KEYWORDS: ***Digital conservation ethics – Cultural sovereignty – Postcolonial heritage***

DIGITAL CONSERVATION ETHICS IN FRENCH AND MALIAN CAVE SITES: A COMPARATIVE ANALYSIS OF THE LASCAUX IV VIRTUAL REPLICATION PROJECT AND THE 3D DOCUMENTATION PRACTICE OF DOGON ROCK ART IN MALI

Jiawei Zeng

Abstract. This study compares ethical dimensions of digital conservation at France's Lascaux Cave (Lascaux IV) and Mali's Dogon rock art. Focusing on cultural sovereignty amid postcolonial dynamics, it analyses technological applications, legal frameworks and community roles. Findings highlight unequal power structures in digital heritage governance, urging decolonised, community-led models to balance innovation and cultural self-determination.

1. Introduction

Cave art represents one of humanity's earliest forms of cultural expression, offering irreplaceable insights into pre-Historic societies' cognitive, spiritual, and social lives (Clottes 2010). Sites such as France's Lascaux Cave and Mali's Dogon rock art complexes are not merely archaeological artefacts but repositories of collective memory and cultural identity. In recent decades, digital technologies—including 3D scanning, virtual reality (VR), and high-resolution imaging—have emerged as critical tools for preserving these fragile sites, enabling documentation, analysis and public access without risking physical damage (Brodie et al. 2010). However, digitisation introduces complex ethical dilemmas, particularly regarding cultural sovereignty: who controls the digital replicas? How are local communities' rights and perspectives integrated into technological processes? These questions are amplified when comparing cases from former colonial powers and postcolonial nations, where historical power imbalances shape contemporary heritage governance (Logan and Reeves 2009).

This study aims to compare the ethical dimensions of digital conservation practices at these two iconic cave art sites. Specifically, it addresses three core questions: (1) How do technological applications in each case reflect or challenge cultural sovereignty? (2) To what extent do legal frameworks and postcolonial power dynamics influence ethical decision-making? (3) What models of digital heritage governance emerge from these comparisons, and how might they inform global practice?

By juxtaposing a European site with a West African counterpart, this research illuminates the uneven impacts of digital conservation in different geopolitical contexts. It contributes to debates on decolonising heritage practices (Matsuda 2018) and highlights the need for context-specific ethical frameworks that prioritise cultural self-determination. Practically, it offers insights for policymakers, archaeologists and technologists seeking to balance technological innovation with respect for local rights.

Methodologically, this study employs a comparative case study design, combining qualitative analysis of project documentation, legal texts and academic literature. Data sources include official reports on Lascaux IV (Centre International de l'Art Pariétal 2016) and Dogon 3D projects (Sarr et al. 2020), UNESCO conventions, national heritage laws and scholarly critiques of digital heritage ethics. Postcolonial theory (Said 1978; Spivak 1999) provides a lens to examine power dynamics, while cultural heritage law (O'Keefe 2007) frames analyses of legal compliance.

2. Literature review

2.1. Digital conservation of cultural heritage

Digital conservation refers to the use of computational tools to record, preserve and disseminate cultural heritage (Cameron and Kenderdine 2010). Its significance lies in its ability to mitigate risks from tourism, climate change and looting, while expanding access to sites otherwise restricted for preservation (Arizona State University 2018). However, digitisation is not neutral: it involves selective representation, transforming intangible cultural meanings into tangible data (MacDonald 2013).

Common technological approaches include photogrammetry (creating 3D models from photo-

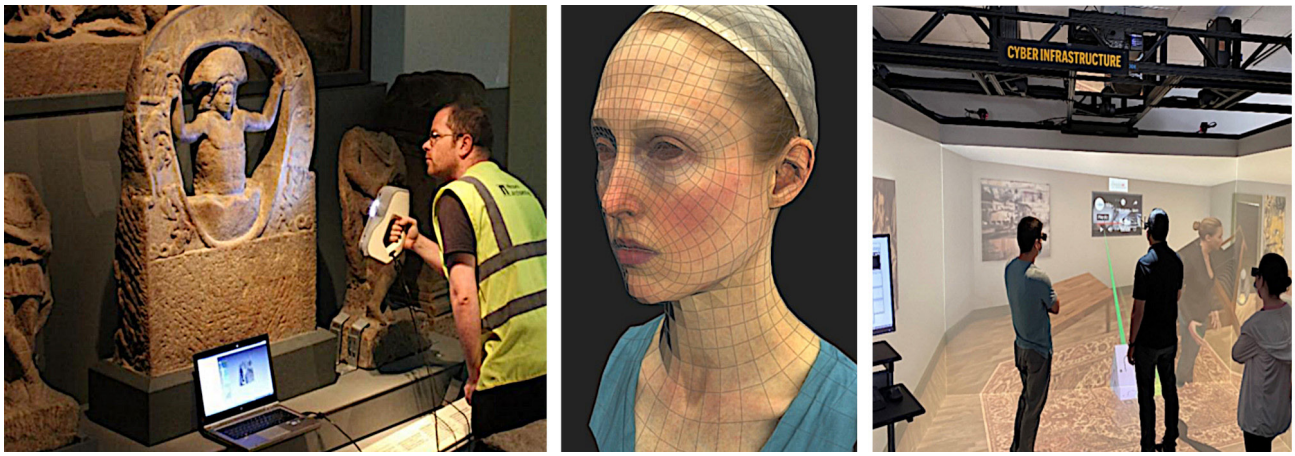

Figure 1. *Common digital conservation technologies. From left to right: laser scanning equipment in use at an archaeological site; 3D model generated via photogrammetry; VR interface allowing virtual exploration of a cave site.*

graphs), laser scanning (capturing millimetre-precise measurements) and VR/AR (immersive simulations). These tools vary in cost, accessibility and accuracy, with high-end laser scanning often requiring external expertise—a factor influencing project ownership (Remondino and El-Hakim 2006). Key ethical considerations include data ownership, authenticity and community consent. For example, digital replicas may commodify heritage or detach it from its cultural context (Waterton and Watson 2010). Additionally, 'digital colonialism' (Parry 2004) arises when external actors control digitisation processes, replicating historical power imbalances.

2.2. Cultural sovereignty, post-colonial theory and digital heritage

Cultural sovereignty denotes a community's right to govern its cultural heritage, including decisions about preservation, interpretation and dissemination (Blake 2009). It encompasses both legal claims (e.g. ownership) and intangible elements (e.g. control over narrative). In digital contexts, it involves regulating access to data and ensuring representation aligns with community values (Smith 2004).

Postcolonial theory critiques how colonialism shaped heritage narratives, privileging Western perspectives over indigenous or local ones (Coombes 2003). For postcolonial nations like Mali, this legacy manifests in reliance on foreign expertise and funding for heritage projects, potentially undermining self-determination (Olwig 2002). Digital technologies complicate this dynamic: while they enable global access, they also risk 'data extraction' (Bouchenaki 2018), where Western institutions hoard digital archives. Conversely, they can empower marginalised communities to reclaim narratives through crowdsourced documentation (Ryzewski 2017).

2.3. Cultural heritage laws: international and national frameworks

UNESCO's *1972 World Heritage Convention* and *2003 Convention for the Safeguarding of the Intangible Cultural Heritage* emphasise state sovereignty over heritage, while promoting international cooperation. The *2019 Recommendation on the Protection and Promotion of Museums and Collections, Cultural Objects and Cultural Heritage Tangible and Intangible in the Digital Era* addresses digital issues but lacks enforceability (UNESCO 2019).

At the national level, France's 2004 Heritage Code asserts state ownership of archaeological finds, centralising decision-making (Service de la Conservation du Patrimoine 2004). Mali's 1985 Heritage Law (Loi No. 85-36) similarly vests ownership in the state but mandates community consultation for sites of living cultural significance, such as Dogon lands (Ministère de la Culture du Mali 1985). However, limited resources hinder enforcement in Mali (Diallo 2015).

3. Case studies

3.1. Lascaux Cave and the Lascaux IV Virtual Replication Project

Discovered in 1940 by a group of teenagers in the Dordogne region, Lascaux Cave's Palaeolithic paintings are celebrated for their artistic sophistication. There is no proper dating of the site's rock art, and some of it, such as the large so-called aurochs mentioned below, is more likely to be of the Holocene (<12 ka BP), as first pointed out by Paul Bahn. None of the numerous radiocarbon-dated charcoal fragments from the uncontrolled excavations can be related to any rock art. All the cave's rock art is essentially undated, but it is clear that various time periods have contributed to the large assemblage. The 'Great Hall of the Bulls', featuring a 5.2-metre-long aurochs, and the 'Shaft of the Dead Man', with its enigmatic composition of a 'bison', 'bird' and 'human' figure, offer unparalleled insights into Upper Palaeolithic symbolism (Bataille 2005). By the 1950s, annual visits exceeded 150,000, leading to visible deterioration: carbon dioxide levels rose, mould proliferated, and calcification began obscuring the paintings. In 1963, the French Ministry of Culture closed the cave to the public, marking a turning point in heritage preserva-

Figure 2. *Original Palaeolithic paintings in Lascaux Cave. A close-up of the 'Great Hall of the Bulls' featuring large animal depictions, including a 5.2-metre aurochs, is one of the most iconic images of Palaeolithic art.*

tion philosophy—prioritising long-term conservation over immediate access (Centre International de l'Art Pariétal 2016).

Lascaux II, a partial replica opened in 1983, used hand-painted copies but lacked the original's spatial complexity. Lascaux IV, unveiled in 2016 after a decade of planning, represents a technological leap. A team of 40 specialists from France, Belgium, and Canada employed terrestrial laser scanning (TLS) with a precision of 0.5 mm to map the cave's 900-square-metre surface. The scans generated 800 billion data points, which were processed into a 3D mesh using software like CloudCompare and MeshLab. For the paintings, high-resolution photography (120 megapixels per image) captured pigments and patina variations, while x-ray fluorescence (XRF) analysis identified mineral compositions—data used to mix custom pigments for the replica (Debray 2016). The final structure, built 300 metres from the original, includes not just the cave replica but a visitor centre with interactive exhibits, costing €66 million (75% funded by the French state, 25% by regional authorities).

The project's ethical dimensions are multifaceted. Technologically, Lascaux IV raises questions about authenticity: while the replica matches the original's geometry and colourimetry, it omits micro-irregulari-

Figure 3. *Lascaux IV virtual replica. Visitors exploring the life-sized replica, with guided tours using AR headsets to overlay interpretive content on the replicated paintings.*

ties (e.g. small cracks, mineral deposits) that carry archaeological meaning. As Debray (2016) argues, this 'hyperrealism' creates a 'museum of absence', where the replica's perfection masks the original's fragility—a deliberate choice to prioritise public engagement over scientific exactitude. Culturally, the French state's framing of Lascaux as a 'national treasure' (Centre International de l'Art Pariétal 2016) reflects a top-down approach to heritage governance. Local communities in Montignac (population 1500) were consulted primarily on tourism infrastructure (e.g. parking, signage) but had no role in decisions about replication methods or data ownership. While 15% of Lascaux IV's revenue supports local development, critics note this economic inclusion does not translate to cultural agency (Van Reybrouck 2018).

Visitor feedback, collected via surveys (n=2000) in 2017–2018, reveals a paradox: 89% reported feeling 'emotionally connected' to the replica, yet 63% expressed curiosity to visit the original—suggesting digital replication may heighten, rather than diminish, demand for access to the authentic site (Centre International de l'Art Pariétal 2018). This underscores a tension between conservation goals and public expectations, a challenge amplified by the project's global reach: 40% of visitors are international, many drawn by Lascaux's status as a UNESCO World Heritage Site.

3.2. Dogon rock art and its 3D documentation practice

The Dogon Plateau, a 20,000-square-kilometre region in central Mali, is home to one of Africa's most extensive rock art complexes. Over 4000 panels, scattered across cliffs, boulders and shelters, span 5000 years—from hunter-gatherer depictions of giraffes and antelopes (3000–1000 BCE) to Iron Age scenes of agriculture and warfare (1000 BCE–1500 CE) (Joffroy 2003). For the Dogon people, who settled the region in the 14th century, these artworks are not mere relics but 'living texts' tied to creation myths, initiation rituals and agricultural cycles. The panel at Sangha, depicting a serpent coiled around a human figure, is believed to mark the spot where the first ancestor descended to Earth; annual ceremonies there involve libations and chants to honour ancestral spirits (Sarr et al. 2020).

Since 2012, the region has faced dual threats: climate erosion (rainfall has increased 15% in the Sahel since 1990, accelerating rock weathering) and conflict-related looting (during the 2012 Tuareg rebellion, armed groups targeted archaeological sites for artefact smuggling) (UNESCO 2013). In response, a coali-

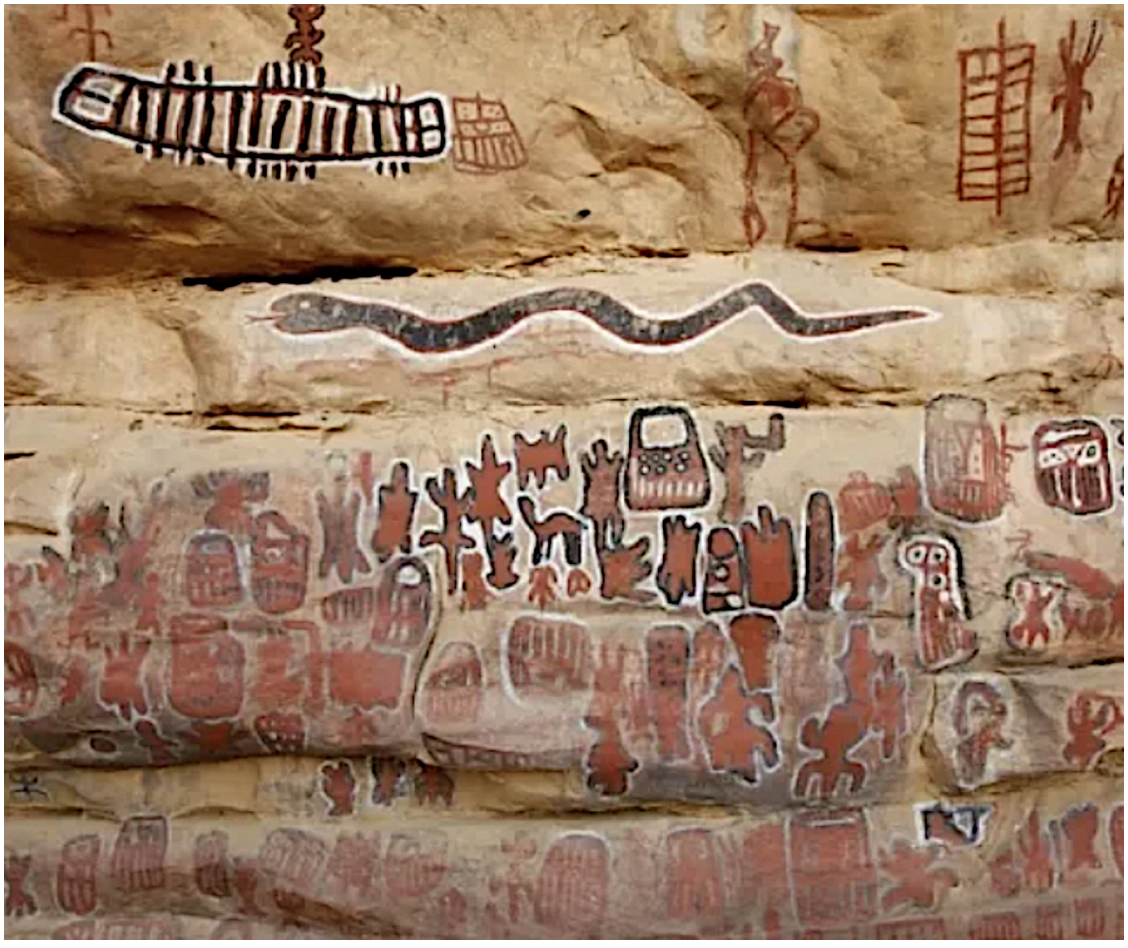

Figure 4. *Dogon rock art panels. A panel at Sangha depicting a serpent and human figure, central to Dogon creation myths and annual ceremonies.*

tion of institutions—including Mali's Institut des Sciences Humaines (ISH), France's University of Tours and the nonprofit African Rock Art Heritage Initiative (ARAHI)—launched a 3D documentation project in 2015.

The project's technical constraints stand in stark contrast to Lascaux IV. With a total budget of €350,000 (funded by the European Union's Culture Programme), the team prioritised cost-effective methods: consumer-grade drones (DJI Phantom 4) for aerial mapping and structure-from-motion (SfM) photogrammetry using DSLR cameras (Canon EOS 5D) instead of laser scanners. For each panel, 200–300 overlapping images were processed into 3D models using Agisoft Metashape, achieving a resolution of 2–3 mm—sufficient for conservation monitoring but not for detailed pigment analysis (Sarr et al. 2020). Fieldwork was logistically challenging: 60% of sites are accessible only by foot or donkey; during the 2018–2019 dry season, temperatures exceeding 45°C damaged camera batteries, requiring midday work stoppages (UNESCO 2020).

Community engagement took two forms: local guides from nearby villages (e.g. Bandiagara) were hired to locate sites and negotiate access to sacred areas, and 12 Dogon youth (ages 18–25) participated in a 10-day training workshop on photogrammetry basics. However, power imbalances persisted: French researchers controlled data processing (models were initially stored on the University of Tours servers), and decision-making was dominated by ISH officials in Bamako, 600 km from the plateau. When Dogon elders requested that certain panels (e.g. those depicting initiation rituals) be restricted from public access, the team agreed but noted that 'technical limitations' (open-source software's difficulty in encrypting 3D models) delayed implementation for 18 months (Sarr et al. 2020).

Data ownership remains contested. While a copy of the archive was transferred to Mali's National Museum in 2021, the University of Tours retains the master files, citing 'long-term preservation needs'. This arrangement mirrors colonial-era practices, where European institutions housed African heritage collections (Coombes 2003). As one elder from Tireli village stated in an interview: "They take pictures of our rocks, but we don't know who looks at them or what they do with them. It's like when the French took our masks a hundred years ago—same story, different tools" (Sarr et al. 2020: 185).

4. Comparative analysis

4.1. Technological applications and their ethical implications

The technological divergence between Lascaux IV and the Dogon project reflects not just resource disparities but differing institutional priorities. Lascaux IV's €66 million budget enabled cutting-edge TLS and custom pigment replication, prioritising visual fidelity for tourism and education. The project's technical report emphasises 'replicating the visitor's sensory experience' (Centre International de l'Art Pariétal 2016: 47)—a goal that required minimising deviations from the original, even if it meant smoothing over archaeological imperfections. This approach aligns with France's tradition of 'heritage as spectacle', seen in initiatives like the Louvre's VR tours, which frame cultural institutions as global entertainment destinations (MacDonald 2013).

In contrast, the Dogon project's €350,000 budget forced trade-offs: prioritising coverage (documenting 500 panels) over precision, using SfM instead of TLS, and forgoing on-site data processing. The team's 2020 report acknowledges that 15% of models had 'artefacts due to motion blur' (Sarr et al. 2020: 178), a consequence of working in low-light cave shelters. Yet these limitations also fostered adaptability: when drone regulations tightened in Mali in 2019, researchers shifted to ground-based photography, collaborat-

Category	Lascaux IV	Dogon 3D
Budget	Large-scale (€57 million) with funding from governments, the EU, and regional bodies.	Modest, fragmented funding (NGOs, crowdfunding, small grants).
Equipment used	Industrial-grade tools: submillimetre laser scanners, high-res (25–32 MP) cameras, resin casting, and environmental simulation systems.	Consumer-grade tools: DSLR cameras, affordable scanners, drones (likely), and 3D printing (limited industrial equipment).
Data resolution	Submillimeter precision (1 mm tolerance), 25–32 MP imagery, and acoustic/environmental replication.	Variable resolution with no published standards; prioritises usability over extreme precision.
Stakeholder access to digital files	Restricted access (controlled by cultural authorities) for research and museum use; public engagement via curated exhibits.	Open access to models (e.g. on Sketchfab) for non-commercial use; unclear community control over raw data.

Table 1. *Technological comparison between the Lascaux IV and Dogon 3D projects. A side-by-side analysis of budget allocation, equipment used, data resolution and stakeholder access to digital files.*

ing with local masons to build scaffolding for hard-to-reach panels. This flexibility, born of constraint, created more opportunities for community input than Lascaux IV's rigid technical plan.

Ethically, both projects grapple with 'digital materiality'—how technological choices shape cultural meaning. Lascaux IV's hyperrealism risks reducing the cave to a visual commodity, stripping it of its potential historical context as a ritual space (Debray 2016). A 2019 study comparing visitor experiences found that 72% of Lascaux IV visitors described the replica as 'impressive' but only 31% connected it to Palaeolithic society, compared to 68% of researchers who accessed the original cave (Martin and Dupont 2020). The Dogon models, while less polished, retain visible 'imperfections' (e.g. shadows from camera equipment) that signal their status as constructed representations—reminding users of the documentation process and, by extension, the presence of human (and cultural) choices in creating the digital archive (Waterton and Watson 2010).

Technology also influences data control. Lascaux IV's reliance on proprietary software (e.g. Leica Cyclone for point cloud processing) limits who can modify or interpret the data; only 12 certified technicians in France have full access. The Dogon project's use of open-source tools (Agisoft Metashape, Blender) allows broader participation. Still, this openness carries risks: in 2022, a low-resolution model of a sacred panel was uploaded to a 3D-sharing platform by a student researcher, prompting protests from Dogon elders (Sarr et al. 2022). This highlights a paradox: closed systems restrict sovereignty, while open systems risk exploitation.

4.2. Cultural sovereignty and community roles

Cultural sovereignty manifests differently in each case, shaped by colonial histories and contemporary power structures (Benjamin 1968). France's approach to Lascaux reflects a 'statist' model of heritage governance, rooted in 19th-century policies that centralised control over archaeological finds as a tool of national identity-building (Service de la Conservation du Patrimoine 2004). The 2004 Heritage Code explicitly states that 'all movable and immovable heritage of pre-Historic origin is the property of the state' (Article L311-1), with no provisions for community co-management. This legal framework enabled the Lascaux IV project to proceed with minimal local input, as the state's right to 'preserve and present' heritage was considered paramount (Centre International de l'Art Pariétal 2016: 12).

Mali's postcolonial context creates a more complex landscape. The 1985 Heritage Law, drafted after independence, balances state ownership with community rights: Article 14 requires 'prior consultation with local populations' for projects affecting 'heritage of living cultural significance' (Ministère de la Culture du Mali 1985). However, implementation is weak: a 2020 audit found that only 30% of heritage projects in Mali complied with consultation requirements, due to underfunded regional offices and a lack of legal penalties for noncompliance (Diallo 2015). In the Dogon project, this translated to perfunctory meetings with village chiefs, who were not empowered to veto decisions—a form of 'token participation' that Spivak (1999) critiques as reinforcing colonial power dynamics.

Community roles also reflect economic disparities. In Montignac, Lascaux IV's tourism generates 120 local jobs (e.g. tour guides, hotel staff), creating a financial stake in the project but not cultural authority. Dogon communities, with fewer economic alternatives, rely on project stipends (guides earn €5/day, below Mali's minimum wage of €1.20/hour) that create dependency. As one Dogon youth trained in photogrammetry noted: "We can take pictures, but we can't decide what to do with them. If we ask questions, they might not hire us next season" (Sarr et al. 2020: 182).

Postcolonial theory helps unpack these dynamics. Said's (1978) concept of 'Orientalism' illuminates how Lascaux is framed as a 'universal' heritage site, while Dogon art is often exoticised as 'primitive' in international discourse—justifications that rationalise differential treatment. French researchers at Lascaux frame their work as 'protecting world heritage', while in Mali, foreign involvement is framed as 'assisting' a 'developing nation'—narrative choices that mask power imbalances (Olwig 2002).

4.3. Legal compliance and its impact

Both projects adhere to national laws but with varying degrees of rigour, reflecting enforcement capacities. France's robust institutional infrastructure facilitates Lascaux IV's compliance: the Ministry of Culture's regional office in Bordeaux conducted 12 site inspections during replication, ensuring adherence to the 2004 Heritage Code's requirements for 'non-destructive documentation' (Article L621-3). The project also complied with the *1978 French Data Protection Act* by restricting access to 3D models of the original cave (only five researchers have full access). However, critics note this secrecy undermines scientific transparency (Debray 2016).

In Mali, legal compliance is hampered by institutional fragility. The 1985 Heritage Law mandates that digital archives of cultural heritage be stored in Malian institutions, but the Dogon project initially stored data in France due to 'security concerns' (Sarr et al. 2020: 176)—a delay that violated Article 23. Mali's National Museum, tasked with oversight, lacks climate-controlled storage for digital media, requiring the use of French servers. This reliance on external infrastructure echoes colonial-era practices, where African heritage was preserved in European museums due to claims of 'superior' conservation capacities (Coombes 2003).

Internationally, both projects engage selectively with UNESCO frameworks. Lascaux IV aligns with the 1972 World Heritage Convention's emphasis on 'preservation through presentation,' using the replica to fulfil the convention's mandate for public access. The Dogon project references the 2003 Intangible Heritage Convention but struggles to implement its community participation requirements due to funding constraints. UNESCO's 2019 Digital Heritage Recommendation, which calls for 'equitable access to digital data', is cited in both projects' reports but not operationalised—highlighting the gap between international ideals and on-the-ground practice (UNESCO 2019).

Legal disparities also affect dispute resolution. When Lascaux IV's replica was criticised for altering a painting's colour (a 2017 study found a 15% hue difference in the aurochs' mane), the Ministry of Culture convened a panel of archaeologists and artists to revise the replica— a process enabled by clear legal protocols. In 2021, when Dogon elders discovered their sacred panel online, Mali's cultural ministry lacked the resources to investigate, relying on ARAHI to request its removal—a slow, informal process that underscored legal powerlessness (Sarr et al. 2022).

5. Discussion

5.1. Broader implications for digital conservation and governance

The comparative analysis reveals that digital conservation is not a neutral technical process but a cultural practice embedded in power relations. Lascaux IV and the Dogon project illustrate two poles of a spectrum: one where technological sophistication and state resources enable control over heritage narratives, and another where limited resources and postcolonial dependencies constrain sovereignty. This spectrum reflects broader global inequalities in heritage governance, where 70% of digital conservation funding goes to European sites, despite Africa housing 30% of the world's archaeological sites (European Commission 2018).

Key lessons emerge for ethical practice. First, technological choices must be culturally informed, not just technically driven. Lascaux IV's hyperrealism, while impressive, prioritises Western notions of 'authenticity as fidelity' over the site's potential ritual significance. This bias could be mitigated by including archaeologists specialising in Palaeolithic spirituality in design decisions. Second, community participation requires structural changes, not just token inclusion. The Dogon project's training program, while well-intentioned, failed to address power imbalances; a more effective model might involve community-owned cooperatives managing data, as seen in Kenya's Lamu Old Town digital archive (Ryzewski 2017).

Postcolonial dynamics demand decolonising digital heritage practices. This could involve 'reverse knowledge transfer', where African teams train European counterparts in community-based documentation, or redistributive funding models that direct 50% of global heritage tech grants to postcolonial nations. As Matsuda (2018) argues, decolonisation requires recognising that 'heritage expertise is not geographically bound'—a principle violated by the Dogon project's reliance on French researchers for data processing.

5.2. Potential solutions to ethical challenges

Addressing technological inequity requires targeted investments in local capacity. Open-source hardware initiatives, such as the African-made 'ScanAfrica' 3D scanner (costing €500, compared to €50,000 for commercial models), could democratise access to technology (Ames et al. 2019). Pilot projects in Senegal and Ethiopia have shown that community members can achieve 1 mm resolution with these tools after 40 hours of training—sufficient for most conservation needs. For Lascaux-like projects, 'ethical impact assessments' (EIAs) could mandate that 20% of funding be allocated to international knowledge-sharing, ensuring that technical expertise flows to resource-poor regions.

Legal reforms are critical to strengthening cultural sovereignty. Mali's proposed heritage bill (Ministère de la Culture du Mali 2023) is a step forward: it mandates that 'digital archives of heritage shall be owned and managed by Malian institutions' (Article 47) and requires 50% community representation on project steering committees. Enforcement mechanisms, such as fines for noncompliance (€10,000 for foreign institutions) and a dedicated digital heritage unit in the Ministry of Culture, address gaps in the 1985 law. France could amend its 2004 Heritage Code to include provisions for indigenous or local community input, even for pre-Historic sites, acknowledging that 'national' heritage often overlaps with regional or minority identities.

International frameworks need teeth. The UNESCO 2019 Recommendation could be strengthened by creating a 'Digital Heritage Ombudsperson' to mediate disputes over data ownership, as well as a global fund to support local archive infrastructure. A precedent exists in the *1970 UNESCO Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property*, which established a clearinghouse for stolen artefacts— a model adaptable to digital contexts.

Community-led governance models offer promise. The Dogon project's 2021 transition to a 'data trust' (a legal entity managed by Dogon elders, ISH representatives, and ARAHI) provides a blueprint: the trust owns the digital archive, approves access requests and reinvests licensing fees in local schools. Initial challenges—elders' limited digital literacy—were addressed through partnerships with Mali's Ecole Normale Supérieure, which provides monthly

training sessions. Similar trusts in Australia's Uluru-Kata Tjuta National Park have successfully managed Anangu rock art digital archives since 2015, demonstrating long-term viability (Blake 2009).

5.3. Future research

Longitudinal studies are needed to assess community responses over time. A five-year follow-up on Lascaux IV could track whether local perceptions shift from economic gratitude to demands for cultural participation. At the same time, a Dogon study could measure how data trust governance affects community attitudes towards preservation. Mixed methods—surveys, interviews and participant observation—would capture both quantitative trends and nuanced qualitative insights.

Comparative research in other postcolonial contexts would enrich understanding. Case studies in India (Ajanta Caves' 3D documentation) and Peru (Nazca Lines digital mapping) could reveal whether similar power dynamics persist, or if regional variations (e.g. India's stronger legal framework for indigenous rights) lead to more equitable outcomes. Cross-cultural analysis could identify transferable strategies, such as India's use of 'heritage custodians' (local residents trained as co-managers) (Logan and Reeves 2009).

Technological innovation demands ethical foresight. As AI (e.g. machine learning for automated rock art classification) becomes more prevalent, research should explore its impact on cultural interpretation: will algorithms trained on Western archaeological data misclassify African motifs? Can AI be programmed to respect 'sensitive content' designations by communities? Collaborative research between computer scientists and cultural anthropologists is essential to developing ethical AI tools.

Finally, historical research into colonial-era digital precursors could inform present practice. French colonial archives from the 1950s contain photographs of Dogon rock art, used to justify 'civilising missions'—a precursor to modern digital extraction. Comparing these historical practices to contemporary projects could illuminate how power dynamics persist or transform, offering lessons for decolonisation (Coombes 2003).

6. Conclusion

Lascaux IV and the Dogon 3D project stand as mirror images of digital conservation's promise and perils. France's technological prowess enables control over a heritage narrative framed as universal, while Mali's resource constraints force reliance on external partners, risking renewed forms of colonialism. Both cases reveal that digitisation amplifies existing power dynamics: it does not create ethical dilemmas but makes visible the inequalities inherent in global heritage governance.

The path forward requires centring cultural sovereignty as a non-negotiable principle, not an afterthought. This means redesigning technological tools for local ownership, reforming laws to enforce community rights and reimagining international partnerships as horizontal collaborations rather than hierarchical 'aid'. For Lascaux, this could involve decentralised access to 3D data for regional researchers, breaking the state's monopoly on interpretation. For the Dogon, it means strengthening the data trust model to ensure long-term community control over digital archives.

Ultimately, digital conservation's ethical potential lies in its ability to expand, rather than restrict, cultural sovereignty. When communities control the tools and narratives of preservation, digitisation becomes a means of self-determination—a way to assert ownership over heritage in a globalised world. As the Dogon elder quoted earlier recognised, the technology may change, but the struggle for sovereignty endures. It is this struggle that must shape the future of digital heritage.

Dr Jiawei Zeng
School of Foreign Languages of Central South University, Changsha City, Hunan Province, China
231111024@csu.edu.cn

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