations and state sovereignty underscores the need for a relational criminological approach to biopiracy—one that moves beyond established authorities to account for the evolving relations that incentivise, enable or constrain harm. What is required, therefore, is not a post-sovereignty approach, but a post-national-sovereignty orientation, redistributing authority towards intra- and transnational networks of actors more directly affected by biopiracy and better positioned to contest and reshape its governance.

Future directions for relational criminology: governing biopiracy in the age of data-driven biology

This section outlines future directions for a relational criminology of biopiracy in the context of data-driven biology. It argues that moving beyond the 'lawful but awful' paradox (Wyatt and Brisman 2017: 325) requires an ontological shift away from IP-centred and state-focused governance frameworks towards an analysis of the relational conditions through which harm is produced, normalized and contested. The accelerating datafication, digitalization and engineering of biological resources have made the limits of existing approaches increasingly visible.

Persisting with these frameworks risks reproducing what Honneth (2008) identifies as a social pathology of reification. In this condition, particular socio-economic practices are uncritically elevated as productive and valuable, while the relations of recognition that

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underpin social life are obscured. Reification occurs when actors come to treat others—and sometimes themselves—as things, forgetting that their engagement with the world is always mediated through intersubjective recognition.

This article, therefore, advances a relational criminological perspective on biopiracy as an ontological shift in criminological inquiry. Rather than merely critiquing the inequities or inadequacies of existing systems, relational criminology interrogates the configurations of relations through which harm is generated, rendered legitimate and unevenly distributed, thereby opening space for alternative governance pathways that complement and move beyond current regulatory and discursive impasses.

This requires forms of academic inquiry that reject both methodological individualism and methodological nationalism and that resist fixed analytical dichotomies such as public/private or state/market. Instead, such perspective recognizes the blurred and evolving boundaries between these domains and focuses on the transformation of social configurations as they are reshaped by knowledge production, scientific innovation and socio-political change (Emirbayer 1997; Crossley 2011; Beck et al. 2013; Donati 2014).

A relational criminological approach opens new ways of addressing emerging biopiracy challenges posed by data-driven biology in at least three respects. First, it offers fresh ways of addressing the limitations of the currently predominant—and often ineffective—biosovereignty strategies that prioritize the restriction of data flows. Rather than asking which types of data should fall within the scope of national surveillance, a relational approach shifts attention to the relations that generate 'data friction'. As Bates *et al.* (2016: 8–9) demonstrate, data friction arises from a wide array of socio-material factors that constrain the circulation of data; these frictions are not merely technical but fundamentally relational. This is evident, for example, in the governance of pathogen sequence data, where capacity gaps have produced what Elbe (2021) describes as a 'new stratification within the field of international security'. Here, apparent data-hoarding or hesitation to share is often less about ownership as such than about relational asymmetries between sample-providing countries and those with greater capacity to translate sequence data into scientific, economic or security value. In some cases, resistance to data sharing reflects not disputes over property but the absence of trust-based relationships (Sedyaningsih *et al.* 2008; Vale *et al.* 2008).

What is at stake, then, is not simply the volume of data flows or the allocation of downstream rewards but the relational infrastructures—of capacity, trust, recognition and institutional support—through which knowledge can be transformed into innovation without dispossession. This dynamic is illustrated by Guizhou Province's often-cited approach to patent protection. As An Shouhai, then, vice-director of the local intellectual property office, candidly observed, 'because we lack the means to turn knowledge into innovation, we have to protect the knowledge for future development' (An in Stone 2008: 73). This admission exposes a core relational harm: in the absence of enabling social and institutional relations, protection becomes a substitute for participation, and intellectual property functions defensively rather than as a pathway to shared innovation.

Second, from a relational criminological perspective, harms persist not only through acts of misappropriation but also through structurally unequal relations of definition that constrain whose knowledge can authoritatively name biopiracy as harm. There is no 'one-stop solution' to biopiracy (Sharma 2017). Instead, a relational approach requires recognizing the multi-dimensional nature of citizenship—across economic, political and civil-cultural spheres—without imposing predetermined boundaries between them (Donati 2014). It also requires acknowledging that interpretations of what constitutes 'fairness' and 'benefit' are diverse and context-dependent. A recent survey across nine countries in both the Global

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North and the Global South, for example, reveals sharply diverging views on whether benefit-sharing should be monetary or nonmonetary, and on who should bear responsibility for maintaining digital sequence information (DSI) infrastructures (Abatayo *et al.* 2025). These findings reinforce the point that addressing biopiracy requires relationally and contextually calibrated governance, rather than uniform solutions.

Finally, a relational lens helps to expose and correct false epistemic categorizations embedded in both legal and social systems. The persistent distinction between 'high-tech' and 'low-tech' knowledge in biopiracy debates warrants reconsideration. Knowledge is neither inherently high nor low, nor are the tools through which it is enacted. Indeed, contemporary life sciences, particularly through modular and engineering approaches in synthetic biology, have often involved processes of deskilling, lowering barriers to entry for practices routinely labelled 'high-tech'. By contrast, many forms of so-called 'low-tech' traditional knowledge are deeply embedded, contextual and tacit, requiring long-term situated learning and social transmission. In this sense, they frequently involve a higher threshold of contextual expertise and tacit knowledge, which remain systematically undervalued within dominant governance frameworks.

While criminology and criminal law are analytically distinct, a relational criminology capable of rendering these relational injustices visible is a necessary precondition for meaningful legislative and regulatory reform in the governance of biopiracy.

Conclusion

This article has shown that prevailing governance discourses and approaches—grounded in IP-centred, state-focused and object-based models—are increasingly ill-equipped to address the harms produced by biopiracy in the age of data-driven biology. The digitalization of genetic data has rendered traditional understandings of biopiracy more difficult to trace and regulate. While biosovereignty has emerged as an important corrective to extractive bioeconomies, its contemporary implementation has frequently resulted in wrongful criminalization and risks generating new forms of epistemic injustice.

By advancing a relational criminology of biopiracy, this article reframes biopiracy not merely in its identifiable harms or rule violation but as the erosion, distortion and strategic management of social relations—relations of recognition, definition, capacity and obligation—through which biological resources and knowledge acquire value. For criminology, the implications are twofold. Conceptually, it calls for an ontological shift towards analyzing the relations themselves and the conditions under which they operate, particularly those that enable knowledge to circulate, be translated and generate benefit without dispossession. Empirically, it positions the discipline beyond critique, towards the promotion of 'relational goods' and the re-imagination of justice in global bio-governance.

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