DIASCA
Digital Integration of Agricultural Supply Chains Alliance

Realizing the Potential of Interoperability for Building More Trustworthy and Transparent Global Agrifood Supply Chains

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Contents

Key Terms, Abbreviations, and Definitions

Analytical Science Methods: Scientific tools, technologies and methods that may be used in a laboratory, on a data analysis system, or even on a mobile device to analyze, measure, and interpret product characteristics to inform decision-making and improve integrity in supply chains.

Critical Tracking Events (CTEs): Key points in the supply chain where data must be captured to ensure traceability and compliance, such as shipping, receiving, and production events.

CSDDD (Corporate Sustainability Due Diligence Directive): A proposed EU regulation to ensure companies identify, prevent, and mitigate adverse human rights and environmental impacts in their supply chains.

Data semantics: Refers to the meaning and interpretation of data, ensuring it is accurately understood within its context. It involves the definitions and relationships among data and key related concepts.

Data syntax: Refers to the structure and format of data, including the arrangement of symbols and rules for constructing valid data sequences. It ensures data is appropriately organized and follows specific patterns or protocols for effective communication and processing.

Deduplication: Refers to removing duplicate data entries, such as geolocation coordinates or supplier information, to ensure each entry is unique and accurate.

Digital Integration in Agricultural Supply Chains Alliance (DIASCA): A group of 260 public, private, and non-profit actors with a shared interest in advancing greater integration and interoperability in agriculture and food supply chains to advance human and economic development and environmental sustainability.

Digital Public Infrastructure (DPI): Foundational digital services and technologies provided by the government or public-private partnerships to support efficient, secure, and accessible digital services and transactions in the public interest.

Digital Traceability: The use of digital tools and systems to track product history, application, and location throughout the supply chain.

EUDR (European Union Deforestation-Free Products Regulation): An EU regulation intended to prevent the importation of products linked to deforestation and promote sustainable supply chain practices.

GDPR (General Data Protection Regulation): An EU regulation that sets guidelines for collecting and processing personal data to protect the privacy and rights of individuals.

Geospatial Systems: Technologies that capture, store, analyze, and present geographical data to support decision-making and tracking in supply chains.

Interoperability: Refers to the ability of different systems, devices, or applications to work together seamlessly, exchanging and using information effectively. This capability ensures that disparate technologies can communicate, operate, and integrate without compatibility issues, enabling seamless collaboration and data sharing.

Key Data Elements (KDEs): Specific information for tracking and managing products throughout the supply chain, such as product IDs, batch numbers, and timestamps.

Polygons: Refers to the geometric representation of a "plot of land" through geospatial data.

Supply Chain Integrity: The assurance that a supply chain operates as intended, maintaining quality, compliance, and reliability throughout all processes.

Transparency: The practice of openly sharing information about supply chain operations, making processes and data accessible and understandable to stakeholders.

Trust: The confidence and belief that all parties, including producers, processors, distributors, and retailers, will act ethically, transparently, and reliably to ensure the safety, quality, and integrity of supply chains.

Trust Framework: A collaborative methodology for establishing common guidelines and standards for how entities can establish, maintain, and ensure trust within a system, particularly regarding data sharing and digital transactions.

1. Introduction

Global food systems[i] contribute to significant environmental, climate, and human development challenges. About 30% of global greenhouse gas emissions are generated by activities related to producing, delivering, and consuming food, most notably: land-use change, farming practices, food distribution, and food waste.[ii,iii,iv] Food systems can disrupt natural ecosystems, threaten biological diversity, and exacerbate food insecurity and malnutrition. Poor access to economic opportunity in food systems can perpetuate a cycle of poverty and underdevelopment, particularly in rural areas and among smallholder farmers.[v,vi]

It does not have to be this way. Governments, researchers, and consumers are calling for transformed food systems that may become critical drivers of human and economic development, climate change mitigation and adaptation, and environmental sustainability. A mix of policy and institutional reforms, international cooperation, and technological innovation will be needed to rise to this challenge.[vii]

Governments and agriculture and food businesses of all sizes are at the center of these transformations. As consumer demand grows—and regulations become more stringent—firms must develop new approaches to build transparency and trust in their supply chains. It is no longer sufficient for companies to say why they deserve consumers' trust; they increasingly must show what they are doing and have the appropriate supply chain integrity and governance mechanisms to prove it. Supply chain management and traceability information systems can help firms meet this need. Still, incompatibilities across these systems often hinder the flow of data to where it is needed for them to be effective. Some large, vertically integrated food and agriculture firms have developed the ability to seamlessly exchange data across their operational units and supply chain trading partners, but most smaller actors are ill-equipped to achieve this. When smaller actors supply several large firms, they may be required to use multiple technology platforms to exchange data. Achieving interoperability across supply chain systems would help level the competitive playing field and enable diverse actors to coordinate actions, share data related to their common goals, reduce transaction costs, and participate more fully in food systems.[viii]

Through this working paper, the authors propose an approach to interoperable digital traceability systems that can serve as a foundation for building more trustworthy agrifood supply chains. A general trend toward supply chain regulation as a tool for human development and environmental goals is examined. Supply chain integrity is proposed as a framework for managing the complex interactions of policy, information systems, society, and the environment necessary for such policies to achieve their aims. Some approaches for building trust and collaboration among supply chain actors are examined. The framework is applied to a specific country-commodity case to generate practical insights and recommendations for solution providers and policymakers.

2. Context: policy and regulation as a force for trustworthy supply chains

Policies addressing environmental concerns, promoting fair labor practices, and increasing transparency and trust in supply chains have grown over the last decade. The European Union and its Member States lead this global trend. The European Green Deal, for example, creates a comprehensive framework guiding public investment, partnerships, and an array of regulatory actions to guide the continent toward being climate-neutral: eliminating pollution, protecting biodiversity, and financing the transition towards a circular economy.[ix]

Several EU-level and country-level regulatory interventions in supply chains that are aligned with the Green Deal are moving rapidly to implementation, including:

> The German Supply Chain Due Diligence Act (LkSG) requires large companies to conduct human rights and environmental due diligence throughout their supply chains. This includes risk assessments, preventive measures, corrective actions, and comprehensive documentation. Initially applicable to companies with over 3,000 employees, it extends to those with over 1,000 employees from January 1, 2024.

> The EU Corporate Sustainability Due Diligence Directive (CSDDD), set to be adopted by 2025, will require companies to identify, prevent, and mitigate adverse human rights and environmental impacts. Compliance involves risk assessments, preventive measures, remediation, policy integration, and public disclosure. It applies to large EU-based companies, significant non-EU companies, and smaller firms in high-risk sectors.

> The European Union Regulation on Deforestation-free Products (EUDR), which entered into effect December 30, 2024, aims to combat deforestation linked to certain commodities by requiring companies to ensure their products do not contribute to deforestation or forest degradation. Compliance will require firms to demonstrate risk assessments, mitigation measures, product traceability, and third-party audits. The regulation covers high-risk commodities and their derivatives, including coffee, cocoa (chocolate), cattle (beef), soy, palm oil, timber (wood), and rubber.

This overall trend toward supply chain regulation as a force for environmental or human development goals will continue to give rise to targeted policies, partnerships, and investments for years to come - and governments, firms, and actors spanning global agricultural supply chains will have to adapt to this shifting policy environment in new ways.

3. Trustworthy supply chains and the "Brussels effect"

The "Brussels effect"[x] refers to the influence of EU policy and regulation on national and global policy and trade relations. The EU General Data Protection Regulation (GDPR) provides a recent example. GDPR has had international influence, not least through the EU's enforcement of the concept of "adequacy," or whether a country offers adequate data protection to permit the free flow of data with the EU without additional safeguards.[xi] This has driven a notable Europeanization of essential aspects of national and international data protection regimes,[xii] which many stakeholders perceive as an external imposition.[xiii]

GDPR has had further unintended consequences, most notably related to competition. Large technology companies with robust regulatory compliance functions, financial means, and infrastructure were ready to comply with GDPR's stringent data protection requirements as soon as the regulation entered into force. In contrast, many smaller firms struggled with compliance. This had the effect of undermining competition and resulted in several market exits by smaller entities.[xiv] Strict limitations on data sharing under GDPR also limited the ability of small firms to use third-party services in support of their operations, further undermining their competitiveness.[xv]

EU regulations aimed at building more sustainable and responsible supply chains could have similar unintended consequences. For example, despite its potential environmental benefits, the EUDR could marginalize smallholder farmers in developing economies who may need significant capacity-building efforts and resources to comply. The regulation (primarily a trade measure) may inadvertently exacerbate inequalities in food systems, ignoring smallholder farmers' complex socio-economic and cultural realities. In contrast, larger and more influential entities in the supply chain are more likely to have the resources to adapt and proactively meet compliance requirements. Multiple organizations (public, private, and non-profit) participating in the DIASCA traceability working group have registered their concerns about the potential unintended consequences of supply chain regulations (particularly EUDR and CSDDD—See Figure 1).

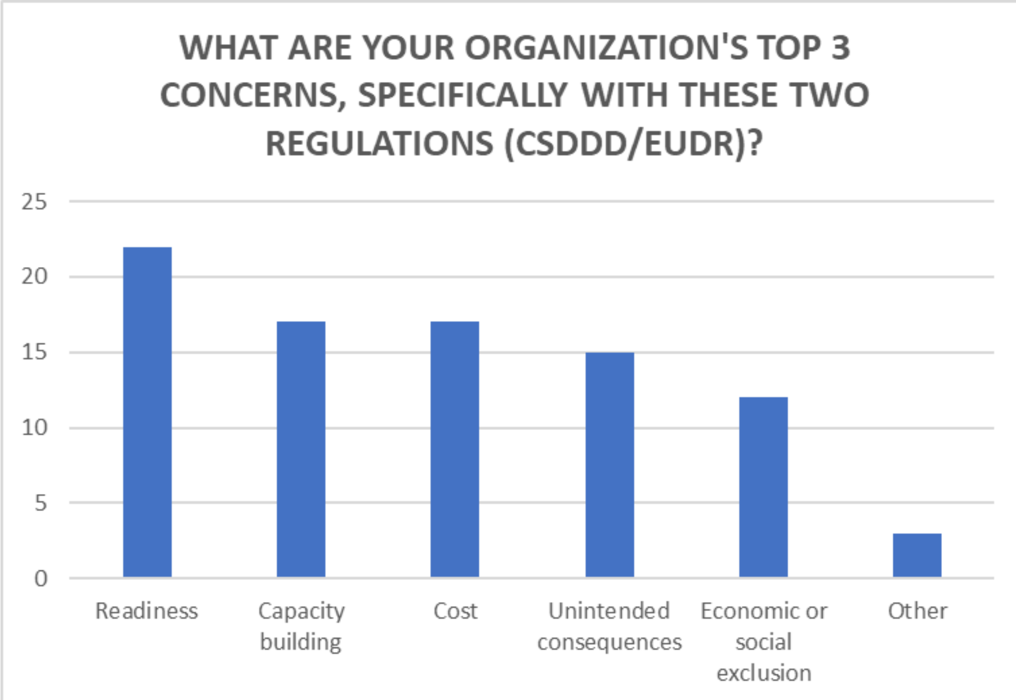

Figure 1. Multiple organizations (public, private, and non-profit) participating in the DIASCA traceability working group are concerned about the potential unintended consequences of the rapid timeline and compliance requirements of supply chain regulations. *(Source: DIASCA Working Group on Traceability)*

3.1 Harmonization vs. Equivalency

Any inconsistencies emerging across global and national policy frameworks can give rise to continued legal challenges[xvi] and trade disputes. Alternatively, the "Brussels effect" could create incentives to integrate the language of EU regulations directly into national policy without adequate localization and public comment to ensure they are context-appropriate. Instead of directly duplicating laws from one jurisdiction to another to meet a mandate or protect trade—often seen as an imposed form of full or partial harmonization of policy language across countries—developing policies tailored to the national context is typically more effective. As a result, in various global and regional political fora, the term "equivalency" is often preferred. The guiding principle is respect for national sovereignty while fostering collaboration and mutual recognition of regulations and standards. Nevertheless, the policy development process varies across nations, and developing equivalent national regulations and standards can take several years.

4. Supply chain integrity: a recipe for trustworthiness

It may be helpful to examine specific regulatory interventions (e.g. trade, labor, environment, food safety, counterfeiting) as parts of a growing overall aspiration to build more responsible, transparent, and trustworthy supply chains for agriculture and food. Europe had a watershed moment related to trustworthy food supply chains over ten years ago when a significant percentage of beef sold in the region was found to be adulterated with horsemeat, and food safety and law enforcement authorities struggled to identify the vulnerabilities that made this fraud possible and find the actors who were responsible.[xvii] Over the last decade the concept of "supply chain integrity" has emerged to describe a more holistic approach to supply chains that can better equip them to respond to such challenges. Supply chain integrity encompasses product tracking (forward) and tracing (backwards), ethical practices, reliable processes, trustworthy personnel, and accurate data management.[xviii]

Supply chain integrity has been described as having four pillars:[xix]

Product Integrity refers to the assurance that the products are genuine, unadulterated, and meet all specified standards and requirements. This includes preventing economically motivated adulteration (EMA), counterfeiting, illicit trade, and ensuring accurate labeling regarding the products' origin, quality, and safety. Maintaining product integrity is crucial for maintaining consumer trust and compliance with regulatory standards.

Process Integrity involves ensuring that all processes within the supply chain are conducted consistently, controlled, and transparently. This includes proper handling, storage, and transportation of products to prevent cross-contamination, theft, diversion, or commingling. Adhering to standardized procedures and best practices helps maintain the reliability and efficiency of supply chain operations.

People Integrity focuses on the ethical behavior and reliability of individuals involved in the supply chain. It encompasses the trustworthiness of employees, suppliers, and partners, ensuring they adhere to ethical standards, local laws, and acceptable industry practices. This pillar also includes measures to prevent insider threats, fraud, bribery and corruption, which can compromise the integrity of the supply chain. People integrity is indispensable for addressing the challenge of "unobservability": it is generally beyond international buyers' capabilities and resources to continuously monitor their suppliers' actions and behaviors in global supply chains.

Data Integrity ensures that all data related to the supply chain is accurate, complete, and secure. This includes maintaining proper records, ensuring the authenticity of documentation, and protecting data from unauthorized access or manipulation. Reliable data is essential for traceability, transparency, and informed decision-making within the supply chain.

These pillars form an approach to managing the complex interactions and dependencies within supply chains to build more sustainable, responsible, and trustworthy global supply chains.

4.1. Action areas for building supply chain integrity

Supply chain integrity is a multifaceted concept. To apply it in practice, coordinated action is required in three broad areas: **Authentication**, **Traceability**, and **Verification**.

- **Authentication** involves confirming the authenticity of products by validating their characteristics. This could involve analytical science methods, unique identifiers assigned for the product and its origin, and any security features that may be associated with the product for anti-counterfeit or anti-illicit trade purposes, such as overt, covert or forensic features on packaging, labels or chemical taggants on products.

- **Traceability** focuses on tracking the history and movement of products through the supply chain, ensuring that each step is documented and that the product can be traced back to its origin.

- **Verification** ensures that all legal and credence claims associated with the product are accurate, through scientific testing or analytic methods. Audits and inspections can verify that the supplier and the product comply with relevant regulations. (One example would be land use verification related to EUDR-compliant commodities.)

Each of these action areas addresses critical aspects of supply chain integrity, and together, they may guide the application of this framework for building ethical and transparent supply chain practices. Figure 2 graphically represents the distinct areas and notes the points of intersection among them.

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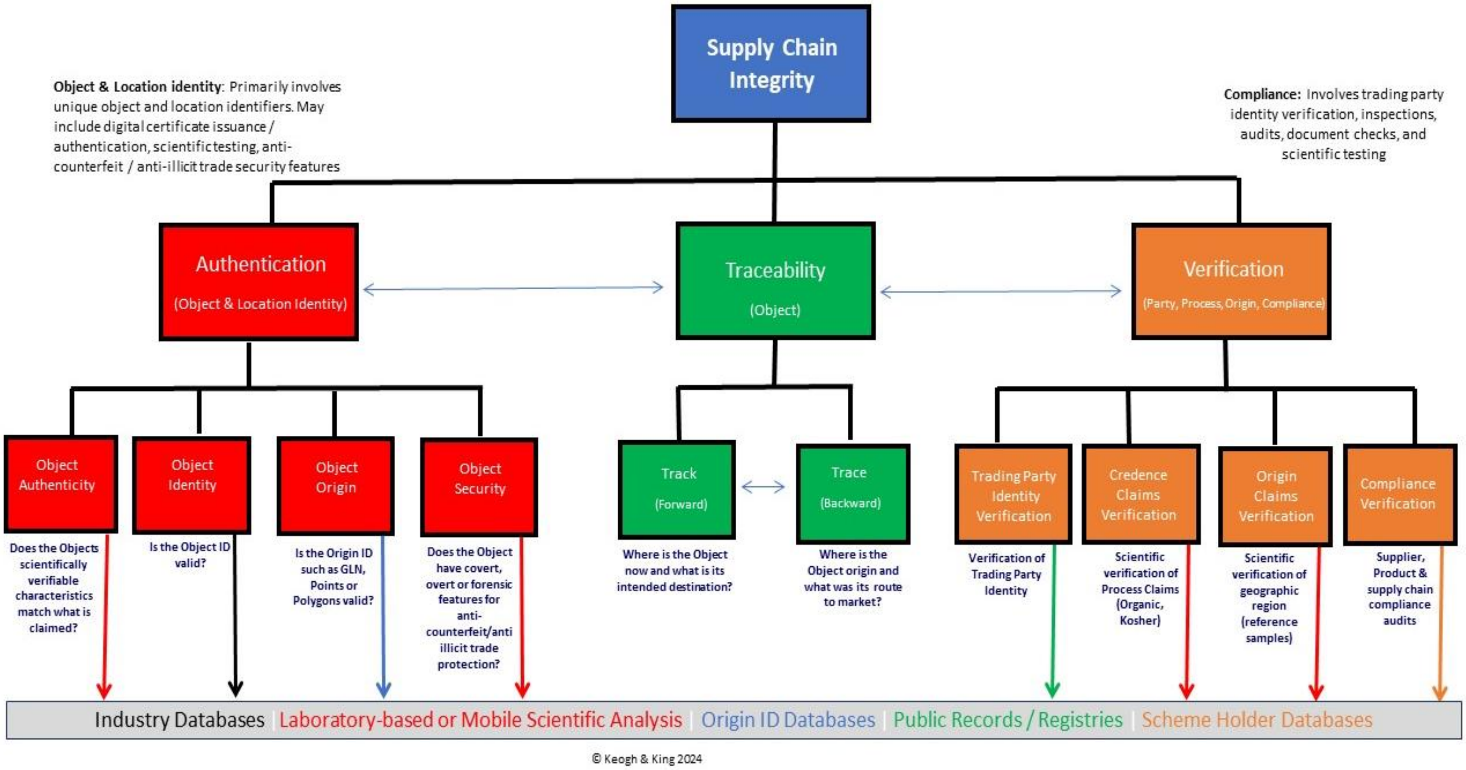

Authentication

- **Object Authenticity**: Ensures that the scientific characteristics of the object match the claims, verified through laboratory-based or mobile scientific analysis.
- **Object Identity**: Validates the object's unique identifiers to confirm its authenticity.
- **Object Origin**: Confirms the validity of origin identifiers such as Global Location Numbers (GLNs), points, or polygons.
- **Object Security**: Checks the security features of the object, including anti-counterfeit measures and protections against illicit trade.

Traceability

- **Track (Forward)**: Monitors the current location of the object and its intended destination.
- **Trace (Backward)**: Examines the origin and the route taken by the object to reach its current point.

Verification

- **Legal Claims**: Verifies the legal aspects of trading party identity, land ownership, and permitted usage.
- **Credence Claims**: Scientific verification of process claims such as "sustainable," organic, or kosher certifications.
- **Origin Claims**: Scientific verification of the geographic origin of products through reference samples.
- **Compliance**: Ensures regulatory compliance through supplier and supply chain audits, inspections, and certifications.

Figure 2. Applying supply chain integrity to build ethical and transparent supply chain practices may be considered in terms of three broad action areas: authentication, traceability, and verification. EUDR compliance intersects with several of these action areas. *(Source: Keogh & King, 2024* [CC BY]*, adapted and expanded from GS1. (2013). The need for global standards and solutions to combat counterfeiting. GS1 AISBL.)*

4.2. Interoperability can support efforts to build integrity, but what does it mean to be interoperable?

Interoperable systems and data will be indispensable for ensuring that multiple supply chain actors can comply with sustainability regulations, yet interoperability has many dimensions. At its highest level, interoperability enables the flow of data and the integration of disparate systems and processes involving various stakeholders, including primary producers, aggregators/cooperatives, processors, manufacturers, distributors, and retailers. It may be described as having technical, semantic, syntactic, and organizational (Table One):

Type of Interoperability	Description	Example
Technical	Focuses on the compatibility and communication between hardware and software systems. Ensures that different systems can connect and exchange data using standardized protocols and interfaces. Enables real-time tracking and traceability for regulatory compliance.	Information systems for autonomous yet linked infrastructures, such as airports.
Semantic	Ensures that the meaning of data is consistently understood across systems and stakeholders. Uses common data standards to ensure key data elements (KDEs) and critical tracking events (CTEs) are understood throughout the supply chain.	The joint ISO/GS1 EPCIS data interoperability standard. EPCIS involves elements of technical and syntactic interoperability but primarily contributes to semantic interoperability.
Syntactic	Deals with the structure and format of the data being exchanged. Ensures that data adheres to syntax rules and formats, enabling consistent interpretation and processing. Minimizes errors and ensures efficient data exchange for regulatory compliance.	The common use of GeoJSON format for geographic data related to regulatory compliance, ensuring geographic information is structured and exchanged in a standardized manner.
Organizational	Enables effective collaboration by aligning business processes, governance, and policies across supply chain entities. Ensures regulatory compliance, streamlined workflows, and enhanced cooperation among parties.	The "Russian Doll" traceability model where data accumulates and grows at each stage in the value chain, shared among value chain actors.

4.3. Supply chain integrity is both global and national

The current wave of supply chain regulation will soon require unprecedented transparency from agriculture and food companies globally. However, achieving true end-to-end transparency will also require coordination at the national level. Each country has unique industry concerns, and each national regulatory environment may differ from international standards. For instance, while the EU's EUDR mandates deforestation-free sourcing, an individual country's internal certification requirements may not align with these standards, creating challenges for companies working across both regions.

Establishing proper governance, technology, and standards choices that are both legal and appropriate in each country's context can only be done effectively through collaboration among stakeholders in country-specific commodity supply chains.

4.4. Trust: the missing ingredient

A global crisis of trust has emerged over the past decade, eroding confidence in governments, businesses, non-profits, and the media.[xx] This crisis is particularly acute in supply chains, where transparency and accountability are coming increasingly into focus. Collaborative governance and data sharing will be necessary for value chain actors to rise to this challenge, yet this will only be possible by first building trust among them.

Several consortia have recently formed to model trustworthy, collaborative use of data and technologies across entire food value chains. For instance, the Trust Alliance of New Zealand (TANZ) established a shared digital platform for food data sharing, linking producers, growers, exporters, retailers and consumers;[xxi] and the Trusted Bytes Alliance advanced decentralized digital supply chains for agri-food in the United Kingdom.[xxii]

To address the need for digital trust in food systems, these consortia often implement elements from a "Trust Framework." This framework provides a structured approach to guide supply chain actors in defining key elements of secure, ethical, and efficient data sharing. These frameworks typically bridge private and public sectors, addressing data security, permissioned data access, and interoperability among disparate systems. Participants collaborate to develop consensus around clear operational procedures, roles, responsibilities, and compliance monitoring. The framework helps ensure that critical information on food safety, certification, and environmental impact can be shared responsibly while creating a foundation for new shared services of interest to members.[xxiii] (See Figure 3.)

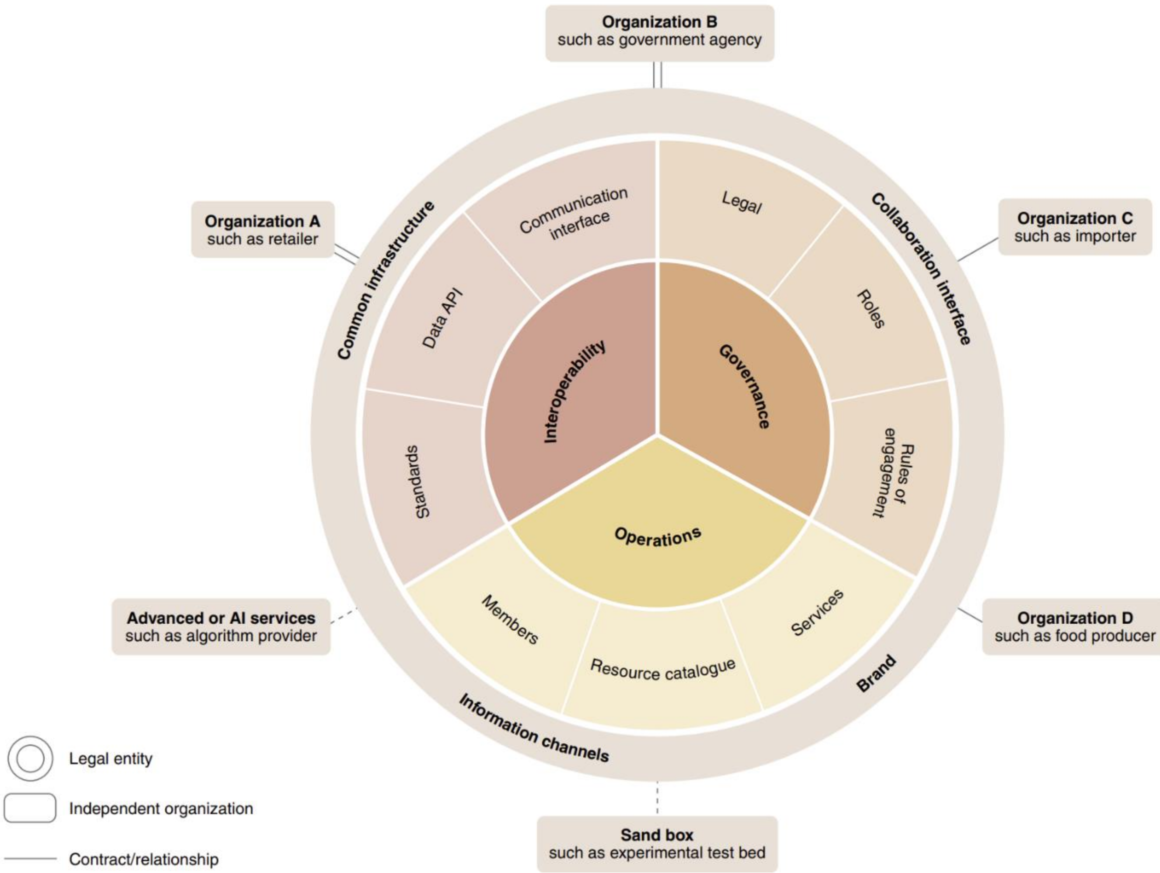

Figure 3. Organizations participating in a supply chain can, through the “Trust Framework” approach, arrive at shared governance and services to advance their common interests. *(Source: Brewer, S., Pearson, S., Maull, R. et al. A trust framework for digital food systems. Nat Food 2, 543–545 (2021))*

Such a country-commodity-specific approach can create a foundation for advancing the shared interests of country-level value chain participants and help them avert the unintended consequences of global regulations in their context.

5. Trying out the recipe: The Case of “Deforestation Free” Honduran Coffee

Compliance with the EUDR will require unprecedented data sharing and pre-competitive collaboration in agricultural value chains. In the case of coffee, actors spanning the Honduran value chain have taken proactive steps to prepare.

Researchers from the Alliance of Bioversity and CIAT (a CGIAR research institute) developed an approach inspired by the Trust Framework to help these stakeholders advance their shared interests related to the EUDR. The team began by conducting semi-structured interviews with diverse actors across the value chain to surface concerns with imminent regulations and assess their willingness to pursue shared services to advance their common goals (See Figure 4).

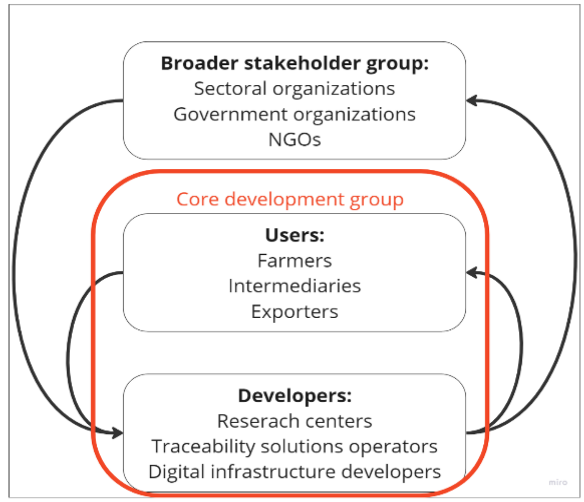

Figure 5. A core group of development teams from a sub-set of the organizations are co-designing and iterating on a shared infrastructure for EUDR compliance. *(Source: Federico Ceballos-Sierra, Alliance Bioversity-CIAT)*

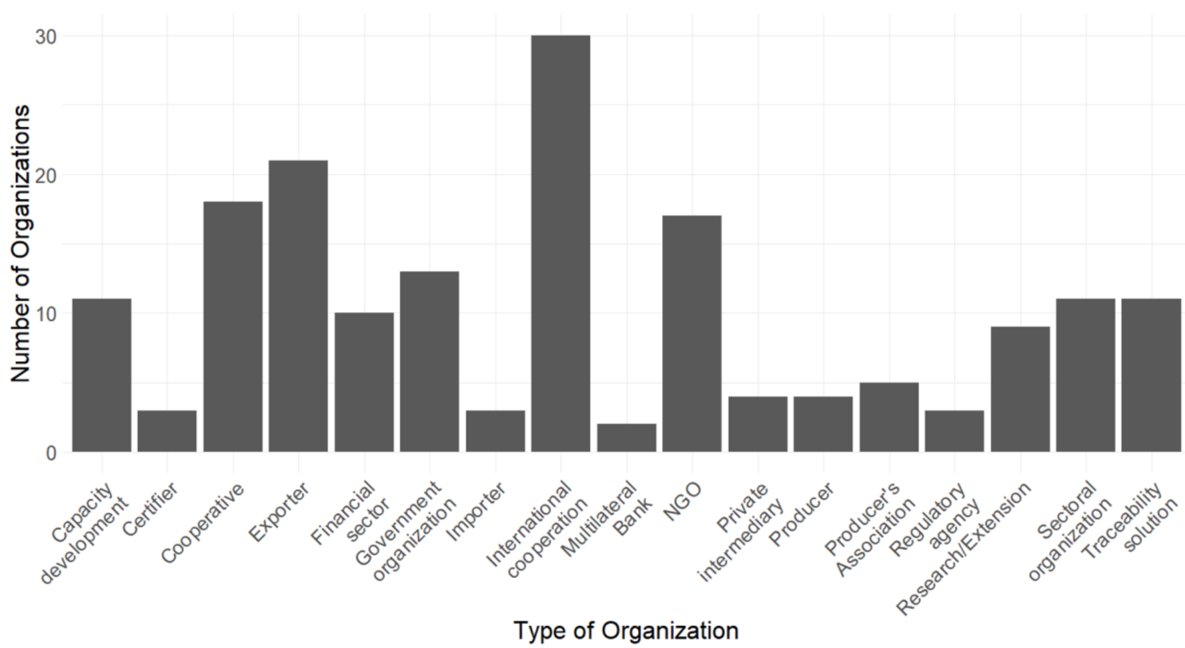

Figure 4. Number and types of organizations consulted in value chain research regarding EUDR compliance for Honduran coffee. *(Source: Alliance Bioversity-CIAT)*

Next, the researchers convened 23 public, private, and non-profit organizations spanning the Honduran coffee value chain for an intensive group mediation. Participants emerged from that process with a consensus statement confirming their shared interests, the need for a shared infrastructure to help them advance these interests, public-private governance of such a platform, and key guiding principles for implementation.

The group mediation process and resulting statement created a clear mandate and momentum for building a shared infrastructure enabling EUDR-compliant Honduran coffee. Seven of the participating organizations volunteered to form a Core Development Group and begin an iterative prototyping process, agreeing that the process would follow an open-source ethos, focusing on open tools, open standards, and open learning (see Figure 5).

This group had the necessary diversity to better define the specific data that will need to be generated and shared at the country level to support the traceability and tracking of Honduran coffee, alongside more general data that will be required for all shipments of EUDR-compliant commodities (see Figure 6).

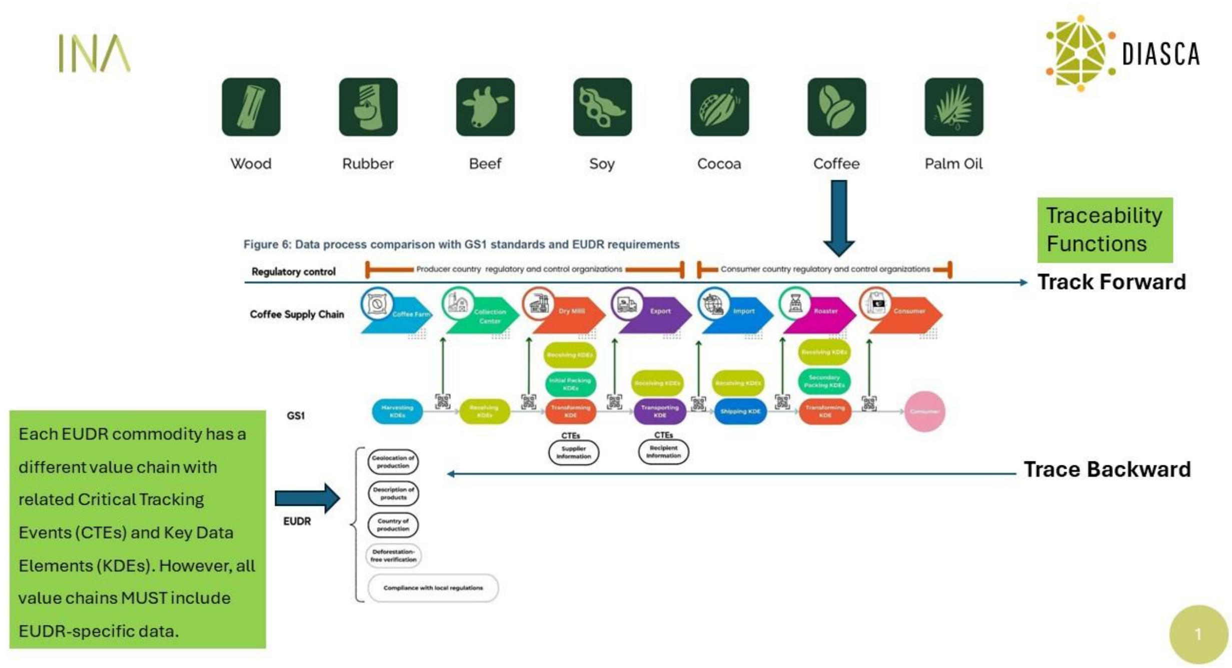

Figure 6. Linkages for establishing traceability for EUDR-compliant coffee in the Honduran context. Note that data on product attributes that flow together with the physical product (Key Data Elements) will include context-specific data as determined by the country's regulatory authority and value chain actors, as well as more general EUDR compliance data. Key transitions or transformations the product goes through (Critical Tracking Events) will also be country- and value-chain-specific. Taken as a whole, using KDEs and CTEs effectively in chain of custody systems supports both "track forward" and "trace back" capabilities.

(Adapted from: Melo-Velasco, J., Padilla-Quiñonez, C., Colindres, M., Ceballos-Sierra, F., & Wiegel, J. (2023). Linkages between EU deforestation-free regulation and traceability tools: An exploration from the Honduran coffee sector. Rethinking Food Markets Initiative Technical Paper, December 2023. International Food Policy Research Institute (IFPRI). https://hdl.handle.net/10568/138419)

5.1. Iterative, collaborative prototype design

A representative swathe of participants in the Honduran coffee value chain arrived at a consensus that shared infrastructure for EUDR-compliant Honduran coffee can provide multiple benefits in their shared interest:

Compliance with EUDR: Ensuring that Honduran coffee is verifiably "deforestation-free" in a credible, transparent way that can support due diligence statements for compliant shipments and produce data as needed (e.g. specific polygons) to be able to demonstrate due diligence and protect the privacy of small producers and intermediaries.

Laying the foundation to address other themes: A unified approach to managing spatial data and product attributes opens the way to examining new topics (e.g., living income, food quality, and safety) and enables new services (e.g., localized crop advisory services, and value chain-specific financial services).

Detecting and addressing vulnerabilities: Active collaboration and data sharing—mediated by a shared infrastructure—can equip supply chain actors to identify and better manage potential risks, shocks, or breaches of integrity (e.g., illegal land use, illicit trade, trade disruptions, and comingling of non-compliant or counterfeit products) along the chain.

The Core Development Group joined efforts to map the functions that must be supported at various points in the value chain to support EUDR compliance and adopted the shared target of exporting the "first container of EUDR-compliant" Honduran coffee, with verifiable due diligence (Figure 8.). This map and its concrete, context-specific goal provide a way to anchor supply chain integrity, prioritize aspects of interoperability, and lay bare what key standards must be applied (or further developed).

5.2 Mapping integrity, interoperability, and standards to build "whole of chain" capabilities in context

A swath of organizations representing the Honduran coffee value chain agrees that several capabilities must exist and be coordinated at the 'whole-of-chain' level to support the export of EUDR-compliant coffee. Development of these capabilities will require the application of key aspects of integrity, interoperability, and standards at key points in the overall flow of data and products across the chain (See Figure 7). These are outlined in Table 1 below and discussed in more detail in Annex Three.

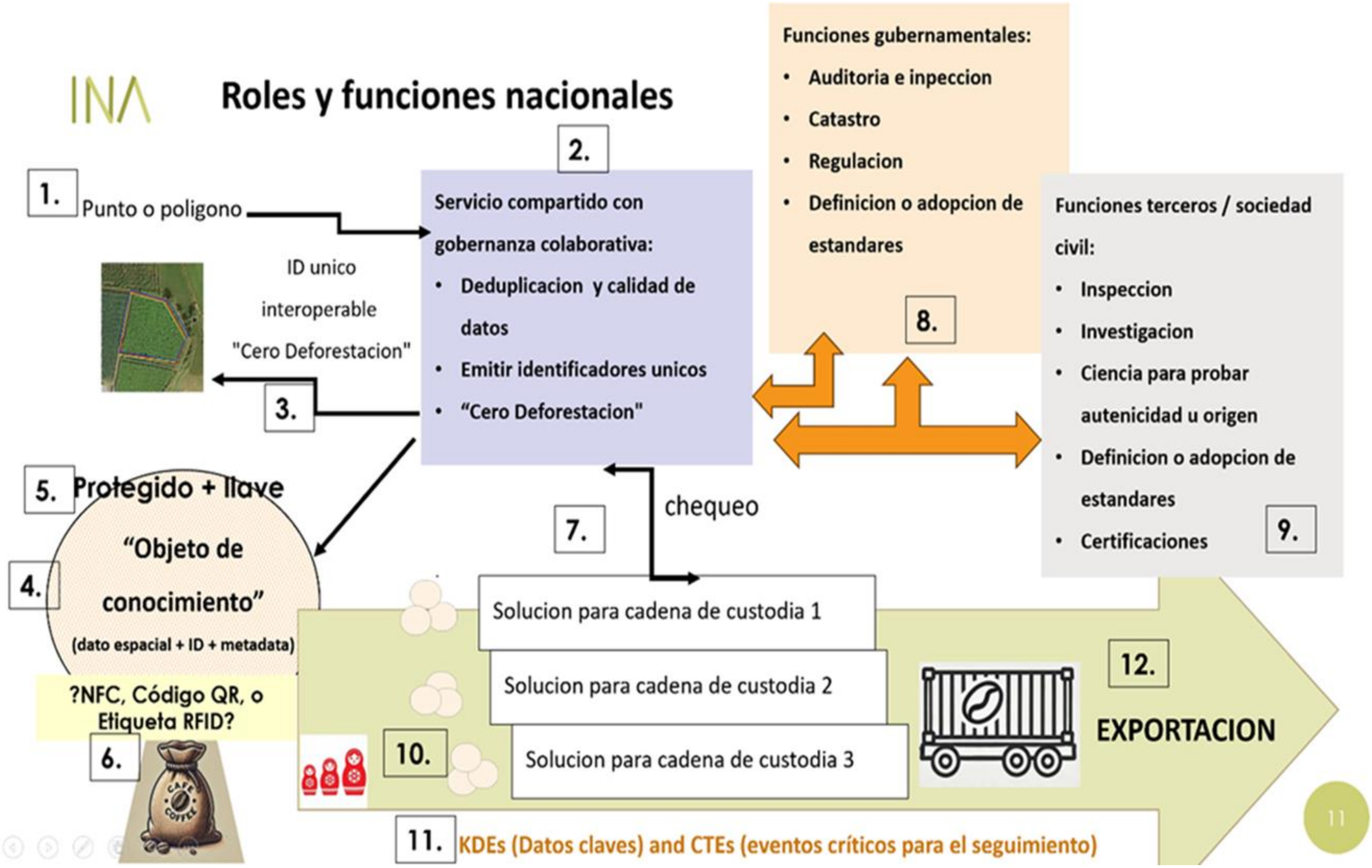

Figure 7. Participants in the prototyping group mapped and validated key functions that must be supported at various points in the value chain to prepare the first EUDR-complaint container of Honduran coffee for export. *(Source: Core Development Group, Honduras)*

Table Two: Mapping integrity, interoperability, and standards to "whole of chain" capabilities for EUDR compliance.

Intersection with Value Chain	Key Elements of Integrity	Key Elements of Interoperability	Key Standards to Consider
1. Generation or capture of points and polygons.	*Process and data* must be as consistent as possible across modes of data collection. Ethical behavior by the *people* involved in capturing, generating, or sharing polygons will be of fundamental importance for protecting the privacy and agency of small producers.	Consistency in operating procedures for capturing or generating polygons as well as in formats used for the resulting spatial data (e.g. GeoJSON) can support comparability, sharing, and re-use of data in different systems, enabling *technical, organizational, and syntactic* interoperability. Common terms for describing these data would enable *semantic* interoperability.	ISEAL guidance, AGROVOC, ISO 19144-2:2012 Land-use Land Cover Meta-language.
2. A shared service for: data quality control, and deduplication of polygons; creation of a shared registry of polygons; and determining if points or polygons are "deforestation free."	Governance mechanisms for shared oversight can safeguard all aspects of integrity.	*Technical and syntactic* interoperability across different platforms for data sharing and quality control.	ISO/IEC 15459 for object identifiers.

3. Minting of interoperable unique IDs **4. Issuance of a standard 'knowledge object'**	Agreed governance on unique identifiers / Agreed governance on knowledge objects linked to attributes like 'deforestation free" can *reinforce data and process integrity.*	Data must be described using agreed-on terms (*semantic interoperability*) and consumable by the array of chain of custody systems and certification approaches (*organizational interoperability*) in the country through common data formats such as JSON or GeoJSON (*syntactic interoperability*), and a 'live' service to ease multiple organizations checking polygons or points against the registry *(technical interoperability*).	ISO/IEC 15459 for unique identifiers, JSON/GeoJSON for data exchange formats.
5. Protection of knowledge objects and provision of a cryptographic key.	Clear *processes* for consent and *data protection*.	Widely-used encryption technologies may be required for technical and *organizational interoperability*, and stakeholders will need to pick one or more that will be acceptable, and align organizations around its use to protect the right to consent of data by data owners and subjects in the Honduran context.	ISO/IEC 15944-17 for Fundamental principles and rules governing Privacy-by-Design (PbD) requirements in a collaboration space context.

6. Association of the knowledge object with the physical unit of traceability	Trustworthy approaches to *people, process, data, and product* must all be defined for the 'first mile' where sacks of coffee are collected.	Systems (*technical interoperability*) must support all aspects of integrity and interoperability specifically in 'offline' mode in rural contexts; the prototyping group must define specific technologies to be applied that will be acceptable to the majority (*organizational interoperability*).	ISO/IEC standards for Near Field Communications, personal identification standards (18092:2013, 14443-1:2018).
7. Chain of custody systems check knowledge objects against the shared registry **8. The registry interfaces with governmental functions.** **9. The registry interfaces with third party/civil society functions**	This is the core of a service for *ensuring data integrity*, and supporting integrity of *people and process*.	Stakeholders must agree (*organizational interoperability*) on application programming interfaces (*technical*) to enable interface of systems, and a data format for knowledge objects (*syntactic interoperability*) that can flow through the chain to support compliance-related capabilities.	ISO 22095:2020 - Chain of Custody standards for APIs.
10. Knowledge objects accrete as physical objects are aggregated and change hands 'Russian doll'-style until they reach the container for export	Agreed standards and controls for aggregation, tracking, and chain of custody support all forms of integrity.	*Technical interoperability standards* for ensuring digital objects are correctly linked to physical objects and can be aggregated seamlessly across multiple actors.	ISO/IEC 15459 standards related to grouping of objects along a chain/string of actions, Identity Preserving supply chains.

11. Key Data Elements and Critical Tracking Events are defined	Defined standards and procedures for KDEs and CTEs that align with traceability and compliance needs, supporting *data and product integrity*.	Defined terms and interoperable frameworks for KDEs and CTEs across systems to ensure compatibility and traceability (*organizational interoperability*).	GS1 Supply Chain Standards showcase how KDEs and CTEs function in supply chains.
12. Interface with EUDR compliance database and the World Customs Organization	Significant engagement (and likely advocacy) with EU authorities will be needed to *promote approaches to people, process, data, and product* that have been validated in the Honduran context to support EUDR compliance.	Ensuring appropriate interface with the World Customs Organization 'single window' service and the EU due diligence database (*technical*).	Standards related to APIs for financial transaction systems, chain of custody, and geospatial/navigation systems.

5.3 Open source, open standard, open learning "building blocks" for EUDR-compliant Honduran coffee

The Core Development Group engaged in prototyping a shared infrastructure for EUDR-compliant coffee, including public, private, and non-profit participants spanning the national coffee value chain. The group adopted an ethos of pre-competitive collaboration across public, private, and non-profit organizations enabled by an "open source, open standards, and open learning" approach to developing solutions. Their overall goal is a modular, replicable solution that could be adopted in whole or part, with any organization free to integrate it into their products and under their own brand.

The group reviewed several open source/open standard solutions that may serve as "building blocks" for the prototype, supporting key capabilities at different points in the overall flow of data and products for EUDR-compliant coffee (See Figure 8), including:

TerraTrac (TechnoServe) supports registering new points and polygons and checking points and polygons against a central registry. It has a simple user interface and offline functionality that will enable its use in rural areas without internet connectivity. Other solutions exist in the marketplace, but it is important to have an open-source option, particularly for enabling interoperability across other solutions.

Asset Registry (Linux Foundation AgStack) supports ingestion and deduplication of points and polygons generated from multiple sources, as well as the creation of a unique alphanumeric geographic ID for each of these points or polygons.

CIAT-First Sale (Alliance Bioversity-CIAT) involves the use of Near Field Communication cards to enable the linkage of polygons, products (i.e. sacks of coffee), and persons (i.e. buyer and seller) associated with a particular transaction.

INATrace (GIZ) is an open-source chain of custody solution developed to ease compliance and ensure that smallholder farmers would not be excluded from the EU market due to sustainability regulations. The digital solution is designed to enhance the traceability of global supply chains, focusing on improving the economic conditions of smallholder farmers. By making supply chain data, such as pricing, processing steps, and actors involved, transparent and accessible—potentially through QR codes for consumers—INATrace aims to ensure better compensation for producers. It also incorporates field polygon mapping and satellite-based forest monitoring to help meet due diligence requirements under the EU Deforestation Regulation (EUDR).

Whisp (FAO). Whisp—or "What is in that plot?"—is an open-source API that can help to produce relevant forest monitoring information and support the due diligence process required under the EUDR. Whisp converges evidence from multiple sources to produce a geospatial analysis of what is contained in any given plot of land.

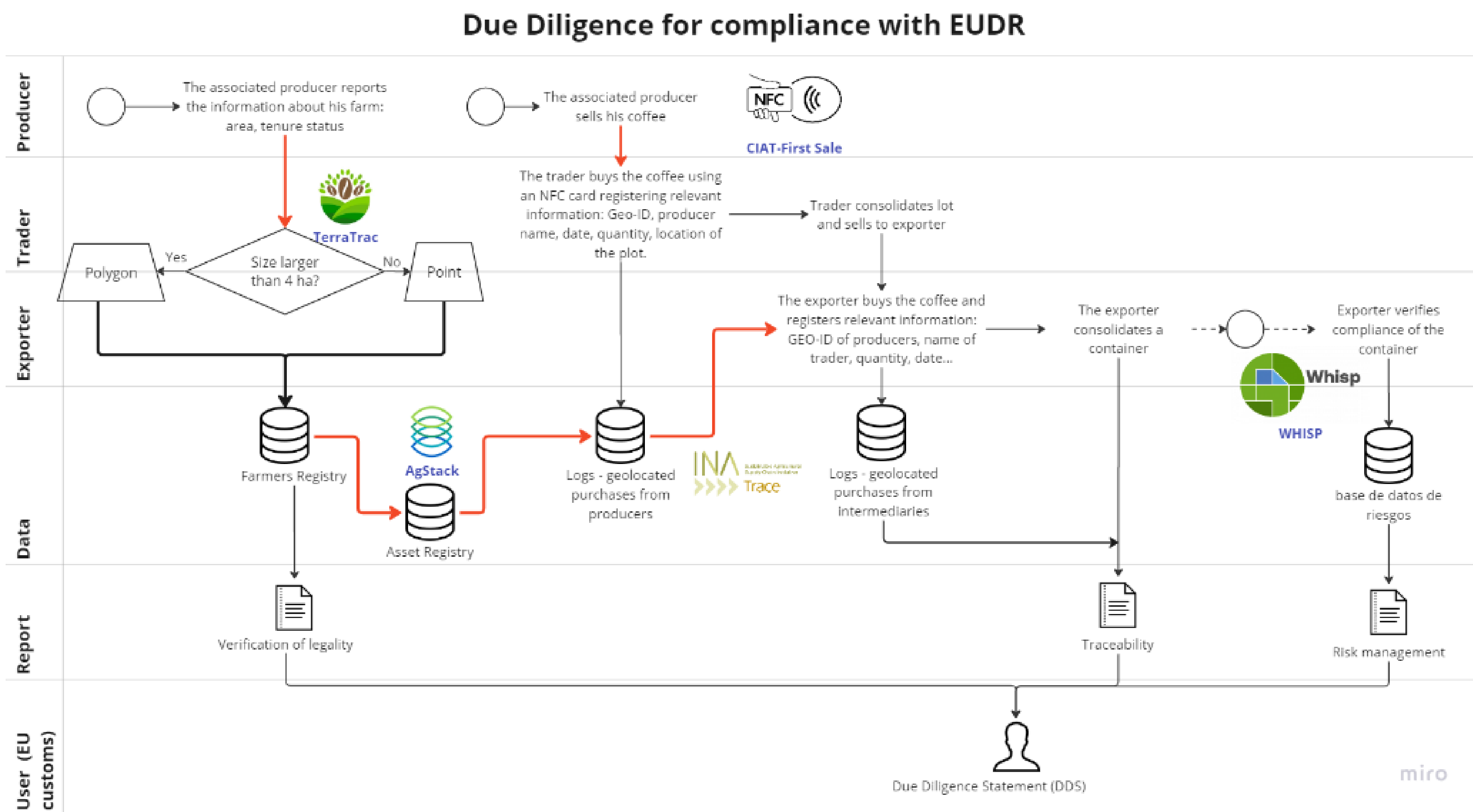

Figure 8. The Core Development Group assessed open source "building blocks" for a national service enabling EUDR-compliant coffee: Asset Registry, Whisp, INATrace, TerraTrac, and NFC cards "CIAT First Sale" as they intersect with capabilities in the value chain. *(Source: Federico Ceballos-Sierra and the Core Development Group.*

The Core Development Group members then ranked each of these along a spectrum of "indispensable" to "nice to have." They found that an open source/open standard approach was important for fostering pre-competitive collaboration in their context overall and that Whisp and Asset Registry, in particular, met acute needs across the Honduran coffee value chain (See Figure 9). The other open source solutions reviewed were found to be important when considering interoperability across disparate systems—enabling stakeholders to leverage open code across organizational boundaries and thus not risk revealing any proprietary code.

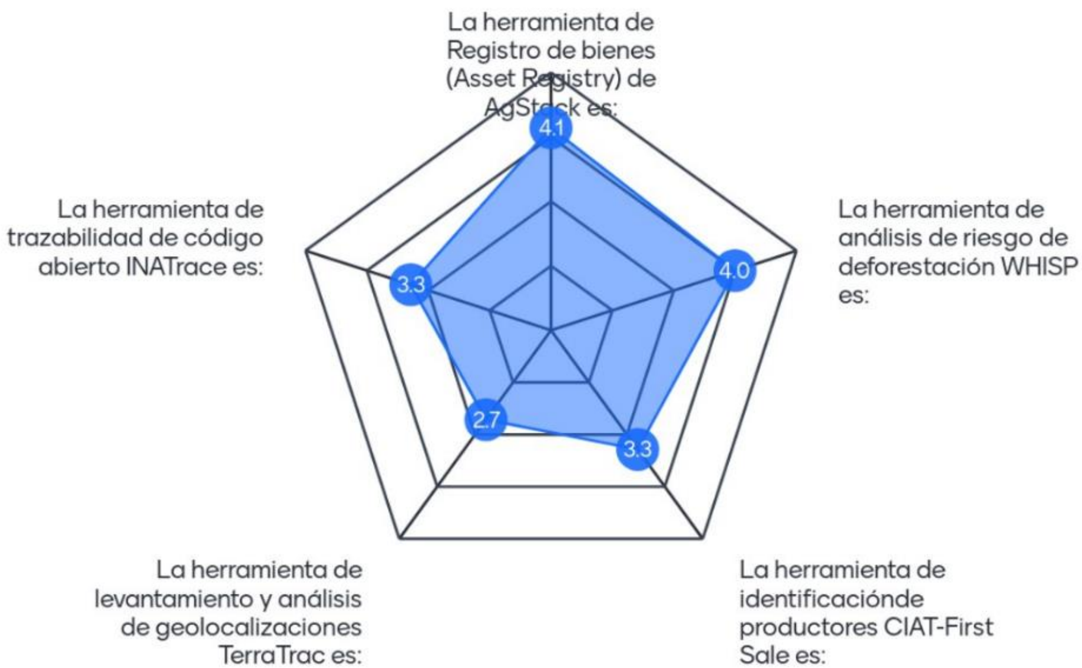

Figure 9. Core Development Group members ranked open source building blocks from "indispensable" to "nice to have." They found that open source/open standard tools are important for enabling pre-competitive collaboration and that Whisp and the Asset Registry, particularly, met acute needs across the Honduran coffee value chain. *(Source: Federico Ceballos-Sierra with Core Development Group)*

5.4 Toward a replicable data model for trustworthy, EUDR-compliant Honduran coffee

Sharing and re-using critical data and information has been recognized for years as a foundation for maintaining supply chain integrity and resilience to shocks.[xxiv] Comprehensive, replicable frameworks for this, however, have proven challenging to develop and use.[xxv] As a result, the agri-food sector continues to have an array of ill-coordinated approaches to data standards and sharing in supply chains.

Information scientists promote using ontologies—semantic knowledge structured in ways that both humans and computers understand—to organize and consistently share data. Ontologies provide precise definitions of important terms and explain how these relate to each other, creating a common language for linking knowledge across domains and organizational boundaries. Using relevant concepts in similar or equivalent ways across different data analytic systems can ease data sharing, comparison, and reuse.

Various ontologies map knowledge related to the agricultural sector. For example, AGROVOC is a multilingual thesaurus that connects data related to agriculture, fisheries, and environmental terms, helping harmonize research across fields like soil science and crop production.[xxvi] The Food Ontology (FoodOn) focuses on the food supply chain, aiming to ease data interoperability from farm production to food consumption. Other important ontologies include the Agronomy Ontology (AgrO) for standardizing crop management data and the Environment Ontology (ENVO), which helps researchers classify environmental factors.

Ontologies can play a key role in replicating data models by harmonizing key terms, clarifying how these concepts are related, and easing consistency and accuracy in complex datasets. Leveraging semantic resources like AGROVOC and FoodOn in developing a supply chain data model can enable researchers and other stakeholders to more easily link with data from different knowledge domains, such as crop yields, soil types, and land use. Many information scientists see ontologies as the "gold standard" for achieving semantic interoperability, and as a result, these ontologies influence data standards. However, it is important to note that ontologies can be time-consuming to develop; they require multiple domain experts to agree on precise definitions of multifaceted concepts. (This is not unique to semantic standards. Development of standards related to data syntax, structure, and associated information systems is a lengthy intergovernmental process.)

A tractable approach to common language for linking semantics, objects, and processes in agriculture: OpenRAL

For urgent needs like regulatory compliance, stakeholders must act quickly for standards to emerge and be widely adopted. A proactive approach is needed that can enable the use or reuse of multiple existing or future standards, can be integrated with both legacy and new information systems,[xxvii] and ensures that stakeholders control access to their own data. A functional, replicable data model need not seek to harmonize the array of evolving ontologies, systems, and standards for agriculture and food. Instead, it can focus on translating these as they are applied to a context-specific challenge. The Core Development Group working on EUDR-compliant Honduran coffee is testing OpenRAL[xxviii] for this purpose.

OpenRAL is a free and open digital description language for "objects" and "processes" and their interactions over time, focusing on enabling data exchange in agriculture. An OpenRAL "object" must have:

- Identity (unique ID, name, site tag, alternate IDs used)
- Definition (a definition text and a URL for the definition source)
- Specific properties (unique properties to this object)
- Current geolocation
- Process history

- Linked objects

"Objects" can be defined as needed to indicate specific locations or containers (e.g. a plot, a processing station, a sack of coffee), persons or entities, and product units to be traced. "Objects" can be aggregated into larger "objects" as needed.

An OpenRAL "process" (alternately called "method" by the OpenRAL maintainers) describes the interactions or transformations of one-to-many inputs resulting in one-to-many outputs, and can include as many sub-processes as may be needed. Each OpenRAL "process" must have:

- Identity (unique identifier, name, site tag)
- Definition (a definition text and URL)
- Specific properties
- Input objects
- Output objects
- Nested processes
- Object connectors
- State the process is in
- Timestamp of start of the process (using ISO 8601 standard for dates and times)
- Timestamp of end of the process (optional—using ISO 8601 standard for dates and times)
- Process duration
- Executor of the process

"Objects" and "Processes" are adaptable high-level concepts that can be defined in-context to mean slightly different things by the use-case—each with its accompanying text on how they have been defined. This is a more flexible approach to use of semantic knowledge than is typically enabled by ontologies, while enabling linking of concepts and associated data across systems and data schemas.

OpenRAL objects and processes can be implemented in the very common JSON and XML languages, forming the basis of interoperable data syntax.

<u>Using OpenRAL in practice for tracking and tracing EUDR-compliant Honduran coffee</u>

Tracking and tracing in agricultural supply is commonly understood to be the interaction of three key elements: product, premise, and party. OpenRAL would define each of these as a type of "object" in a supply chain, and associated "processes" would capture their interactions.

At least three types of supply chain actor (all a type of "object") interact with a product through various processes from harvest to export. An OpenRAL object "container" will be assigned to an agricultural plot with at least one unique identifier associated with it; "Harvest" will be a process, "farmer" will be an object that has a role in the process, and the output of that process will be one or more sacks of EUDR compliant coffee (each of them a “container”). “Consolidation” is a process of changing containers along the path toward export. (See Figure 11.)

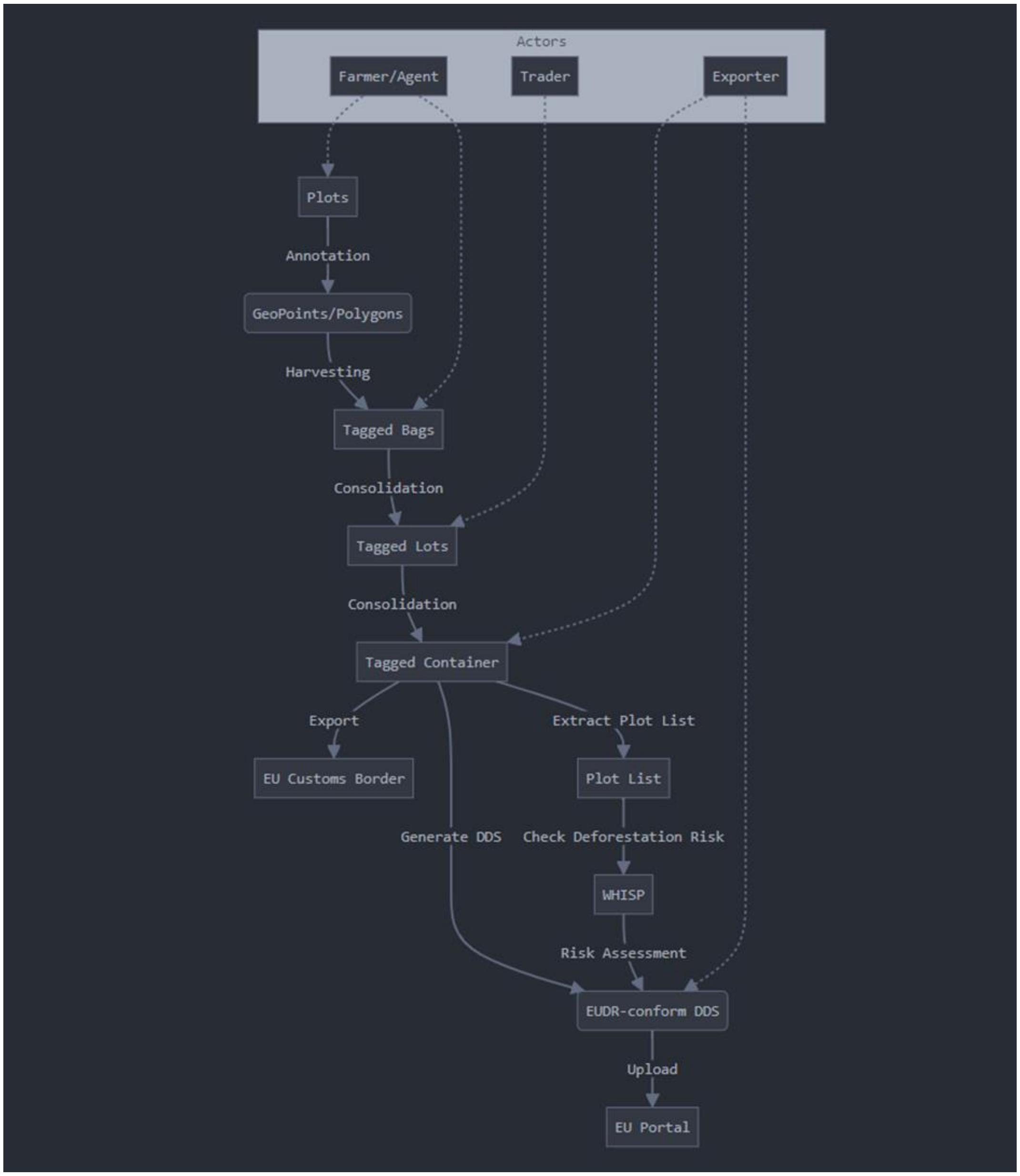

Figure 11. OpenRAL high-level concepts can be configured to accommodate as many “objects” and “processes” as may be required to track and trace agricultural products in supply chains, and the key changes in state of the product at each stage from harvest to export. *(Source: Permarobotics data interoperability group).*

Any process can accommodate nested sub-processes, such as those that might happen at points of consolidation (e.g. processes for “pulping,” or “drying”) as depicted in Figure 12.

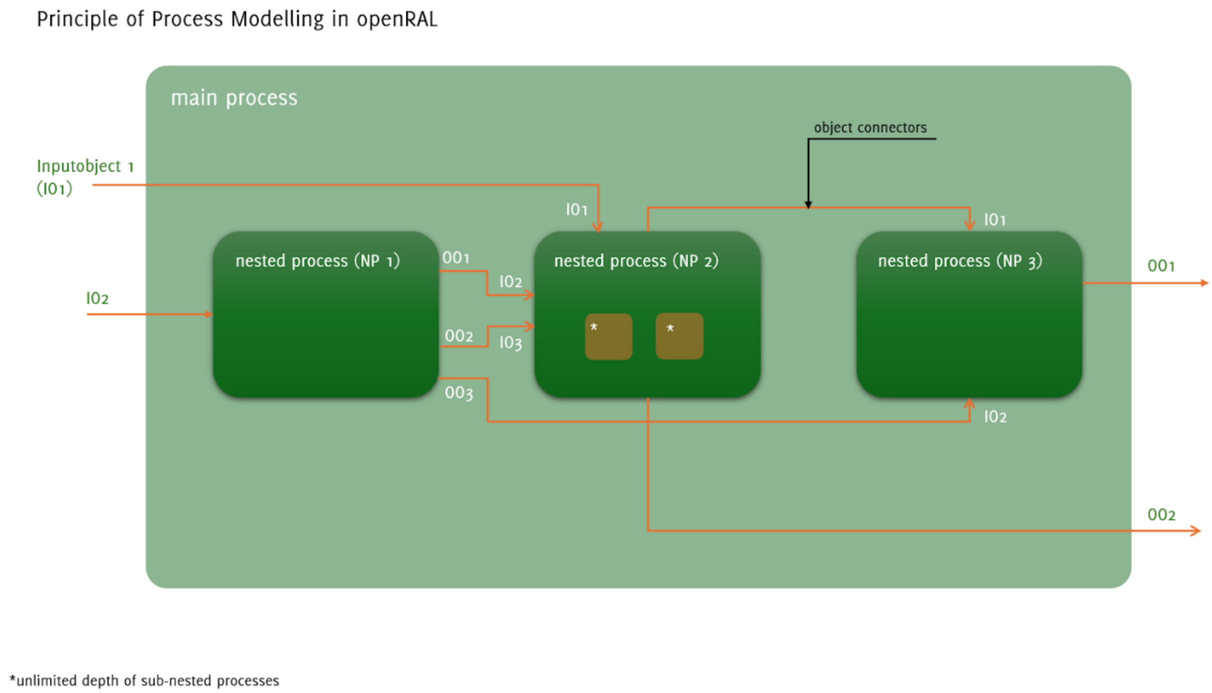

Figure 12. OpenRAL description language enables definition of processes that result in a change in state of an object, and can include as many linked sub-processes as needed. *(Source: Permarobotics data interoperability group).*

Processes can also include programming code ("bring your own code") about how input objects should be transformed into output objects, enabling a computer to execute the code and generate/modify the output objects or execute resulting tasks. Alternatively, processes can interface with a machine learning or large generative artificial intelligence (AI) model via a prompt ("bring your own prompt") for the model to perform the process. Both approaches could provide important capabilities for modeling and managing supply chain processes. For example, raw coffee cherries from compliant farms arriving at a processing station will go through several processes (e.g. aggregation, pulping, fermentation, drying) and each of these processes will result in specific transformations. The steps and expected outputs of each of these processes can be defined in the process itself—enabling more agile tracking of these transformations and providing a way to detect any variances.

For example, one key OpenRAL process supporting consolidation is "changeContainer" (a "container" can be anywhere the product is, such as a plot, sack, warehouse, shipping container etc.). Figure 13 shows the OpenRAL process "changeContainer" which includes or generates python code to manage consolidation of units ("items") into a new container, and follow-on disaggregation of product units to other containers, managing the unique identifiers and other OpenRAL object data of each. This consolidation process can also link sub-processes describing transformations that happen at the consolidation point.

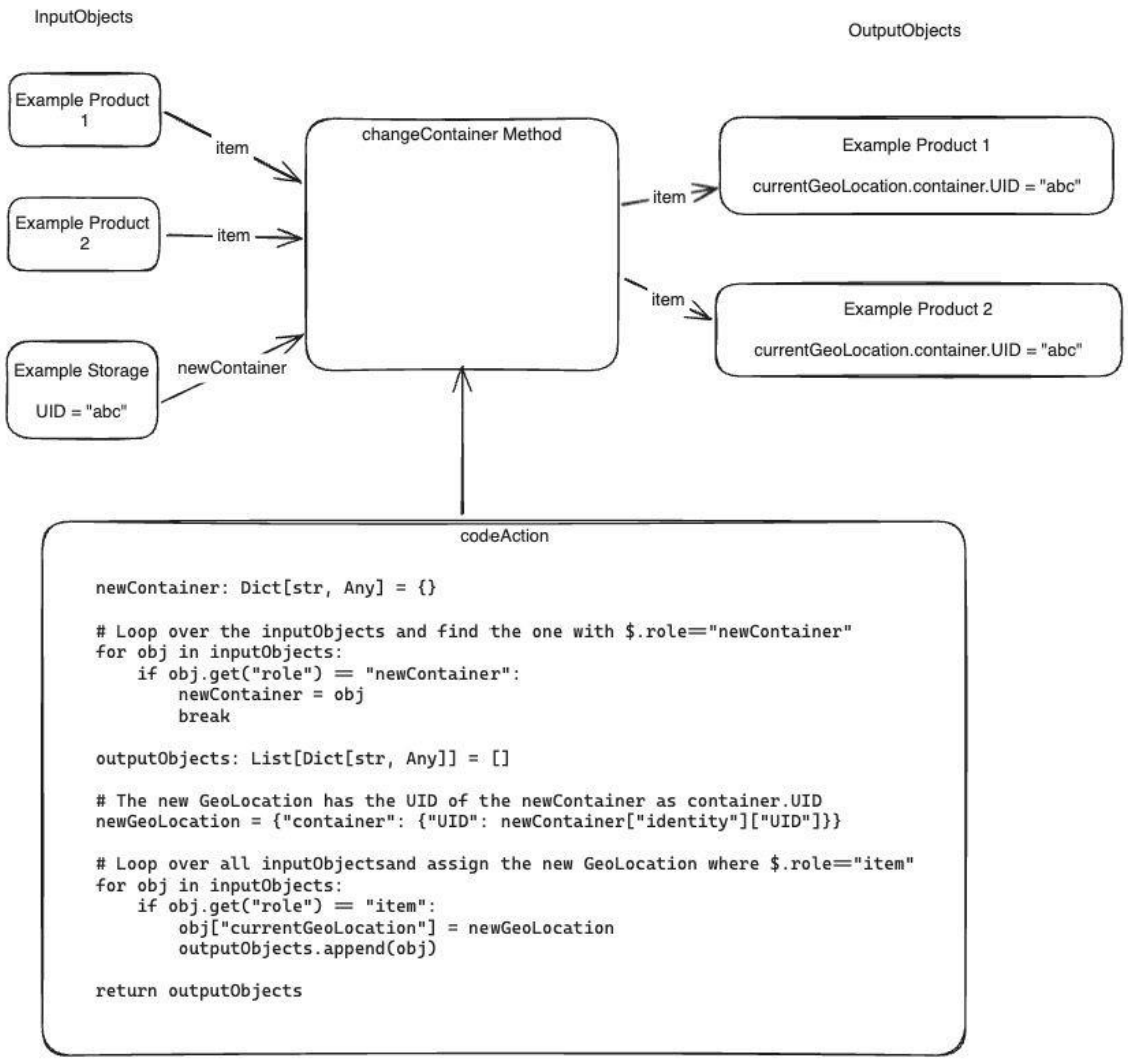

Figure 13. The OpenRAL process "changeContainer" includes or, with the help of generative AI models, generates python code to manage consolidation of units ("items") into a new container, and follow-on disaggregation of product units to other containers, managing the unique identifiers and other object data of each. This process can also link sub-processes describing transformations that happen at the consolidation point. *(Source: Permarobotics data interoperability group.)*

OpenRAL "objects" and "processes" are defined directly in their code with explanatory text and a link to a URL definition if one is available. This enables some semantic information to be coded directly into how an "object" or "process" has been defined in-context and provides a way both humans and machines can interpret how to link with other systems or processes.

Applying these high level concepts with some accompanying information about how they have been linked and applied in-context provides a way to bridge data semantics and structures. OpenRAL accommodates the very common JSON and XML languages, and as a result can enable interoperable data syntax.

In the context of the Honduran coffee project, the objects that are used in different roles (see Figure 12) are:

- Human
- legalEntity
- bag/sack
- container
- building
- transportVehicle
- plot
- coffee

The key processes used are:

- Harvesting
- change of location (transport, aggregation of coffee or its containers)
- change of ownership (selling or buying coffee)
    - The first sale process for coffee needs to be done by using a CIAT first sale card containing information about the plot as a GeoID. All subsequent sale processes will inherit this information so it will be available for every subsequent buyer
    - In addition, for the first sale process, additional information like amount and quality criteria must be entered that allow for weight adjustments and plausibility checks after later processing and sales processes.
- processing of coffee and sub-processes (from freshly harvested coffee to dried beans)
- generating an EUDR due diligence statement (for testing purposes only at prototype stage)—using Asset Registry GeoIDs and Whisp to link deforestation risks data)

The Core Development Group will continue to test OpenRAL as a flexible, extensible data model that can accommodate a diversity of semantics such as those used for Key Data Elements and Critical Tracking events (*See Annex Two*); any current or evolving industry data standards or syntax (See *Annex Three: GS1 approach to data models for traceability*), and new and legacy information systems. Through the use of open source/open standard building blocks and an open, configurable data model and description language, the group aims to demonstrate an open, modular, and effective cross-cutting new “interoperability layer” for EUDR compliant Honduran coffee that is replicable for other commodities. The code for the prototype of a shared service for EUDR-compliant coffee is wholly open and available for unrestricted use under an open license.[xxix]

Mini-case: the Rainforest Alliance

In May, 2024 the Rainforest Alliance (RFA) announced the first container of EUDR-Compliant verified by RFA had been shipped the Europe.

RFA was able to achieve this through three interlinked approaches:

- **Working with one farm**
- **Leveraging over 10 years' experience monitoring deforestation and providing certification**
- **Working with "identity preserving" supply chains.**

Working with one farm.
The container in question originated from High Range Coffee Curing (HRCC) in India, a specific coffee farm verified by RFA as not having contributed to deforestation. RFA advised HRCC on compliance requirements, and supported the farm with verifying that its coffee production was "deforestation free."

Leveraging 10 years' experience monitoring deforestation.
RFA began formally monitoring deforestation over ten years ago, with a cut-off date of on January 1, 2014, and this has been the foundation of their certification. Two of the commodities in scope for EUDR (cacao and coffee) were already a focus for RFA certification for some years before the regulation was drafted. Similar to EUDR requirements, RFA certifications must be consistent with national law.

The analytics supporting RFA certification were also largely in place before the arrival of EUDR. RFA was already tracking farm units using polygons and GPS coordinates (albeit with slightly less precision than required by EUDR). It was only a matter of updating these aspects of their certification to support EUDR compliance.

Identity-preserving supply chains

RFA has for several years worked with "identity-preserving" supply chains that ensure that the specific attributes and origins of a product are maintained throughout the trajectory of lots of the commodity. While RFA does not directly provide full traceability (and the supply chain providers it works with may or may not be able to do so), the approach does appear to create credible documentation that a shipment came from a 'deforestation free' area.

6. Discussion and Conclusions

The EUDR has created a sense of urgency among supply chain actors in its target commodities to get ready for compliance, and there is still much work to do. While EUDR presents a complex challenge, it may be useful to consider it as one example in a long history of shocks. Extreme weather events, financial crises, conflict, a global pandemic—all have created sudden and multifaceted pressures on supply chains. A review of the literature on supply chain resilience can even be a bit discouraging as a familiar pattern is repeated: a shock arises, supply chain participants rush to respond, and the lessons about how to navigate those particular shocks are learned too late. There are some indications, however, that active collaboration and knowledge sharing help make supply chains more agile and adaptive as they respond to new challenges.[xxx] Regulations related to living income, fair labor practices, food quality and safety, and illicit trade will all certainly be the focus of future regulations, and they could generate new regulatory "shocks" in addition to the climatic, political, and financial shocks that will continue to arise.

The 'recipes' for supply chain integrity, interoperability, and trust examined in this working paper may help supply chain actors equip themselves with new tools to address emergent challenges, a key contribution toward building more resilient food systems overall.[xxxi,xxxii] Future work in this area could focus on expanding the open source, open standard, and open learning "interoperability layer" outlined here for bridging data semantics, structure, syntax, and systems in new contexts. This could inform more comprehensive "how-to" guidance for multiple stakeholders aiming to create more resilient and sustainable supply chains, benefiting producers, consumers, and the environment.

Annex One: Key standards for building supply chain integrity

A number of existing standards should be considered related to the proposed action areas for building supply chain integrity.

Authentication	Traceability	Verification
Object Authentication ISO 22383:2020 Security and resilience — Authenticity, integrity and trust for products and documents — Guidelines for the selection and performance evaluation of authentication solutions for material goods. https://www.iso.org/standard/50285.html ISO/IEC 20248:2022 Information technology — Automatic identification and data capture techniques — Digital signature data structure schema. https://www.iso.org/standard/81314.html **Object Identity** GS1 Standards Global standards for identification, capturing, and sharing of supply chain data, including barcodes and RFID. https://www.gs1.org/standards ISO/IEC 15459-1:2014 (part of a 6-part series 15459-1-6) Unique identification of transport units, individual products, and returnable transport items. Assigns roles to Issuing Agencies. https://www.iso.org/standard/54779.html There are many recognized systems for generating	**Traceability** ISO 9001:2015 Quality management systems, including requirements for traceability. https://www.iso.org/standard/62085.html ISO 22000:2018 Food safety management systems, which include requirements for traceability. https://www.iso.org/standard/65464.html GS1 Traceability Standard. https://www.gs1.org/standards/gs1-global-traceability-standard/current-standard Fresh Fruit and Vegetables Traceability Guidelines (GS1) https://ref.gs1.org/guidelines/fruit-veg/ GS1 Global Meat and Poultry Traceability Guideline, Part 2. Beef Supply Chain (2015) https://www.gs1.org/docs/traceability/GS1_Global_Meat_and_Poultry_Guideline_Part2_Beef_Supply_Chain.pdf ISO/TS 24533:2012 Intelligent transport systems — Electronic information exchange to facilitate the movement of freight and its intermodal transfer — Road transport information exchange methodology https://www.iso.org/standard/46422.html ISO 22005:2007	**Verification** ISO 19011:2018 Guidelines for auditing management systems. https://www.iso.org/standard/70017.html ISO 17020:2012 Requirements for the operation of various types of bodies performing inspection. https://www.iso.org/standard/52994.html ISO 19144-2:2012 - Geographic information — Classification systems — Part 2: Land cover meta language (LCML). Provides a key semantic standard related to land cover (e.g. forest) and land use (e.g. farming) that is important for harmonizing verification of environmental credence claims. https://www.iso.org/obp/ui/#iso:std:iso:19144:-2:ed-1:v1:en **Origin verification** ISO 22005:2007 Traceability in the feed and food chain, general principles, and basic requirements for system design and implementation. https://www.iso.org/standard/36297.html ISO 17065:2012 Conformity assessment – Requirements for bodies certifying products, processes, and services.

UUIDs and these are documented in a variety of standards. These include ISO/IEC 11578:1996 "Information technology –Open Systems Interconnection – Remote Procedure Call (RPC)" and, more recently, ITU-T Rec. X.667 | ISO/IEC 9834-8:2014. **Object Origin** ISO 22005:2007 Traceability in the feed and food chain, general principles, and basic requirements for system design and implementation. https://www.iso.org/standard/36297.html GlobalGAP - Standards for good agricultural practices, including traceability from origin to point of sale. https://www.globalgap.org/ **Object Security** ISO 28000:2022 Security and resilience — Security management systems — Requirements. https://www.iso.org/standard/79612.html ISO/IEC 27001:2022 Information security, cybersecurity and privacy protection — Information security management systems — Requirements. https://www.iso.org/standard/27001 ISO/IEC 15459-2:2015 Information technology — Automatic identification and data capture techniques — Unique identification. Part 2: Registration procedures https://www.iso.org/standard/54780.html ISO/IEC 15459-3:2014 Information technology — Automatic identification and	Traceability in the feed and food chain — General principles and basic requirements for system design and implementation https://www.iso.org/standard/36297.html ISO/IEC 15944-5:2008 Information technology — Business operational view. Part 5: Identification and referencing of requirements of jurisdictional domains as sources of external constraints https://www.iso.org/standard/38629.html ISO/IEC 14662:2010 Information technology — Open-edi reference model https://www.iso.org/standard/55290.html ISO/IEC 15944-17:2024 Information technology — Business operational view. Part 17: Fundamental principles and rules governing Privacy-by-Design (PbD) requirements in an EDI and collaboration space context https://www.iso.org/standard/87331.html ISO/IEC 15944-21:2023 Information technology — Business operational view. Part 21: Guidance on the application of the Open-edi business transaction ontology in distributed business transaction repositories https://www.iso.org/standard/78924.html ISO 22095:2020 - Chain of Custody — General Terminology and Models defines a framework for chain of custody by providing: — a consistent generic approach to the design, implementation and management of chains of custody; — harmonized terminology; — general requirements for different chain of custody models;	https://www.iso.org/standard/52994.html **Compliance (EUDR)** ISO 19600:2014 Compliance management systems, guidelines. https://www.iso.org/news/2014/12/Ref1919.html ISO 37301:2021 Compliance management systems, requirements with guidance for use. https://www.iso.org/standard/75080.html ISO 5127:2017 Information and documentation — Foundation and vocabulary https://www.iso.org/standard/59743.html ISO 22388:2023 Security and resilience — Authenticity, integrity and trust for products and documents — Guidelines for securing physical documents https://www.iso.org/standard/80716.html ISO 22300:2021 Security and resilience — Vocabulary https://www.iso.org/standard/77008.html

data capture techniques — Unique identification. Part 3: Common rules https://www.iso.org/standard/54781.html ISO/IEC 15459-6:2014Information technology — Automatic identification and data capture techniques — Unique identification. Part 6: Groupings https://www.iso.org/standard/54786.html ISO/IEC 15459-1:2014Information technology — Automatic identification and data capture techniques — Unique identification. Part 1: Individual transport units https://www.iso.org/standard/54779.html ISO 22380:2018 Security and resilience — Authenticity, integrity and trust for products and documents — General principles for product fraud risk and countermeasures https://www.iso.org/standard/73857.html ISO 22388:2023 Security and resilience — Authenticity, integrity and trust for products and documents — Guidelines for securing physical documents https://www.iso.org/standard/80716.html	— general guidance on the application of the defined chain of custody models, including initial guidance on the circumstances under which each chain of custody model might be appropriate.	

Annex Two: Key Data Elements (KDEs) & Critical Tracking Events (CTEs)

Key Data Elements (KDEs) and Critical Tracking Events (CTEs) are essential components of supply chain traceability, and they play a crucial role in maintaining supply chain integrity and interoperability.

KDEs are specific pieces of information that need to be captured and recorded at various stages of the supply chain. These elements provide detailed data about the products, such as their origin, batch numbers, processing details, and more. CTEs, on the other hand, are the significant points in the supply chain where KDEs must be recorded. These events include production, transportation, processing, and distribution, and they are critical for tracking the movement and transformation of products. These components enable businesses to monitor and manage the flow of goods, information, and resources effectively, ensuring compliance with regulatory requirements, maintaining quality standards, and improving overall efficiency.

The significance of KDEs and CTEs is underscored by their incorporation into the revised traceability regulations by the US Food and Drug Administration (FDA) as part of its Food Safety Modernization Act (FSMA). According to the FDA, "At the core of this rule is a requirement that persons subject to the rule who manufacture, process, pack, or hold certain foods, maintain records containing Key Data Elements (KDEs) associated with specific Critical Tracking Events (CTEs); and provide information to the FDA within 24 hours or within some reasonable time to which the FDA has agreed. The final rule aligns with current industry best practices and covers domestic, as well as foreign firms producing food for U.S. consumption, along the entire food supply chain in the farm-to-table continuum."[xxxiii]

Key Data Elements (KDEs)

KDEs are specific pieces of information that must be collected and recorded at various points within the supply chain. They provide detailed insights into the attributes and status of products, materials, and transactions. KDEs are crucial for tracking the provenance, movement, and condition of goods.

Examples of KDEs:

1. **Product Identification**: Unique identifiers such as SKU (Stock Keeping Unit), GTIN (Global Trade Item Number), or serial numbers.
2. **Batch/Lot Number**: Information linking a product to a specific production batch or lot for traceability.
3. **Date and Time Stamps**: Information on when specific events occur, such as production dates, shipment dates, or receipt dates.
4. **Location Data:** Geographic identifiers indicating where an event takes place, such as production sites, warehouses, or retail locations.

5. **Quantity:** Information on the number of units or volume of goods involved in a specific event.
6. **Supplier Information**: Details about the supplier, including name, address, and contact information.
7. **Quality Attributes:** Data on quality parameters, such as inspection results, temperature conditions, or compliance certifications.

Critical Tracking Events (CTEs)

CTEs refer to the key events or milestones within the supply chain where KDEs must be captured and recorded. They represent points where goods change status, ownership, or location, and are essential for maintaining traceability and accountability.
Examples of CTEs:

1. **Receiving**: The event of goods being received at a warehouse or production facility. KDEs captured might include date, time, quantity, and condition of goods.
2. **Production**: The event of goods being manufactured or processed. KDEs here could include batch numbers, production date, and quality control results.
3. **Shipping:** The event of goods being dispatched from a facility. Relevant KDEs might be shipment date, carrier information, destination, and tracking numbers.
4. **Storage:** The event of goods being stored in a warehouse. KDEs could include location within the warehouse, duration of storage, and environmental conditions.
5. **Transformation**: The event of goods being transformed, such as assembly, mixing, or repackaging. KDEs would include details of the transformation process and the new product identifiers.
6. **Distribution:** The event of goods being distributed to retailers or end customers. KDEs might include distribution route, delivery date, and receiving party details.
7. **Recall:** The event of goods being recalled due to quality or safety issues. KDEs would include recall date, affected batch/lot numbers, and reason for recall.

A practical example might help. CTEs applied to a food supply chain for a product like canned tomatoes could defined as follows:

- **Receiving**: Tomatoes are received at the processing plant. KDEs recorded include supplier information, batch number, quantity, and receiving date.
- **Production:** Tomatoes are processed and canned. KDEs recorded include production date, canning line used, and quality test results.
- **Shipping:** Canned tomatoes are shipped to a distribution center. KDEs recorded include shipment date, carrier details, and destination.
- **Storage**: Canned tomatoes are stored at the distribution center. KDEs recorded include storage conditions, location within the warehouse, and storage duration.
- **Distribution**: Canned tomatoes are distributed to retail stores. KDEs recorded include delivery date, store details, and quantities delivered.

Annex Three: Mapping Integrity, Interoperability, and Standards to Capabilities for EUDR-Compliant Honduran Coffee

A swath of organizations representing the Honduran coffee value chain agree that several capabilities must exist and be coordinated at the 'whole-of-chain' level to support export of EUDR-compliant coffee. Development of these capabilities will require application of key aspects of integrity, interoperability, and standards at key points in the overall flow of data and products across the chain. These are outlined in Table 1 below, and discussed in more detail here.

1. **Generation or capture of points and polygons.** Points and polygons related to agricultural fields are generated by an array of actors using an array of technologies, from applications that support generation or registry of polygons in the field, to remote sensing-based solutions.[xxxiv] (EUDR compliance requires that due diligence of farms 4 hectares or larger be supported with specific polygons on the globe, and that farms smaller than this be linked to points.)

    - **Integrity:** ***Process and data*** must be as consistent as possible across modes of data collection. Ethical behavior by the ***people*** involved in capturing, generating, or sharing polygons will be of fundamental importance for protecting the privacy and agency of small producers.
    - **Interoperability:** Consistency in operating procedures for capturing or generating polygons as well as in formats used for the resulting spatial data (e.g. GeoJSON) can support comparability, sharing, and re-use of data in different systems—enabling ***technical, organizational, and syntactic*** interoperability. Common terms for describing these data (e.g. 'field' or 'plot') would enable ***semantic*** interoperability.
    - **Standards:** ISEAL, the international alliance for sustainability standards, has issued guidance[xxxv] on the collection of polygon location data for sustainability systems that may inform ***standard operating procedures*** for these data, to which formal international metadata standards for spatial data could be applied.

      The closest thing to an international ***semantic standard for "field" or "plot"*** may be in AGROVOC, the multilingual agricultural thesaurus managed by the Food and Agriculture Organization (FAO), which includes terms related to agricultural fields and plots under the more general concept of "site." In AGROVOC, the concept of a "field" is typically referred to under terms like "agricultural field" or "plot" depending on the context and language variations.[xxxvi]

      The FAO/ISO standard 19144-2:2012 Geographic information - Classification systems — Part 2: Land Cover Meta Language[xxxvii] is also important to consider, since the concepts of "forest" land cover or agriculture uses are central to EUDR compliance, but as of September 2024 an update of this standard was in the final stages of revision.

To build on EUDR data and systems to advance sustainability (i.e. going beyond just its trade dimensions), linking data regarding land use and its environmental impacts is also an underlying need at this stage. Standards for doing this, however, are still emergent. One tractable way forward appears to be the adoption and use of HESTIA, a University of Oxford-stewarded data format for harmonizing agri-environmental impact and activity data.[xxxviii]

2. **A shared and collaboratively governed service supporting**:
    - data quality control and deduplication of polygons,
    - creation of a shared registry of polygons,
    - determining (leveraging either via hosted geospatial analytics or an external service) if points or polygons are "deforestation free."
3. **Minting of interoperable unique IDs** for that can be associated with each specific polygon.
4. **Issuance of a standard "knowledge object":** a string of code/data comprised of the polygon ID and key attribute of "deforestation free"

    - **Integrity:** Stakeholders must define and collaboratively govern trustworthy approaches to people, process, and data supporting these capabilities.
    - **Interoperability:** Data must be described using agreed-on terms (semantic interoperability) and consumable by the array of chain of custody systems and certification approaches (organizational operability) in the country through common data formats such as JSON or GeoJSON (syntactic interoperability), and a 'live' service to ease multiple organizations checking polygons or points against the registry (technical interoperability).
    - **Standards:** There are multiple international standards related to object identification (see a more expansive list of these in *Annex One*), but critical for the establishment of this shared service will be compliance with the ISO/IEC 15459 group, which provides information on the identification of Issuing Agencies for such unique identifiers linked to objects.

5. **Protection of knowledge objects and provision of a cryptographic key** is at the heart of an approach to architecture intended to protect privacy and support the agency of data owners and subjects, supporting their ability to give and revoke consent for using data linked to specific plots.
    - **Integrity:** Stakeholders must develop a trustworthy approach to people, processes, and data across a diversity of contexts to ensure this step supports the right to consent to use of data by data owners and subjects.
    - **Interoperability:** Widely-used encryption technologies may be required for technical and organizational interoperability, and stakeholders will need to pick one

or more that will be acceptable, and align organizations around its use to protect the right to consent of data by data owners and subjects in the Honduran context.

- **<u>Standards:</u>** International standards for cybersecurity will be important to consider, including ISO/IEC 15944-17:2024 Information technology — Business operational view. Part 17: Fundamental principles and rules governing Privacy-by-Design (PbD) requirements in a collaboration space context.

6. **Association of the knowledge object with the physical unit of traceability (offline functionality)** the ability to link the point or polygon for where coffee was harvested to specific sacks of coffee must work in rural areas, even beyond the reach of data connectivity.
   - **<u>Integrity:</u>** Trustworthy approaches to people, process, data, and product must all be defined for the "first mile" where sacks of coffee are collected.
   - **<u>Interoperability:</u>** Systems (technical interoperability) must support all aspects of integrity and interoperability specifically in "offline" mode in rural contexts; the prototyping group must define specific technologies to be applied that will be acceptable to the majority (organizational interoperability). One solution considered for the knowledge object itself is JSON code for product ID with the unique geographic identifier minted for each field point or polygon encoded into it, enabling checking of compliant polygons against a shared registry.
   - **<u>Standards:</u>** The Core Development Group has elected to test a combination of Near Field Communications (NFC) cards and devices with associated QR codes for linking specific sacks of coffee in a given transaction to both location (point or polygon) and actors (seller, purchaser), which will require observance of ISO/IEC standards on data exchange by NFC devices (18092:2013) and cards for personal identification (14443-1:2018).

     In addition, an array of established and emergent standards for ensuring that digital objects correspond to their physical objects must be taken into account (several of these are noted in *Annex One*).

7. **Chain of custody systems check knowledge objects against the shared registry**
8. **The registry interfaces with governmental functions:** the shared service must interface appropriately with cadastral systems, quality control, any regulatory databases or systems, licensing systems, and other state functions.
9. **The registry interfaces with third party/civil society functions:** the shared service must interface appropriately with third party functions such as independent certification schemes, laboratory or systems, licensing systems, and other state functions.

   - **<u>Integrity:</u>** This is the core of a service for ensuring data integrity, and supporting integrity of people and process.
   - **<u>Interoperability:</u>** Stakeholders must agree (organizational interoperability) on application programming interfaces (technical) to enable interface of systems, and a data format for knowledge objects (syntactic interoperability) that can flow through the chain to support compliance-related capabilities.

- **Standards:** Any existing standards regarding application programming interfaces (APIs) linked to ISO 22095:2020 - Chain of Custody.

10. **Knowledge objects accrete as physical objects are aggregated and change hands "Russian doll"-style until they reach the container for export**
    - **Interoperability:** The joint ISO/GS1 EPCIS data interoperability standard enabling event tracking, featuring elements of technical, syntactic, and interoperability.
    - **Standards:** ISO/IEC 15459 standards related to grouping of objects along a chain/string of actions. Standards standard operating procedures for "Identity Preserving" supply chains.

11. **Key Data Elements and Critical Tracking Events are defined:** the value chain participants jointly define what key characteristics (corresponding to Key Data Elements-or "KDEs") and transformations or transactions (corresponding to Critical Tracking Events or "CTEs") that must be registered to enable the flow of data alongside the physical units of coffee destined for a container of EUDR-compliant coffee (See more detailed discussion of these in *Annex Two*).
    - **Standards:** GS-1 standards for KDEs and CTEs will be important to review and, if needed, complement or fine-tune for EUDR compliance purposes.

12. **Interface with EUDR compliance database and the World Customs Organization:**

    - **Integrity:** Significant engagement (and likely advocacy) with EU authorities will be needed to promote approaches to people, process, data, and product that have been validated in the Honduran context to support EUDR compliance.
    - **Interoperability:** Ensuring appropriate interface with the World Customs Organization 'single window' service and the EU due diligence database (technical).
    - **Standards:** any existing standards regarding application programming interfaces (APIs) related to classes of systems (e.g. financial transaction systems, chain of custody, geospatial/navigation systems) that may intersect with the flow of the product and regulatory systems.

Annex Four: GS1 Standards, Semantics, and Syntax for Configurable Data Models for Traceability

To support compliance with the coming wave of sustainability regulations, supply chains will need to adopt data models easing the capture and exchange of comparable and critical information. These models must encompass, at a minimum, unique identifiers for every product, location, and business entity involved. Furthermore, key data elements (KDEs) such as geolocation coordinates, certification statuses, and timestamps of critical tracking events (CTEs) are essential. Additionally, the data model must be interoperable with global standards, to facilitate seamless information sharing across systems and regulatory environments.

Structuring data in a standardized, accessible manner can support transparency and trustworthiness in agricultural supply chains, through providing verifiable evidence of their processes. With increasing demand for sustainable products, the role of tractable, interoperable data models becomes more critical. For instance, traceability systems ensure that commodities sourced from forested regions travel with all the necessary data points (such as origin, transport times, and certification) and are recorded and shared to demonstrate that the specific product did not contribute to deforestation.

While no one-size-fits-all model exists for traceability, industry-developed standards like those facilitated by GS1 offer a useful foundation. The GS1 Traceability Toolkit Traceway guides a user through the process of ensuring that each agent, location, and product in the supply chain is uniquely identified.[xxxix] For example, using GS1 Traceway, a timber company could equip itself to track their product from forest to retailer, meeting all regulatory and certification requirements throughout the process.

A GS1-enabled approach to data models: dynamic and static data

GS1 Germany released a discussion paper (or “Green Paper”) seeking to outline specifically how GS1 standards can be applied for EUDR compliance.[xl] According to the GS1 Green Paper, the data required by the EUDR can be categorized into two types:

1. Dynamic Data (Event Data) – This type of data is generated as supply chain events occur. It captures the movements and transactions related to products, such as the timestamp of a logging operation or the location of a storage facility.
2. Static Data (Master Data) – Static data elements remain relatively unchanged over time and serve as reference points, such as the physical address of a processing plant or the company’s legal entity information.

Dynamic Data: ISO/GS1 Electronic Product Code Information Services(EPCIS)

Central to dynamic, event-driven data the global GS1 standard EPCIS that enables businesses to capture and share information about the movement and status of products as they move through the supply chain. For example, an EPCIS entry might resemble the following:

Field Name	Data Type	Description
EventTime	Date and Time Stamp	The time the event occurred (e.g., 2024-09-15T08:00:00Z).
EventTimeZoneOffset	String	Time zone offset from UTC.
Action	Code value (OBSERVE)	Indicates the type of action (e.g., Observe, Add, Delete).
BizStep	URI	Describes the business step (e.g., import declaration process).
ReadPoint	Location (Wrapper)	The place where the event occurred.
BizTransactionList	List	Business transactions (e.g., purchase order, delivery notes).
HarvestDate	Date	The harvest date of raw materials (conditional on product type).
QuantityList	List of QuantityElements	Amount of product involved in the event (e.g., 100 cubic meters of logs).

In this standard format, dynamic data about the “who, what, when, why, or where” of the product journey can be recorded in real-time throughout its journey and shared across systems. For instance, a timber company using the EPCIS standard could access event records showing the entire journey from logging to shipment.

EPCIS Origin Declaration Event

The EPCIS standard is applied from the point of origin, through the generation of an EPCIS Origin Declaration Event that is structured to capture specific data points related to a product's origin. Each event within this structure records timestamps, location IDs, business transactions, and product classifications, ensuring critical information is standardized and accessible throughout the supply chain.

For example, an EPCIS event related to a shipment of timber logs could include:

- **EventTime**: **2024-09-15T08:00:00Z**
- **Action**: Observe (indicating a record of observation)
- **Location ID**: **Location12345 (Amazon Rainforest, Brazil)**
- **Business Transaction**: **Import declaration submitted on 2024-09-16**
  This structured approach ensures that data remains compliant with regulations like EUDR by capturing essential information at each checkpoint, maintaining data integrity across the supply chain.

Static Data: Master Data for Supply Chain Integrity

Master data provides static descriptions of entities within the supply chain, such as legal entities, physical locations, and trade items. This data, though unchanging, plays a crucial role in verifying the integrity of the supply chain.

Party Master Data

For EUDR compliance, companies must maintain records of the businesses from which they receive products and the ones to which they supply them. For example, the master data for **ABC Timber Co.**, identified by a Global Location Number (GLN), may include:

- Organization Name: **ABC Timber Co.**
- PartyGLN: **GLN1234567890123**
- Address: **123 Timber Lane, Sweet Home, Oregon, USA**
- Postal Code: **12345**
- Country: **USA**

Location Master Data

Location master data refers to the physical sites involved in production or storage. For example, the master data for a processing plant in Germany might resemble the following:

- Location Name: **Berlin Processing Plant**
- LocationGLN: **GLN0987654321098**
- Address: **45 Industrial Way, Berlin, Germany**
- GeoCoordinates: **52.5200° N, 13.4050° E**

Product Master Data

Product master data describes the trade items themselves. For example, a product like processed timber planks would have master data including:

- Product Name: **Sustainably Sourced Oak Timber Planks**
- GTIN: **GTIN12345678901234**
- Country of Origin: **USA**
- Commodity Description: **Wood, Oak, Sawn or chipped lengthwise**

GS1 standards provide important building blocks for traceability in supply chains. They are highly configurable to accommodate the diversity of firms, regions, contexts and commodities where they are applied. A completely replicable GS1 data model for traceability has not been developed due to the diversity of organizations that must use them and contexts within which they are applied. Nevertheless, as demand for sustainable products grows, GS1 tools and standards will continue to play an important role in building global supply chain integrity.

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