Highlighting the Roles of Producers and Consumers in Land and Water use for Agricultural Production in Southern Amazonia

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Abstract

For decades, agricultural expansion in Southern Amazonia has relied on deforestation to increase the national and global supplies of cattle and soybean products. Research on the use of land and water for increasing the region's pasture and cropland outputs has provided important insight into the role of producers in managing these resources. However, the roles of other actors on cattle and soybean production systems (e.g. traders) have been less apparent. For instance, some private initiatives, such as the Cattle Agreement or the Soybean Moratorium, have been proposed to curb deforestation through the cattle and soybean supply chains as a means to influence the production process. Here, we highlight the role of producers and consumers in the use of land and water resources for agricultural production in the state of Mato Grosso, Brazil, by combining field measurements and modelling with trade mapping. We use the Transparency for sustainable economies platform (Trase, https://trase.earth) to highlight the role of trade actors by combining high resolution trade information (e.g. custom declarations) with up-to-date deforestation and water scarcity maps. In 2015, up to five traders with zero deforestation commitments exported over 40% of soybean produced in the state of Mato Grosso. Within this context, producers can increase agricultural output by irrigating cropland, and/or concentrating cattle production on current pastureland, but this combined system has the potential to increase water scarcity in the dry season. Our analysis provides additional information on the drivers shaping the Brazilian agricultural frontier and attempts to bring producers and consumers closer together in agricultural supply chains.

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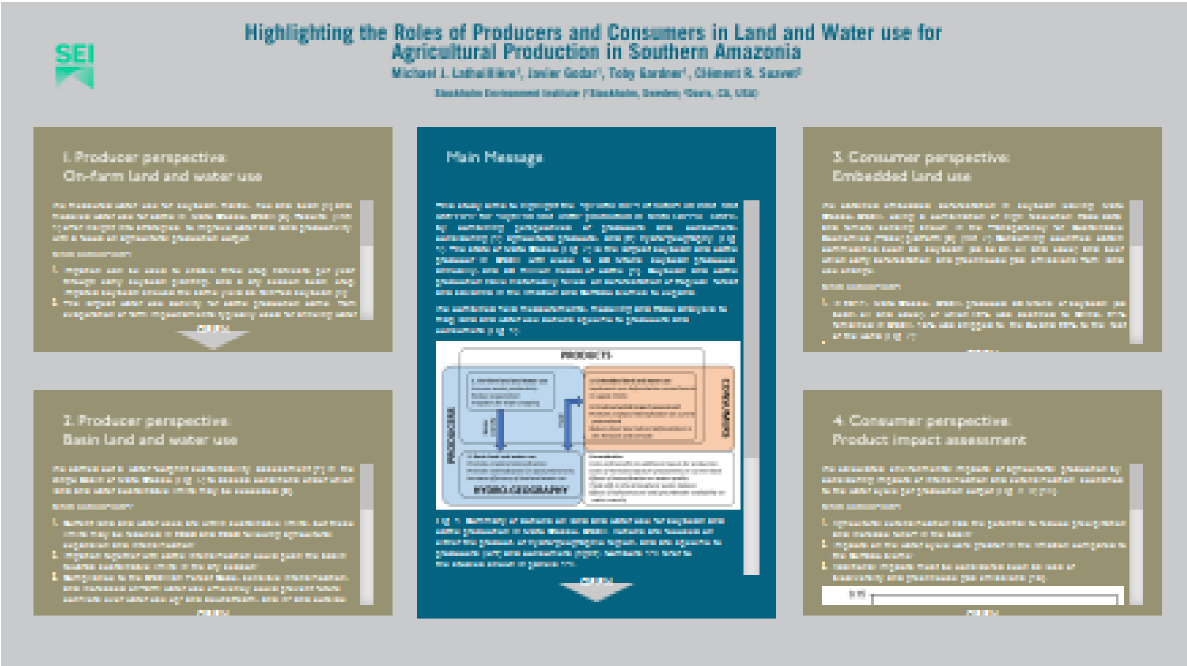

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PRESENTED AT:

1. PRODUCER PERSPECTIVE:
ON-FARM LAND AND WATER USE

We measured water use for soybean, maize, rice and bean [4] and modeled water use for cattle in Mato Grosso, Brazil [5]. Results (**Tab. 1**) offer insight into strategies to improve water and land productivity with a focus on agricultural production output.

Main conclusions

1. Irrigation can be used to enable three crop harvests per year through early soybean planting, and a dry season bean crop. Irrigated soybean showed the same yield as rain-fed soybean [4];
2. The largest water use activity for cattle production came from evaporation of farm impoundments typically used for drinking water (**Fig. 2**). Total Mato Grosso impoundment area reached 44,000 ha in 2014 [5].

Tab. 1. Water use for crop and cattle respectively measured [4] and modeled [5] in Mato Grosso, Brazil.

Product	***Water use***	
Soybean	800-1300	L/kg
Maize	320-500	L/kg
Rice	725-950	L/kg
Bean	1500-1800	L/kg
Cattle	251-255	L/kg live weight

Methods and Materials

1. Water use for cropland

Crop evapotranspiration (ET) was measured with an eddy covariance tower [4] installed at Capuaba Farm in Lucas do Rio Verde, Mato Grosso, Brazil (**Fig. 3**) (18 Sep 2015 to 4 Feb 2017). Crop water use was calculated as the sum of crop ET over the course of the crop development cycle (**Vid. 1**), to derive a crop water use per kg of soybean from the yield reported by the farmer [4].

Fig. 3. The eddy covariance tower installed at Capuaba Farm in Lucas do Rio Verde, Mato Grosso, Brazil Link (http://ameriflux.lbl.gov/sites/siteinfo/BR-CMT).

[VIDEO] https://www.youtube.com/embed/MUFU0k3yek0?feature=oembed&fs=1&modestbranding=1&rel=0&showinfo=0

Vid. 1. The soybean development cycle at Capuaba Farm in Lucas do Rio Verde, Mato Grosso, Brazil [4]

2. Water use for cattle

We modeled average water use for cattle in Mato Grosso, Brazil, following the model of Ridoutt *et al* [6] which combines water use with the cattle development cycle. We considered an average cattle development cycle of 48 months with both pasture or feedlot finishing in the 6 months leading up to slaughter. Evaporation from small farm impoundments (W_{res} in **Fig. 4**) were obtained using remote sensing by detecting total reservoir surface area within pasture land uses mapped by LAPIG (http://www.lapig.iesa.ufg.br/lapig/)(upper limit of 1 km^2 per reservoir).

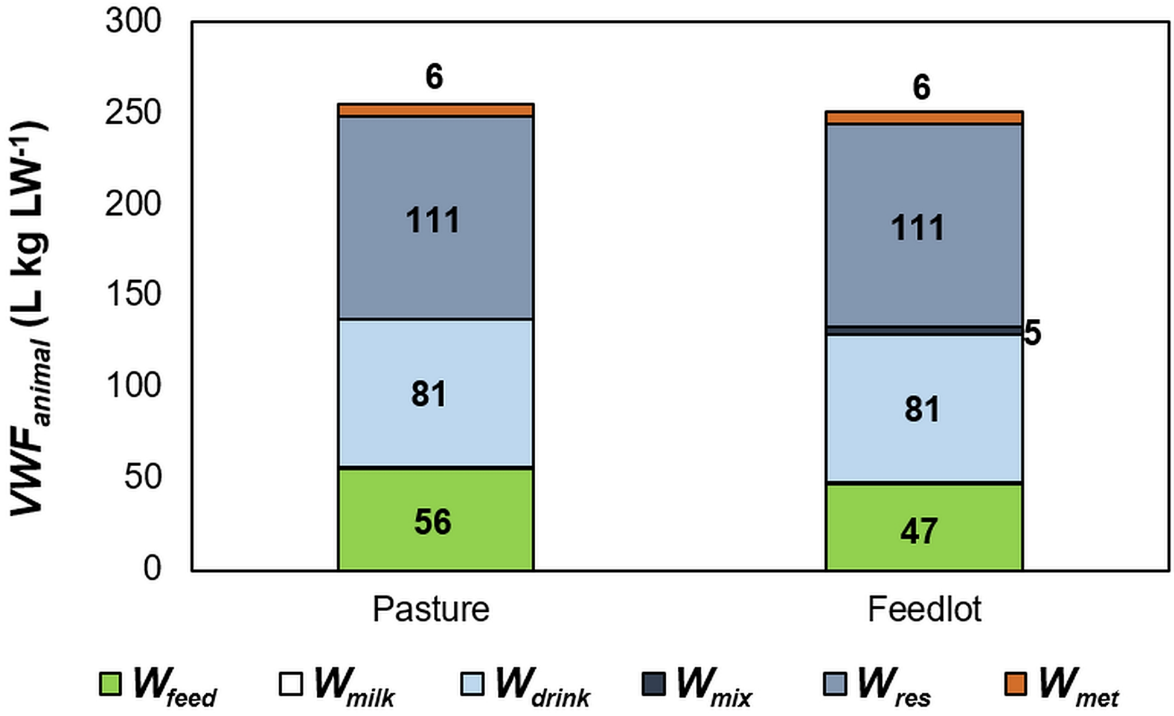

Fig. 4. Average water consumption modeled for cattle (VWF_{animal}) in Mato Grosso, Brazil, considering both pasture and feedlot finishing (6 months prior to slaughter): water use for feed (W_{feed}), milk consumption (W_{milk}), water drunk by the animal (W_{drink}), water used to mix feed (W_{mix}), evaporation from reservoirs (W_{res}), and metabolic water (W_{met}) [5].

2. PRODUCER PERSPECTIVE: BASIN LAND AND WATER USE

We carried out a water footprint sustainability assessment [7] in the Xingu Basin of Mato Grosso (**Fig. 5**) to assess conditions under which land and water sustainable limits may be exceeded [8].

Main conclusions:

1. Current land and water uses are within sustainable limits, but these limits may be reached in 2030 and 2050 following agricultural expansion and intensification;
2. Irrigation together with cattle intensification could push the basin towards sustainable limits in the dry season;
3. Compliance to the Brazilian Forest Code, sensible intensification, and increased on-farm water use efficiency could prevent future conflicts over water use up- and downstream, and in- and outside the basin.

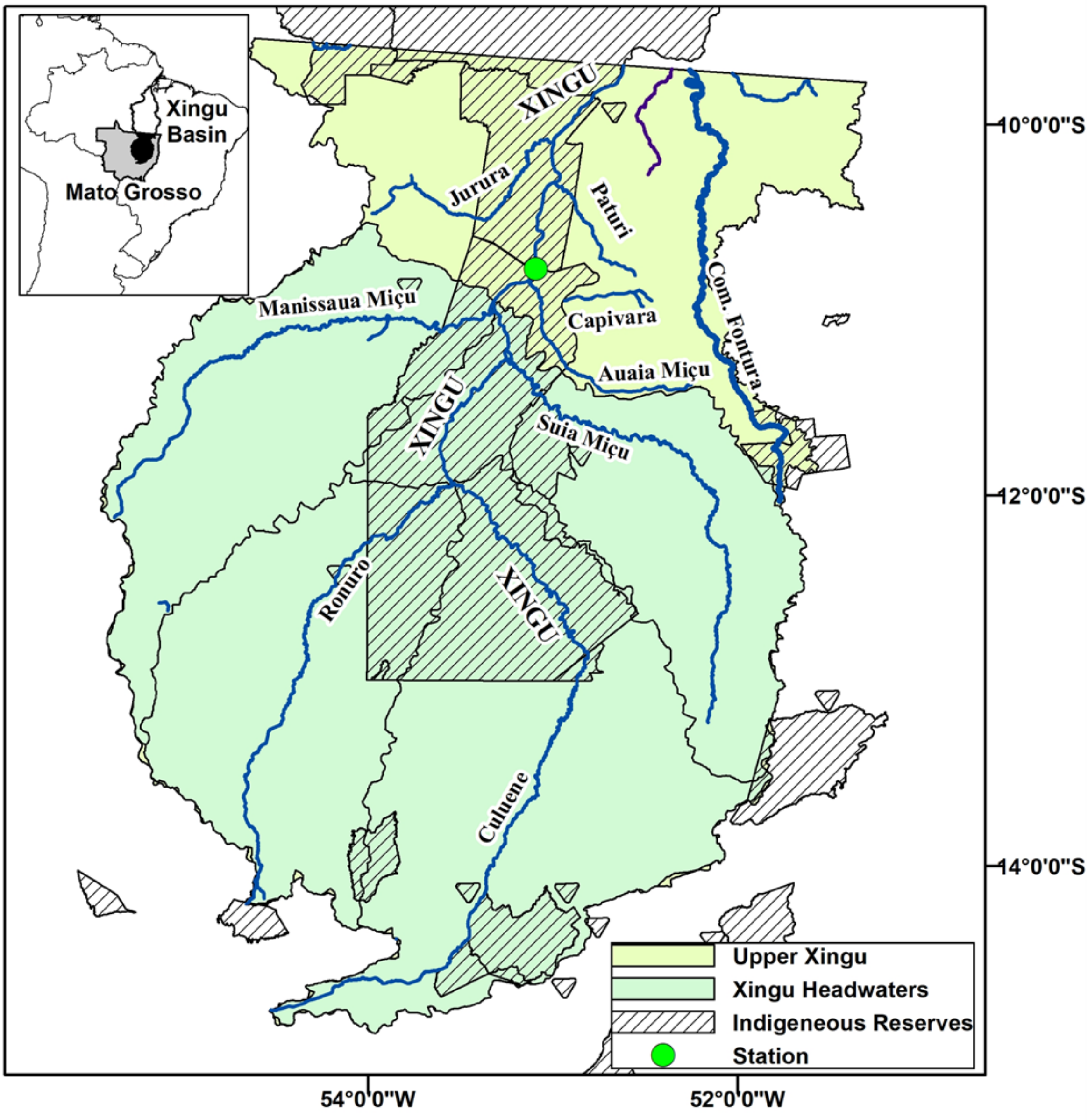

Fig. 5. The Xingu Basin of Mato Grosso, Brazil, separated into the Upper Xingu Basin and Xingu Headwaters [8].

Methods and Materials

We calculated water scarcity for the basin (**Fig. 5**) in 2000, 2014, 2030 and 2050 by computing the ratio of total water use (agricultural, industial and domestic) with water availability (as natural runoff minus demand) [7].

Land and water use in the basin were obtain following agricultural production scenarios and assumptions about livestock population and production, and domestic and industrial water uses (**Fig. 6**) [8]. Water availability was obtained using the IBIS model combined to land use information (2000, 2014), and deforestation scenarios (2030, 2050) [8].

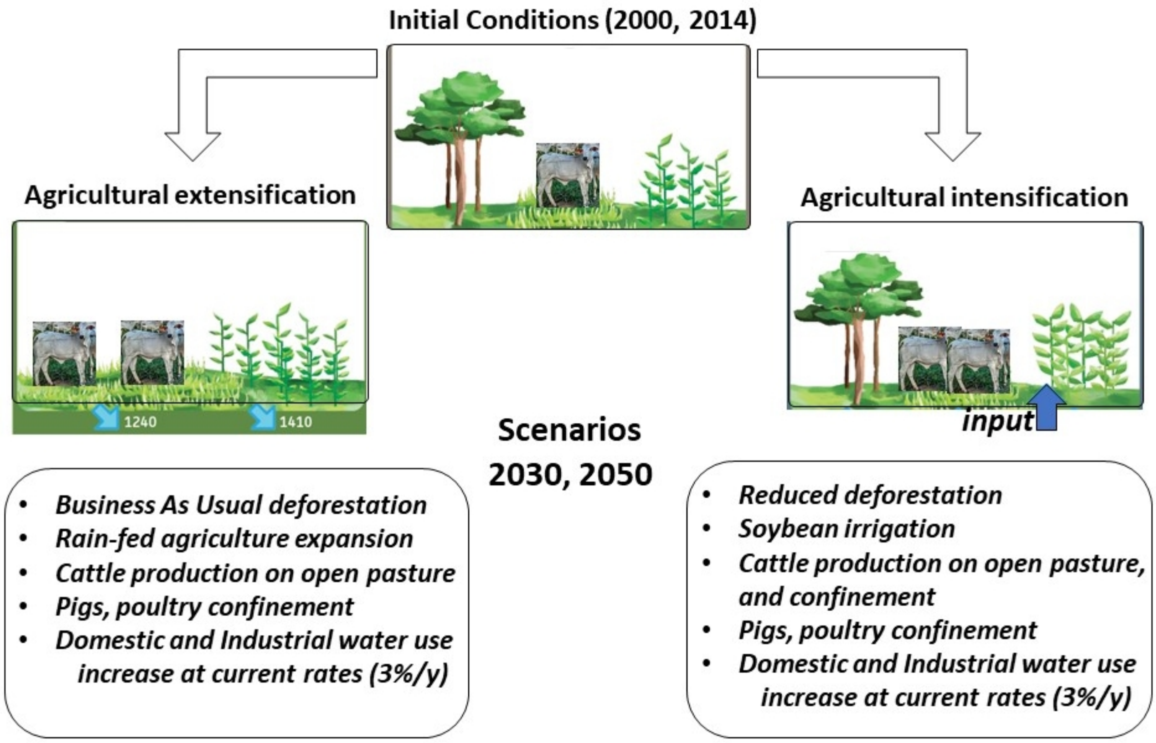

Fig. 6. Initial conditions (2000, 2014) and agricultural production scenarios (2030, 2050) considered for estimating land and water use in the Xingu Basin of Mato Grosso [8].

MAIN MESSAGE

This study aims to highlight the **specific roles of actors on land and water use for soybean and cattle production in Mato Grosso, Brazi**l, by combining perspectives of producers and consumers, considering (1) agricultural products, and (2) hydro-geography (**Fig. 1**). The state of Mato Grosso (**Fig. 2**) is the largest soybean and cattle producer in Brazil with close to 30 Mtons soybean produced annuallly, and 30 million heads of cattle [1]. Soybean and cattle production have historically relied on deforestation of tropical forest and savanna in the Amazon and Cerrado biomes to expand.

We combined field measurements, modeling and trade analysis to map land and water use actions specific to producers and consumers (**Fig. 1**).

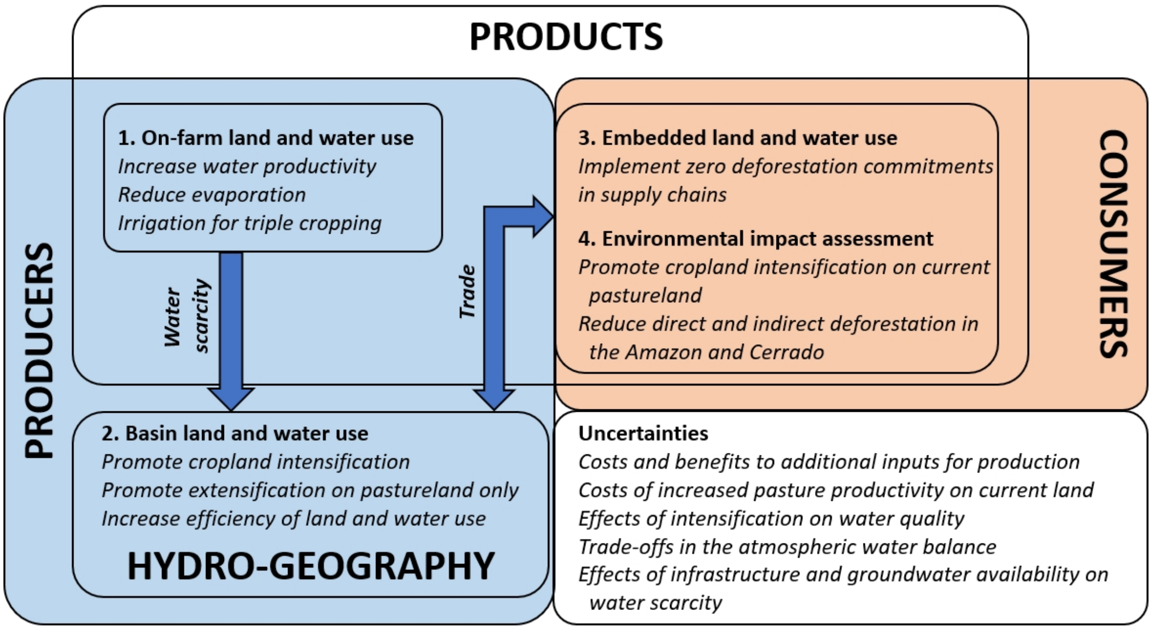

Fig. 1. Summary of actions on land and water use for soybean and cattle production in Mato Grosso, Brazil. Actions are focused on either the product, or hydro-geographic region, and are specific to producers (left) and consumers (right). Numbers 1-4 refer to the studies shown in panels 1-4.

Approach

We carry out product- and hydro-geographic focussed assessments [2] of land and water use in Mato Grosso, Brazil (**Fig. 2**), described in detail in the four panels:

1. Producer land and water use at the field level;
2. Producer land and water use at the river basin level;
3. Consumer land use through trade;
4. Consumer land and water product impact assessment.

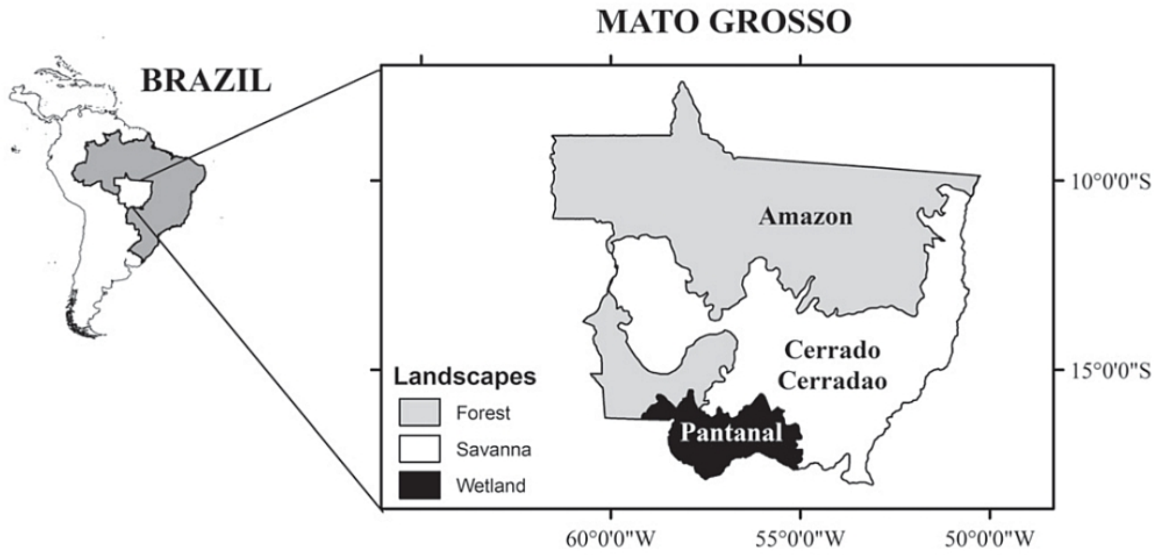

Fig. 2. The state of Mato Grosso in central western Brazil with its Amazon, Cerrado and Pantanal biomes [3]

3. CONSUMER PERSPECTIVE: EMBEDDED LAND USE

We obtained embedded deforestation in soybean leaving Mato Grosso, Brazil, using a combination of high resolution trade data and remote sensing shown in the Transparency for Sustainable Economies (Trase) platform [9] (**Vid. 2**). Consuming countries obtain commodities such as soybean (as bean, oil and cake) and beef which carry deforestation and greenhouse gas emissions from land use change.

Main conclusions

1. In 2017, Mato Grosso, Brazil, produced 30 Mtons of soybean (as bean, oil and cake), of which 42% was destined to China, 21% remained in Brazil, 15% was shipped to the EU and 22% to the rest of the world (**Fig. 7**);
2. These exports were associated with almost 15,000 ha deforestation in 2017, leading to 2.8 Mtons of CO_2 emission. There was greater soy deforestation in the Amazon biome (58%) than in the Cerrado (43%);
3. Roughly half of soy trade was made under a zero deforestation commitment in 2017.

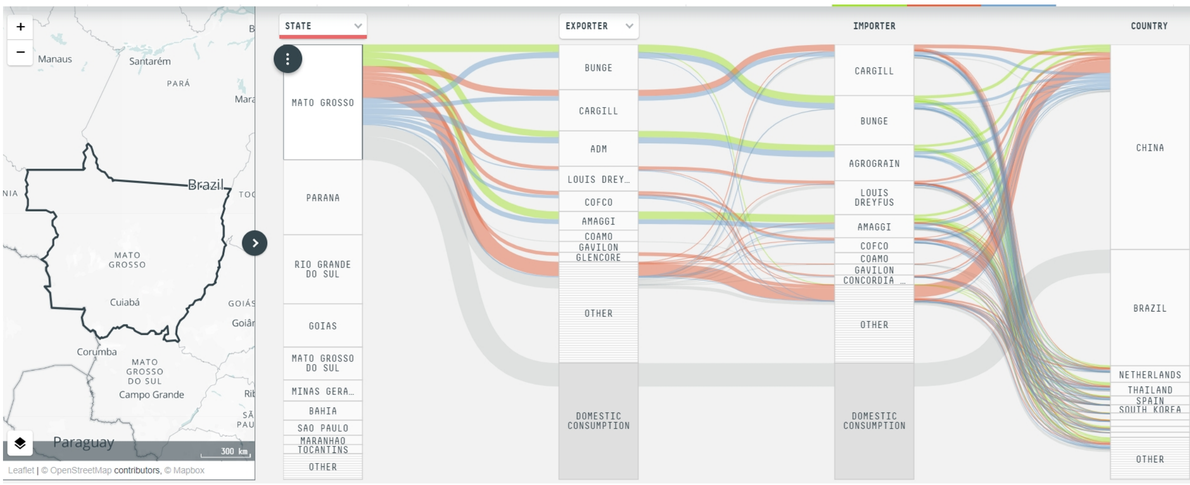

Fig. 7. Soybean trade flows from Mato Grosso, Brazil, used in Brazil and exported internationally [9]. Trade flows are coloured by zero deforestation commitment: Soy Moratorium (blue), Company commitment (green), or None (red)

Methods and Materials

1. Trade analysis

The Transparency for Sustainable Economies (Trase) platform **(Vid. 2**) relies on the combination of high resolution trade information, asset information (silos, ports) and tax information to link Brazilian municipalities of production to destination countries [9]. This information is then combined to production [10] and deforestation maps [11,12] to derive soybean deforestation. Greenhouse gas emissions were estimated using publicly available carbon maps [13].

[VIDEO] https://www.youtube.com/embed/wMnAQJBptj8?feature=oembed&fs=1&modestbranding=1&rel=0&showinfo=0

Vid. 2: Introducing the Transparency for Sustainable Economies (TRASE) platform [9]

2. Soybean deforestation and zero deforestation commitments

Zero deforestation commitments are distinguished between "Soy Moratorium" and "Company commitments" based on whether soybean has been sourced from the Amazon biome, or whether a trader has made a specific pledge to zero deforestation (identified through company websites).

4. CONSUMER PERSPECTIVE: PRODUCT IMPACT ASSESSMENT

We calculated environmental impacts of agricultural production by considering impacts of intensification and extensification scenarios to the water cycle per production output (**Fig. 8, 9**) [14].

Main conclusions

1. Agricultural extensification has the potential to reduce precipitation and increase runoff in the basin;
2. Impacts on the water cycle were greater in the Amazon compared to the Cerrado biome;
3. Additional impacts must be considered such as loss of biodiversity and greenhouse gas emissions [15].

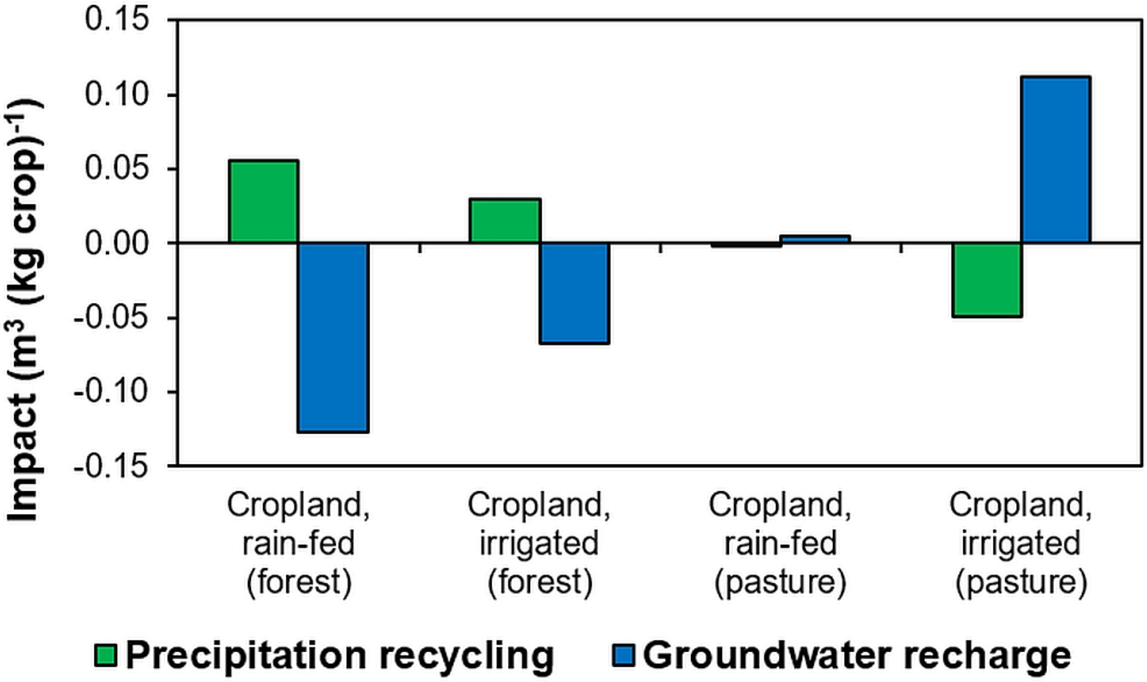

Fig. 8. Impacts of agricultural production in the Amazon biome (m^3 per kg of crop) considering rain-fed and irrigated cropland extensification onto tropical forest (labeled as "forest"), and intensification on current pastureland (labeled as "pasture"). Cropland includes options of growing rain-fed soybean, maize, or irrigated soybean, rain-fed rice, and irrigated bean [14].

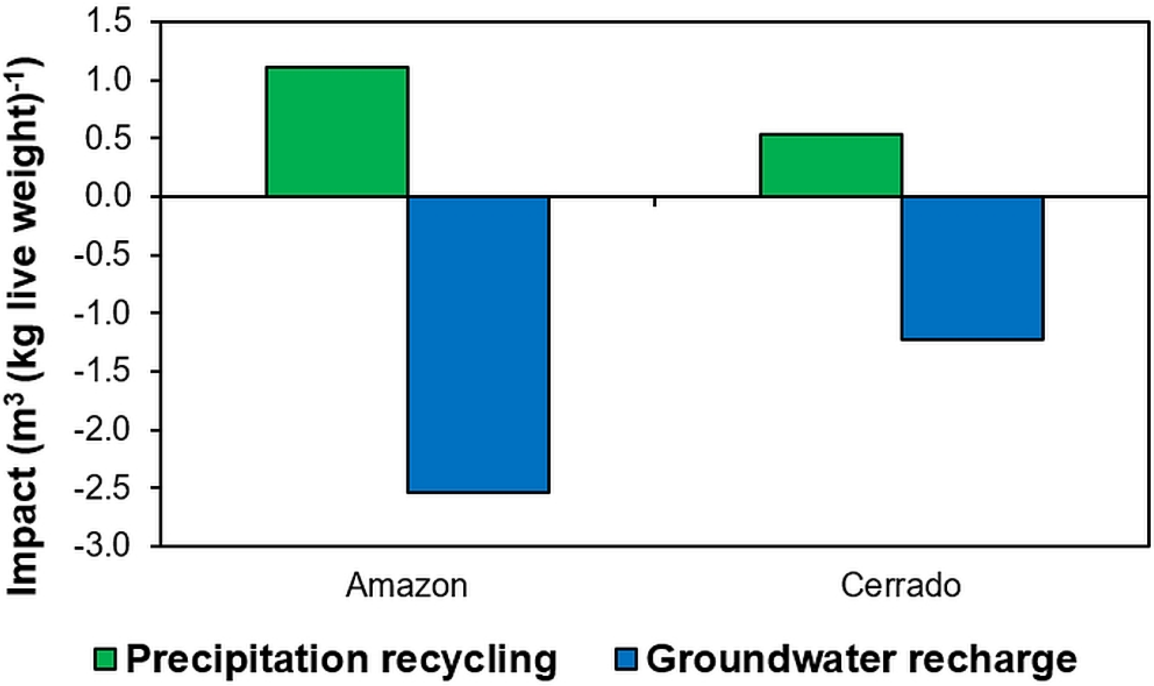

Fig. 9. Impacts of cattle production in Amazon and Cerrado biomes (m^3 per kg of live weight) considering pasture expansion onto tropical forest in both biomes [14].

Methods

We use life cycle assessment (LCA) to estimate impacts per kg of product using water use estimated in panels 1 and 2, and using the Xingu Basin as the geographic boundary (**Fig. 5** shows a portion of this basin which extends further north). The method follows the framework for including land use in LCA [16], focussing specifically on impacts of deforestation on precipitation recycling [17] and groundwater recharge [18] following the equation **Impact** = *A***Factor*, where **Impact** is the impact to the water cycle (positive of negative flows per kg), *A* (ha (kg product)$^{-1}$) is the area required for 1 kg of product, and *Factor* (m^3 ha^{-1}) is the impact factor allowing to allocate the impact per kg of product [16].

DISCLOSURES

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ABSTRACT

For decades, agricultural expansion in Southern Amazonia has relied on deforestation to increase the national and global supplies of cattle and soybean products. Research on the use of land and water for increasing the region's pasture and cropland outputs has provided important insight into the role of producers in managing these resources. However, the roles of other actors on cattle and soybean production systems (e.g. traders) have been less apparent. For instance, some private initiatives, such as the Cattle Agreement or the Soybean Moratorium, have been proposed to curb deforestation through the cattle and soybean supply chains as a means to influence the production process. Here, we highlight the role of producers and consumers in the use of land and water resources for agricultural production in the state of Mato Grosso, Brazil, by combining field measurements and modelling with trade mapping. We use the Transparency for sustainable economies platform (Trase, https://trase.earth) to highlight the role of trade actors by combining high resolution trade information (e.g. custom declarations) with up-to-date deforestation and water scarcity maps. In 2015, up to five traders with zero deforestation commitments exported over 40% of soybean produced in the state of Mato Grosso. Within this context, producers can increase agricultural output by irrigating cropland, and/or concentrating cattle production on current pastureland, but this combined system has the potential to increase water scarcity in the dry season. Our analysis provides additional information on the drivers shaping the Brazilian agricultural frontier and attempts to bring producers and consumers closer together in agricultural supply chains.

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