SEI-PCS Brazilian beef v2.0 documentation

SEI-PCS Brazilian beef v2.0 maps the municipal origin of Brazilian exports of beef, offal, and live cattle, from 2015 to 2017. First, we linked cattle exports back to slaughterhouses by crossing customs data against information on slaughterhouse tax registrations, ownership, and their export licenses. Second, we identified which municipalities the cattle slaughtered in those slaughterhouses were raised in, using a large dataset of cattle movements between farms and from farms to slaughterhouse, and government data on the origin of cattle slaughtered in export-approved slaughterhouses.

Summary statistics

	2015	2016	2017
Number of cattle (heads)	215.22	218.2	214.9
Beef & live cattle exports (Mtons)	1.40	1.40	1.43
Municipalities linked to cattle exports	3194	3215	3227
Exporting companies	138	138	142
Importing countries	127	130	130
Percentage of trade flows with unknown municipal origin	1.3	1.2	0.35

Data sources

1. Trade data

1.1. Export

Customs data for the 2015 – 2017 period covering all beef, offal, and live cattle exports under the NCM codes listed in Table 1.

Table 1 – Cattle product NCM codes and conversion coefficients (from product to carcass and offal equivalents).

Product	NCM code	Conversion coefficient
Beef products (frozen), forecuts	02022010	
Beef products (frozen), hindcuts	02022020	1
Beef products (frozen), other	02022090	
Beef products (frozen), deboned	02023000	1.372560001
Beef products (fresh or chilled), forecuts	02012010	
Beef products (fresh or chilled), hindcuts	02012020	1
Other boned bovine meats (fresh or chilled)	02012090	
Beef products (fresh or chilled), deboned	02013000	1.372560001
Edible bovine meats and offal, fresh or frozen	02061000	
Edible bovine meats and offal, tongue (frozen)	02062100	1
Edible bovine meats and offal, liver	02062220	
Bovine tails, frozen	02062910	
Edible bovine meats and offal, other	02062990	
Edible bovine meats and offal, processed	02102000	1.611111112

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

1.1. Domestic

1.1.1. Animal movement 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). 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 gender. In total, 16.7 million records were downloaded, covering cattle movements from 2012-2017 for 23 states in Brazil. These data were cleaned, duplicates removed, and records with errors in the dates or locations were discarded, resulting in a sample of 15.6 million records (Table 2).

Table 2 – Number of cleaned cattle animal movement records available per state. None were available for Acre, Amapá, Amazonas, and Roraima.

State	Number of cattle movement records (millions)
ALAGOAS	0.38
BAHIA	0.9
CEARA	0.03
DISTRITO FEDERAL	0.01
ESPIRITO SANTO	0.18
GOIAS	0.13
MARANHAO	0.62
MINAS GERAIS	2.57
MATO GROSSO DO SUL	0.76
MATO GROSSO	1.42
PARA	0.91
PARAIBA	0.25
PERNAMBUCO	2.21
PIAUI	0.1
PARANA	0.16
RIO DE JANEIRO	0.22
RIO GRANDE DO NORTE	0.12
RONDONIA	0.42
RIO GRANDE DO SUL	1.59

SANTA CATARINA	1.21
SERGIPE	0.22
SAO PAULO	0.96
TOCANTINS	0.22

Second, municipal-level data on the origin, the number, and the ages of cattle slaughtered in export-approved (SIF) slaughterhouses per state (MAPA - Ministério da Agricultura, Pecuária e Abastecimento 2018b). These data were used 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 where the specific slaughterhouse was not known (but the state of slaughter was).

2. Production data

2.1. Cattle head per municipality

Cattle heads per municipality per year from IBGE's Pesquisa Pecuária Mensual (PPM).

2.2. Slaughter rates

The slaughter rate was calculated as the herd size divided by the number of cattle slaughtered per state (Informa Economics IEG | FNP 2019, IBGE 2015), accounting for inter-statement movements to slaughter (MAPA - 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 2015-2017, 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 estimates from (Instituto de Economia Agrícola 2017, 2018, Assocon 2007).

2.3. Carcass weights

Carcass weights were calculated using state- and year-specific data, dividing the IBGE trimestral slaughter survey data on the total tons of cattle carcasses per state by the number of slaughtered heads (IBGE 2019). Offal weights were included assuming offal makes up 6.3% of live weight (450kg), 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.

2.4. Supply chain waste

We assumed 1.1% losses from cattle deaths during transport to slaughter and carcass condemnation at 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).

2.5. 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). Ages were converted into liveweights using standard conversion factors (Table 3). These data were used during the calculation of the municipal-origin of cattle slaughtered per slaughterhouse when accounting for animal movements between municipalities (see methods).

Table 3 - The liveweights 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	Liveweight (kg)
Male calves < 1 yr	0.25 * 1 AU = 112.5 kg
Female calves < 1 yr	0.25 * 1 AU = 112.5 kg
Male cattle 1-2 yrs	0.5 * 1 AU = 250 kg
Female cattle 1-2 yrs	0.5 * 1 AU = 250 kg
Male cattle 2-3 yrs	1.25 * 1 AU = 562.5 kg
Female cattle 2-3 yrs	1 * 1 AU = 450 kg
Male cattle >3 yrs	1.25 * 1 AU = 562.5 kg
Female cattle >3 yrs	1 * 1 AU = 450 kg

Unspecified cattle	1 * 1 AU = 450 kg

3. Logistics data

3.1. Export-approved slaughterhouses

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

4. Companies

4.1. Subsidiary relationships

Subsidiary companies were identified by downloading related company names from the Google Knowledge Graph.

4.2. Zero deforestation commitments

Slaughterhouses were classified as having signed a TAC based on (Amaral *et al* in review). Exports sourced from JBS, Minerva, and Marfrig slaughterhouses in the Amazon are in addition covered by the G4 cattle agreement. The top 24 exporters were also reviewed for additional commitments, based on information on company websites and corporate social responsibility reports. We considered subsidiaries to be covered by their parent company commitments.

5. Boundaries

5.1. Municipal boundaries

Municipal boundaries are based on 2017 data from IBGE.

SEI-PCS Implementation

1. Linking customs data to slaughterhouses

A logic-based decision tree was used to link exports back to slaughterhouses. The decision tree triangulated information in customs data with internal trade data to map flows back first to a specific state, and then to individual slaughterhouses (MDIC 2018). Exports were linked to slaughterhouses by crossing the information in the customs 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. A summary of the decision tree is shown below:

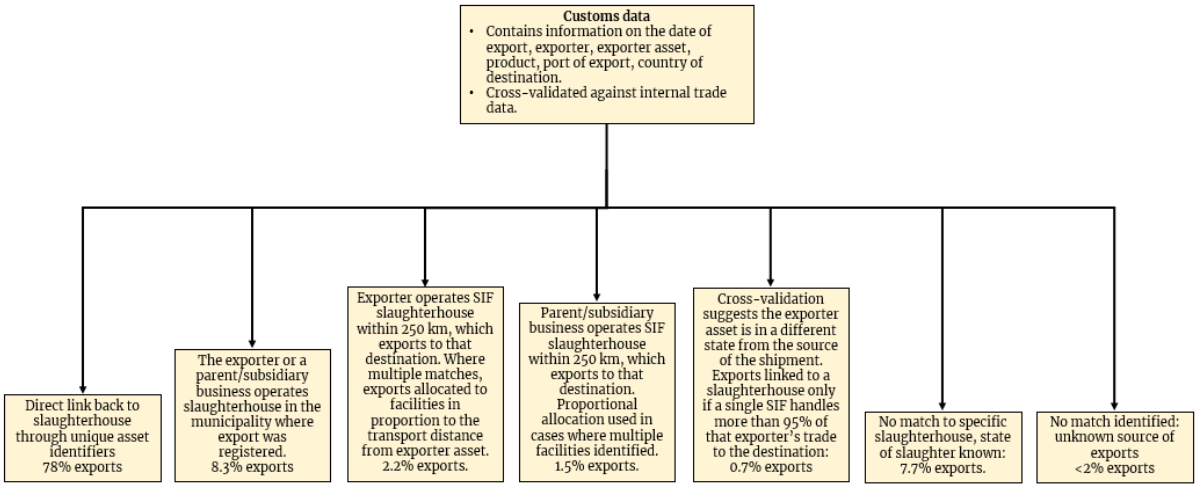

Figure 1- Simplified version of the logic-based decision tree, showing how exports are linked to specific slaughter facilities. Matches are attempted in preferential order from left-to-right. SIF = Federally inspected slaughterhouse, licensed for international export.

(ii) Identifying the source of cattle slaughtered per slaughterhouse

We identified the network of properties and animal movements which supplied each slaughterhouse, by loading animal movement data into TigerGraph and doing traversal searches on animal movements which were connected to each slaughterhouse. The networks of properties supplying each slaughterhouse included "indirect suppliers", i.e. the properties which rear cattle, sell them on to other properties, who may fatten them before sending them for slaughter.

The network of animal movements were converted into liveweight movements (in kg) using conversion factors for cattle of different ages (Table 3), 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 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).

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):

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

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), A was calculated as:

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

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:

$$x = p + Z \cdot i$$

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 cattle heads), the herd composition (split into nine age/gender groups; Table 4), and the standardized weights of cattle of each age/gender group.

Table 4 - Farm size classifications available with the number of farms per municipality, from (IBGE 2006)

Farm size (head 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

The resulting maps of municipal supply sheds of each slaughterhouse were visually inspected (Figure 2); we discarded non-representative results (e.g. where long-distant, 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 was used to map 50.4% of exports back to municipalities of cattle production.

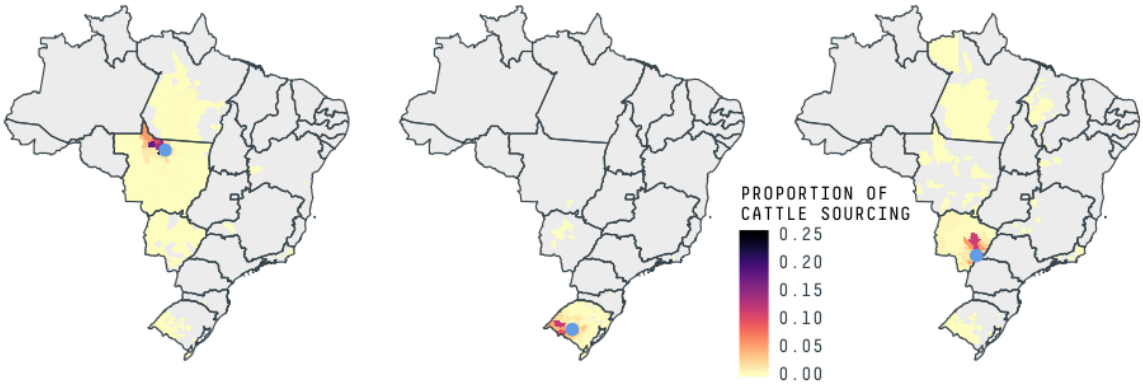

Figure 2 – Modelled municipal-level supply of cattle to three slaughterhouses in Mato Grosso, Rio Grande do Sul, and Mato Grosso do Sul.

Where we were not able to link slaughterhouses to animal movement data, we used municipal-level data on the origin, the number, and the ages of cattle slaughtered in export-approved (SIF) slaughterhouses per state (MAPA - Ministério da Agricultura, Pecuária e Abastecimento 2018b). We converted cattle heads into live weights as above, and calculated the proportion of SIF-slaughter per state (between 2015-2017) which originated in each municipality (Figure 3). These data differ from our slaughterhouse-specific mapping in that they do not account for indirect suppliers. Overall, this state-specific approach was used to map 49.2% of exports (mostly associated to slaughter in São Paulo, Goiás, and Rondônia) back to a municipality of production.

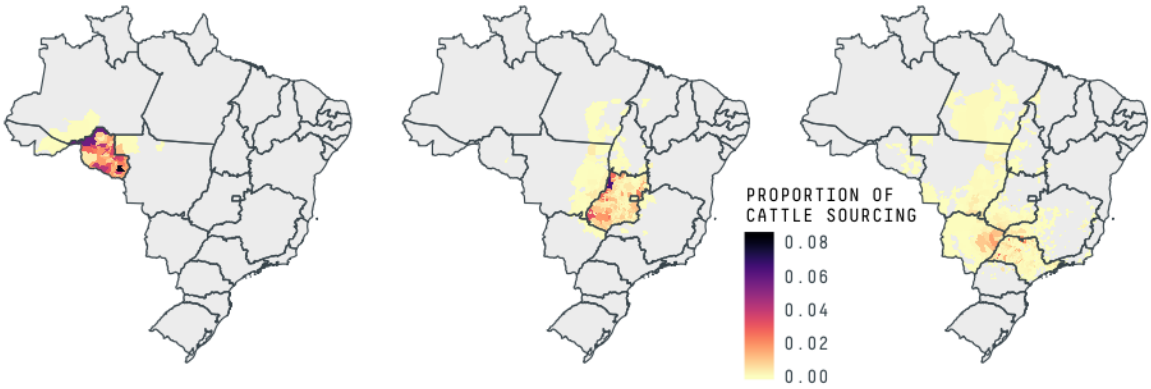

Figure 3 - the origin of cattle slaughtered in SIF-slaughterhouses in Rondonia (RO), Goias (GO) and Sao Paulo (SP) between 2015-2017.

The connection of these supply chain data to indicators (e.g. on cattle-associated deforestation) is described in the Trase indicator manual.

References

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

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

ABIEC 2018 *Perfil da Pecuária no Brasil: 2018* (São Paulo, Brazil: Associação Brasileira das Indústrias Exportadoras de Carnes) Online: 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* (Cuiabá-MT: Assocon) Online: www.assocon.com.br/pdf/prod_carne_br_cuiaba.pdf

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

Gustavsson J, Food and Agriculture Organization of the United Nations and ASME/Pacific Rim Technical Conference and Exhibition on Integration and Packaging of MEMS N and Electronic Systems 2011 *Global food losses and food waste: extent, causes and prevention : study conducted for the International Congress "Save Food!" at Interpack 2011 Düsseldorf, Germany* (Rome: Food and Agriculture Organization of the United Nations)

IBGE 2015 Pesquisa Pecuária Municipal (PPM) Online: https://sidra.ibge.gov.br/pesquisa/ppm/quadros/brasil/2015

IBGE 2019 Pesquisa Trimestral do Abate de Animais Online: https://www.ibge.gov.br/estatisticas/economicas/agricultura-e-pecuaria/9203-pesquisas-trimestrais-do-abate-de-animais.html?=&t=downloads

IDARON 2018 Consulta de GTA Online: http://www.idaron.ro.gov.br/index.php/consulta-de-gta/

INDEA 2018 Consulta de GTA.

Informa Economics IEG | FNP 2019 *ANUALPEC - Anuário da Pecuária Brasileira 2019* (São Paulo–SP: Informa Economics IEG | FNP)

Instituto de Economia Agrícola 2017 Estimativa da Produção Animal no Estado de São Paulo para 2017 Online: http://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 Online: http://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 - Ministério da Agricultura, Pecuária e Abastecimento 2018a Plataforma de Gestão Agropecuaria Online: http://pga.agricultura.gov.br/sispga/webclient/consultaPublica.jsp

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

MDIC 2018 Comex Stat Online: 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: Livestocks and Products Annual 2016* (USDA) Online: http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Livestock%20and%20Products%20Annual_Brasilia_Brazil_8-30-2016.pdf

USDA 2017 *Brazil: Livestocks and Products Annual 2017* (USDA) Online: https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Livestock%20and%20Products%20Annual_Brasilia_Brazil_9-19-2017.pdf

USDA 2018 *Brazil: Livestocks and Products Annual 2018* (USDA) Online: https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Livestock%20and%20Products%20Semi-annual_Brasilia_Brazil_2-28-2018.pdf