

Data Traceability and Digital Quality Infrastructure in Africa: A Systematic Review of Export Compliance for EU, US, and East Asian Markets

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Abstract:

The current scenario of international trade is undergoing a major change, where data traceability and DQI are becoming crucial factors that will determine access to markets for products from Africa. The current literature review aims to systematically review existing literature on the challenges faced by African exporters to meet the rigorous compliance standards in Europe, the USA, and East Asia. It is observed that the main barriers faced by African producers include poor metrology systems, supply chain issues, poor digital connectivity, and high compliance costs of about USD 20,000 for small and medium-sized enterprises. Such issues are further complicated by increasingly complex regulatory regimes like the EU Deforestation Regulation (EUDR), Carbon Border Adjustment Mechanism (CBAM), and Corporate Sustainability Due Diligence Directive (CSDDD), which require a new level of supply chain visibility, geolocation confirmation, and verified carbon measurement. While continental bodies like the Pan African Quality Infrastructure (PAQI) and Intra-Africa Metrology System (AFRIMETS) offer institutional frameworks, there remain substantial gaps in implementation. Innovations at the national level, such as Ethiopia's Coffee Traceability and Management System, show the possibilities of customized solutions. The paper has been able to highlight important gaps in the literature and provide some recommendations that will be helpful for policymakers, exporters, and development partners. The study claims that the use of digital technology to improve the quality of infrastructure, harmonize standards, and build capacity could help turn compliance into an advantage for African exporters. Considering the fact that the deadline for EUDR compliance is fast approaching in December 2026, it is imperative to act now to ensure Africa's place in global value chains.

Keywords:

Data Traceability; Digital Quality Infrastructure; Export Compliance; African Trade; EUDR and CBAM

I. Introduction

1.1 Background and Rationale

The global trade landscape is undergoing a profound transformation, driven by the increasing digitization of supply chains and the proliferation of data-driven regulatory requirements in major import markets. For African exporters, this shift presents both a significant challenge and a critical opportunity. The growing importance of data traceability and digital quality infrastructure (DQI) as determinants of market access cannot be overstated. In an era where sustainability credentials, product origin verification, and carbon footprints are becoming non-negotiable conditions for entry into high-value markets, the ability to generate, manage, and share verifiable data along supply chains has emerged as a new dimension of export competitiveness.

The stakes are considerable. Sub-Saharan Africa is projected to contribute 19% of all additional global agricultural production over the next decade, up from 13% in the previous decade (OECD & FAO, 2025). This represents a decisive shift in which the region is not only essential to global food supply chains today but is rapidly becoming a significant driver of global agricultural output growth. Yet this growth potential is contingent upon African producers' ability to meet the increasingly stringent compliance requirements of destination markets. East Africa alone risks over €2.75 billion in export earnings if compliance gaps persist, with only 15% of agribusinesses fully aware of incoming regulatory requirements (Danish Industry Report, 2024).

Traditional trade barriers, tariffs and quotas have gradually given way to data-driven compliance requirements as the primary gatekeepers of market access. The European Union, the United States, and East Asian markets have all enacted or are in the process of enacting regulations that demand unprecedented levels of supply chain transparency, product traceability, and sustainability verification. This shift represents a fundamental change in the architecture of global trade: compliance is no longer merely a matter of meeting product standards at the point of entry but requires the continuous generation and verification of data throughout the entire value chain.

1.2 Problem Statement

Despite the growing importance of data traceability and digital quality infrastructure for market access, African exporters face systemic measurement and data challenges that fundamentally undermine their competitiveness in high-value markets. These challenges manifest across multiple dimensions, creating a compliance gap that threatens to exclude African producers from the very markets that offer the greatest returns.

The first dimension concerns weak metrology infrastructure. African countries continue to struggle with effective metrology institutes, limiting their ability to prove measurement equivalence and provide analytical assurances for export products. The continent's quality infrastructure remains fragmented, with a disconnect between standardization, accreditation, metrology, and conformity assessment elements that creates multiple technical barriers to trade. Existing gaps such as manual certification, limited technical capacity, outdated standards, and weak international recognition persist across the continent. For example, only about 60% of Ethiopia's 12,600 standards are harmonised with ISO, Codex, or ARSO, and key export standards such as Maximum Residue Limits remain outdated.

The second dimension concerns fragmented supply chains and lack of verifiable data. Agricultural supply chains across Africa are characterised by multiple layers of intermediaries; village collectors, aggregators, traders, processors, and exporters, resulting in weak visibility and information silos. More than 75% of agriculture in Ethiopia, Kenya, Tanzania, and Uganda depends on smallholder farmers, many of whom lack formal land documentation required for geolocation verification. Farmers interviewed in Uganda and Tanzania reported being asked by exporters to provide exact farm coordinates despite lacking smartphones, formal land documents, or reliable internet connectivity. Smartphone penetration in East Africa lingers below 30%, making digital mapping an operational challenge rather than a simple technological upgrade.

The third dimension concerns the high cost of compliance. International standards compliance for African SMEs carries a medium cost of approximately USD 20,000, which significantly affects margins and participation in global trade. These costs are often incurred

upfront, while the benefits of compliance are realised only over time and through sustained market access. For smallholder farmers, the burden is even more disproportionate, some may be required to spend up to 75% of their annual income on compliance, while larger exporters absorb a much smaller share of their revenue.

The fourth dimension concerns the gap between existing African quality infrastructure and evolving digital compliance demands. While continental frameworks such as the Pan African Quality Infrastructure (PAQI) and the Intra-Africa Metrology System (AFRIMETS) exist, their capacity to support the digital transformation required for compliance with regulations like EUDR, CBAM, and CSDDD remains limited. The continent's ability to prove measurement equivalence and provide analytical assurances for export products is crucial, yet current capabilities fall short of what is required.

1.3 Research Objectives and Questions

The primary objective of this systematic review is to synthesize existing research on data traceability and digital quality infrastructure challenges facing African exporters, with particular attention to compliance requirements in the European Union, United States, and East Asian markets.

This review is guided by the following research questions:

- a. What is the current state of data traceability and digital quality infrastructure in Africa?
- b. What are the specific compliance requirements for EU, US, and East Asian markets?
- c. What are the barriers to achieving compliance?
- d. What strategies and initiatives are addressing these challenges?

II. Review of Literature

2.1 Defining Data Traceability in the Export Context

Traceability constitutes the foundational capability upon which contemporary export compliance regimes are built. The International Organization for Standardization (ISO) defines traceability as the “ability to trace the history, application or location of an entity by means of recorded identifications” (ISO, 199.). The Codex Alimentarius Commission adopts a complementary definition, framing traceability as “the ability to follow the movement of a food through specified stage(s) of production, processing and distribution”. These definitions, while technically precise, require significant operational elaboration when applied to the African export context.

In the contemporary trade environment, a critical distinction must be drawn between physical traceability, the capacity to track the movement of goods through supply chains and data traceability, the capacity to generate, manage, and transmit verifiable information accompanying products through each stage of production, processing, and distribution. Data traceability encompasses not only the location and movement of products but also the environmental, social, and governance attributes that increasingly determine market access. These include geolocation coordinates of production plots, evidence of deforestation-free sourcing, verifiable legal origin documentation, carbon emissions data, and compliance with labour and environmental standards.

For African exporters, data traceability represents both a formidable challenge and a strategic imperative. The European Union absorbs over 60% of East African Community coffee exports, and with regulations such as the EU Deforestation Regulation (EUDR) and the Corporate Sustainability Due Diligence Directive (CSDDD) now in force, more than

€2.75 billion in trade value is at risk if compliance gaps persist. Only 15% of agribusinesses fully understand these incoming regulations, and most supply chains continue to operate with major traceability gaps; fragmented data, limited geolocation coverage, and inconsistent farmer records.

The structural characteristics of African agricultural supply chains compound these traceability challenges. Supply chains are highly fragmented, involving multiple layers of intermediaries; village collectors, aggregators, traders, processors, and exporters, resulting in weak visibility and inconsistent documentation at each stage. More than 75% of agriculture in Ethiopia, Kenya, Tanzania, and Uganda depends on smallholder farmers, many of whom lack formal land documentation required for geolocation verification. Farmers in Uganda and Tanzania have reported being asked by exporters to provide exact farm coordinates despite lacking smartphones, formal land documents, or reliable internet connectivity. Smartphone penetration in East Africa lingers below 30%, making digital mapping an operational challenge rather than a simple technological upgrade. These structural constraints fundamentally shape the feasibility and cost of implementing data traceability systems across African supply chains.

2.2 Digital Quality Infrastructure: Components and Functions

Quality Infrastructure (QI) is defined by the International Network on Quality Infrastructure (INetQI) as “the system comprising the organizations (public and private) together with the policies, relevant legal and regulatory framework, and practices needed to support and enhance the quality, safety and environmental soundness of goods, services and processes”. The United Nations Industrial Development Organization (UNIDO) elaborates that QI is “a system contributing to governmental policy objectives in areas including industrial development, trade competitiveness in global markets, efficient use of natural and human resources, food safety, health, the environment and climate change”. INetQI further emphasizes that QI “enables access to foreign markets, promoting and sustaining economic development and environmental and social wellbeing”.

Traditional QI comprises five interconnected pillars: standardization, accreditation, metrology, conformity assessment, and market surveillance. A disconnect between these elements in Africa has a negative impact on intra-Africa trade, as goods cannot move from one point to another without being subjected to multiple quality tests. The absence of functional quality infrastructure (QI) undermines companies’ competitiveness in domestic, regional and global markets. It gives rise to multiple technical barriers to trade, compromises safety in industrial production environments, leaves consumers unprotected from unsafe products, and impedes digitalization and innovation.

The digital transformation of quality infrastructure, referred to as Digital Quality Infrastructure (DQI) represents a paradigm shift in how quality assurance, conformity assessment, and market access are managed. The important aim of improving infrastructure quality in the digitalization of metrology is to strengthen the three main pillars: metrology services, accreditation, and standardization. Digitalizing the quality infrastructure is a very substantial objective for public and industrial stakeholders, requiring the thorough transformation of a huge variety of quality-related documents into appropriate digital representations.

Key components of DQI include:

Digital Calibration Certificates: The transformation from paper-based to digital calibration certificates enables real-time verification, reduced administrative burden, and enhanced traceability of measurement results.

Digital Product Passports (DPPs)

DPPs represent a transformative tool for African exporters facing increasingly stringent EU compliance requirements. The Africa DPP Registry provides SHA-256 forensic Digital Product Passports for African exporters facing EU ESPR and Battery Regulation compliance, serving as “the compliance bridge between African exporters and the mandatory EU digital verification systems that will govern market access for physical goods sold into the European Union”. Without registered Digital Product Passports, African exporters risk automated customs rejection and loss of EU market access as the regulatory system goes live.

Federated Data Spaces

Interoperable and secure data-sharing environments are required to enable the reliable exchange of quality-related information across supply chains, regulatory bodies and market actors.

A versatile digital quality infrastructure benefits from a common structural concept supporting the variety of quality-related documents and bears synergies across different applications and sectors. For African exporters, the development of DQI is not merely a technical upgrade but a fundamental prerequisite for maintaining and expanding market access in an increasingly data-driven regulatory environment.

2.3 The African Quality Infrastructure Landscape

The African continent has established a comprehensive institutional architecture to coordinate quality infrastructure development, centred on the Pan African Quality Infrastructure (PAQI). Established in August 2013, PAQI serves as “the continental platform for all matters related to standardization, metrology, accreditation, and conformity assessment”. PAQI was created to provide a unified voice for Africa in the global quality landscape and to serve as a technical engine for the African Continental Free Trade Area (AfCFTA), ensuring that African goods and services are competitive globally and fostering regional integration.

PAQI comprises four continental institutions, each specializing in a critical component of Quality Infrastructure:

AFRIMETS (Intra-Africa Metrology System) : Established in 2006, AFRIMETS promotes the harmonization of scientific, industrial, and legal metrology, ensuring accurate measurements across Africa. The main objective of AFRIMETS is to promote metrology and related activities in Africa with the view of facilitating intra-African and international trade and to ensure the safety and health of the public and environmental protection. AFRIMETS is internationally recognized as the regional metrology organization (RMO) for Africa by the International Committee for Weights and Measures (CIPM) through the International Bureau of Weights and Measures (BIPM) and the International Organisation of Legal Metrology (OIML).

ARSO (African Organisation for Standardisation) : Africa's intergovernmental standards body formed in 1977, ARSO develops tools for standards development, standards harmonization, and implementation of these systems to enhance Africa's internal trading capacity and increase Africa's product and service competitiveness globally.

AFRAC (African Accreditation Cooperation): Established in 2010, AFRAC provides accreditation support to industry and trade and contributes to the protection of health and safety of the public and the protection of the environment.

AFSEC (African Electrotechnical Standardisation Commission) : Established in 2008, AFSEC supports African electricity infrastructure development with standards and conformity assessment services.

Despite this robust institutional framework, significant implementation gaps persist. A systematic review found that 48.3% of State Parties would not fully comply with the requirements of Annex 6 as described by the PAQI TBT Stocktaking document 2020. The level of adoption of harmonized African Standards and Conformity Assessment Regimes by Regional Economic Communities and AU Member States is increasing, yet a number of initiatives of Mutual Recognition Arrangements exist among African Member States.

2.4 The Compliance-Regulation Nexus

The relationship between compliance and regulation has undergone a fundamental transformation in international trade. Trade compliance has evolved from a declarative exercise—where exporters simply declared product characteristics at the point of entry—to a verification-intensive process requiring continuous data generation, documentation, and validation throughout the supply chain.

This transformation is particularly evident in the regulatory instruments reshaping market access for African exporters:

The EU Deforestation Regulation (EUDR) requires that commodities such as cocoa, coffee, timber, palm oil, and rubber sold in the European Union be proven deforestation-free and legally produced. The regulation mandates that products be linked to specific plots of land through geolocation coordinates, with due diligence statements submitted through the EU's TRACES system. Proving that a bag of cocoa or a container of sawed timber is deforestation-free requires a digital trail from the farm to the European market, depending on satellite imagery, geolocation data, and verifiable documentation. The rules apply to large and medium-sized EU operators from December 30, 2026, and to micro and small operators from June 30, 2027.

The Carbon Border Adjustment Mechanism (CBAM) imposes a carbon charge on certain imports, matching the cost faced by EU producers under the Emissions Trading System. The CBAM could cause a fall of up to 13.9% in exports from Africa to the EU of aluminium; of iron and steel by 8.2%; of fertiliser by 3.9% and cement by 3.1%. Research by the London School of Economics projected that African export losses could amount to USD 27 billion annually if the CBAM is extended to all industrial sectors. The UN Economic Commission for Africa and the African Development Bank have warned that CBAM's impact extends well beyond emissions reduction and could influence investment decisions, industrial development, and export opportunities across developing economies. CBAM measures, while

designed to support decarbonization, can act as de facto barriers for exporters who cannot prove origin, required practices, or plant-level emissions.

The Corporate Sustainability Due Diligence Directive (CSDDD) requires verifiable legal origin and deforestation-free proof, mandating end-to-end supply-chain transparency. These regulations span multiple sectors, applying not only to high-risk commodities but to nearly all agriculture-linked exports destined for European companies.

III. Research Methods

3.1 Current State of Data Traceability and Digital Quality Infrastructure in Africa

a. Metrology Infrastructure: Status and Gaps

National Metrology Institutes (NMIs) across Africa exhibit marked unevenness in development and capacity. A small number of institutes, principally the National Metrology Institute of South Africa (NMISA), the National Institute of Standards (NIS) of Egypt, and the Kenya Bureau of Standards (KEBS), possess internationally recognised Calibration and Measurement Capabilities (CMCs) published in the BIPM Key Comparison Database. The majority of other NMIs remains at earlier stages of capability development, with limited participation in inter-laboratory comparisons and restricted scope of services (AFRIMETS, 2025; BIPM, 2025).

Fourth Industrial Revolution (IR4.0) technologies, digital twins, remote calibration, and cloud-based measurement systems are only beginning to be adopted. Most African NMIs continue to rely on traditional physical artefacts and manual procedures, creating a growing gap relative to global digital metrology trends (Rotich, 2025).

Traceability of measurements in manufacturing processes is increasingly demanded by both domestic regulators and export markets. Without reliable national measurement standards, manufacturers face difficulties demonstrating conformity, thereby encountering technical barriers to trade.

AFRIMETS, the Intra-Africa Metrology System, is the Regional Metrology Organisation recognised by the International Committee for Weights and Measures (CIPM) under the CIPM Mutual Recognition Arrangement (BIPM, 2025). Its mandate encompasses the promotion of scientific, industrial and legal metrology, capacity building, and the facilitation of intra-African and international trade.

Regional disparities remain pronounced. Ethiopia, Ghana, Tanzania, Uganda and Kenya illustrate a spectrum of maturity: Kenya and Ethiopia have made measurable progress in selected quantities, while several others still lack fully operational primary standards laboratories (AFRIMETS, 2025).

Figure 1 presents the institutional architecture of the Pan-African Quality Infrastructure (PAQI). At the centre is PAQI itself, which serves as the coordinating platform for Africa's quality infrastructure. Four specialised continental bodies radiate from this core: AFRIMETS (Intra-Africa Metrology System), responsible for scientific, industrial and legal metrology; ARSO (African Organisation for Standardisation), which develops and harmonises African standards; AFRAC (African Accreditation Cooperation), which oversees accreditation of conformity-assessment bodies; and AFSEC (African Electrotechnical Standardisation Commission), which addresses electrotechnical standards.

The bidirectional links illustrated in Figure 1 indicate that each pillar both contributes technical expertise to, and receives strategic guidance from, the central PAQI structure. This coordinated arrangement is designed to support the effective implementation of the African Continental Free Trade Area (AfCFTA) by reducing technical barriers to trade, ensuring measurement traceability, and promoting mutual recognition of conformity-assessment results across the continent.

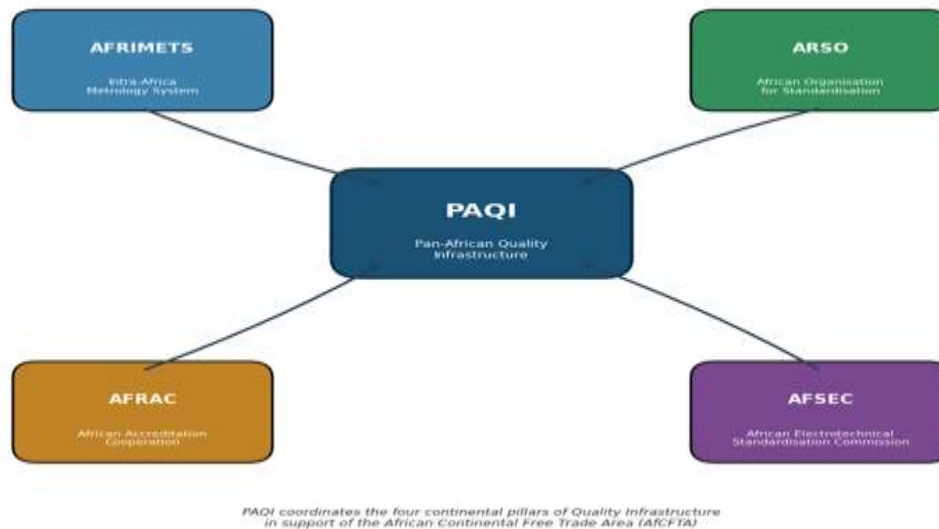


Figure 3.1 Schematic of the PAQI architecture and its four pillars (AFRIMETS, ARSO, AFRAC, AFSEC).

3.2 Digital Traceability Systems: Adoption and Maturity

African agricultural supply chains are characteristically fragmented, involving multiple intermediaries, village collectors, aggregators, traders, processors and exporters. This structure generates information silos and weak end-to-end visibility from farm to fork (Kamilaris et al., 2019; Mwangakala et al., 2024).

Digital traceability solutions, including blockchain-based platforms, are emerging as potential remedies for food-safety and transparency deficits. However, adoption remains concentrated in a few countries (notably Kenya, Nigeria and South Africa) and is constrained by infrastructure, cost and regulatory gaps (Link.springer, 2025).

A prominent recent example is the Ethiopian Coffee Traceability and Management System (ECTMS). Developed with support from GIZ and handed over in 2026, ECTMS integrates geolocation data capture via mobile application, supply-chain tracking and deforestation-risk assessment tools. It is explicitly designed to meet the requirements of the European Union Deforestation Regulation (EUDR) and to protect market access for Ethiopia's approximately USD 2 billion coffee export sector (Ethiopian Coffee and Tea Authority, 2026; Ecofin Agency, 2026).

Table 1 presents a comprehensive overview of compliance cost ranges across nine international standards relevant to African agri-food Small and Medium-sized Enterprises (SMEs). The data reveal significant financial barriers, with EUDR Traceability System compliance emerging as the most expensive requirement at USD 15,000–40,000, reflecting the substantial investment needed for geolocation data collection, digital infrastructure, and supply chain transparency systems required under the European Union Deforestation Regulation (EUDR) (European Commission, 2023; UNCTAD, 2025). FSMA

Compliance follows closely at USD 10,000–30,000, driven by FDA registration, Foreign Supplier Verification Programs, and preventive controls mandated by the US Food Safety Modernization Act (FDA, 2021).

The table further reveals that annual maintenance costs represent a significant recurring burden, typically ranging from 30–40% of initial investment, with EUDR maintenance estimated at USD 5,000–15,000 annually. This ongoing financial commitment is particularly challenging for SMEs operating on thin margins (OECD & FAO, 2025). Time to compliance varies considerably, with organic certification requiring the longest period (12–24 months) due to transition periods for farming practices, while Fair Trade and HACCP implementation can be achieved within 3–6 months (Fairtrade International, 2022; Codex Alimentarius Commission, 2020).

Table 1. Indicative Compliance Cost Ranges for Selected International Standards Relevant to African Agri-Food SMEs

Standard/Requirement	Cost Range (USD)	Annual Maintenance (USD)	Estimated Time to Compliance	Typical SME Applicability
GlobalG.A.P. Certification	5,000-15,000	2,000-5,000	6-12 months	High
Organic Certification (EU/USDA)	8,000-25,000	3,000-8,000	12-24 months	Medium
Fair Trade Certification	3,000-10,000	1,500-4,000	3-6 months	Medium
FSMA Compliance (FDA)	10,000-30,000	3,000-10,000	12-18 Months	High
EUDR Traceability System	15,000-40,000	5,000-15,000	6-18 Months	High
Carbon Footprint Verification	5,000-20,000	2,000-6,000	3-9 Months	Medium
HACCP Implementation	3,000-12,000	1,000-4,000	3-6 months	High
ISO 22000 Food Safety Management	8,000-25,000	3,000-8,000	6-12 months	Medium
Rainforest Alliance Certification	4,000-15,000	1,500-5,000	6-12 months	Medium

Notably, GlobalG.A.P

Certification, FSMA, EUDR, and HACCP all demonstrate "High" applicability to SMEs, indicating that these standards are either mandatory or expected by buyers, making them unavoidable investments for market access. The median cost of USD 8,000 for initial compliance across all standards aligns with industry estimates that African SMEs face compliance costs of approximately USD 20,000 when combining multiple standards, a burden that disproportionately affects smallholder farmers and cooperatives (UNIDO, 2022; Danish Industry Report, 2024).

At the regional level, the Intergovernmental Authority on Development (IGAD) has initiated digital trade solutions aimed at facilitating cross-border agricultural trade, although these remain at an early stage of implementation.

Figure 2 presents a geographic mapping of National Metrology Institutes (NMIs) across Africa under the Intra-Africa Metrology System (AFRIMETS), revealing a distinct spatial hierarchy in metrological capability. The figure demonstrates that North Africa (MAGMET) and Southern Africa (SADCMET) exhibit high maturity, characterized by internationally recognised Calibration and Measurement Capabilities (CMCs), indicating robust technical infrastructure and global recognition. East Africa (EAMET) displays medium maturity with growing capabilities, while West Africa (SOAMET/UEMOA) shows emerging maturity with basic services established. Central Africa remains at a limited stage, reflecting early-stage development with significant capacity gaps.

This distribution reveals a pronounced North-South advantage compared to East and West Africa, which aligns with historical patterns of industrial development, institutional investment, and technical assistance. Critically, this geographic disparity in metrological capability directly impacts exporters' ability to generate internationally validated measurement data required for compliance with regulations such as the EU Deforestation Regulation and Carbon Border Adjustment Mechanism. The least mature regions correspond precisely to areas with the highest concentration of smallholder farmers and fragmented supply chains, compounding the compliance challenges discussed in preceding sections. As noted in the figure, actual capability varies by measurement quantity and is subject to continuous development, suggesting that while the overall picture reflects current capacity gaps, targeted investments could accelerate maturity in underserved regions.

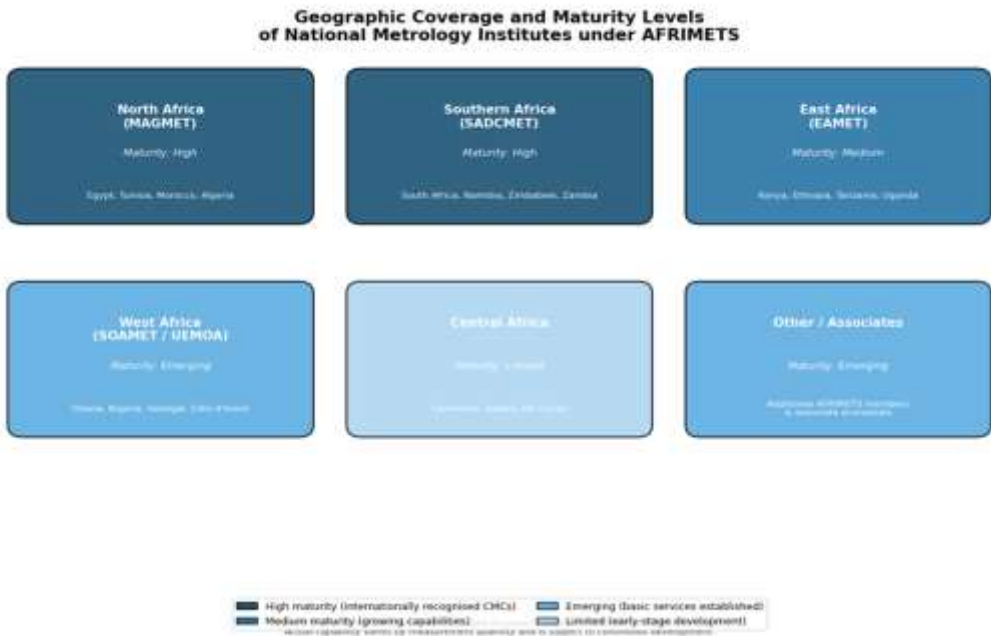


Figure 2. Geographic Distribution and Maturity of National Metrology Institutes under AFRIMETS Across African Regions.

3.3 Data Infrastructure and Digital Readiness

Smartphone penetration remains below 30 % in many rural areas of East and West Africa, constituting a fundamental barrier to the uptake of digital traceability systems that rely on mobile data capture (Food Systems Africa, 2026). Limited formal land documentation further complicates geolocation requirements mandated by regulations such as the EUDR. Measurement of embedded carbon content and Scope 3 emissions is particularly challenging. Most African countries lack standardised methodologies, and supply chains that incorporate

hundreds of small or informal suppliers render accurate quantification difficult (United Nations Environment Programme, 2023).

3.4 Regional Initiatives and Continental Frameworks

The Pan-African Quality Infrastructure (PAQI), comprising AFRIMETS, the African Organisation for Standardisation (ARSO), the African Accreditation Cooperation (AFRAC) and the African Electrotechnical Standardisation Commission (AFSEC), provides the continental coordination framework for quality infrastructure (PAQI, 2025).

AFRIMETS' strategic priorities for digital metrology include: (i) establishment of digitally connected metrology networks; (ii) harmonisation of digital measurement frameworks in support of the African Continental Free Trade Area (AfCFTA); (iii) expansion of capabilities in emerging technologies; and (iv) investment in human capital (AFRIMETS, 2025).

ARSO has undertaken benchmarking of African standards against EUDR requirements, identifying areas of alignment, gaps and pathways for continent-led compliance support (ARSO, 2025).

3.5 The Compliance Cost Challenge

Compliance with international standards imposes substantial costs on African small and medium-sized enterprises (SMEs). Indicative medium costs for common certifications frequently reach or exceed USD 20 000 when consultancy, audit, laboratory testing and infrastructure upgrades are included (Export Direct Info, 2025; Maskus et al., 2005). These costs fall disproportionately on smallholder farmers and small-scale exporters, who lack the financial and technical capacity of larger firms.

Delayed action on traceability carries further economic risk. Five interrelated barriers—fragmented data systems, low digital literacy, inadequate connectivity, high compliance costs and weak regulatory coordination, continue to threaten the competitiveness of East African agricultural exports in increasingly demanding international markets.

3.6 Export Compliance Requirements in Destination Markets

a. European Union Market Requirements

The European Union represents one of the most significant and demanding export destinations for African agricultural and manufactured products. The EU absorbs over 60% of East African Community coffee exports, making it the region's most influential buyer across Uganda, Kenya, Tanzania, Ethiopia, Rwanda, and Burundi (SEI, 2024, as cited in Koltiva, 2026). However, the regulatory landscape has undergone a fundamental transformation, with three major legislative instruments collectively reshaping market access conditions for African exporters.

3.7 United States Market Requirements

a. FDA Food Safety Modernization Act (FSMA)

The US Food Safety Modernization Act (FSMA), enacted in 2011, represents the most comprehensive reform of US food safety laws in more than 70 years. For African exporters, the FSMA introduces significant compliance requirements, particularly through the Foreign Supplier Verification Programs (FSVP).

Foreign Supplier Verification Programs (FSVP): The FSVP requires importers of most imported foods to take steps to verify that the foods they import into the United States are produced so they are safe and properly labeled with respect to allergens. The FSVP requires food manufacturers to not only audit and verify their own food safety practices, but also those of each of their suppliers.

Core Requirements: Importers must conduct a hazard analysis for each type of food they import. They must then approve each foreign supplier they use, taking into consideration the results of that analysis, the identity of the entity that will be minimizing or preventing any hazards, and the foreign supplier's performance. Importers must maintain detailed, accessible records for each imported product, available to the FDA within 24 hours of request and retained for at least two years.

Traceability Requirements: The FSMA's Food Traceability Rule requires the identification of Key Data Elements (KDEs) and Critical Tracking Events (CTEs) in the food supply chain, with food traceability expected to be a major FDA focus moving forward.

b. Conformity Assessment Burdens

African exporters face multiple conformity assessment burdens when accessing the US market:

FDA Registration Requirements: Food facilities must register with the FDA and renew their registration biennially.

Certification, Testing, and Inspection: Products may require third-party certification, laboratory testing, and inspection to verify compliance with US standards. These requirements represent significant barriers, particularly for SMEs with limited resources.

Private Standards: In addition to regulatory requirements, African exporters must often meet private standards imposed by US buyers, including GlobalG.A.P., Rainforest Alliance, and various retailer-specific standards. These private standards frequently exceed regulatory requirements and add to the compliance burden.

3.8 East Asian Market Requirements

a. Japan

Japan maintains one of the most rigorous import regulatory regimes in the world, with the Positive List System under the Food Sanitation Law governing pesticide residues in imported food and beverages.

Positive List System: The system regulates approximately 800 agricultural chemicals, including feed additives and veterinary drugs. For pesticides without a specific MRL, Japan imposes a default limit of 0.01 ppm. The system applies to foods including processed foods made from them from the production where agricultural chemicals, veterinary drugs, and feed additives may be used.

Testing Protocols: At ports, Japan's Ministry of Health, Labour and Welfare (MHLW) normally monitors between 3-10% of imports for antimicrobials, chemical residues, food additives, microorganisms, fungal toxins, and unapproved genetically engineered products.

Traceability Requirements: Japanese importers increasingly demand comprehensive traceability documentation, including information on production practices, pesticide application records, and supply chain transparency

b. China

China has emerged as an increasingly significant market for African agricultural products, with growing demand for traceable, high-quality commodities. However, regulatory requirements are tightening rapidly.

Customs Announcement No. 219 (2025) : On November 7, 2025, China's General Administration of Customs (GAC) released the Announcement on the Declaration and Management Requirements for Overseas Enterprises Exporting Agriculture Products to China, significantly raising the bar for traceability and compliance. The announcement requires accurate registration and comprehensive documentation for continued market access, with overseas official recommendation and registration required before products can be exported to China.

Sectoral Coverage: The regulations apply to listed agricultural product categories, including soybeans and other commodities, with importers required to ensure that products originate from overseas enterprises with valid registration status as published by Customs.

Emerging Sustainability Requirements: China is increasingly imposing origin verification and sustainability requirements, shifting from tariff-driven supply adjustment toward end-to-end regulatory enforcement.

c. South Korea and Other East Asian Markets

South Korea maintains stringent phytosanitary requirements for agricultural imports. Importers must declare plants subject to plant quarantine inspection upon arrival at designated sites including ports, airports, or train stations. Phytosanitary certificates issued by the exporting country's government authorities are required for most plant-based products.

3.9 Comparison of Regional Requirements

Table 2 presents a comparative analysis of regulatory requirements across the European Union, United States, and East Asian markets, revealing a hierarchy of stringency that has significant implications for African exporters. The EU emerges as the most demanding market, mandating geolocation data under the EU Deforestation Regulation (EUDR) and carbon data under the Carbon Border Adjustment Mechanism (CBAM) (European Commission, 2023). These requirements reflect the EU's comprehensive approach to sustainability compliance, with end-to-end traceability and mandatory due diligence obligations under the Corporate Sustainability Due Diligence Directive (CSDDD) (Sinnig & Zetzsche, 2025).

The United States adopts a risk-based approach, with traceability requirements under the Food Safety Modernization Act (FSMA) contingent on product risk classification rather than universal application (FDA, 2021). While geolocation and carbon data requirements are limited or vary by product, conformity assessment centres on FDA registration. East Asian markets demonstrate emerging to very stringent requirements, with Japan's Positive List System imposing a default 0.01 ppm Maximum Residue Limit (MRL) for pesticides—the most stringent globally, while China and South Korea's requirements remain product-specific and evolving.

The table clearly illustrates that African exporters face a fragmented regulatory landscape requiring differentiated compliance strategies. The EU's comprehensive data requirements present the greatest challenge, particularly for exporters relying on smallholder supply chains lacking geolocation and traceability capabilities (UNCTAD, 2025). This regulatory asymmetry underscores the urgent need for harmonized digital quality infrastructure capable of meeting multiple, often conflicting, market requirements.

Table 2. Comparison of Regulatory Requirements across EU, US, and East Asian Markets for African Exporters

Requirement Type	EU	US	East Asia
Geolocation data	✓ (EUDR)	Varies	Emerging
Carbon data	✓ (CBAM)	Limited	Limited
Traceability	End-to-end	Risk-based (FSMA)	Product-specific
Conformity assessment	CE marking	FDA registration	Varies by country
Sustainability reporting	✓ (CSDDD)	Emerging	Emerging
MRLs for pesticides	Stringent	Stringent	Very stringent (Japan: 0.01 ppm default)
Due diligence	Mandatory (EUDR, CSDDD)	Risk-based	Emerging

3.10 The Data Gap: What African Exporters Cannot Currently Provide

The regulatory requirements outlined above expose fundamental data gaps that undermine African exporters' ability to comply with destination market requirements:

Misaligned Environmental Data: African exporters are often forced to rely on European or North American databases (such as Ecoinvent) to calculate their carbon footprints and environmental impacts. These databases fail to capture the specific operational conditions, localized energy mixes, and logistics unique to Africa. This systematically misrepresents the realities of African production; potentially erasing efficiency gains and making African goods appear more environmentally damaging than they are. Under CBAM, this results in exporters being assigned high default emissions values rather than verified, context-appropriate data.

Lack of Measured Carbon Data: Most African countries lack standard approaches for measuring CO₂ emissions at the facility and product level. A scope 3 emission reporting is particularly complex to measure, especially where supply chains rely on hundreds of smaller or informal suppliers. Without verified emissions data, exporters face punitive default values under CBAM.

Inability to Provide Geolocation Coordinates: More than 75% of agriculture in Ethiopia, Kenya, Tanzania, and Uganda depends on smallholder farmers, many of whom lack formal land documentation required for geolocation verification. Farmers have reported being asked by exporters to provide exact farm coordinates despite lacking smartphones, formal land documents, or reliable internet connectivity.

Absence of Standardized, Verifiable Traceability Documentation: Most African supply chains still operate with fragmented data, limited geolocation coverage, and inconsistent farmer records. The report shows that 65% of companies need clearer guidance, 57% require practical compliance frameworks, and 52% lack access to the digital tools necessary to meet

these new expectations. Slow adoption is hindered by low digital literacy, limited smartphone access, weak connectivity, fragmented systems, and concerns over data privacy.

IV. Result and Discussion

4.1 Challenges, Strategies, and Future Directions

a. Synthesis of Key Challenges

The preceding analysis of Africa's data traceability and digital quality infrastructure (DQI) landscape, juxtaposed against the stringent compliance requirements of major export markets, reveals a multi-dimensional crisis. The challenges confronting African exporters are not merely technical but are deeply embedded in infrastructural deficits, digital divides, capacity constraints, and regulatory complexity. This section synthesises these challenges, which collectively threaten to exclude African producers from high-value global markets.

b. Infrastructure Deficits

The foundational challenge confronting African exporters is the weakness of the continent's physical and institutional quality infrastructure. A disconnect between the elements of Quality Infrastructure (QI)—namely Standardisation, Accreditation, Metrology, Conformity Assessment, and Market Surveillance—negatively impacts intra-Africa trade, as goods cannot move from one point to another without being subjected to multiple quality tests. This fragmentation creates a labyrinth of technical barriers that stifle both regional and international trade.

At the heart of this deficit are weak national metrology institutes (NMIs). Research indicates that the digital transformation of metrology has yet to be initiated in developing countries, with African countries lagging behind their Asian counterparts in utilising Fourth Industrial Revolution (IR4.0) technologies to advance metrological operations (Nzumile et al., 2024). This technological lag means that many African NMIs cannot provide the internationally recognised Calibration and Measurement Capabilities (CMCs) required for export certification. Minister of Trade and Regional Integration Dr. Kassahun Gofe has called on African NMIs to urgently accelerate digital transformation, adopt machine-readable calibration certificates, and establish regional centres of excellence to eliminate non-tariff trade barriers under the African Continental Free Trade Area (AfCFTA) (EBC, 2026).

Furthermore, supply chains are highly fragmented, involving multiple intermediaries; village collectors, aggregators, traders, processors, and exporters, which results in weak visibility and inconsistent documentation at each stage (Koltiva, 2026). This structural complexity is compounded by inadequate laboratory and testing facilities, leaving exporters without the means to conduct the product testing and certification required for compliance with Maximum Residue Limits (MRLs) and other food safety standards (SEATINI, 2025).

c. Data and Digital Gaps

The transition from physical to digital trade has exposed profound data and digital gaps across the continent. A core challenge is the absence of standard approaches for measuring CO₂ emissions at the facility and product level (ATAF, 2026). Without verified emissions data, African exporters face punitive default values under the Carbon Border Adjustment Mechanism (CBAM), turning a climate policy into a de facto trade barrier (UNECA, 2025). This data gap is exacerbated by the fact that many countries lack the sophisticated monitoring and verification systems necessary to track and report on environmental metrics (ATAF, 2026).

The digital divide is another critical barrier. Smartphone penetration in East Africa lingers below 30%, making digital mapping, data collection, and farmer engagement an operational challenge rather than a simple technological upgrade (Koltiva, 2026). This is compounded by limited formal land documentation, as more than 75% of agriculture in countries like Ethiopia, Kenya, Tanzania, and Uganda depends on smallholder farmers who lack formal land titles (SEI, 2024). The result is information silos and a lack of interoperable systems that prevent the seamless flow of data from farm to export, undermining the creation of a verifiable, end-to-end digital trail (Koltiva, 2026).

d. Capacity and Capability Constraints

The infrastructure and data gaps are mirrored by severe human and financial capacity constraints. The cost of compliance is prohibitively high. International standards compliance for African SMEs carries a medium cost of approximately USD 20,000, a sum that can represent a significant portion, and in some cases up to 75%, of a smallholder farmer's annual income (FAO webinar, 2026; SEATINI, 2025). This financial burden often forces SMEs to choose between immediate operational costs and long-term market access.

This financial strain is compounded by a lack of skilled personnel. There is a limited number of experts in metrology and data management across the continent (EBC, 2026), a gap that is perpetuated by the underrepresentation of African experts in international standard-setting bodies (FAO webinar, 2026). AFRIMETS President Dr. Henry Rotich has advised member states to invest in human capital through specialized digital training platforms (EBC, 2026). However, without such investment, the standards being set often do not account for African production realities, creating a compliance framework that is both difficult and costly to meet.

e. Regulatory Complexity

Finally, African exporters must navigate an increasingly complex and fragmented regulatory landscape. The multiplication of standards across different markets (EU, US, East Asia) forces exporters to develop multiple, often incompatible, compliance systems (FAO webinar, 2026). This is exacerbated by evolving and increasingly stringent requirements, as seen with the EUDR and CBAM, which are not static but are becoming more demanding over time. The short compliance timelines, such as the December 2026 deadline for large and medium-sized operators under the EUDR (European Commission, 2023; Lexology, 2025), add immense pressure, leaving little room for the systemic changes required. SEATINI's Executive Director Jane Nalunga has warned that without urgent technical, financial, and informational support, many African producers could face exclusion from lucrative EU markets (SEATINI, 2025). Critics argue that while these regulations are framed as tools for environmental sustainability and accountability, they risk becoming non-tariff barriers, with many EU sustainability rules being "self-defined without input from third countries" (Häberli, as cited in SEATINI, 2025).

4.2 Existing Strategies and Initiatives

Despite the formidable challenges, a range of strategies and initiatives are underway at the continental, national, and private-sector levels to address these deficits.

a. Continental Frameworks

The primary institutional response to the QI challenge has been the establishment of the Pan African Quality Infrastructure (PAQI). PAQI serves as the continental platform for all matters related to standardisation, metrology, accreditation, and conformity assessment

(PAQI, 2013). Established in August 2013, PAQI was created to provide a unified voice for Africa in the global quality landscape and to serve as a technical engine for the AfCFTA (PAQI, 2013). By harmonizing quality policies, PAQI ensures that African goods and services are competitive globally, fostering regional integration and improving the quality of life for all African citizens (PAQI, 2013).

Key institutions under its umbrella include:

AFRIMETS (Intra-Africa Metrology System)

Established in 2006, AFRIMETS promotes the harmonisation of scientific, industrial, and legal metrology, ensuring accurate measurements across Africa (PAQI, 2013). AFRIMETS has advised member states to execute four strategic priorities: establishing digitally connected African metrology networks, harmonizing digital measurement frameworks for the AfCFTA, expanding capabilities in emerging technologies, and investing in human capital through specialized digital training platforms (EBC, 2026).

ARSO (African Organisation for Standardisation)

Africa's intergovernmental standards body formed in 1977, ARSO develops tools for standards development and harmonisation to enhance Africa's internal trading capacity and global competitiveness (PAQI, 2013). ARSO is actively working to benchmark African standards against international requirements, such as those of the EUDR. A recent paper by the International Institute for Sustainable Development (IISD, 2026) benchmarks ARSO's agriculture and forestry standards against the EUDR to identify where alignment is strong, where gaps remain, and what targeted updates would allow ARSO standards to become a reliable, continent-led pathway to support compliance. According to the European External Action Service (EEAS, 2026), the African Standard takes on board all EUDR requirements in terms of traceability and due diligence, and also aligns with Environmental, Social Governance (ESG) frameworks, as well as certification labels such as Fair Trade and Rainforest Alliance.

AFRAC (African Accreditation Cooperation) : A cooperation of accreditation bodies that facilitates trade by providing internationally recognised acceptance of conformity assessment results (testing, inspection, and certification) (PAQI, 2013).

AFSEC (African Electrotechnical Standardisation Commission)

A subsidiary of the African Energy Commission dedicated to improving access to electricity through harmonized electrotechnical standards (PAQI, 2013).

These continental bodies are working to create a more cohesive and robust QI ecosystem, but their efforts are often hampered by a lack of resources and the varying capacities of their member states. The 19th AFRIMETS General Assembly, held in Addis Ababa in August 2026 under the theme "Metrology for Digital Transformation: Building Trusted Measurements for Africa's Future," marked a transformative milestone in establishing a unified, digitally integrated metrology ecosystem designed to power Africa's automated industries and secure its economic future (EBC, 2026).

b. National-Level Initiatives

Several African nations are pioneering innovative traceability and QI solutions:

Ethiopia's Coffee Traceability and Management System (ECTMS)

Ethiopia has completed and operationalized its first national digital coffee traceability platform, developed with Germany's GIZ (Ecofin Agency, 2026). The platform, dubbed the Ethiopian Coffee Traceability and Management System (ECTMS), replaces paper-based processes that left the country exposed to losing access to its biggest foreign buyer, the

European Union (Ecofin Agency, 2026). The ECTMS integrates geolocation data, supply chain tracking, and deforestation risk assessment tools, with a mobile application allowing data to be collected directly from farms (Ecofin Agency, 2026). Coffee generates more than \$2 billion in export revenue annually, supporting the livelihoods of nearly 20 million people, around a quarter of Ethiopia's population (ODI, 2025). However, a major structural challenge remains: the Ethiopia Commodity Exchange (ECX), through which most coffee exports are traded, mixes beans from thousands of smallholder farmers before sale, making it nearly impossible to trace coffee back to specific plots of land, a core requirement under EU rules (ODI, 2025). Adapting the ECX to handle segregated, traceable lots would require coordinated reforms involving the Ministry of Agriculture, the ECTA, and private exporters (ODI, 2025).

Uganda's QR-coded certificates for coffee exports provide a simple yet effective method for verifying product origin and preventing fraud. However, challenges persist due to the large number of farmers, limited institutional coordination, and gaps in national policies that align with EUDR requirements (Independent, 2025).

Ghana's progress in refining temperature, mass, and electricity measurements demonstrates how targeted investments in metrology can yield tangible improvements in export readiness. Ghana is also exploring blockchain technology to improve transparency and sustainability in its cocoa supply chain.

Digital traceability projects in Kenya and Tanzania are leveraging mobile technology to collect field-level data from smallholder farmers, bridging the digital divide at the grassroots level. Startups such as FarmShine in Kenya are connecting farmers with information, suppliers, and service providers by eliminating layers of middlemen through traceable and transparent distributed value chains (BitKE, 2026).

c. Private Sector and Development Partner Interventions

The private sector and international development partners are playing a crucial role in bridging the compliance gap:

Blockchain-based traceability solutions are being deployed across various supply chains. For example, the Ilima platform uses a blockchain backbone to facilitate traceability, certification, and other functions that require trust in information (Semantic Scholar, 2025). In Ethiopia, the startup WAGA is piloting a blockchain-driven platform in the coffee supply chain to fully harness the country's vast agricultural potential, aiming to streamline trade processes, increase transparency, and connect farmers to decentralised finance (DeFi) markets (BitKE, 2026). A blockchain-based traceability framework specifically designed for African agricultural supply chains has been proposed, integrating smart contracts with electronic labelling (E-labelling) technologies to address socioeconomic constraints, with automated QR code generation enabling smallholder farmers to participate in transparent supply chains without extensive technical expertise (IEEE, 2025).

Development partners like the World Bank and Germany's Physikalisch-Technische Bundesanstalt (PTB) are providing critical support for NQI development, funding infrastructure projects, and facilitating technology transfer. The first exchange meeting between PAQI and the Quality Infrastructure Council of the Americas (QICA) in June 2023, facilitated by PTB experts, set the stage for fruitful collaboration and exchange on topics such

as digital transformation, circular economy, and global recognition of conformity assessment results (SIM-Metrologia, 2023).

Digital Product Passport (DPP) initiatives are emerging as a key tool for compliance, providing a digital record of a product's lifecycle and sustainability credentials. As the EU moves towards mandatory DPP requirements, African exporters must prepare to meet these new documentation standards.

4.3 Recommendations for African Stakeholders

Addressing the identified challenges requires a coordinated, multi-stakeholder approach. The following recommendations are tailored for different actors within the African trade ecosystem.

V. Conclusions

This systematic review has established that data traceability and digital quality infrastructure (DQI) are critical determinants of African export competitiveness in an increasingly data-driven global trade environment. The analysis reveals that African exporters face systemic barriers, including weak metrology infrastructure, fragmented supply chains, limited digital connectivity, and prohibitive compliance costs that collectively threaten their access to high-value markets in the European Union, United States, and East Asia. The regulatory landscape is evolving rapidly, with the EUDR compliance deadline of December 2026 and the definitive phase of CBAM commencing January 2026, creating an urgent imperative for action.

However, this moment of regulatory transformation also presents a significant opportunity. By investing in robust, digitally-enabled quality infrastructure, harmonising standards through PAQI and AFRIMETS, and leveraging innovations such as blockchain-based traceability and Digital Product Passports, Africa can build a comparative advantage in sustainable, verifiable production. The development of national systems like Ethiopia's Coffee Traceability and Management System demonstrates that African nations can pioneer solutions tailored to their unique contexts.

Realising this potential requires coordinated action across continental, national, and firm levels. Policymakers must accelerate investment in metrology infrastructure and human capital. Regional bodies must harmonise digital measurement frameworks for the AfCFTA. Exporters must treat compliance as a strategic advantage and invest early in traceability systems. Development partners must facilitate technology transfer and capacity building. The cost of inaction is clear: billions in lost export earnings and the exclusion of millions of smallholder farmers from global value chains.

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