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Trase 'SEI-PCS Brazil beef v2.0.1' supply chain map: Data sources and methods

Trase maps supply chains for agricultural commodities, making it possible to link products and supply chain actors with specific areas of production, and associated sustainability risks and opportunities. It uses an approach called Spatially Explicit Information on Production to Consumption Systems (SEI-PCS) as the basis for this work (see this webpage or our manual for more detail). This document describes the data and methods that Trase used to map the subnational supply chain for Brazilian beef exports from 2015-2017, using a model called **'SEI-PCS Brazil beef v2.0.1'.**

For all beef, offal and live cattle exports from 2015-2017, this model mapped the likely municipality of origin. It used trade and production data, slaughterhouse tax registrations, company asset-ownership information, export licences, a large dataset of cattle movements between farms and from farms to slaughterhouses, and government data on the origin of cattle slaughtered in export-approved slaughterhouses. The model used a decision tree to link exports to slaughterhouses. It then used data on animal transport movement to identify the likely municipalities of origin of cattle sourced from each slaughterhouse. Table 1 provides an overview of key statistics.

Table 1. Summary statistics

	2015	**2016**	**2017**
Brazil cattle herd (million heads of cattle)	215.22	218.2	214.9
Beef and live cattle exports (million tonnes)*	1.40	1.40	1.43
Municipalities that produce cattle linked to exports	3194	3215	3227
Number of exporting companies	138	138	142
Number of importing countries	127	130	130
Exports with unknown source of origin (%)	1.3	1.2	0.35

* = metric tons

Data and sources

Trade data

The model used per-shipment data (such as customs data, bills of lading and/or cargo manifests) for 2015 - 2017 covering all exports of beef, bovine offal, and live cattle exports classified under the NCM (Nomenclatura Comum do Mercosul; a system for classifying traded goods) codes listed in Table 2. We used a commodity-equivalence factor (see Table 2) to convert different products to a standard commodity equivalent, in this case carcass equivalent. This made it possible to quantify and communicate as a single value (tonnes) the total quantity of beef and beef products that Brazil exports. We confirmed the quality of the trade data by comparing it with other data sources and with data in different aggregated forms (such as the aggregated data of the Ministry of Development, Industry and Foreign Trade; MDIC).

Table 2. Cattle product NCM codes and commodity-equivalence factors (from product to carcass equivalent)

Product	**NCM code**	**Commodity-equivalence factor**
Beef products (frozen), forecuts	02022010	1.000
Beef products (frozen), hindcuts	02022020	1.000
Beef products (frozen), other	02022090	1.000
Beef products (frozen), deboned	02023000	1.373
Beef products (fresh or chilled), forecuts	02012010	1.000
Beef products (fresh or chilled), hindcuts	02012020	1.000
Other boned bovine meats (fresh or chilled)	02012090	1.000
Beef products (fresh or chilled), deboned	02013000	1.373
Edible bovine meats and offal, fresh or frozen	02061000	1.000
Edible bovine meats and offal, tongue (frozen)	02062100	1.000
Edible bovine meats and offal, liver	02062220	1.000
Bovine tails, frozen	02062910	1.000
Edible bovine meats and offal, other	02062990	1.000
Edible bovine meats and offal, processed	02102000	1.611
Processed and canned bovine products	16025000	2.333
Pure-bred bovine animals for reproduction — pregnant or with calf at foot	01021010	0.599
Other reproductive pure breed animals	01021090	0.599
Pure-bred bovine animals for reproduction — pregnant or with calf at foot	01022110	0.599
Other reproductive pure breed animals	01022190	0.599
Other live bovine animals	01029000	0.599
Other bovine animals, for reproduction — pregnant or with calf at foot	01029011	0.599
Other live domestic bovines	01022990	0.599
Other bovine animals	01029090	0.599

Production data

Cattle heads per municipality

We obtained data on the numbers of cattle heads per municipality per year from the Institute of Geography and Statistics (IBGE) and its municipal livestock research (IGBE 2015).

Slaughter rates

We calculated the slaughter rate as the number of cattle slaughtered divided by herd size per state (IEG FNP Agribusiness 2019; IBGE 2015), accounting for inter-state movements to slaughter (MAPA

2018a). In Amazonas, Amapá, Pernambuco, and Bahia slaughter rates exceeded 25%, despite low intensity cattle ranching in each state, so we correct these outliers to the nationwide average for 2015-2017, of 18.1% (ABIEC 2016, 2017, 2018). The slaughter rate for São Paulo, where our calculations otherwise underestimated production, was also corrected to 40.72%, based on published estimates (Instituto de Economia Agrícola 2017, 2018; Assocon 2007).

Carcass weights

We calculated carcass weights using state- and year-specific data, taking the IBGE's quarterly slaughter survey data on the total tonnes of cattle carcasses per state and dividing it by the number of slaughtered heads (IBGE 2019). We included offal weights, assuming that offal makes up 6.3% of average live weight (450 kg), based on the Brazil-specific offal conversion factors published by the Food and Agriculture Organization of the United Nations (FAO 2018). Where carcass or slaughter data were missing (as was the case for some years in Amapá, Distrito Federal, and Rondônia), we used the nationwide average carcass weight per quarter.

Supply chain waste

We assumed 1.1% losses from cattle deaths during transport to slaughter and carcass condemnation at slaughterhouses, and a further 5% because of trimming spillage during slaughtering and industrial processing, based on FAO estimates of livestock supply chain waste in Latin America (FAO 2011).

Municipal herd composition

The age-profile of cattle in each municipality come from the 2006 agricultural census (the most recent available at the time of analysis). We converted ages into live weights using standard conversion factors (Table 3). We used these data during the calculation of the municipal-origin of cattle slaughtered per slaughterhouse, when accounting for animal movements between municipalities (see **SEI-PCS Implementation**).

Table 3. Live weights of cattle of different ages, used to calculate the cattle stock per municipality in the network of each slaughterhouse: AU = animal units, of 450 kg; adapted from Schielein and Börner (2018)

Cattle group	**Live weight (kg)**
Male calves < 1 year	0.25 * 1 AU = 112.5 kg
Female calves < 1 year	0.25 * 1 AU = 112.5 kg
Male cattle 1-2 years	0.5 * 1 AU = 225 kg
Female cattle 1-2 years	0.5 * 1 AU = 225 kg
Male cattle 2-3 years	1.25 * 1 AU = 562.5 kg
Female cattle 2-3 years	1 * 1 AU = 450 kg
Male cattle >3 years	1.25 * 1 AU = 562.5 kg
Female cattle >3 years	1 * 1 AU = 450 kg
Unspecified cattle	1 * 1 AU = 450 kg

Supply chain data

Asset data

Export-approved slaughterhouses

We downloaded from MAPA lists of federally-inspected slaughterhouses (http://sigsif.agricultura.gov.br/sigsif_cons/%21ap_estabelec_nacional_cons) and lists of export-approvals per slaughterhouse and country (http://sigsif.agricultura.gov.br/sigsif_cons/!ap_exportador_nac_pais_rep_net).

Data on movements of animals within Brazil

We used two sources of data on the origin of cattle slaughtered in different facilities in Brazil. First, we downloaded cattle movement records from three state and federal sources (MAPA 2018a, INDEA 2018, IDARON 2018). These data detail the movement of batches of cattle between properties, listing the date of each movement, the farms or slaughterhouse sending and receiving cattle, the number of cattle, and their ages and genders. In total, we downloaded 16.7 million records, covering cattle movements from 2012-2017 for 22 states and the Federal District in Brazil (this data was not available for Acre, Amapá, Amazonas, and Roraima). We cleaned these data, removing duplicates and any records with errors in the dates or locations. This resulted in a sample of 15.6 million records (Table 4).

Second, we used municipal-level data on the origin, numbers and ages of cattle slaughtered in slaughterhouses approved for exports by the Federal Inspection Service (SIF by its Portuguese acronym) in each state (MAPA 2018b). We used these data in cases where the available animal movement data did not cover transport to a particular slaughterhouse (mostly for the states of São Paulo, Goiás, and Rondônia), or when the specific slaughterhouse was not known but the state of slaughter was.

Company data

We used the National Registry of Legal Entities (CNPJ) for company data. This enabled us to link customs records with taxation records, and to identify the subsidiaries of the main traders (e.g. JBS and Minerva), which we then combined into corporate groups according to their parent company. We also identified subsidiary companies by downloading related company names from the Google Knowledge Graph.

Boundaries

The model's municipal boundaries are based on 2017 data from the Brazilian Institute of Geography and Statistics (IBGE).

Table 4. Number of cleaned cattle-movement records per state (none were available for four states: Acre, Amapá, Amazonas, and Roraima)

State	Number of records (millions)
Alagoas	0.38
Bahia	0.90
Ceará	0.03
Distrito Federal	0.01
Espírito Santo	0.18
Goiás	0.13
Maranhão	0.62
Mato Grosso	1.42
Mato Grosso do Sul	0.76
Minas Gerais	2.57
Pará	0.91
Paraíba	0.25
Paraná	0.16
Pernambuco	2.21
Piauí	0.10
Rio de Janeiro	0.22
Rio Grande do Norte	0.12
Rio Grande do Sul	1.59
Rondônia	0.42
Santa Catarina	1.21
São Paulo	0.96
Sergipe	0.22
Tocantins	0.22

SEI-PCS implementation

Linking customs data to slaughterhouses

We used a logic-based decision tree (see Annex 1) to link exports back first to a specific state, and then to individual slaughterhouses (MDIC 2018). The decision tree allocated exports to logistics hubs based on a series of conditional rules. It triangulated information in the per-shipment export data against asset-level tax registration numbers and official lists of slaughterhouse export permissions: in other words, countries to which each slaughterhouse is licensed for export (e.g. halal slaughter for export to the United Arab Emirates). The decision tree also used data on asset-ownership (e.g. which slaughterhouses JBS owns) and subsidiary relationships among companies.

Identifying the source of cattle slaughtered per slaughterhouse

We identified the network of properties and animal movements that supplied each slaughterhouse, by loading animal movement data into the graph database TigerGraph and doing traversal searches on animal movements connected to each slaughterhouse. The networks of properties supplying each slaughterhouse included so called “indirect suppliers”. These are properties that rear cattle then sell them on to other properties, which may fatten them before sending them for slaughter.

We converted the network of animal movements into live-weight movements (in kg) using conversion factors for cattle of different ages (Table), and summed into a square matrix of the inter-municipal flows of cattle that ultimately ended up at each slaughterhouse (with one row and column per municipality and for the slaughterhouse). Note that we repeated this process once for each slaughterhouse, so that the matrix of inter-municipal flows was unique to each slaughterhouse. We then identified how much of each slaughterhouse’s supply originated from each municipality, by adapting input-output methods previously used for studying the origin of international trade flows (Kastner et al. 2011).

Specifically, we calculated a matrix, R, where each element, r*ij*, represents the supply to a municipality or slaughterhouse *i* of cattle originating from municipality *j* (we were, of course, specifically interested in the row referring to the slaughterhouse’s supply):

$$\mathrm{R} = (\mathrm{I} - \mathrm{A})^{-1} \cdot \hat{p}$$

Where A was a matrix of the share of each municipality’s total cattle supply that arises from inter-municipal cattle movements, I was the identity matrix, and $\hat{p}$ was a diagonal matrix containing the liveweight sum of each municipality’s cattle herd. $\hat{p}$ represents the cattle which were raised in the municipality, rather than moving between municipalities. Consistent with (Kastner *et al* 2011), we calculated A as:

$$\mathrm{A} = \mathrm{Z} \cdot x^{-1}$$

Where $\hat{x}$ was a diagonal matrix built up by the reciprocal elements of *x*, the vector of the cattle supply per municipality, calculated from the cattle herd and inter-municipal movement data as:

$$\mathrm{x} = \mathrm{p} + \mathrm{Z} \cdot \mathrm{i}$$

We calculated the vector of cattle in each municipality, *p*, as the sum of cattle weights from the properties in each municipality that appeared in the slaughterhouse’s network. Since we aggregated cattle movements across multiple years, but cattle are born each year, we calculated this stock by counting each year separately. So, if a farm appeared in the network in 2015 and 2017, then we calculated the farm stock as the sum of the size of the herd in both years. We calculated the cattle stock using the weighted-mean farm size (in heads of cattle; Table 5) in each municipality, the herd composition (split into nine age/gender groups; Table), and the standardized weights of cattle of each age/gender group.

Table 5. Farm size classifications available with the number of farms per municipality; from IBGE (2006)

Farm size (heads of cattle)	Number of animals assumed when calculating weighted-mean farm size per municipality
1-2	1.5
3-4	3.5
5-8	6.5
9-19	14
20-49	34.5
50-99	74.5
100-199	149.5
200-499	349.5
500+	1250

We visually inspected the resulting maps of municipal supply sheds of each slaughterhouse (Figure 1). We discarded non-representative results (e.g. where long-distance, inter-state movements were more common than local sourcing, as was the case for several slaughterhouses in São Paulo, Goiás, and Rondônia states, where our data under-represented local movements). To be conservative, we also discarded cases where we had fewer than 50 known movements between farms and each slaughterhouse. Where a slaughter facility had several associated identifiers (CNPJs) in a given municipality, the supply sheds of these were merged by weighting their supply by the volume of cattle slaughtered linked with each CNPJ. Overall, this slaughterhouse-specific approach enabled us to map 50.4% of exports back to municipalities of cattle production.

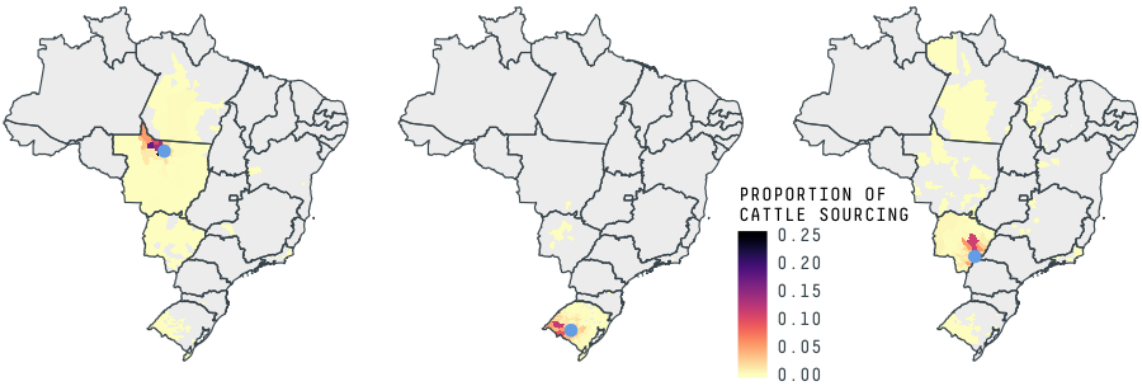

Figure 1. Modelled municipal-level supply of cattle to three slaughterhouses (light blue circles) in Mato Grosso (left), Rio Grande do Sul (middle), and Mato Grosso do Sul (right).

Where we were not able to link slaughterhouses to animal movement data, we used municipal-level data on the origin, number and ages of cattle slaughtered in each state in slaughterhouses that the Federal Inspection Service (SIF) had approved for exports (MAPA 2018b). We converted cattle heads into live weights as above, and calculated the proportion of SIF-approved slaughter per state (between 2015-2017) that had originated in each municipality (Figure 2). These data differ from our slaughterhouse-specific mapping in that they do not account for indirect suppliers. Overall, we used this state-specific approach to map 49.2% of exports (mostly associated to slaughter in São Paulo, Goiás, and Rondônia) back to a municipality of production.

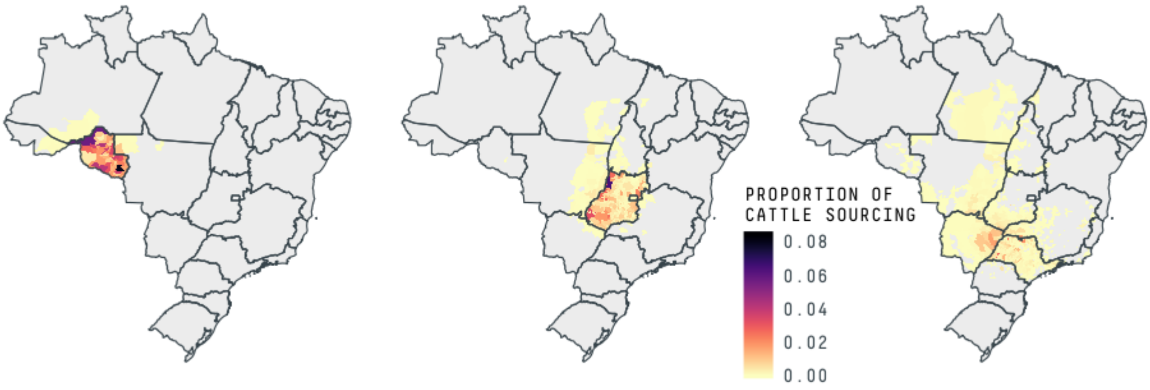

Figure 2. The origin of cattle slaughtered in SIF-approved slaughterhouses in Rondônia (left), Goiás (middle) and Sao Paulo (right) between 2015-2017.

Subnational and company sustainability indicators

The Trase indicator manual for Brazil describes the connection of these supply chain data to municipal level sustainability indicators including cattle driven deforestation risk. The indicators cover agriculture, environment, territorial governance, actor commitments, socio-economic and contextual (e.g. biomes).

Changes from previous version(s)

Version	Publication date	Changes
2.0.1	June 2020	• Update of deforestation data; revision of indicators: pasture deforestation, cattle deforestation risk
2.0.0	September 2019	• First release

References

ABIEC. (2016). *Perfil da Pecuária no Brasil: 2016.* Associação Brasileira das Indústrias Exportadoras de Carnes (ABIEC), São Paulo, Brazil. http://abiec.siteoficial.ws/images/upload/sumario-pt-010217.pdf

ABIEC. (2017). *Perfil da Pecuária no Brasil: 2017*. Associação Brasileira das Indústrias Exportadoras de Carnes (ABIEC), São Paulo, Brazil. http://gtps.org.br/wp-content/uploads/2017/08/Sumario_2017_screen.pdf

ABIEC. (2018). *Perfil da Pecuária no Brasil: 2018.* Associação Brasileira das Indústrias Exportadoras de Carnes (ABIEC), São Paulo, Brazil. http://www.abiec.com.br/Sumario.aspx

Amaral, T., Gibbs, H. and Rausch, L. L. (in review). Zero-deforestation in the Brazilian Amazon: The evolving role of the federal public prosecutors.

Assocon. (2007). *Produção de carne no Brasil.* Associação Nacional da Pecuária Intensiva (Assocon), Cuiabá, Brazil. www.assocon.com.br/pdf/prod_carne_br_cuiaba.pdf

FAO. (2018). *Technical Conversion Factors for Agricultural Commodities*. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. www.fao.org/fileadmin/templates/ess/documents/methodology/tcf.pdf

FAO. (2011). *Global Food Losses and Food Waste: Extent, Causes and Prevention*. Food and Agriculture Organization of the United Nations, Rome, Italy. http://www.fao.org/3/a-i2697e.pdf]

IBGE. (2015). Pesquisa Pecuária Municipal (PPM). Instituto Brasileiro de Geografia e Estatística (IGBE) https://sidra.ibge.gov.br/pesquisa/ppm/quadros/brasil/2015

IBGE. 2019. Pesquisa Trimestral do Abate de Animais. Instituto Brasileiro de Geografia e Estatística (IGBE). www.ibge.gov.br/estatisticas/economicas/agricultura-e-pecuaria/9203-pesquisas-trimestrais-do-abate-de-animais.html?=&t=downloads

IDARON. (2018). Consulta de GTA. Agência de Defesa Sanitária Agrosilvopastoril do Estado de Rondônia (IDARON). www.idaron.ro.gov.br/index.php/consulta-de-gta/

INDEA. (2018). Consulta de GTA. Instituto de Defesa Agropecuária do Estado de Mato Grosso (INDEA). www.indea.mt.gov.br/-/8565985-gta?ciclo=

IEG FNP Agribusiness. (2019). *ANUALPEC — Anuário da Pecuária Brasileira 2019*. IEG FNP Agribusiness, São Paulo, Brazil.

Instituto de Economia Agrícola. (2017). Estimativa da Produção Animal no Estado de São Paulo para 2017. Instituto de Economia Agrícola. www.iea.sp.gov.br/out/LerTexto.php?codTexto=14370

Instituto de Economia Agrícola. (2018). Estimativa da Produção Animal no Estado de São Paulo para 2018. Instituto de Economia Agrícola www.iea.sp.gov.br/out/TerTexto.php?codTexto=14514

Kastner, T., Kastner, M. and Nonhebel, S. (2011). Tracing distant environmental impacts of agricultural products from a consumer perspective. *Ecological Economics,* 70. 1032–40.

MAPA. (2018a). Plataforma de Gestão Agropecuaria. Ministério da Agricultura, Pecuária e Abastecimento (MAPA) http://pga.agricultura.gov.br/sispga/webclient/consultaPublica.jsp

MAPA. (2018b). Quantidade de Abate Estadual por Ano/Espécie. Ministério da Agricultura, Pecuária e Abastecimento (MAPA) http://sigsif.agricultura.gov.br/sigsif_cons/!ap_abate_estaduais_cons?p_select=SIM

MDIC. (2018). Comex Stat. Ministério da Indústria, Comércio Exterior e Serviços (MDIC) http://comexstat.mdic.gov.br/en/home

Schielein, J. and Börner, J. (2018). Recent transformations of land-use and land-cover dynamics across different deforestation frontiers in the Brazilian Amazon. *Land Use Policy* 76, 81–94.

USDA. (2016). *Brazil: Livestock and Products Annual 2016.* United States Department of Agriculture (USDA), Washington, DC. http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Livestock%20and%20Products%20Annual_Brasilia_Brazil_8-30-2016.pdf

USDA. (2017). *Brazil: Livestock and Products Annual 2017*. United States Department of Agriculture (USDA), Washington, DC. https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Livestock%20and%20Products%20Annual_Brasilia_Brazil_9-19-2017.pdf

USDA. (2018). *Brazil: Livestock and Products Annual 2018.* United States Department of Agriculture (USDA), Washington, DC. https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Livestock%20and%20Products%20Semi-annual_Brasilia_Brazil_2-28-2018.pdf

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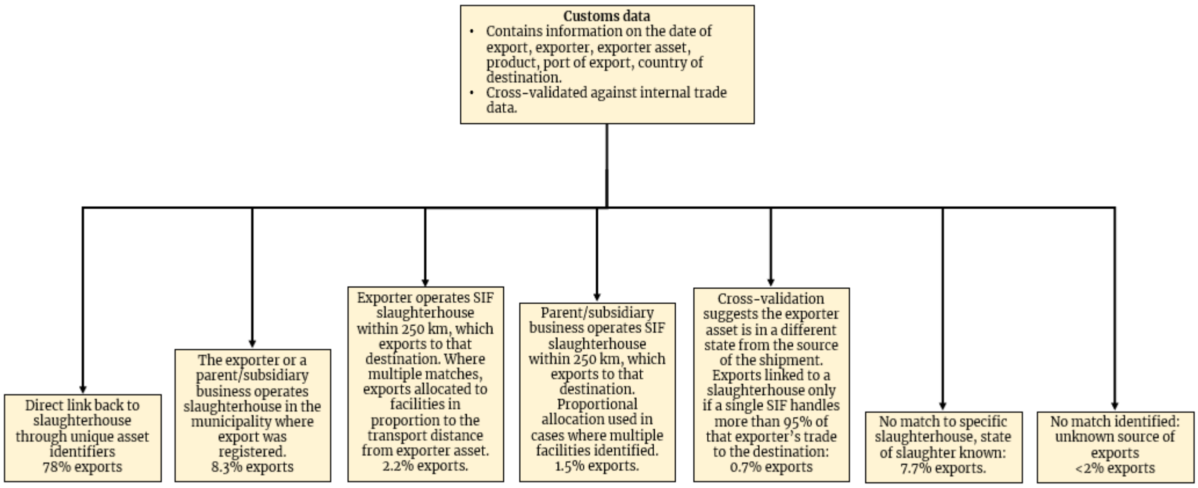
Annex 1: Decision tree for the 'SEI-PCS Brazil beef v2.0' supply chain model

This is a simplified version of the logic-based decision tree, showing how exports were linked to specific slaughter facilities. Matches were attempted in preferential order from left-to-right. SIF = denotes a federally-inspected slaughterhouse, licensed for international export.



Annex 2: Glossary

Term	Definition	Example
Asset	In the context of Trase, a physical or material resource owned by a business or an economic entity that relates to the production, storage or processing of a commodity.	Soy silo, slaughterhouse, refinery, mill, farm.
Commodity equivalent	Measure used to relate the trade flows of different products to a commodity equivalent. This is obtained by using the commodity equivalence factor.	Soy oil and cake products are converted into soybean equivalents.
Commodity-equivalence factor	Factor used to convert the amount of a product into a commodity equivalent.	1 kg of soy meal and oil are equivalent to 1.031 kg of soybeans (3 g are waste).
Decision tree	Outlines the conditional filtering of trade data in order to link commodity exports to a logistic hub.	Each supply chain map manual contains a figure of their respective decision trees.
Distance matrix	The distances between different demand and supply nodes. This is used in the linear programming step to solve the problem of	Supply nodes are jurisdictions of production.

	minimising the total distance incurred in meeting all of the demand.	Demand nodes include exports from ports and domestic demand nodes such as chicken farms for Brazil soy. Distances are based on the available road networks.
HS code	Unique code from the Harmonized System (HS) which describes the nature of the products being traded internationally.	1201: Soya beans, whether or not broken 120110: Soya beans, seed; whether or not broken
Jurisdiction	The territorial administrative units into which a country is divided.	Municipality in Brazil, kabupaten (district) in Indonesia, department in Argentina, department in Paraguay (lower resolution, with departments comprised of districts).
Linear programming	Linear programming (LP, also called linear optimisation) is a method to achieve the best outcome (such as maximum profit or lowest cost) in a mathematical model whose requirements are represented by linear relationships.	Use linear program to minimise the distance between logistic hubs and production municipalities.
Logistics	Activities related to the production, storage, processing, transport, trade, etc., of commodities in supply chains.	Chicken rearing, cattle slaughtering, soybean crushing, palm oil bulking, shipping.
Logistics hub	Jurisdiction containing one or more assets that are nodes in the commodity supply chain.	Municipality, department of silo location, slaughterhouse, palm oil mills.
Node	Jurisdiction, asset, trader or country representing a point of aggregation or transfer of a commodity through its supply chain.	
Supply chain	Sequence of nodes linking a jurisdiction of production to a country of import.	