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Trase 'SEI-PCS Paraguay beef v1.1.1' 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 Paraguayan beef exports, using a model called **'SEI-PCS Paraguay beef v1.1.1'.**

For all beef exports, this model determined the likely department in which cattle were raised and where the cattle were slaughtered. It used trade and production data, as well as information on company-specific slaughterhouses, and road networks. The model used linear programming to link exports to slaughterhouses, and then to link slaughterhouses to the departments where the cattle were raised. Table 1 provides an overview of key statistics.

Table 1. Summary statistics

	2014	2015	2016	2017	2018
Beef exports (million tonnes*)	0.41	0.39	0.40	0.42	0.47
Number of exporting groups	12	16	12	13	12
Number of importing countries	50	58	66	67	54
Exports with unknown origins	0	0	0	0	0

* = metric tons

Data and sources

Trade data

The model used per-shipment data (customs data, bills of lading and/or cargo manifests) for 2014-2018 covering all exports of cattle classified under the 'HS' customs codes in Table 2. We used a commodity-equivalence factor (see Table 2) to convert different products to a standard commodity equivalent, in this case cattle meat equivalent. This made it possible to quantify and communicate as a single value (tonnes) the total quantity of beef and beef products that Paraguay exports. We confirmed the quality of the data by comparing it with other data sources (such as GAIN reports from the US Department of Agriculture).

Table 2. Commodities, their HS codes and commodity-equivalence factors

Product	HS code	Commodity-equivalence factor
Meat; of bovine animals, carcasses and half-carcasses, fresh or chilled	020110	1.000
Meat; of bovine animals, cuts with bone in (excluding carcasses and half-carcasses), fresh or chilled	020120	1.000
Meat; of bovine animals, boneless cuts, fresh or chilled	020130	1.373
Meat; of bovine animals, carcasses and half-carcasses, frozen	020210	1.000
Meat; of bovine animals, cuts with bone in (excluding carcasses and half-carcasses), frozen	020220	1.000
Meat; of bovine animals, boneless cuts, frozen	020230	1.373
Offal, edible; of bovine animals, fresh or chilled	020610	0.833
Offal, edible; of bovine animals, tongues, frozen	020621	0.833
Offal, edible; of bovine animals, livers, frozen	020622	0.833
Offal, edible; of bovine animals, (other than tongues and livers), frozen	020629	0.833
Meat; salted, in brine, dried or smoked, of bovine animals	021020	1.611
Animal products; guts, bladders and stomachs of animals (other than fish), whole and pieces thereof, fresh, chilled, frozen, salted, in brine, dried or smoked	050400	0.833
Meat preparations; of bovine animals, meat or meat offal, prepared or preserved (excluding livers and homogenised preparations);	160250	2.333
Bovine animals; live	0102	0.560

Domestic demand

We used two approaches to calculate domestic demand for beef. First, we calculated demand for live cattle as the total number of cows sent to all slaughterhouses in Paraguay, minus the number of cows sent to slaughterhouses that were certified to export (i.e. total supply minus demand from exporting slaughterhouses). We calculated domestic demand for cattle meat from these export-certified slaughterhouses as the total output of these slaughterhouses (tonnes) minus the total demand for beef from exports that year. We then split these two quantities (domestic demand for live cattle and domestic demand for beef) across Paraguayan departments, in the same relative proportions as the human population distribution in 2017 (DGEEC 2017). We used human population as a proxy for domestic demand because of an absence of data on slaughterhouses that are slaughtering solely for the domestic market (see *Slaughterhouses*, below), or of other consumption data, which would in theory improve the accuracy of the model.

Production data

We derived production data from two datasets: a) the total number of cattle that are sent to slaughter according to the National Animal Quality and Health Service (SENACSA); and b) data from the Department of Agriculture (MAG), which provides department-level herd sizes for 2014-2018 (MAG 2015-2019). We divided the total number of cattle sent to slaughter proportionately across cattle-producing departments according to the size of the departments' herd during the year in question. We used an average carcass weight of 250 kg to convert the number of cattle slaughtered per year into the equivalent weight, in kilograms, of cattle meat.

Supply chain data

Asset data

Slaughterhouses

There are 15 slaughterhouses registered for export according to SENACSA. We collated each slaughterhouse's status (active/inactive) and ownership for the years 2014-2018. We also recorded a maximum daily capacity for each.

We used the maximum daily capacities as a proxy for understanding each facility's relative annual throughput, which we then used, together with statistics on the numbers of cattle slaughtered in facilities that are registered to export (SENACSA 2015-2018), to estimate the annual number of cattle going to slaughter in each slaughterhouse. We converted this input (number of cattle heads) to slaughterhouse output (cattle meat mass) by multiplying by the average carcass weight of 250 kg.

Data on slaughterhouses serving the domestic market are not available. Furthermore, it has been estimated that some 200,000-300,000 cattle are slaughtered each year in unofficial abattoirs in Paraguay. Our calculations do not include this part of the beef market, as data on unofficial abattoirs are not available (USDA 2018).

Transportation data

Road network

We used a map of the road network to calculate a matrix of distances between a) slaughterhouses and all points of export and domestic demand, and b) slaughterhouses and the geometric centres of all cattle-producing departments (DIVA-GIS 2018). The road map we used was inconsistent with satellite data. This is a key area for improvement in the next iteration of the model.

Ports and customs offices

We identified 33 ports and customs offices associated with beef/cattle exports, and we assigned each of them a unique ID and geographical coordinates.

Company data

Each trader has a unique identifying tax ID number which we used to identify traders in the trade data and to link traders to any slaughterhouses they owned.

Boundaries

We sourced jurisdictional boundaries from the Government Directorate of Statistics and Surveys (DGEEC), which provided the departmental boundaries of Paraguay as of 2012 (DGEEC 2012).

SEI-PCS implementation

We used a logic-based decision tree (see Annex 1) to define weighting factors for a linear program that links 1) ports to slaughterhouses and then 2) links slaughterhouses to the departments where cattle are raised.

Stage 1 of implementation used a simple linear program to allocate exports of cattle meat to slaughterhouses. The linear program used the distance matrix to minimise the overall distance beef products would travel between demand nodes (exports from ports and Paraguayan departments for domestic demand) and supply nodes (slaughterhouses). The model used trader-specific sourcing information and information on asset-ownership to apply constraints and/or a 'discount' to the distance, to reflect that exporters preferentially source from their own facilities. Supply nodes were constrained by maximum annual throughput of slaughterhouses.

Stage 2 of implementation used a linear program to link slaughterhouses (demand nodes) to departments of cattle production (supply nodes). Demand nodes were constrained by the slaughterhouses' annual throughput capacity, and supply nodes were constrained by the department's estimated production (heads of cattle sent to slaughter). The linear program minimised the overall distance cattle would have travelled between supply and demand nodes based on the distance matrix. We also constrained slaughterhouse sourcing based on contextual knowledge of the business activities of certain traders.

Finally, we combined the two stages of the linear programs (exports to slaughterhouses in Stage 1 and slaughterhouses to production in Stage 2) to link exports to departments of production.

Subnational and company sustainability indicators

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

Changes from previous version(s)

Version	Publication date	Changes from previous version
1.1.1	June 2020	• Includes pasture deforestation and cattle deforestation risk in the Chaco as well as cleaned exporter trader names.
1.1.0	December 2019	• We updated results to include expected sourcing of exporters in 2018.

		• We incorporated trader asset-ownership into the linear programming. This meant that we could apply a 'discount' to transport distances (see 'SEI-PCS implementation'). • We incorporated contextual knowledge of trader sourcing behaviour to constrain the sourcing of some slaughterhouses to appropriate departments of activity.
1.0	March 2019	• First release (for development purposes)

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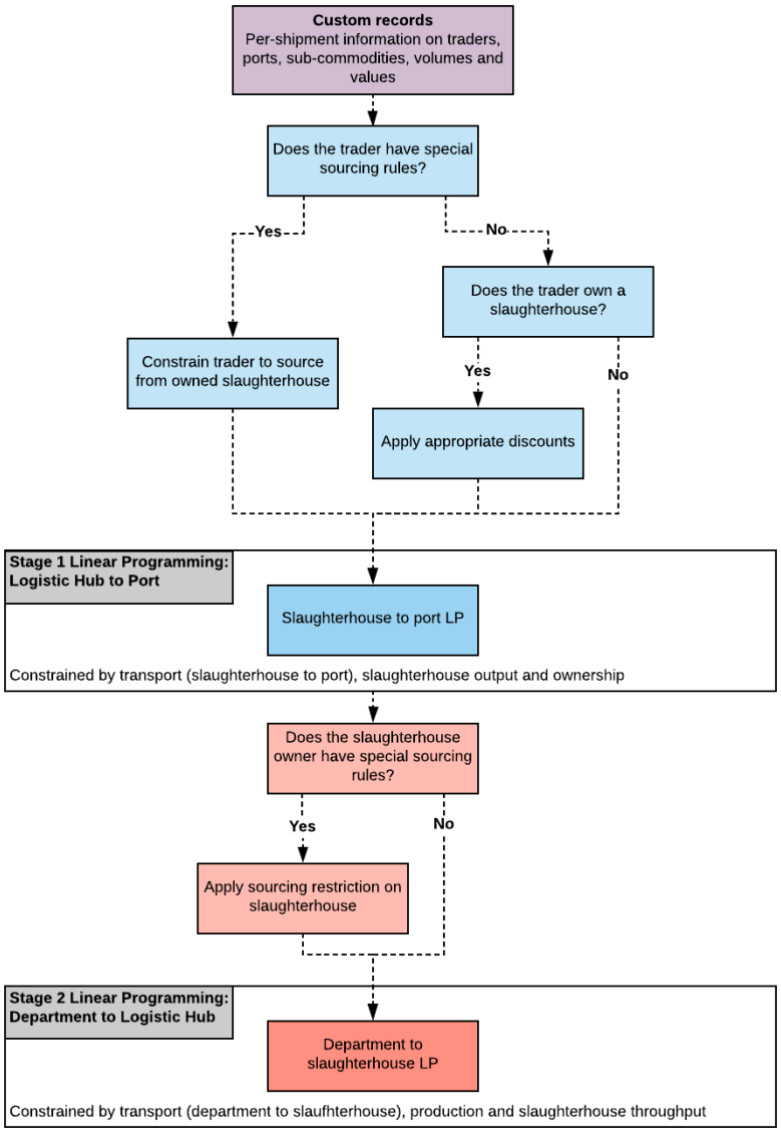
Annex 1: Decision tree for the 'SEI-PCS Paraguay beef v1.1' supply chain model



Annex 2

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 minimising the total distance incurred in meeting all of the demand.	Supply nodes are jurisdictions of production. 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.	