

The Biodiversity of Africa in the Digital Genomics Era: A Systematic Analysis of Institutional Gaps and Benefit-Sharing Trajectories under the Cali Fund.

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ABSTRACT

Background: A structural governance failure sits at the intersection of international biodiversity law and the digital genomics revolution. The Convention on Biological Diversity (CBD) and the Nagoya Protocol on Access and Benefit-Sharing (ABS) were designed to ensure that countries of biological origin share equitably in commercial benefits from their genetic resources. Critically, these instruments apply exclusively to non-human genetic resources: plants, animals, fungi, and microbiota. Human genetic resources are deliberately excluded from the CBD and Nagoya ABS framework and are governed separately through bioethics instruments, including the World Health Organization (WHO) framework and the Declaration of Helsinki. This study focuses on non-human digital sequence information (DSI), nucleotide and protein sequence data derived from non-human organisms deposited in open-access databases, which underpins industries generating over USD 1.56 trillion in annual revenue. Africa, hosting approximately 25% of global terrestrial species and nine of the world's 36 biodiversity hotspots, provides a disproportionate share of the genetic resources from which non-human DSI is derived, yet receives negligible monetary returns because digitisation severs the traceability chain that ABS governance requires. Human genomic data is presented here solely as a secondary indicator of Africa's broader infrastructure; it does not constitute the legal basis for Africa's modelled allocation share under the Cali Fund.

Objectives: This study systematically characterises (i) Africa's non-human biodiversity endowment as the basis for Cali Fund claims; (ii) ABS governance readiness across 54 African Union (AU) member states; (iii) the commercial trajectories of non-human DSI-dependent industries and projected Cali Fund benefit-sharing flows; and (iv) Africa's human genomic representation as a secondary infrastructure indicator, explicitly distinguished from the non-human DSI benefit-sharing argument.

Methods: A structured evidence synthesis was conducted following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 reporting elements, where applicable to a secondary data analysis design. Literature was searched across PubMed, Scopus, Web of Science, Google Scholar, and official repositories of the CBD, Food and Agriculture Organization of the United Nations (FAO), International Union for Conservation of Nature (IUCN), and United Nations Environment Programme (UNEP). The search was restricted to January 2022 - April 2026 to capture post-Kunming-Montreal Global Biodiversity Framework (KMGBF) literature. A total of 412 records were identified before screening; 34 peer-reviewed articles and 19 institutional documents met all inclusion criteria. Quantitative Cali Fund scenario modelling used the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) and KPMG (2024) non-human DSI sector revenue baseline (CBD/WGDSI/2/2/Add.2). The 12.5% net profit margin is a cross-sector proxy from that study; actual margins vary by sector. Africa's modelled allocation share (20–25%) is the authors' analytical construct based on Africa's non-human species richness and hotspot share; it is not an internationally agreed formula.

Results: Africa's non-human biodiversity endowment is exceptional: 25% of terrestrial species, nine of 36 biodiversity hotspots, and the world's second-largest tropical forest system. Non-human DSI from African genetic resources is a critical input to industries generating USD 1.56 trillion annually, yet Africa contributes a marginal and unmeasured fraction of International Nucleotide Sequence Database Collaboration (INSDC) sequences. As a

secondary indicator, 94.48% of genome-wide association study (GWAS) participants as of 2024 were of European ancestry (Corpas et al., 2025); this human genomic data is presented for contextual illustration only and is not the basis for Africa's Cali Fund modelled allocation share. Zero African Union member states have enacted legislation explicitly covering non-human DSI in their ABS framework. Africa's modelled allocation share ranges from USD 312 million (Scenario A, 20% weight) to USD 5.83 billion (Scenario C, 25% weight) annually.

Conclusions: Africa is among the most biologically rich continents on Earth for non-human life, yet structurally excluded from the benefit-sharing framework the CBD intended to create. The Cali Fund represents the first mechanism capable of correcting this at scale. Realising Africa's modelled allocation share requires urgent legislative reform, institutional capacity investment, sequencing infrastructure development, and a coordinated African position at COP17 scheduled in Yerevan, October 2026.

Keywords: *digital sequence information; non-human genetic resources; access and benefit-sharing; Nagoya Protocol; Cali Fund; African biodiversity; genomic underrepresentation; biodiversity governance; Kunming-Montreal Global Biodiversity Framework; bioeconomy; COP16; policy implications.*

1. INTRODUCTION

The governance of genetic resources and the information derived from them sits at the intersection of international law, biotechnology, conservation science, and global equity. Since the adoption of the Convention on Biological Diversity (CBD) in 1992, the foundational premise has been that countries exercising sovereign rights over biological resources on their territories are entitled to share in the benefits generated from the commercial use of those resources.

Advances in high-throughput DNA sequencing have transformed this governance landscape. It is now possible to encode the informational content of a physical genetic resource: a plant specimen, a soil sample, a pathogen isolate, into a digital string of nucleotides that can be transmitted, stored, and accessed globally at near-zero marginal cost. These strings, referred to in CBD negotiations as digital sequence information (DSI), are now the primary substrate for innovation in pharmaceuticals, agricultural biotechnology, cosmetics, and a growing range of industrial processes. From the outset, it is essential to state that DSI in the context of the CBD and the Cali Fund refers exclusively to sequence data derived from *non-human organisms*: plants, animals, fungi, and microbiota. Human genetic resources are deliberately excluded from the CBD's sovereign rights framework and from the Nagoya Protocol on Access and Benefit-Sharing. Human genomic data, including GWAS datasets, is governed by separate bioethics and human rights instruments, including the WHO framework and the Declaration of Helsinki. For-profit companies that use African human genomic data to develop drugs and diagnostics face no international legal mandate under the CBD to share those profits with source communities, a distinct governance failure documented separately in the literature.

Once a non-human genetic sequence is uploaded to a public database, GenBank, the European Nucleotide Archive (ENA), or the DNA Data Bank of Japan (DDBJ), it becomes globally accessible with no mechanism for the source country to track its downstream use or enforce any ABS obligation. The Nagoya Protocol, which entered into force in 2014, governs physical transfer of non-human genetic resources but does not effectively regulate their digitised equivalents. In the words of Lawson, Humphries, and Rourke (2024), this creates a governance gap that inhibits fair and equitable benefit-sharing and renders the bilateral ABS architecture structurally inadequate for the genomic era.[1,2]

Africa provides the empirical focal point for these concerns. The continent is home to approximately one-quarter of global terrestrial species, nine of the 36 globally recognised biodiversity hotspots, and the world's second-largest tropical forest system, the Congo Basin[3,4]. Africa also possesses the greatest human genetic diversity on the planet, accumulated over more than 300,000 years of modern human evolutionary history, as dated by the Jebel Irhoud fossil record (Hublin et al., 2017).[5,6] These two dimensions of Africa's genomic richness are related but legally distinct: non-human biodiversity forms the direct basis for Africa's modelled allocation share under the Cali Fund; human genomic diversity is presented here as contextual evidence of a parallel scientific marginalisation, not as an ABS allocation claim.

At CBD Conference of the Parties (COP) 15 (Montreal, December 2022), Parties adopted Decision 15/9, establishing a multilateral mechanism for benefit-sharing from the use of DSI. At COP16 (Cali, Colombia, October–November 2024), Parties adopted Decision 16/2, establishing the Cali Fund with indicative, voluntary contribution rates of 1% of profits or 0.1% of revenue. The Fund was formally launched in Rome on 25 February 2025 at the resumed session of COP16; that session finalised the broader finance package but did not alter the DSI modalities adopted in November 2024 in Cali. Final contribution rates and compliance mechanisms remain for COP17 (Yerevan, Armenia, October 2026).

This paper makes four contributions. First, it quantitatively characterises Africa's non-human biodiversity endowment. Second, it maps Africa's representation in non-human DSI databases. Third, it systematically

assesses ABS legislative readiness across 54 AU member states. Fourth, it models Cali Fund economic trajectories and identifies six policy actions for African institutions before COP17.

2. CONCEPTUAL AND REGULATORY BACKGROUND

2.1 Defining Digital Sequence Information and the Critical Human/Non-Human Legal Distinction

The term “digital sequence information” was introduced into CBD negotiations at COP13 (Cancún, 2016) through Decision XIII/16. It encompasses nucleotide sequence data (DNA and RNA sequences) from non-human organisms deposited in publicly accessible databases, and may extend to protein sequence data and associated functional annotations, though no internationally agreed definition has been formally adopted.

As of 2024, GenBank, the flagship member of the International Nucleotide Sequence Database Collaboration (INSDC), maintained by the US National Center for Biotechnology Information (NCBI), contains 25 trillion base pairs from over 3.7 billion nucleotide sequences for 557,000 formally described species. The INSDC’s 2023 update, requiring collection-location and collection-date metadata for all new BioSample registrations, is the most significant step toward non-human DSI traceability; however, billions of legacy records carry no country-of-origin metadata.[7]

CRITICAL LEGAL DISTINCTION: Non-human DSI (from plants, animals, fungi, microbiota) is the proper legal subject matter of the CBD, Nagoya Protocol, and Cali Fund. Human genetic resources, including GWAS data and whole-genome sequences from human populations, are deliberately excluded from the CBD’s Article 15 sovereign rights framework and from the Nagoya Protocol’s ABS provisions. Human genomic data is governed by the United Nations Educational, Scientific and Cultural Organization (UNESCO) Universal Declaration on the Human Genome and Human Rights (1997), the Organisation for Economic Co-operation and Development (OECD) Guidelines on Human Biobanks and Genetic Research Databases (2009), and the WHO framework. The GWAS representation statistics presented in this paper (Sections 4.1.2 and 4.2.2) concern human genomic equity, a scientifically valid analogy and governance illustration, but are NOT the legal basis for Africa’s Cali Fund modelled allocation share. All Cali Fund modelling in this paper uses exclusively non-human DSI sector revenues

2.2 The International Regulatory Architecture

The CBD (1992, 196 Parties) establishes three co-equal objectives: conservation of biological diversity; sustainable use of its components; and fair and equitable sharing of benefits from the use of genetic resources. The Nagoya Protocol (adopted 2010, entered into force 2014), ratified by 142 countries as of 2025, confirms against the CBD ratification tracker (cbd.int/abs/nagoya-protocol/signatories) at submission, operationalises the third objective through a bilateral ABS framework governing non-human genetic resources.[8,9]

The Kunming-Montreal Global Biodiversity Framework (KMGBF), adopted at COP15 in December 2022, sets 23 global targets for 2030 and four goals for 2050. Target 13 addresses non-human DSI directly, and Goal C stipulates fair and equitable sharing of benefits from the utilisation of non-human genetic resources and DSI on such resources. CBD Decision 15/9 established the multilateral mechanism and the Ad Hoc Open-ended Working Group on DSI (WGDSI), which met twice (Geneva, November 2023; Montreal, August 2024) before modalities were adopted at COP16.[10,11]

CBD Decision 16/2 (November 2024; authoritative text: CBD/COP/16/L.19) operationalised the Cali Fund. It established indicative, voluntary contribution rates (1% of profits or 0.1% of revenue), designated sectors within scope (all characterised by commercial dependence on non-human DSI: pharmaceutical, cosmetics, plant and animal breeding/agricultural biotechnology, laboratory equipment, and IT/scientific platforms),

stipulated that at least 50% of fund resources be allocated to indigenous peoples and local communities (IPLCs) activities, and established hosting under the United Nations Multi-Partner Trust Fund Office (MPTFO) in partnership with the United Nations Development Programme (UNDP) and UNEP. Final contribution rates and compliance mechanisms are to be determined at COP17.[12,13]

2.3 The Provider-User Asymmetry for Non-Human DSI

The DSI governance literature characterises the core inequity as a provider-user asymmetry: biodiversity-rich countries in the Global South provide the non-human genetic resources from which DSI is derived, while the commercial capacity to exploit that DSI is concentrated in high-income countries.[14,15,16] Scholz and colleagues (2022) documented that “biodiverse nations, many of which are low- and middle-income countries, believe their sovereign rights have been undermined because any potential monetary gains from DSI through commercialisation are not shared back to them.”[17]

Ljungqvist and colleagues (2025), in the most comprehensive cross-national ABS policy review, documented that as of May 2024, only 22 of 193 countries (11%) had any legislative reference to DSI, while 171 (89%) had no codified position whatsoever.[18]

3. MATERIALS AND METHODS

3.1 Study Design

This study employs a structured evidence synthesis following PRISMA 2020 reporting elements, where applicable, to a secondary data analysis design. Unlike a clinical systematic review, no primary data were collected, and no formal risk-of-bias assessment was conducted. The study synthesises data from peer-reviewed biodiversity and genomics literature, international policy databases, and commissioned sectoral revenue studies. A PRISMA flow diagram showing records identified, screened, excluded, and retained is presented in Figure 1.

The search was restricted to January 2022 to April 2026 to focus on literature produced after the adoption of the KMGBF and DSI Decision 15/9 (December 2022), which constitutes the current governance baseline for the Cali Fund. Earlier foundational legal instruments (CBD, Nagoya Protocol, Decision 16/2 text) were included as primary institutional sources irrespective of date. A total of 412 records were identified across all databases before deduplication; 298 proceeded to title/abstract screening; 61 proceeded to full-text review; 34 peer-reviewed articles and 19 institutional documents met all inclusion criteria and were retained.

3.2 Literature Search and Eligibility Criteria

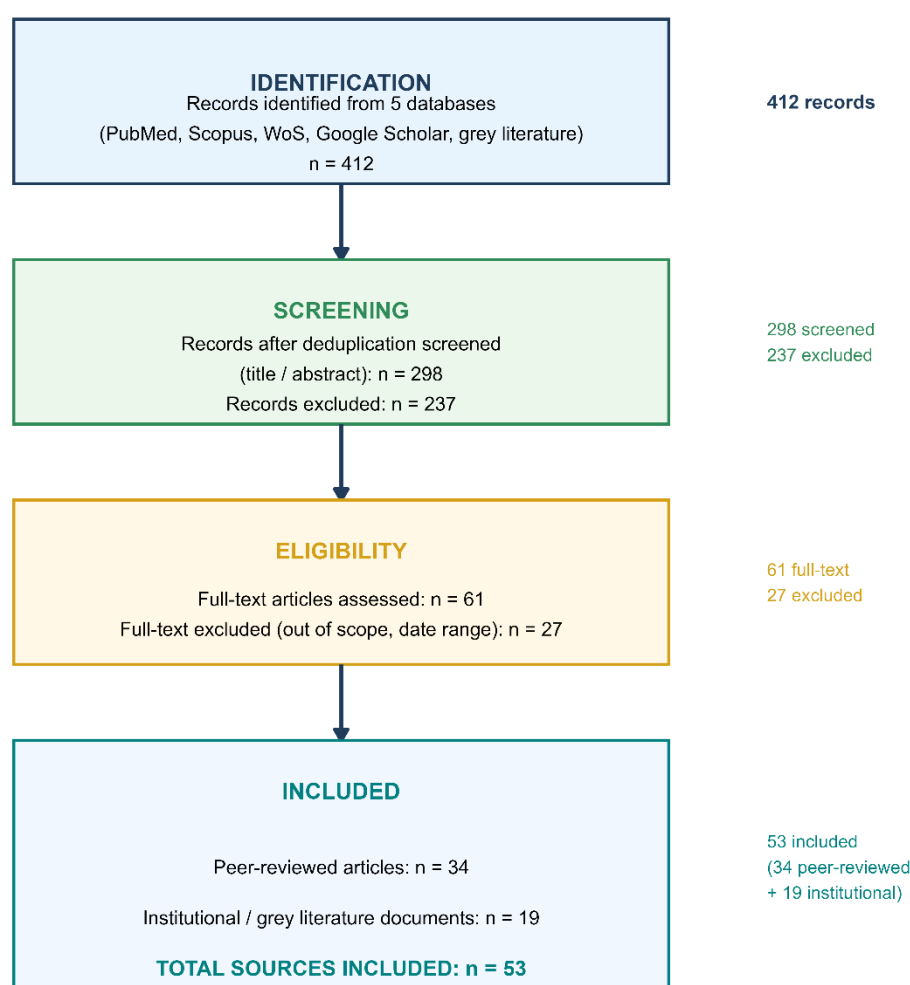
A systematic search was conducted in April 2026 across PubMed, Scopus, Web of Science, and Google Scholar, supplemented by targeted retrieval from the CBD document portal (cbd.int), FAO Commission on Genetic Resources for Food and Agriculture records, IUCN databases, UNEP-WCMC publications, and INSDC/GenBank official documentation. Search strings:

(1) (“digital sequence information” OR “DSI”) AND (“Africa” OR “Sub-Saharan Africa”) AND (“benefit sharing” OR “access and benefit” OR “genetic resources”); (2) (“genomic representation” OR “genome sequencing”) AND (“African species” OR “African taxa” OR “African flora” OR “African fauna”); (3) (“Nagoya Protocol” OR “ABS legislation”) AND (“Africa” OR “developing countries”); (4) (“Cali Fund” OR “COP16 DSI” OR “multilateral mechanism DSI”); (5) (“biodiversity hotspots” OR “Africa biodiversity” OR “species richness Africa”). A sixth string — (“GWAS diversity” OR “genomic representation Africa”) — was applied solely to document human genomic underrepresentation as a secondary contextual indicator, not as a Cali Fund allocation basis.

Inclusion criteria: peer-reviewed or authoritative institutional publication between January 2022 and April 2026; direct relevance to at least one study objective; availability in English. Grey literature was included only for primary empirical data (CBD decisions, INSDC statistics, IUCN assessments) not available through peer-reviewed sources.

Flow Diagram

Screening process for the structured evidence synthesis following PRISMA 2020 reporting elements.



Note: This is a structured evidence synthesis, not a clinical systematic review. PRISMA 2020 elements are applied where applicable.
Search dates: January 2022 – April 2026. Earlier foundational legal instruments included irrespective of date.

Figure 1: Structured Evidence Synthesis

3.3 ABS Governance Assessment

The ABS governance readiness of each of the 54 AU member states was assessed using the CBD ABS Clearing-House Online System (absch.cbd.int, accessed April 2026), the Nagoya Protocol ratification tracker (cbd.int/abs), and the policy database assembled by Ljungqvist and colleagues (2025). Countries were classified into four categories: (I) comprehensive ABS law with explicit non-human DSI inclusion; (II) ABS law with ambiguous or partial DSI coverage; (III) Nagoya Protocol ratified but no domestic ABS implementation law; and (IV) Nagoya Protocol not yet ratified. Category assignments were cross-validated against the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) ABS Capacity Development Initiative database [19]. Classifications reflect evidence as of April 2026 only.

3.4 Quantitative Modelling

Revenue projections were constructed using the UNEP-WCMC/KPMG (2024) commissioned study (CBD/WGDSI/2/2/Add.2) as the primary baseline for non-human DSI-dependent sectors. These figures represent total sector revenues, not revenues attributable solely to DSI-enabled products, the UNEP-WCMC/KPMG methodology estimates DSI-dependent fractions through sector-by-sector assessment, and this attribution itself represents a source of uncertainty acknowledged by the study. No human genomics revenues are included.

The 12.5% average net profit margin is a cross-sector proxy applied uniformly by the commissioned study. Actual margins vary substantially, pharmaceutical net margins typically range 20–30%, cosmetics margins differ, meaning the proxy introduces parametric uncertainty that is acknowledged as a study limitation.

Africa's modelled allocation share of 20 to 25% is an analytical construct devised by the authors of this study, based on Africa's approximate share of global non-human terrestrial species richness (20 - 25%) and its share of globally recognised biodiversity hotspots (9 of 36 = 25%). This allocation is NOT contained in any agreed Cali Fund disbursement formula; the actual formula will be negotiated at COP17. All projections are illustrative scenarios and should not be interpreted as actuarial forecasts. R code (version 4.6.0, tidyverse and scales packages).

4. RESULTS

4.1 Africa's Non-Human Biodiversity Endowment: Quantitative Characterisation

4.1.1 Terrestrial species richness and endemism

Africa, comprising 20% of the Earth's land surface, harbours extraordinary non-human biological diversity. Bezeng and colleagues (2025) confirm that the continent hosts approximately one-quarter of the world's mammal and bird species, with large fractions of global plant richness endemic to the continent.[4] A preprint systematic assessment (Sinsin et al., 2025), not yet peer-reviewed, documents approximately one-sixth of global plant richness, 17% of global mammal richness, 2,500 bird species, 950 amphibian species, and 5,000 freshwater fish species on the continent.[20] Bezeng and colleagues (2025) further confirm that only 19% of Africa's landscape and 17% of its seascape are formally protected, well below the KMGBF 30×30 target.[4]

Nine of the world's 36 formally recognised biodiversity hotspots fall wholly or substantially within African borders: the Cape Floristic Region, Succulent Karoo, Maputaland-Pondoland-Albany, Coastal Forests of Eastern Africa, Eastern Afromontane, Guinean Forests of West Africa, Horn of Africa, Madagascar and the Indian Ocean Islands, and the Mediterranean Basin (partially).[3,21] Conservation International (2024) confirms that collectively the 36 hotspots, covering just 2.5% of the Earth's land surface, harbour over half the world's endemic plant species and nearly 43% of endemic terrestrial vertebrates.[21] Africa's 25% share

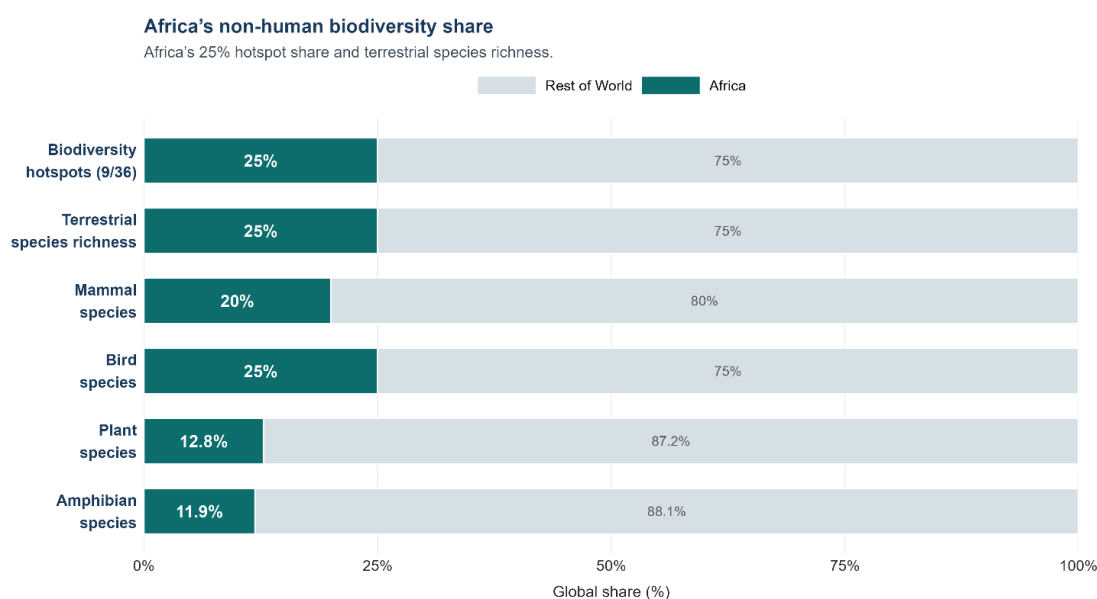
of global biodiversity hotspots is the primary quantitative basis for the upper bound (25%) of its modelled Cali Fund allocation share.

The Congo Basin warrants specific attention as a DSI resource. Covering approximately 240 million hectares across eight African countries, it represents the world's second-largest tropical rainforest system, is among the least genomically characterised ecosystems on Earth, and harbours tens of thousands of plant and animal species whose sequences have not been deposited in any public database. Africa's 25% global biodiversity share is largely missing from INSDC databases, a powerful argument for non-monetary benefit-sharing (bioinformatics capacity building and sequencing infrastructure) to be prioritised for African laboratories alongside monetary Cali Fund contributions.

Table 1. Summary of Africa's non-human biodiversity metrics relative to global benchmarks.

Non-Human Biodiversity Metric	Africa (estimate)	Global Total	Africa Share
Land area (km ²)	30.4 million	149 million	20%
Terrestrial species richness	≈25% of global species	All species	~25%
Biodiversity hotspots	9 hotspots	36 globally	25%
Mammal species	≈1,100	≈5,500	~20%
Bird species	≈2,500	≈10,000	~25%
Amphibian species	≈950	≈8,000	~12%
Plant species	≈50,000	≈390,000	~13%
Protected terrestrial area	19%	30% (KMGBF target)	Below target
Congo Basin forest area (Mha)	~240 Mha	Amazon ~550 Mha (world #1)	~44% of tropical #2

Sources: [3,4,20,21]. Non-human biodiversity figures only. Sinsin et al. (2025) [20] is a preprint and not peer-reviewed. Africa's 9/36 hotspot share (25%) is the primary basis for the upper bound of the modelled Cali Fund allocation share.



Sources: Bezeng et al. Phil Trans R Soc B (2025); Conservation International (2024); Africa Center for Strategic Studies (2024); Sinsin et al. bioRxiv (2025) (preprint, not peer-reviewed). Figures are approximate estimates from published peer-reviewed sources.
Note: These data relate exclusively to non-human organisms. Human genetic diversity data are presented separately in Figure 1b and Figure 2.

Figure 2: Africa Biodiversity vs the rest of the world by taxonomic group

4.1.2 Human genomic diversity: contextual indicator only — outside CBD/Cali Fund scope

This section presents human genomic data as a secondary indicator of Africa's broader scientific infrastructure exclusion. Human genetic resources are outside the CBD and Nagoya Protocol ABS framework and do not directly constitute a basis for Cali Fund benefit-sharing claims. Africa's extraordinary human genetic diversity is presented here to illustrate the same structural forces — investment asymmetries and research infrastructure deficits, that simultaneously marginalise Africa in non-human DSI databases.

Africa's status as the evolutionary cradle of anatomically modern *Homo sapiens* confers genetic diversity that is scientifically without parallel. Genetic diversity accumulated across more than 2,000 ethnolinguistic groups reflects over 300,000 years of in situ divergence, as dated by the Jebel Irhoud fossil record (Hublin et al., 2017, *Nature*).[5]

Fan and colleagues (2023) conducted high-coverage whole-genome sequencing ($\geq 30\times$) of 180 individuals from 12 indigenous African populations and identified millions of previously unreported functionally important variants.[22] The African Genome Variation Project (Gurdasani et al., 2015, *Nature*) — the primary empirical source for the three million novel variants finding — sequenced 320 individuals from 18 ethnically diverse African populations and identified over three million novel variants not previously described, demonstrating extraordinary genomic discovery yield even from small, unrepresented African cohorts.[23]

The Assessing Genetic Diversity in Africa (AGenDA) project (Ramsay et al., 2026, *Nature*) generated whole-genome sequences from over 1,000 individuals across nine African countries: Angola, Democratic Republic of Congo, Kenya, Libya, Mauritius, Rwanda, South Africa, Tunisia, and Zimbabwe.[24]

African populations carry three to five times more genetic variants than populations from other continents, with some intra-African lineages diverging more than 200,000 years ago, predating the separation of all non-African populations.[25,26]

4.2 Africa's Representation in Global DSI Databases

4.2.1 Non-human genomic databases: the primary governance concern

Africa's underrepresentation in non-human genomic databases is the primary scientific driver of the benefit-sharing equity argument in this paper and the most directly relevant to the Cali Fund. Precise continent-level statistics on African non-human species representation in INSDC databases are not published in summary form, itself a research gap identified in Section 7, but multiple proxy indicators converge on the conclusion that African non-human taxa are severely undersequenced relative to their 25% share of global biodiversity.

The African BioGenome Project (AfricaBP), formally launched in 2021 with the objective of sequencing 105,000 African species, has documented that the vast majority of Africa's known biological diversity remains unsequenced. The AfricaBP Consortium (2026, *Nature Reviews Biodiversity*) reports that the Open Institute organised 31 workshops reaching researchers across 50 African countries in 2024, training 401 individuals in genomics and bioinformatics.[27,28]

Hayah and colleagues (2025, *npj Biodiversity*) document that meeting the KMGBF goals in Africa is contingent on scaling up non-human genomics research and DSI infrastructure.[28] The Genomic Reference Resource for African Cattle (GRRFAC) (Tijjani et al., 2024, *Scientific Data*) illustrates the concrete scale: despite Africa hosting over 150 indigenous cattle breeds adapted over millennia, fewer than 300 individuals had reference-quality genome sequences prior to the GRRFAC initiative.[29]

4.2.2 Human genomic databases: a secondary indicator of structural exclusion

Africa's underrepresentation in human genomic databases is presented as a secondary indicator documenting the same structural forces, investment asymmetries, and infrastructure deficits that simultaneously constrain Africa's contribution to non-human DSI databases. This section relates to human genomics, which falls outside the CBD/Nagoya ABS framework and does not constitute the basis for any Cali Fund allocation claim.

Corpas and colleagues (2025) documented that, as of September 2024, participants of European ancestry constituted 94.48% of samples in the GWAS Diversity Monitor, while African-ancestry participants constituted less than 1%.[30] Sub-Saharan African ancestry samples constituted approximately 0.47% of the GWAS Catalog as of 2023, having declined from approximately 1.1% in 2019, both figures drawn from the longitudinal GWAS Diversity Monitor analysis in Corpas et al. (2025)[30]

Fatumo and colleagues (2022) documented that polygenic risk score (PRS) models built on European cohorts exhibit substantially reduced predictive accuracy in African populations.[31] Wonkam and Adeyemo (2023) summarise that fewer than 2% of human genomes analysed have been those of people with African ancestry.[26]

The H3Africa (Human Heredity and Health in Africa) consortium, after more than a decade spanning 30 African countries, has produced over 700 publications and trained approximately 950 researchers, a significant achievement but a fraction of the capacity needed for equitable participation in global human genomics.[32]

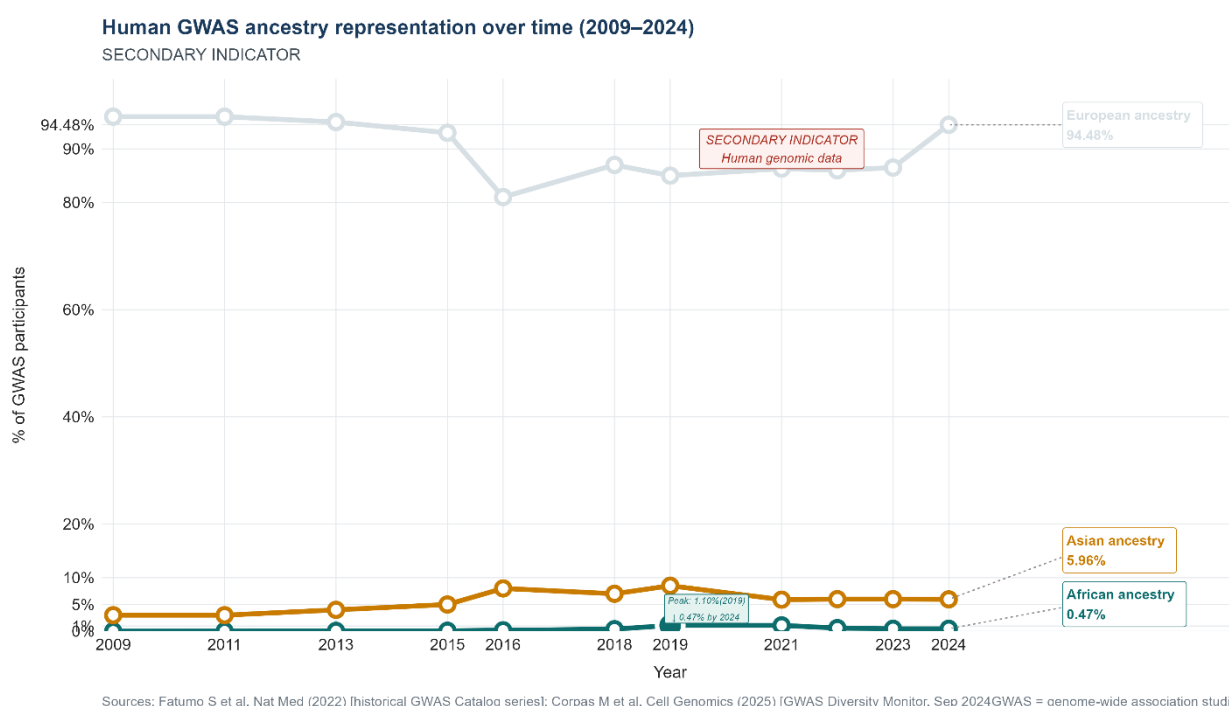


Figure 3: Time-series line chart: GWAS ancestry representation (%European, %Asian, %African) 2009 – 2024.

4.3 Commercial Non-Human DSI Utilisation: Sector Revenue Analysis

The UNEP-WCMC/KPMG (2024) commissioned study provides the most authoritative published estimate of revenues generated by non-human DSI-dependent sectors. The figures represent total sector revenues, not

revenues attributable solely to DSI-enabled products; the study's methodology for DSI attribution is a source of acknowledged uncertainty.[1]

Table 2. Annual revenue of non-human DSI-utilising sectors: 2024 estimates and 2030 projections.

Sector (non-human DSI-dependent)	2024 Revenue (USD bn)	2030 Projection (USD bn)	CAGR (%)
Pharmaceutical	593.24	836.60	5.9
Cosmetics	333.90	474.00	6.0
Plant & animal breeding / agri-biotech	581.62	904.23	7.6
Laboratory equipment (DSI hardware)	43.36	66.40	7.3
IT platforms / scientific services (DSI)	7.65	22.44	19.7
TOTAL (all five sectors)	1,559.77	2,330.67	~7.0

Source: UNEP-WCMC/KPMG UK (2024), CBD/WGDSI/2/2/Add.2 [1]. CAGR = compound annual growth rate (authors' calculations, 2024–2030 projections). Revenues are total sector revenues, not DSI-attributable fractions. No human genomics revenues included. These five sectors are characterised by commercial dependence on non-human DSI.

The aggregate revenue of USD 1.56 trillion in 2024 substantially understates the commercial significance of non-human DSI as it excludes downstream value chains. A case study by the DSI Scientific Network (2023) demonstrates that the development of messenger RNA (mRNA) vaccines involved access to pathogen sequence data from public databases, illustrating the operational centrality of non-human DSI to modern pharmaceutical development.[33]

Non-human DSI-utilising sector revenue shares (2024)

Total: USD 1,559.77 billion (2024) | Projected: USD 2,330.67 billion by 2030 | Tile area proportional to revenue.



Source: UNEP-WCMC and KPMG UK (2024). CBD/WGDSI/2/2/Add.2.

Revenue figures represent total sector revenues, not revenues attributable solely to DSI-enabled products.

CAGR = compound annual growth rate (2024–2030). The UNEP-WCMC/KPMG methodology estimates DSI-dependent revenue fractions per sector.

Figure 4: Treemap of non-human DSI-dependent sector revenue shares (2024)

4.4 The ABS Governance Landscape in Africa: Systematic Assessment

4.4.1 Continental overview

Systematic assessment of the ABS legislative landscape across all 54 AU member states reveals a deeply fragmented governance picture for non-human DSI.[18]

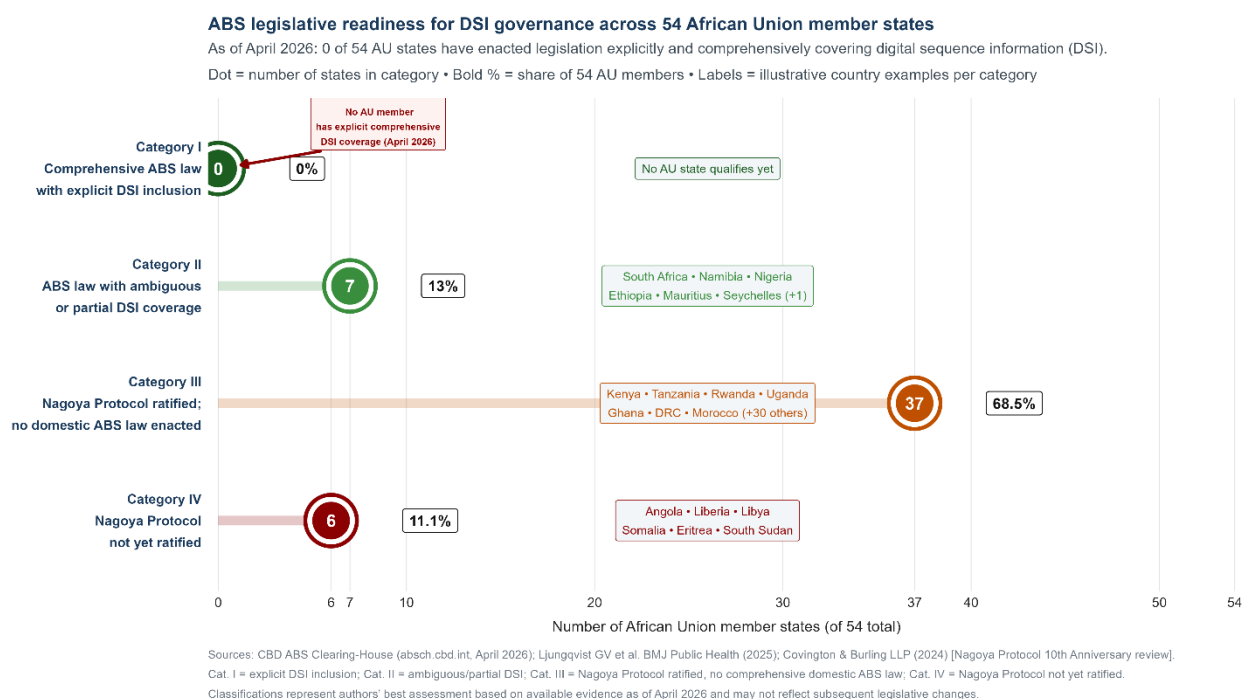


Figure 5: Lollipop chart: Non-human DSI ABS legislative readiness across 54 AU member states by category (I-V).

4.4.2 The three most critical structural barriers to non-human DSI governance implementation

Rather than enumerating governance barriers at equal weight, this section identifies the three most analytically significant structural impediments.

The most fundamental barrier is database traceability. Once a non-human genetic sequence is uploaded to an open-access database, tracking its downstream commercial use requires computational infrastructure, persistent identifier systems, and international data governance arrangements that most African institutions currently lack. The INSDC's 2023 spatiotemporal annotation policy partially addresses this for future submissions, but billions of legacy records carry no country-of-origin metadata.[7]

The second barrier is bioinformatics and scientific sequencing capacity. Africa lacks the sequencing infrastructure, computational resources, and trained scientific workforce to generate non-human DSI at a scale commensurate with its 25% biodiversity share, or to participate as an equal partner in DSI governance. The AfricaBP's training of 401 researchers in 2024 represents meaningful progress but an inadequate scale.[27,28] Relly, Tittor, and Schlender (2024) warn that artificial intelligence (AI)-mediated molecular design may increasingly substitute for direct sequence access, potentially rendering DSI governance frameworks obsolete before they are fully implemented.[14]

The third barrier is international negotiating capacity. Reports from COP16 negotiations recorded that the Central African Republic cited "a lack of capacity and general unawareness of the process" as the reason for

low Global Environment Facility (GEF)-8 ABS funding uptake, and Togo called for Secretariat consultations on ABS funding barriers. These statements, made in plenary at a COP, illustrate the gap between legal aspirations and institutional realities.[35]

4.5 Cali Fund: Revenue Modelling and Africa's Modelled Allocation Share

4.5.1 Fund revenue scenarios

Using the UNEP-WCMC/KPMG (2024) non-human DSI sector baseline and applying the indicative, voluntary rates specified in Decision 16/2, Table 4 presents projected annual Cali Fund revenues under five scenarios.[1] Africa's modelled allocation share (20–25%) is the authors' analytical construct, as described in Section 3.4, and is not an internationally agreed disbursement formula. Both the 20% and 25% weights are shown for both 2024 and 2030 to make this explicit.

Table 3. Illustrative Cali Fund scenarios and Africa's modelled allocation share from non-human biodiversity (2024 and 2030). NOTE: The 20% and 25% allocation weights are the authors' analytical constructs based on Africa's non-human species richness and hotspot share; they are not contained in any agreed Cali Fund disbursement formula.

Scenario	Levy Rate	Total Fund 2024 (USD bn)	Total Fund 2030 (USD bn)	Africa 20% share* (2024 / 2030)	Africa 25% share* (2024 / 2030)
A: COP16 minimum (revenue)	0.1% revenue	1.56	2.33	0.31 / 0.47	0.39 / 0.58
B: Mid-range (revenue)	0.5% revenue	7.80	11.65	1.56 / 2.33	1.95 / 2.91
C: High ambition (revenue)	1.0% revenue	15.60	23.31	3.12 / 4.66	3.90 / 5.83
D: COP16 minimum (profit)	1.0% net profit	1.95	2.91	0.39 / 0.58	0.49 / 0.73
E: High ambition (profit)	5.0% net profit	9.75	14.57	1.95 / 2.91	2.44 / 3.64

**Africa's 20% and 25% allocation shares are the authors' analytical constructs; they are not an agreed Cali Fund formula. Revenue base 2024: USD 1,559.77 bn (non-human DSI sectors only; no human genomics). Net profit proxied at 12.5% (cross-sector average; actual sector margins vary). CAGR: 7.0% (2024–2030). Source: UNEP-WCMC/KPMG (2024) [1]; authors' calculations (2026).*

At the COP16 indicative minimum (0.1% of revenue), the Cali Fund would generate approximately USD 1.56 billion in 2024 and USD 2.33 billion by 2030. At 1% of revenue, Africa's modelled allocation share rises to USD 3.12–3.90 billion in 2024 and USD 4.66–5.83 billion by 2030, a figure that substantially exceeds any single existing international biodiversity financing mechanism directed at the continent. The KMGBF's Target 19 calls for international financial flows to developing countries of at least USD 20 billion per year by 2025, a target that Official Development Assistance (ODA) commitments have already failed to meet.[36]

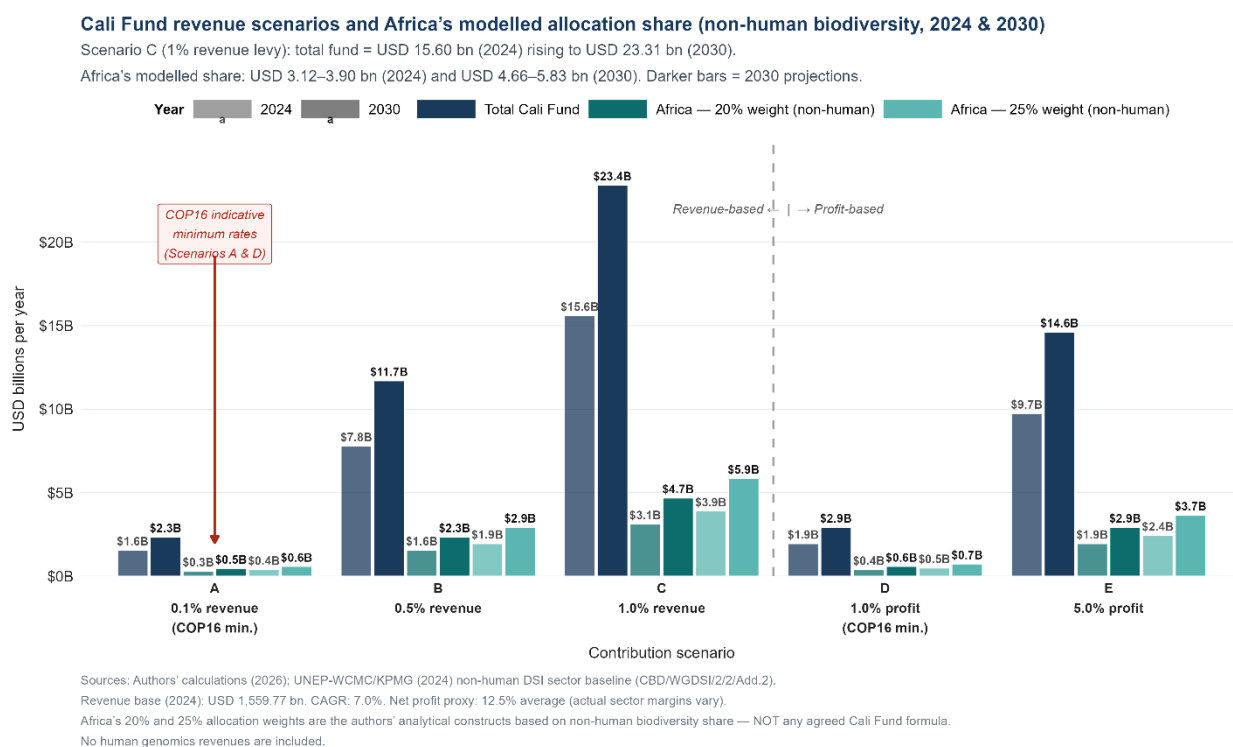


Figure 6: Grouped bar chart: Cali Fund Scenarios A-E, total fund vs Africa modelled allocation share at 20% and 25% non-human biodiversity weight.

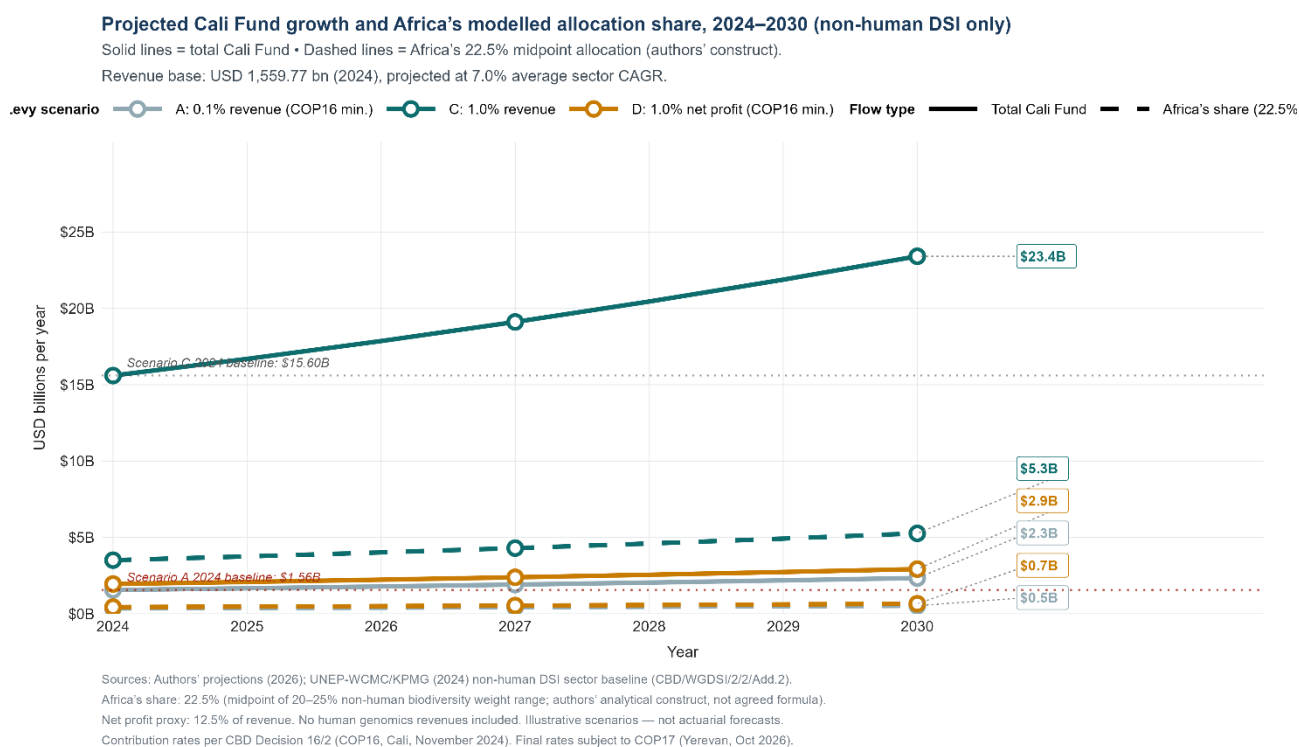


Figure 7: Multi-line projection chart: Cali fund total and Africa modelled allocation share (22.5% midpoint), 2024–2030, under scenarios A, C, and D.

4.5.2 Structural risks to realising Africa's modelled allocation share

Decision 16/2 establishes indicative, voluntary contribution rates, not mandatory obligations. The International Federation of Pharmaceutical Manufacturers and Associations (IFPMA) stated publicly after COP16 that the decision “does not get the balance right,” signalling likely resistance from at least part of the pharmaceutical sector.[37] This quote is verified against the IFPMA press release of 2 November 2024.

Even if contributions are made, Africa's institutional readiness to access disbursements represents a second-order risk. The Cali Fund's disbursement modalities remain unfinished; Decision 16/2 stipulates that at least 50% of resources be allocated to IPLC-linked activities and support National Biodiversity Strategy and Action Plan (NBSAP) implementation. Both purposes align with African priorities in principle, but accessing funding requires institutional infrastructure, accredited implementing agencies, project development capacity, and compliance reporting systems that is unevenly distributed across the continent.

5. DISCUSSION

5.1 The Structural Determinants of Africa's Non-Human DSI Governance Gap

Africa's underrepresentation in non-human DSI databases is not a reflection of biological poverty. Three specific, identifiable mechanisms explain the gap.

First, the historical concentration of research investment in high-income countries with established sequencing infrastructure meant that the INSDC databases grew predominantly from laboratory systems in North America, Europe, and East Asia, where sequencing technology was first commercially available. African research institutions were excluded from initial knowledge accumulation through structural funding disparities, not biological irrelevance.

Second, open-access database architecture was designed prioritising data sharing over data sovereignty. As Karsch-Mizrachi and colleagues (2025) acknowledge from within the INSDC, “we now need to consider the rights of sovereign states for nature-derived DSI” — a recognition that the governance framework must be retrofitted to a world its architects did not anticipate.[38]

Third, international negotiating dynamics systematically favour technically resourced actors. Countries with dedicated delegations, legal expertise in ABS law, and financial capacity to sustain multi-year participation have shaped DSI governance to minimise contribution obligations. Relly, Tittor and Schlender (2024) additionally warn that AI-mediated molecular design may render DSI governance frameworks obsolete before they are fully implemented, posing a particular risk for Africa.[14]

5.2 The Cali Fund: Potential and Structural Limitations

The Cali Fund represents a genuine institutional innovation: for the first time, a mechanism exists that decouples benefit-sharing from physical access to non-human genetic resources.[12,13]

The quantitative modelling demonstrates that at 1% of revenue, the fund could generate USD 15–23 billion annually, sufficient to materially close the biodiversity finance gap in Africa if disbursed equitably. Three structural limitations warrant attention. First, the voluntary model creates a free-rider problem with no enforcement backstop. Second, the unresolved disbursement formula, deferred to COP17, leaves Africa's modelled allocation share contingent on future negotiations. Third, the fund's operational architecture through the MPTFO creates access barriers analogous to those documented for GEF funding.

5.3 Scientific Implications: What Africa's Non-Human and Human Genomic Exclusions Cost the World

The consequences of Africa's exclusion from global genomics extend beyond Africa, across both the non-human and human dimensions documented in this study.

For non-human biodiversity, Africa's undersequenced crop wild relatives, soil microbiomes, marine fauna, and endemic flora represent an irreplaceable reservoir of stress tolerance, disease resistance, and productivity traits that agricultural biotechnology and conservation science will increasingly require as climate change intensifies selection pressures.

For human genomics, governed separately from the Cali Fund, but equally important as evidence of the broader infrastructure exclusion, Corpas and colleagues (2025) document that genomic research biased toward European populations produces models with reduced predictive accuracy.[30] Fatumo and colleagues (2022) show that PRS models trained on European cohorts have substantially attenuated performance in African populations.[31] Cytochrome P450 2D6 (CYP2D6), which metabolises an estimated 20–25% of clinically used drugs, a well-established pharmacogenomics finding (Gaedigk et al., 2018), exhibits substantially different variant frequencies in African populations, yet African CYP2D6 data remains underrepresented in global pharmacogenomic databases, propagating dosing errors globally.[39]

6. POLICY IMPLICATIONS FOR AFRICAN INSTITUTIONS

The evidence assembled in this paper has concrete implications for African governments, regional bodies, research institutions, and civil society organisations seeking to participate equitably in the emerging DSI governance architecture. Six priority action areas are identified.

First, strengthening ABS legislation to address non-human DSI explicitly. No African Union member state currently has ABS legislation that explicitly and comprehensively addresses non-human DSI. As Ljungqvist and colleagues (2025) document, this legislative vacuum leaves African countries unable to assert ABS rights over non-human DSI under any existing mechanism, including the Cali Fund's incentive-based national legislation pathway.[18] Priority should be given to: (a) updating existing ABS laws (South Africa, Nigeria) to include explicit non-human DSI definitions and coverage; (b) accelerating the development of standalone ABS legislation in countries without it; and (c) adopting harmonised non-human DSI provisions at the Regional Economic Community (REC) level to prevent forum shopping by multinational DSI users.

Second, investing in sequence provenance and metadata infrastructure. Africa's ability to demonstrate its contribution to non-human DSI in global databases depends on the quality of metadata — collection location, collector identity, and date of collection, associated with deposited sequences. The INSDC's 2023 spatiotemporal annotation requirement provides a technical hook, but Africa's research institutions need support to submit sequences with complete, verifiable metadata.[7] Investment in national sequencing programmes, metadata standards, and biodiversity informatics training is required at institutional and national levels.

Third, building institutional capacity to access Cali Fund resources. Even at the indicative minimum rate, the Cali Fund represents a potential USD 310–580 million annual opportunity for Africa. Realising even a fraction of this requires: accredited national implementing agencies; technical capacity for project design and Cali Fund compliance reporting; engagement with the Fund's Steering Committee through the African Group of Negotiators (AGN); and early alignment between NBSAP implementation priorities and Cali Fund disbursement criteria.

Fourth, ensuring IPLC participation and benefit-sharing safeguards. Decision 16/2 allocates at least 50% of Cali Fund resources to IPLC-linked activities.[12] For Africa's more than 2,000 ethnolinguistic groups, many

of whom are custodians of the biological resources from which non-human DSI is derived, this allocation represents both an opportunity and a risk. Without domestically enforceable IPLC benefit-sharing protocols, national governments may absorb Cali Fund disbursements intended for community-level distribution. African governments should develop IPLC participation frameworks and community benefit-sharing protocols before COP17.

Fifth, protecting open science while creating equitable benefit-sharing mechanisms. A critical tension in DSI governance is between open scientific access and equitable benefit-sharing. Overly restrictive DSI governance could impede African researchers' own access to international databases, undermine disease surveillance, and disadvantage African institutions in international scientific collaborations. African negotiating positions before COP17 should prioritise non-monetary benefit-sharing, capacity building, technology transfer, joint research agreements, and training as the primary immediate benefit for African scientific communities, alongside monetary contributions to the Cali Fund.

Sixth, developing a coordinated AU/REC-level negotiating position before COP17. The Yerevan COP17 (October 2026) will determine final Cali Fund contribution rates, disbursement criteria, and compliance mechanisms. A coordinated African position, developed through the African Ministerial Conference on the Environment (AMCEN) and the AGN, is essential for ensuring that Africa's non-human biodiversity-based claims are reflected in the fund's architecture. Coordination should begin no later than mid-2026 to allow sufficient preparation before the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA)-28 and Subsidiary Body on Implementation (SBI)-7 intersessional meetings in Nairobi (July–August 2026).

7. LIMITATIONS

This study employs a structured evidence synthesis based entirely on secondary data. Four specific limitations must be stated precisely.

First, continent-level statistics on African non-human species representation in INSDC databases are not available in published summary form. The conclusion that African non-human taxa are severely undersequenced is supported by proxy indicators, AfricaBP documentation, the GRRFAC cattle genomics gap, AfricaBP training activity, but cannot be precisely quantified without systematic extraction and analysis of INSDC country-of-origin metadata, itself an identified research priority.

Second, the ABS governance classification of 54 AU member states reflects the best available evidence as of April 2026. The ~44/54 Nagoya ratification figure should be confirmed from the CBD ratification tracker at submission. Legislative developments after April 2026 are not captured.

Third, the Cali Fund revenue projections are illustrative scenarios under stated parametric assumptions. The 12.5% average net profit margin is a cross-sector proxy that may meaningfully misestimate fund revenue in individual sectors. The 7.0% CAGR does not account for macroeconomic shocks or AI-driven substitution effects. Africa's 20–25% allocation share is not an agreed formula and would require actuarial determination through the COP17 process.

Fourth, the PRISMA 2020 reporting elements are applied where applicable to this structured evidence synthesis; a PRISMA flow diagram is provided in Figure 1. No formal risk-of-bias assessment of included studies was conducted, as this is a secondary data analysis, not a clinical systematic review. The 2022 search date restriction may exclude some relevant pre-KMGBF foundational literature.

These limitations define the research agenda: field-based primary data collection across African countries, systematic country-of-origin metadata extraction from INSDC non-human sequence records, empirical

analysis of corporate DSI supply chains, and interviews with IPLCs on Cali Fund awareness and expectations.

8. CONCLUSIONS

This study presents five key conclusions:

First, Africa is among the most biologically rich continents on Earth for non-human life, by species richness, endemism, hotspot density, and the evolutionary depth of its microbial and plant diversity. This endowment is the direct and appropriate basis for Africa's modelled allocation share under the Cali Fund, which is grounded exclusively in CBD non-human biodiversity objectives.

Second, Africa is profoundly underrepresented in both non-human and human genomic databases through structurally related but legally distinct mechanisms. Africa's non-human DSI underrepresentation, evidenced by multiple proxy indicators, represents a direct loss of benefit-sharing leverage under the Cali Fund. Africa's human genomic underrepresentation is a secondary indicator of the same structural forces and is not part of the Cali Fund allocation argument.

Third, the ABS governance architecture in Africa is inadequate for the non-human DSI era. Zero AU member states have enacted legislation explicitly and comprehensively covering non-human DSI; fewer than one-third have comprehensive ABS legislation of any kind; and the technical capacity to trace downstream non-human DSI use or access multilateral mechanisms is severely limited.

Fourth, the Cali Fund represents a structurally significant opportunity. Africa's modelled allocation share, conservatively estimated at 20–25%, ranges from USD 312 million to USD 5.83 billion annually across five modelled scenarios. These figures are contingent on contribution rates and disbursement formula decisions to be made at COP17.

Fifth, realising Africa's modelled allocation share is not automatic. The fund's voluntary contribution model, unresolved disbursement formula, documented corporate resistance, and Africa's institutional unpreparedness are structural barriers that, if unaddressed, will result in Africa receiving substantially less than its proportional share. The six policy actions identified in Section 6 provide a prioritised roadmap for African institutions before COP17.

DECLARATIONS

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AUTHOR CONTRIBUTIONS (CREDIT TAXONOMY)

Yves Shema: Conceptualization, Methodology, Analysis, Visualization, Writing: original draft.

Suwilanj Sinyangwe: Conceptualization, Writing: original draft, review and editing, Project administration.

Fredrick Ayodele: Conceptualization, Writing: original draft, review and editing, Validation.

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