March 2026

SEI-PCS Brazil beef v2.2 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 their associated deforestation. It uses an approach called Spatially Explicit Information on Production to Consumption Systems (SEI-PCS) (Godar et al 2015) as the basis for this work. This document describes the data and methods that Trase has used to map the supply chain for Brazilian beef, generating data called 'SEI-PCS Brazil beef v2.2'.

The beef supply chain map tracks exports of beef (as live cattle, fresh and frozen beef products) back to specific municipalities by (1) making connections between individual shipments leaving Brazilian ports and slaughterhouses; and (2) identifying from which municipalities these slaughterhouses purchased cattle. Table 1 and 2 provides an overview of key statistics for Brazil's beef industry during 2010–2023.

Together with the map of the commodity supply chain, Trase offers a variety of sustainability indicators showing the environmental, economic, social and territorial impacts of commodity production. Trase's core indicators include commodity production, deforestation, land-use emissions, and trader zero-deforestation commitments, with additional indicators added on a case-by-case basis depending on demand and availability.

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Table 1: Summary statistics for Brazil's beef industry, 2010–2023

	Number of cattle (million head)	Beef & live cattle exports (million tonnes CWE**)	Municipalities linked to cattle exports	Exporting companies	Importing countries	Percentage of trade flows with unknown origin*
2011	213	1.54	2,553	109	138	17
2012	211	1.87	2,625	113	135	14
2013	212	2.26	2,916	123	136	14
2014	212	2.29	2,808	122	131	13
2015	215	2.02	2,933	126	126	14
2016	218	2.03	3,016	132	129	13
2017	215	2.22	2,883	149	144	13
2019	215	2.95	2,815	189	114	33
2020	218	3.16	2,939	172	112	27
2021	225	2.86	3,003	160	117	28
2022	235	3.51	2,951	165	115	23
2023	239	3.57	2,988	144	124	26

** exports for which a municipality of origin cannot be established*
*** carcass weight equivalent*

Trase's sustainability indicators for Brazil have been updated for the 2010–2023 period and include beef production (Table 3 and 4), area of pasture, yield, territorial deforestation and associated land-use emissions, pasture deforestation and associated land-use emissions (all Brazilian biomes) and the percent of beef traded under a zero-deforestation commitment.

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Table 2: Summary of key indicators, 2010–2023

	Pasture area (million hectares)	Pasture deforestation (million hectares)	Cattle deforestation (national average in ha per tonnes of beef)	Net CO_2 emissions from pasture deforestation (million tonnes CO_2-eq)	Net CO_2 emissions from cattle deforestation (national average in tonnes CO_2-eq per tonne of beef)	Percentage of beef exported under zero-deforestation commitments
2010	155.9	6.1	-	1850.2	-	-
2011	155.7	5.1	-	1563.6	-	13
2012	155.5	4.6	0.706	1326.2	194.4	19
2013	155.1	4.2	0.575	1127.9	178.8	27
2014	155.0	4.7	0.477	1174.0	139.5	30
2015	155.1	4.8	0.429	1237.0	121.4	31
2016	155.2	5.3	0.428	1373.8	116.1	29
2017	154.6	5.4	0.440	1467.0	117.4	30
2018	154.4	5.3	0.483	1479.9	130.9	-
2019	154.7	5.5	0.506	1657.0	139.2	51
2020	154.7	5.8	0.499	1816.9	143.4	52
2021	155.2	6.4	0.500	2039.5	147.8	53
2022	155.9	7.1	0.561	2336.1	173.6	54
2023	156.2	7.4	0.647	2416.5	210.3	62

Changes from previous versions

Version 2.2.2 of Trase's map of the Brazilian beef supply chain adds small corrections to version 2.2.1. These include:

- EU membership association
- Correction to name of ports and importers

Version 2.2.1 of Trase's map of the Brazilian beef supply chain includes the following changes from version 2.2.0:

- The model is updated to additionally cover 2021–2023.
- Removal of 2010 due to unavailability of production data.
- The cattle stocking rate indicator was removed due to data unavailability.

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- The threshold for anonymising small flows was increased from 250kg to 500kg carcass weight equivalent. This reduces the row count of the results but increases the volume for which a municipality of production cannot be identified.
- Municipalities were associated with the Brazilian Biomes based on IBGE definition of predominant biomes (IBGE, 2024). Previously Trase used municipality centroids.
- The model is padded with a total volume of domestic consumption, calculated as remaining production after export.
- Marfrig's flows outside the Amazon were moved to NO COMMITMENTS, reflecting its zero-deforestation commitment in the Amazon only (2010–2020).

Version 2.2.0 of Trase's map of the Brazilian beef supply chain includes the following changes from version 2.1:

- The model is updated to cover 2010–2020, rather than 2015–2017.
- A new source of trade data is used for 2019 and 2020. The effects of this change are as follows:
    a. The country importing products should be interpreted as the 'country of destination' of beef in 2010–2018, but the 'country of first import' in 2019–2020. This difference is due to the nature of the trade data which identifies the port of destination in 2019–2020 instead of the commodity destination in 2010–2018. As a result, some countries that appear as 'country of first import' in 2019–2020 (e.g. Turkey) may not be the final destination of the commodity as declared by official Brazilian export data (e.g. Iran);
    b. Trade data in 2019 and 2020 only covers maritime shipments as opposed to 2010–2018 data which covered both maritime and non-maritime exports. All non-maritime exports have been labelled as 'unknown' in both 2019 (representing 0.19 million tonnes) and 2020 (0.15 million tonnes).
- The transportation matrix used to select distances has been updated using a new source (see the transportation matrix section).
- Deforestation data has been updated to cover all biomes in the country.
- Cattle deforestation exposure is restricted to the 2016–2020 period because deforestation data is available from 2008 onwards and is linked to cattle production assuming a five-year cattle lifecycle and a time lag between deforestation and the establishment of pasture (see the sustainability indicators section).
- Both gross and net carbon emissions from deforestation are now available. Net emissions for cattle deforestation and supply chain actor exposure are also included.
- Cattle deforestation exposure (formerly called 'cattle deforestation risk') is no longer provided as an annualised value (based on a mean risk split between multiple years), but rather as a sum of the total pasture expansion onto recently deforested land. This means that each trade year should be considered individually and cattle deforestation exposure should not be summed across multiple trade years (see the interpretation of data section).

Interpretation of data

Trase decided not to publish supply chain mapping results for the year 2018 due to inconsistencies in the source data. Using publicly available data, we could only identify 26% of all Brazilian beef flows with a level of unknown flows higher than 50%. The methodology used for 2018 also differs from the rest of the Brazil beef data, resulting in three different approaches for this supply chain map. Publishing data for 2018 could lead to time series analyses across biomes and subnational regions (a key use case) which have misleading results and interpretations. Consequently, we have published data only for 2010–2017 and 2019–2023.

Users must be cautious when comparing time series results between the 2010–2017 and 2019–2023 periods. Given the differences in sources of trade data and methods used to derive the supply chain map between both periods, we do not recommend that direct comparisons be made across periods for specific actors (countries or companies) or regions of production that are linked to supply chains. Where comparisons are made, these should be conducted with full understanding and communication of the differences between data sources available across years.

Comparisons across periods and time series can, however, be made with the jurisdictional indicators when not linked to the supply chain data (e.g. territorial deforestation, pasture deforestation, greenhouse gas emissions from deforestation).

Cattle deforestation exposure now represents the total pasture coverage occupying areas recently deforested that are allocated to the beef supply chain. Because the same area can be classified as pasture deforestation for up to five consecutive years, users must not sum cattle deforestation exposure across multiple trade years, but rather consider each trade year individually. To sum across trade years, users need to use the annual mean cattle deforestation risk. Please contact Trase at info@trase.earth for assistance with calculating commodity deforestation for a range of years rather than a specific year.

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Data version history

Table 2: Version history for Brazilian beef data

Version	Publication date	Change
2.2.2	March 2026	Data fixes to 2.2.1: UK and Croatia had European Union membership years slightly misaligned, 9 Brazilian ports were not using the official name, importer name fields have been normalized.
2.2.1	October 2025	Addition of 2021–2023.
2.2.0	November 2023	Subnational trade flows covering a longer time series: 2010–2020. This includes a change in the processing of trade data for 2018–2020.
2.1	July 2020	Subnational trade flows from 2015–2017, as published in zu Ermgassen et al 2020. This includes a correction to the live cattle export data, which are underestimated for the year 2017 in previous versions. These data are available at: https://zenodo.org/record/3949782
2.0	September 2019	Subnational trade flows covering 2015–2017, updated deforestation data linked to trade flows (Mapbiomas cf. Lapig & PRODES)
2.0	September 2019	Subnational trade flows covering 2015–2017
1.0	2015	First release

How to cite this document

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Supply chain mapping

Data and sources

Production data

Cattle production is the amount of beef produced per municipality (in tonnes of carcasses) calculated as

$$Cattle\ production = herd\ size \times slaughter\ rate \times carcass\ weight$$

Where the herd size (head of cattle per municipality and year) is the cattle population per municipality, the slaughter rate (per state and year) represents the proportion of animals slaughtered each year, and the carcass weight is the tonnes of carcass per head (per state and year).

Head of cattle per municipality per year were obtained from IBGE's Pesquisa da Pecuária Municipal (PPM). The PPM data is the only freely available annual estimate of municipal herd size, and is official government data.

Slaughter rates were calculated as the herd size per state divided by the number of cattle slaughtered per state according to Anualpec (Informa Economics IEG FNP 2019, IBGE 2015), accounting for inter-state movements to slaughter (from the Ministério da Agricultura, Pecuária e Abastecimento – 2018a). Outliers in Amazonas, Amapá, Pernambuco and Bahia (where slaughter rates exceeded 25%, despite low-intensity cattle ranching in each region) were corrected to the nationwide average for 2010–2020: 19.9%. The slaughter rate for São Paulo, where our calculations otherwise underestimated production, was also corrected to 40.72% based on estimates from Instituto de Economia Agrícola 2017, 2018.

To calculate cattle deforestation exposure for the 2010–2023 period, a longer time series of slaughter is needed (covering 2006–2019) than is available from Anualpec (2011–2020 only). We therefore interpolate the difference between the Anualpec and IBGE slaughter statistics, for earlier years (pre-2011 and post-2019) where we do not have Anualpec slaughter data.

Carcass weights were calculated using state and year-specific data, dividing the IBGE trimestral slaughter survey data by the total tonnes of cattle carcasses per state by the number of slaughtered head available at this link (IBGE 2019). Offal weights were included assuming offal makes up 6.3% of live weight (450 kg), based on Brazil-specific FAO offal conversion factors (FAO 2018). Where carcass or slaughter data were missing (for some years in Amapá, Distrito Federal, and Rondônia), we used the nationwide average carcass weight per trimester.

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Supply chain waste

We assumed 1.1% losses from cattle deaths during transport to slaughter and carcass condemnation at the slaughterhouse, 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 (Gustavsson et al 2011).

Municipal herd composition

The age profile of cattle in each municipality came from the 2006 agricultural census (the most recent available on herd composition). Ages were converted into live weights using standard conversion factors (see Table 4). This data was used during the calculation of the municipal origin of cattle slaughtered per slaughterhouse when accounting for animal movements between municipalities. The live weight of cattle of different ages was used to calculate the cattle stock per municipality in the network of each slaughterhouse. In Table 4, adapted from Schielein and Börner (2018), AU is an abbreviation for animal units, representing 450 kg.

Table 4: The live weights of cattle of different ages

Cattle group	Liveweight (kg)
Male calves < 1 year	0.25 x 1 AU = 112.5 kg
Female calves < 1 year	0.25 x 1 AU = 112.5 kg
Male cattle 1–2 years	0.50 x 1 AU = 225 kg
Female cattle 1–2 years	0.50 x 1 AU = 225 kg
Male cattle 2–3 years	1.25 x 1 AU = 562.5 kg
Female cattle 2–3 years	1.00 x 1 AU = 450 kg
Male cattle >3 years	1.25 x 1 AU = 562.5 kg
Female cattle >3 years	1.00 x 1 AU = 450 kg
Unspecified cattle	1.00 x 1 AU = 450 kg

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Trade data

Trade data includes shipment data for 2010–2023 covering exports of beef, offal and live cattle. Product volumes (i.e. tonnes of beef or offal) were converted into 'carcass weight equivalents' using standard conversion coefficients as in Table 5.

The 2010–2023 time series was constructed using two different sets of trade data:

- Trade data including maritime and non-maritime shipments (2010–2017) for which the importing country represents the 'country of destination' of the commodity;
- Trade data with only maritime shipments (2019–2023) for which the importing country represents the 'country of first import' of the commodity.

The difference in country-designation is linked to the trade data itself for which a country is either the final destination of the commodity (2010–2017, from customs declarations) or the port of entry of the vessel (2019–2023) from which the commodity can travel further onto the country of destination.

Table 5: Cattle product NCM codes and conversion coefficients (from product to carcass and offal equivalents) (2010–2023)

NCM code	Description	Commodity equivalence factor
02022010	Beef products (frozen), forecuts	1
02022020	Beef products (frozen), hindcuts	1
02022090	Beef products (frozen), other	1
02023000	Beef products (frozen), deboned	1.372560001
02012010	Beef products (fresh or chilled), forecuts	1
02012020	Beef products (fresh or chilled), hindcuts	1
02012090	Other boned bovine meats (fresh or chilled)	1
02013000	Beef products (fresh or chilled), deboned	1.372560001
02061000	Edible bovine meats and offal, fresh or frozen	1
02062100	Edible bovine meats and offal, tongue (frozen)	1
02062220	Edible bovine meats and offal, liver	1
02062910	Bovine tails, frozen	1

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02062990	Edible bovine meats and offal, other	1
02102000	Edible bovine meats and offal, processed	1.611111112
01021010	Pure-bred bovine animals for reproduction - pregnant or with calf at foot	0.599
01021090	Other reproductive pure breed animals	0.599
01022110	Pure-bred bovine animals for reproduction - pregnant or with calf at foot	0.599
01022190	Other reproductive pure breed animals	0.599
01029000	Other live bovine animals	0.599
01029011	Other bovine animals, for reproduction – pregnant or with calf at foot	0.599
01022990	Other live domestic bovines	0.599
01029090	Other bovine animals	0.599
16025000	Processed and canned bovine products	2.333333334

Slaughterhouse information

Lists of federally inspected ('SIF') slaughterhouses and country-specific export-approvals were downloaded from MAPA.

Logistics data

We used two sources of data on the origin of cattle slaughtered in different facilities in Brazil. First, cattle movement records were downloaded from state and federal sources (MAPA – Ministério da Agricultura, Pecuária e Abastecimento 2018a, INDEA 2018, IDARON 2018). This data details the movement of batches of cattle between properties, listing the date of each movement, the farms or slaughterhouses sending and receiving cattle, the number of cattle, and their ages and gender. Cattle movements were downloaded for 23 states in Brazil from 2012–2019. This data was cleaned, duplicates removed, and records with errors in the dates or locations were discarded, resulting in a sample of 33.3 million records (Table 6).

Table 6: Number of cleaned cattle animal movement records available per state.*

State	Number of cattle movement records (millions)	State	Number of cattle movement records (millio
Alagoas	0.65	Pernambuco	2.93
Bahia	1.58	Piauí	0.10
Ceará	0.14	Paraná	0.20
Distrito Federal	0.01	Rio de Janeiro	0.22
Espírito Santo	0.29	Rio Grande do Norte	0.12
Goiás	0.67	Rondônia	2.48
Maranhão	1.35	Rio Grande do Sul	2.63
Minas Gerais	3.37	Santa Catarina	1.96
Mato Grosso do Sul	1.99	Sergipe	0.22
Mato Grosso	5.25	São Paulo	1.62
Pará	3.46	Tocantins	1.76
Paraíba	0.25		

*No records were available for Acre, Amapá, Amazonas and Roraima.

As can be seen in Table 6, the availability and completeness of the GTA data vary between states. Where we were not able to identify the movement of cattle to an exporting slaughterhouse in the GTAs, we instead used municipal-level data on the origin and number of cattle slaughtered in export-approved (SIF) slaughterhouses per state published by (MAPA – Ministério da Agricultura, Pecuária e Abastecimento 2018b).

Deriving the cattle supply shed

We identified the network of properties that supplied each slaughterhouse by loading animal movement data into a graph database and doing traversal searches to identify movements which were connected to each slaughterhouse. The networks of properties supplying each

slaughterhouse included indirect suppliers, who rear cattle and sell them on to be fattened before sending them to slaughter.

The network of animal movements was converted into live weight movements (measured in kilogrammes) using conversion factors for cattle of different ages (Table 4), 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). This process was repeated 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). This method is described in detail in zu Ermgassen et al (2020).

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

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

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 was a diagonal matrix containing the live weight 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), A was calculated as

$$A = Z . x^{-1}$$

Where Z 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

$$x = p + Z . i$$

The vector of cattle in each municipality, p, was calculated as the sum of cattle weights from the properties in each municipality which appeared in the slaughterhouse's network. Since we aggregated cattle movements across multiple years, but cattle are born each year, this stock was calculated counting each year separately – if a farm appeared in the network in 2015 and 2017, then the farm stock was calculated as the sum of the size of the herd in both years. The cattle stock was calculated using the weighted mean farm size in each municipality (in head of

cattle), the herd composition (split into nine age/gender groups; Table 7), and the standardised weights of cattle of each age/gender group.

Table 7: Farm size classifications available with the number of farms per municipality, from the Brazilian agricultural census (2006)

Farm size (head 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

Company information

Subsidiary companies were identified by downloading related company names from the Google Knowledge Graph. For example, from 2017 onwards Mato Grosso Bovinos (CNPJ8 15514479) became a subsidiary of Minerva (CNPJ8 67620377).

Transportation matrix

Trase constructed a matrix to estimate the cost of transporting beef between all Brazilian municipalities. The matrix was obtained using the osrmtime framework applied to OSRM and the Open Street Maps (http://project-osrm.org/docs/v5.24.0/api/#) to derive the average time (in seconds) needed to travel between two municipalities using the fastest route between 2015 and 2019. We applied the default rule of routing (what roads can be routed) implemented using the CAR profile which includes motorway, trunk (main road), primary, secondary, tertiary roads, unclassified, residential, living streets and service. The average travel time was used for all export years (2010–2023).

The cost matrix is available for download here.

Geographic boundaries

The 2023 municipalities boundaries were provided by the Brazilian Institute of Geography and Statistics (IBGE, 2025). Municipalities were associated with the Brazilian Biomes based on the IBGE definition (IBGE, 2024).

Anonymisation of small flows

The method by which supply sheds are applied to the flows can result in a proliferation of flows with very small volume. To reduce noise and bloat of row counts in the output we "anonymise" these small flows; setting the municipality of production and slaughter to be unknown when a flow is smaller than 500kg carcass weight equivalent.

Supply chain mapping method (SEI-PCS)

The SEI-PCS supply chain mapping method is the approach used to link international exports to municipalities within Brazil, via individual trading companies. The beef supply chain is constructed by combining per-shipment beef trade data (as per commodity NCM codes, Table 5) together with trader information, slaughterhouse location and ownership. This means that the supply chain is mapped from export to production, against the flow of commodity production, from left to right in the graphic below.

The method consists of two steps discussed in turn, which are (1) connecting individual shipments to slaughterhouses; and (2) linking these slaughterhouses to municipalities (Figure 1).

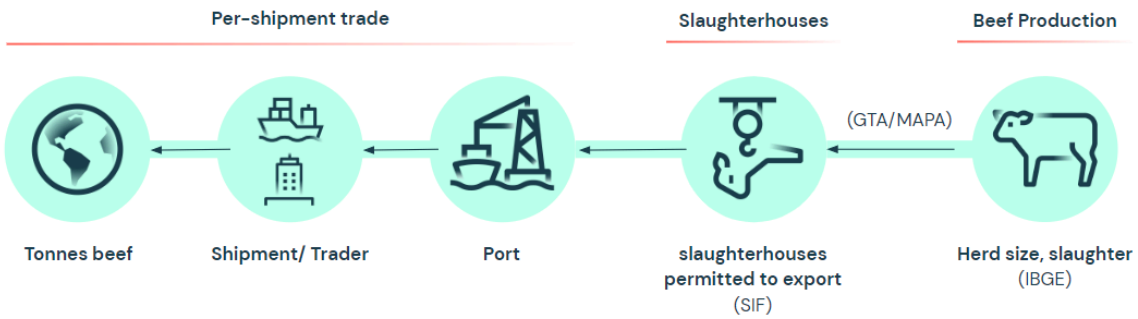


Figure 1: SEI-PCS process for mapping the Brazilian beef supply chain (read from left to right).

Logic-based decision tree

A logic-based decision tree was used to link exports back to slaughterhouses. The decision tree triangulates information in the export data with internal trade data to map flows back first to a specific state, and then to individual slaughterhouses (Comex Stat 2018). Exports were linked to slaughterhouses by crossing the information in the trade data against asset-level tax registrations, and official lists of slaughterhouse export permissions (i.e. which countries each slaughterhouse is licensed for export to, e.g. halal slaughter for export to the United Arab Emirates). The decision tree also makes use of asset ownership data (e.g. JBS' slaughterhouses) and subsidiary relationships between companies.

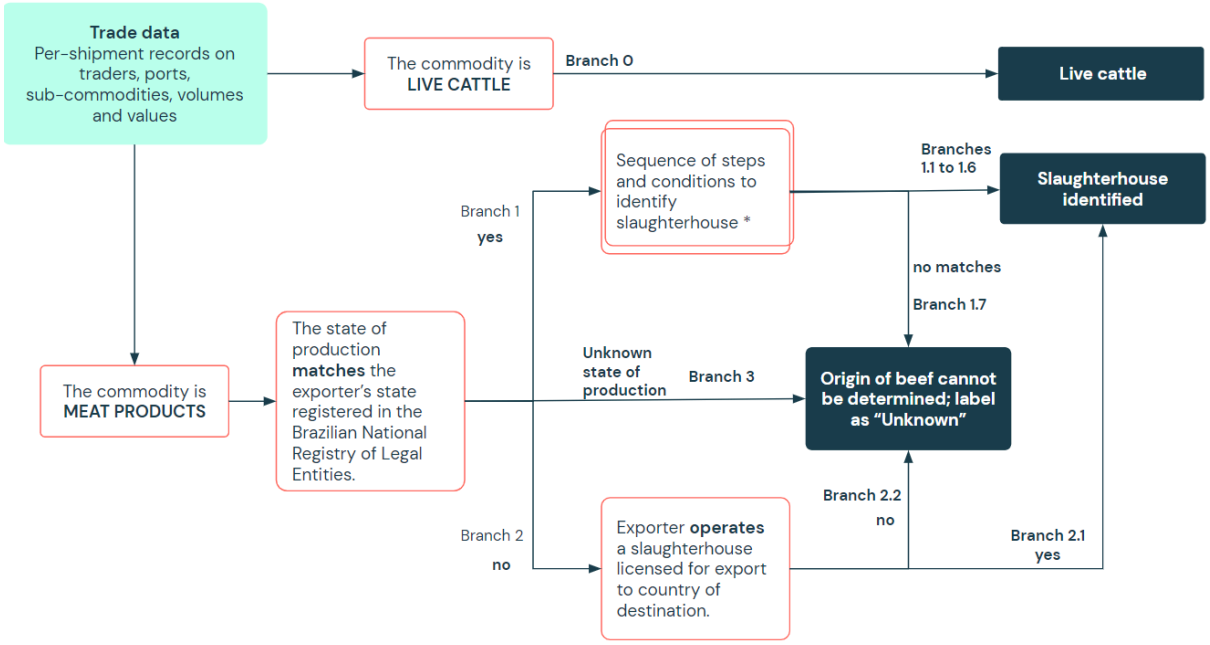


Figure 2: Logic-based decision tree used for SEI-PCS Brazil Beef v.2.2. Notes: * Full details of the logic-based decision tree are available in Appendix 3.

Domestic consumption

Domestic consumption is provided as a single value, calculated as the remaining Brazilian cattle production after export. For all flows of the domestic supply chain the municipality origin of the production is set to unknown. More detailed information of the domestic market can be found at the 'do Pasto ao Prato' initiative (www.dopastoaoprato.com.br/).

Sustainability indicators

Cattle production

Cattle production (tonnes of carcasses) is the total beef production in a given year and municipality. More details on how it is calculated are in the production data section above. The metric is available in the map section.

Pasture area

Pasture area (hectares) is the total area of pasture in a given year and municipality according to MapBiomas collection 10 (MapBiomas Project). The data is available both as a map and a supply chain indicator.

Product type

Beef products is an indicator available in the supply chain that recolours each one of the trade flows based on product description. The descriptions are assigned according to the products HS codes (see Table 5). The indicator is available together with the trade flows.

Deforestation and emissions

Territorial deforestation

Territorial deforestation (hectares) is the area of native vegetation (or old regrowth) that was removed (clear-cut) in each municipality and year. In the Amazon and Cerrado biomes, we derived this metric from Prodes (INPE-PRODES 2022) by using the annual increments of deforestation. For 2008 to 2012, Prodes Cerrado aggregates the increment in two images; 2009 and 2010 together, and 2011 and 2012 together. For these years, we consider half of the deforestation detected in the municipality for each one of the aggregated years. For the other biomes, we used MapBiomas deforestation collection 10 (Souza et al 2020), which includes the Atlantic Forest, Pantanal, Caatinga and Pampa biomes. We only considered the primary vegetation loss detected in the MapBiomas collection.

Gross greenhouse gas emissions from territorial deforestation

Gross greenhouse gas emissions from territorial deforestation (tonnes of CO_2-eq) were calculated by estimating the maximum CO_2-eq potentially emitted due to the full removal of the native primary vegetation, estimated in a given year and municipality (SEEG 2024). The carbon stocks are quantified considering the stocks in the total biomass stored in the vegetation above and below ground, litter and deadwood. To calculate the total carbon lost per municipality, the territorial deforestation indicator (see above) is multiplied with the carbon

density in native primary vegetation provided by SEEG 12 (2024)). The carbon stocks are based on the values used in the Fourth National Inventory by Brazil (SEEG 2024) when estimating the emissions from land use change. Carbon is converted into CO_2-eq by multiplying the values by 3.67, based on the ratio between the molecular weight of C and CO_2.

Pasture deforestation and Cattle deforestation exposure

Cattle deforestation exposure estimates how much deforestation is associated with the beef supply chain, addressing specifically how much pasture occurring in areas recently deforested is used in the areas used for animal rearing. Cattle deforestation exposure is obtained by (1) calculating pasture deforestation before (2) associating multiple years of pasture deforestation to beef production to subsequently (3) allocate this deforestation to supply chain actors (traders, countries) to create an exposure metric (Figure 3).

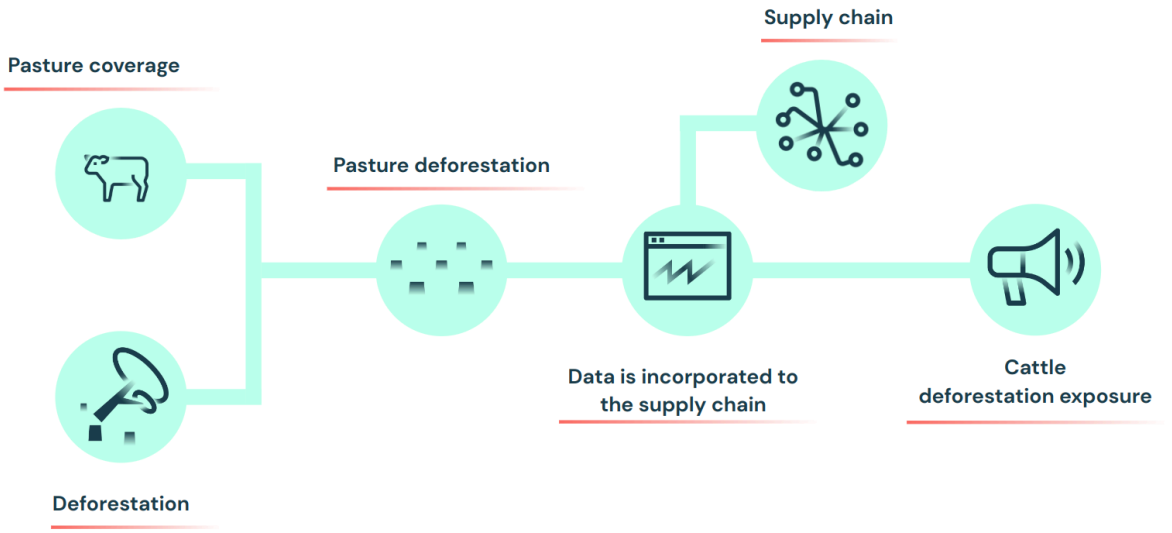


Figure 3. Data sources and process steps to calculate cattle deforestation exposure from the overlap between land used for pasture and deforestation.

Pasture deforestation is the estimate of the amount of deforestation across a five-year allocation period that is considered to be associated with animal rearing in a given year. To calculate it, we overlapped the annual pasture maps from MapBiomas (MapBiomas Project) with the annual territorial deforestation (see above) five years prior to the target year for pasture, including the year the pasture was detected, to provide a total area of pasture deforestation aggregated per municipality (Figure 4).

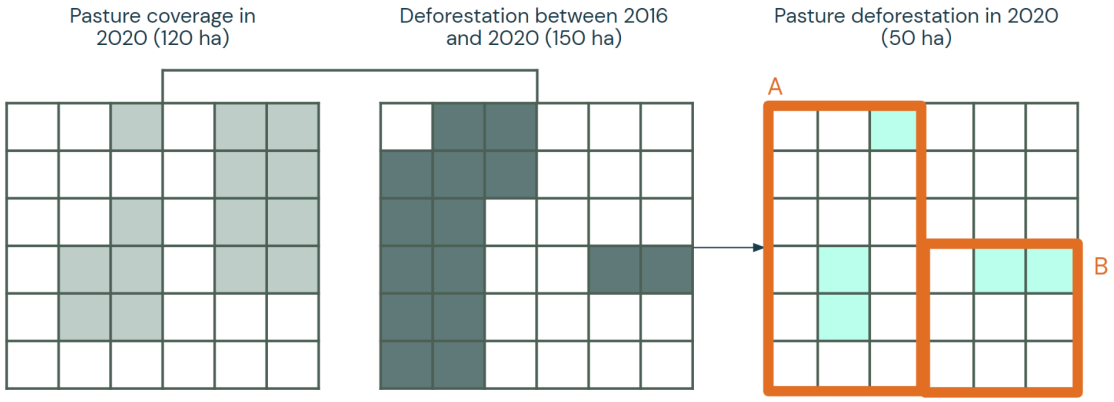


Figure 4: Illustration of the spatial assignment of territorial deforestation(2016–2020) to pasture field coverage in 2020 to derive pasture deforestation (2020) in two municipalities (A and B).

Cattle deforestation is then calculated by associating, per municipality, an average of five years of pasture deforestation divided by five years of beef production in tonnes of carcass weight. As an example, the cattle deforestation in a given municipality in 2020 is the average of pasture deforestation from 2016 to 2020 divided by the average production in the same municipality in the same period of time. We account for five years of pasture deforestation assuming that animals are fed for five years before being slaughtered. After dividing the average of five years of pasture deforestation with the average of five years production, we create a relative measure in hectares per tonne of beef.

Pasture and cattle deforestation exposure measure the area of commodity deforestation a supply chain actor is linked to through its sourcing patterns. Commodity deforestation exposure is calculated based on the per municipality commodity deforestation per ton and multiplied with the export flows ("known" flows). Export flows with unknown municipalities, but known states ("state known" flows) are assigned the states mean remaining commodity deforestation per ton (remaining commodity deforestation (ha) divided by remaining production (ton)) after accounting for the already allocated commodity deforestation and production tons in "known" flows. Unknown export flows have neither a known municipality nor a known state. We allocate the remaining national-level commodity deforestation exposure to these 'unknown' flows proportionally, after exposure to "known" and "state known" flows are assigned.

Gross greenhouse gas emissions from pasture deforestation and cattle deforestation exposure

Gross greenhouse gas emissions from pasture and cattle deforestation (see above), expressed in tonnes of CO_2-equivalent (t CO_2-eq), are determined by calculating the emissions resulting from the removal (land conversion) of native vegetation carbon stocks.
Carbon stocks include the above and below ground biomass including necromass. The carbon stocks are based on the values provided by SEEG v12 (SEEG 2024). Carbon is converted into CO_2-eq by multiplying the values by 3.67, based on the ratio between the molecular weight of C and CO_2. Gross emission from pasture deforestation are converted to gross emission from cattle deforestation by associating, per municipality, an average of five years of gross emissions from pasture deforestation divided by five years of beef production in tonnes of carcass weight (see above, conversion of deforestation for pasture to deforestation for cattle).

Net greenhouse gas emissions from pasture deforestation and cattle deforestation exposure

Net greenhouse gas emissions from pasture and cattle deforestation (see above), expressed in tonnes of CO_2-equivalent (t CO_2-eq), are determined by calculating the emissions resulting from the removal of native vegetation carbon stocks, due to deforestation for pasture, and the carbon stored in pasture. Carbon stocks include above and below ground biomass including necromass. Both the native vegetation and the pasture carbon stocks are based on estimates provided by SEEG v12 (SEEG 2024). Carbon is converted into CO_2-eq by multiplying the values by 3.67, based on the ratio between the molecular weight of C and CO_2. Net emission from pasture deforestation are converted to net emission from cattle deforestation by associating, per municipality, an average of five years of net emissions from pasture deforestation divided by five years of beef production in tonnes of carcass weight (see above, conversion of deforestation for pasture to deforestation for cattle).

As described above for cattle deforestation exposure, net emissions are assigned to the beef supply chain by multiplying the trade flow volume in an actor's supply chain (country or company) by a relative metric describing the net tonnes of CO_2 emissions per tonnes of beef produced in each municipality.

Zero-deforestation commitment

Beef traded under a zero-deforestation commitment (ZDC) describes the percentage of traded beef, in a given municipality, that is covered by ZDC commitments.

ZDCs are obtained by Global Canopy's annual assessment which determines whether a trader has a commitment to zero deforestation in their supply chain (net or gross deforestation are both acceptable) for a given commodity, covering a specific country and time period. A

commitment is accepted as zero deforestation if the trader (or trader group) explicitly uses the phrases 'zero deforestation' or 'zero conversion' in their sustainability goals or current policies, or has a policy (or target) for 100% certification where the certification is equivalent to a zero-deforestation standard as minimum. In Brazil, a ZDC is either a 'company commitment' (if the specific company has a ZDC), 'no commitment' (if the company does not have one), 'TAC' or 'G4' (if the company or slaughterhouse is committed to either of them and trades from municipalities in the Amazon), or 'unknown' (if the company's ZDC position was not checked; typically the assessment focuses on the top companies that trade 90% of the commodity volume in a given year). Specifically for the TAC, a complementary search was conducted to determine whether slaughterhouses have adopted the terms of conduct adjustment and in which year they did so. This search for the year of commitment signing was carried out using the list provided by Boi na Linha as a reference.

Forest 500

The Forest 500 indicator scores corporate deforestation commitments according to Global Canopy's Forest 500 assessments (https://forest500.org/). The selection of the Forest 500 score is based on two main criteria: (1) risk of being linked to tropical deforestation through involvement in or potential exposure to forest risk commodity supply chains; and (2) influence within the political economy of tropical deforestation. The Forest 500 value represents the commodity specific score categorised in groups, with, 0 representing none, 1 fulfilling >0% to <20%, 2: 20% to <40%, 3: 40% to <60%, 4: 60% to <80% and 5 fulfilling 80% to 100% of the assessed criteria. The metric is embedded into Trase's supply chain flows based on the Exporter Group.

Glossary

Common terms used in Trase methods.

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.	Slaughterhouse, meatpacking facility.
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.	Deboned beef, offal, and live cattle are converted into carcass equivalents.
Commodity-equivalence factor	Factor used to convert the amount of a product into a commodity equivalent.	1 tonne of live cattle are equivalent to 599 kg of carcass equivalents.
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 minimising the total distance incurred in meeting all of the demand.	Supply nodes are jurisdictions of production (i.e. the location of an exporter and nearby slaughterhouses). 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.	E.G. 0102 refers to live cattle
Jurisdiction	The territorial administrative units into which a country is divided.	Municipality in Brazil.
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.

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Logistics hub	Jurisdiction containing one or more assets that are nodes in the commodity supply chain.	Municipality where the relevant slaughterhouse is located.
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.	

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Appendix 1: Results of implementation (2015-2023)

Branch description	Relative export volume in each trade year (%)							
	2015	2016	2017	2019	2020	2021	2022	2023
0 Live Cattle	3	3	4	3	1	0	0	0
1.1 Exporter has an authorised exporter slaughterhouse under the Brazilian National Registry of Legal Entities	75	78	80	64	72	72	77	76
1.2 Exporter has an authorised exporter slaughterhouse in the municipality of production	1	1	0	3	4	4	3	1
1.3 Exporter has a subsidiary that operates an authorised slaughterhouse in the municipality of production	5	5	1	1	1	0	0	0
1.4 Exporter operates a non-authorised slaughterhouse in the municipality of production	7	7	8	1	0	0	0	0
1.5.1 Exporter operates an authorised slaughterhouse within 250 km within the state of production which exports to a country that it is authorised for exports	0	0	0	0	0	0	0	0
1.5.2 Exporter operates an authorised slaughterhouse within 250 km within the state of production which exports to a country that it is not authorised for exports	1	1	0	0	0	0	0	0

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1.6 Exporter has subsidiary that operates an authorised slaughterhouse within 250 km within the state of production which exports to the country of destination	0	0	0	0	0	0	0	0
1.7 Origin of beef cannot be determined. Unknown slaughterhouse	6	3	3	1	2	1	1	1
2.1 Exporter has an authorised slaughterhouse in state of production, but do not matches the state registered in the Brazilian National Registry of Legal Entities	1	0	0	0	0	0	0	0
2.2 Origin of beef cannot be determined. Unknown slaughterhouse in the state of production	3	2	4	6	5	6	5	6
3. Origin of beef cannot be determined. State of production is unknown	0	0	0	21	15	17	13	15

Appendix 2: Results of implementation (2010–2014)

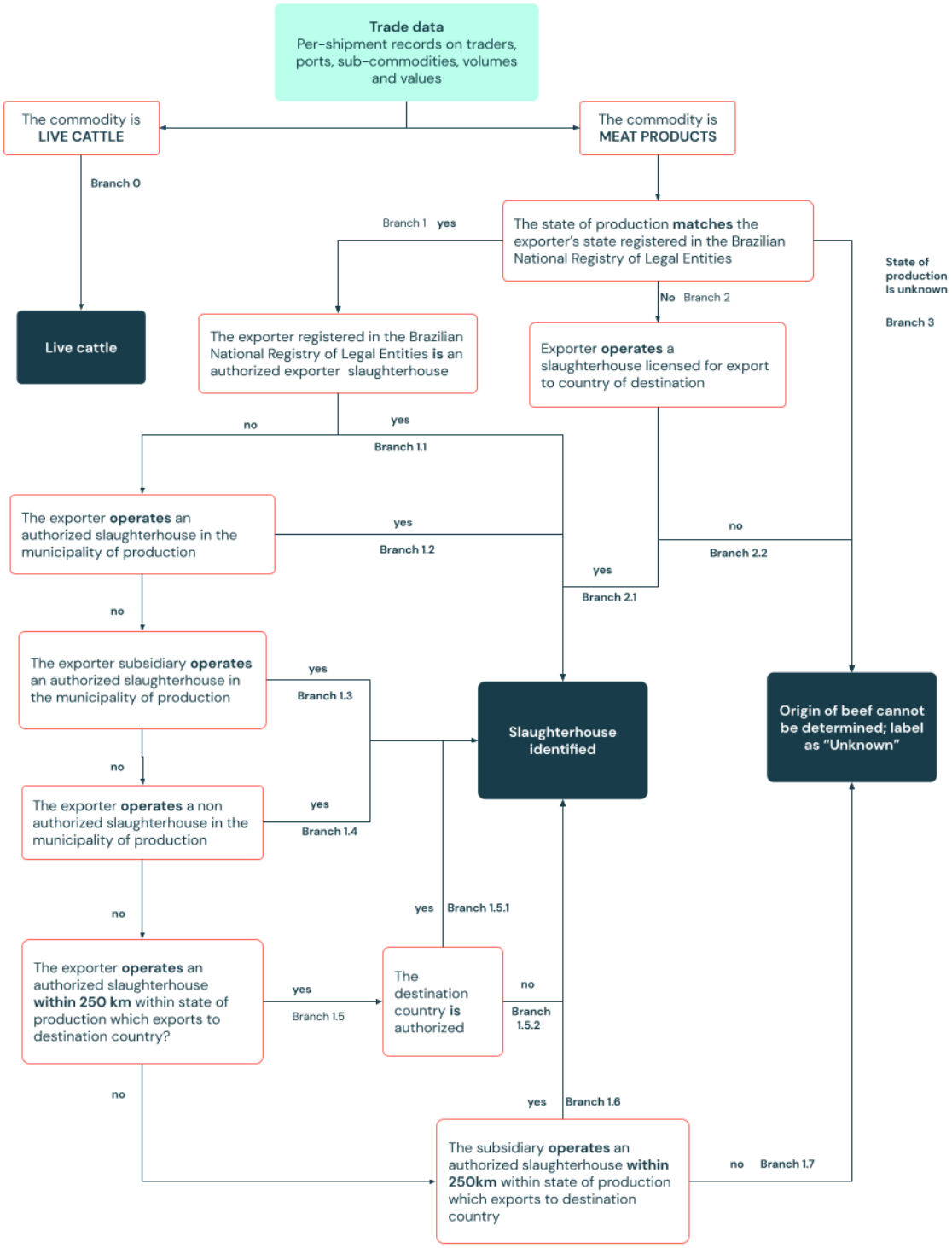
Branch description	Relative volume in each trade year (%)				
	2010	2011	2012	2013	2014
0 Live Cattle	0	0	15	17	15
1.1 Exporter has an authorised exporter slaughterhouse under the Brazilian National Registry of Legal Entities	69	81	66	63	64
1.2 Exporter has an authorised exporter slaughterhouse in the municipality of production	1	1	0	1	1
1.3 Exporter has a subsidiary that operates an authorised slaughterhouse in the municipality of production	0	0	0	1	2
1.4 Exporter operates a non authorised slaughterhouse in the municipality of production	2	3	4	5	5
1.5.1 Exporter operates an authorised slaughterhouse within 250 km within the state of production which exports to a country that it is authorised for exports	1	1	0	0	0
1.5.2 Exporter operates an authorised slaughterhouse within 250 km within the state of production which exports to a country that it is not authorised for exports	2	2	1	2	1
1.6 Exporter has subsidiary that operates an authorised slaughterhouse within 250 km within the state of production which exports to the country of destination	0	0	0	0	0
1.7 Origin of beef cannot be determined. Unknown slaughterhouse	16	7	7	8	9

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2.1 Exporter has an authorised slaughterhouse in state of production, but does not match the state registered in the Brazilian National Registry of Legal Entities	0	0	0	0	0
2.2 Origin of beef cannot be determined. Unknown slaughterhouse in the state of production	8	7	5	5	4
3. Origin of beef cannot be determined. State of production is unknown	0	0	0	0	0

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Appendix 3: Full Logic-Based Decision Tree



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