Spatially Explicit Assessment of Suitable Conditions for the Sustainable Production of Aviation Fuels in Brazil

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Supplementary Material

1. Land Prices

In Figure S1 average land prices for natural pasturelands, in R$ (2018), at municipal level, are presented. The prices were estimated from [1-3].

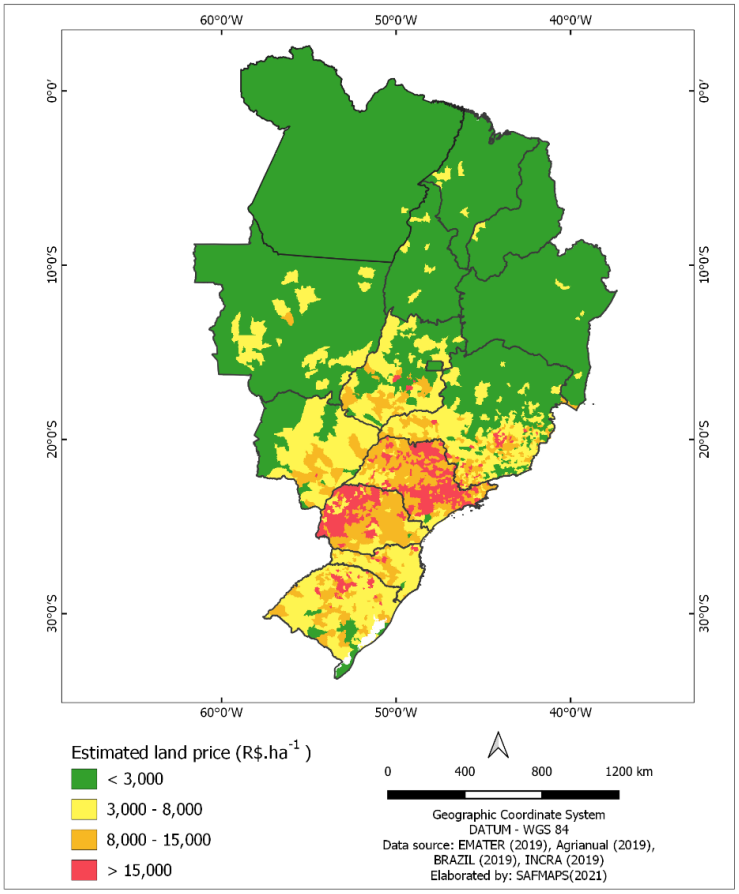
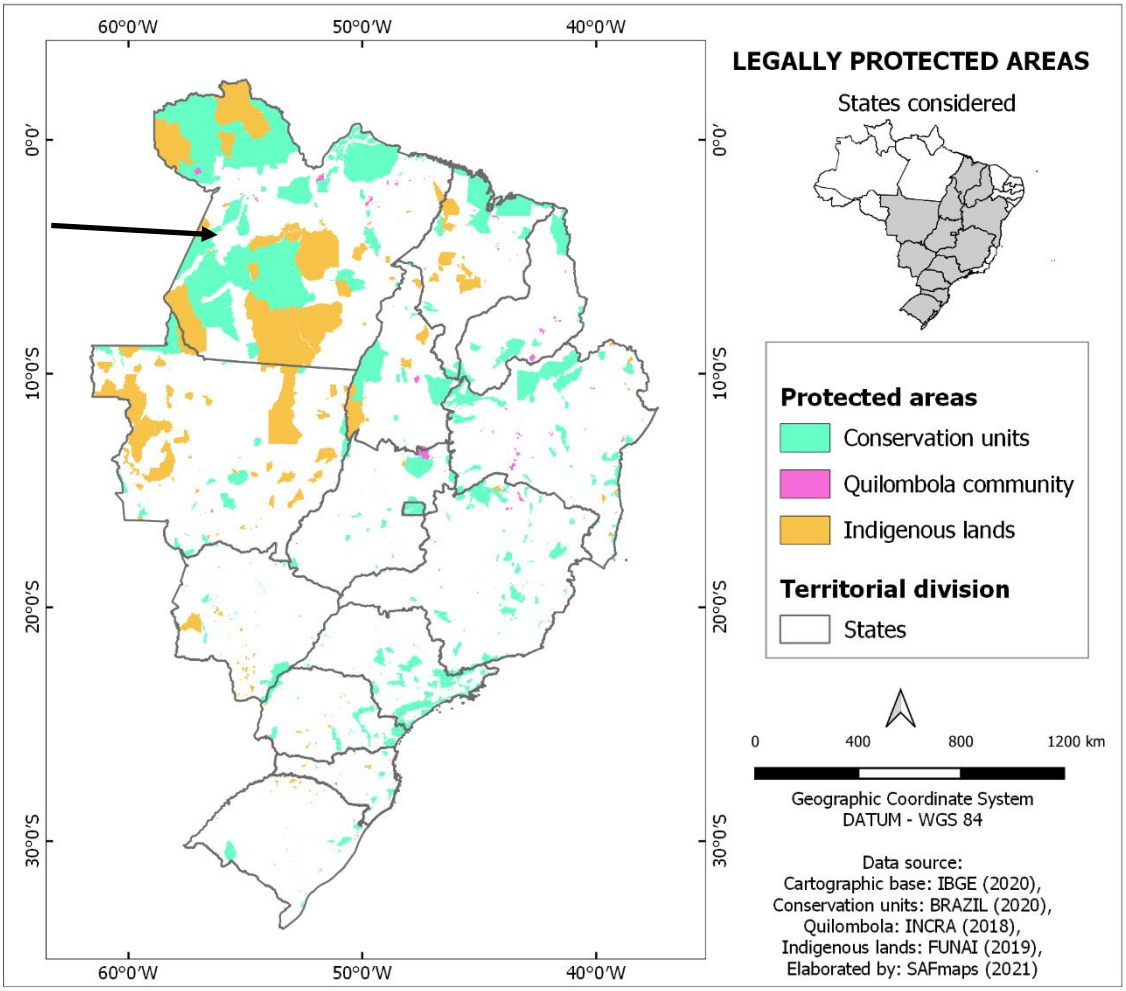


Figure S1. Estimated land prices in 2018, for natural pasturelands.

2. Legally Protected Areas

Figure S2 shows the location of legally protected areas in Brazil. The category includes three groups: (1) conservation units due to environmental reasons (as for March 2020), (2) traditional Afro-Brazilian settlements in 2020 (i.e. Quilombola areas), and (3) the indigenous reserves (as for 2019).



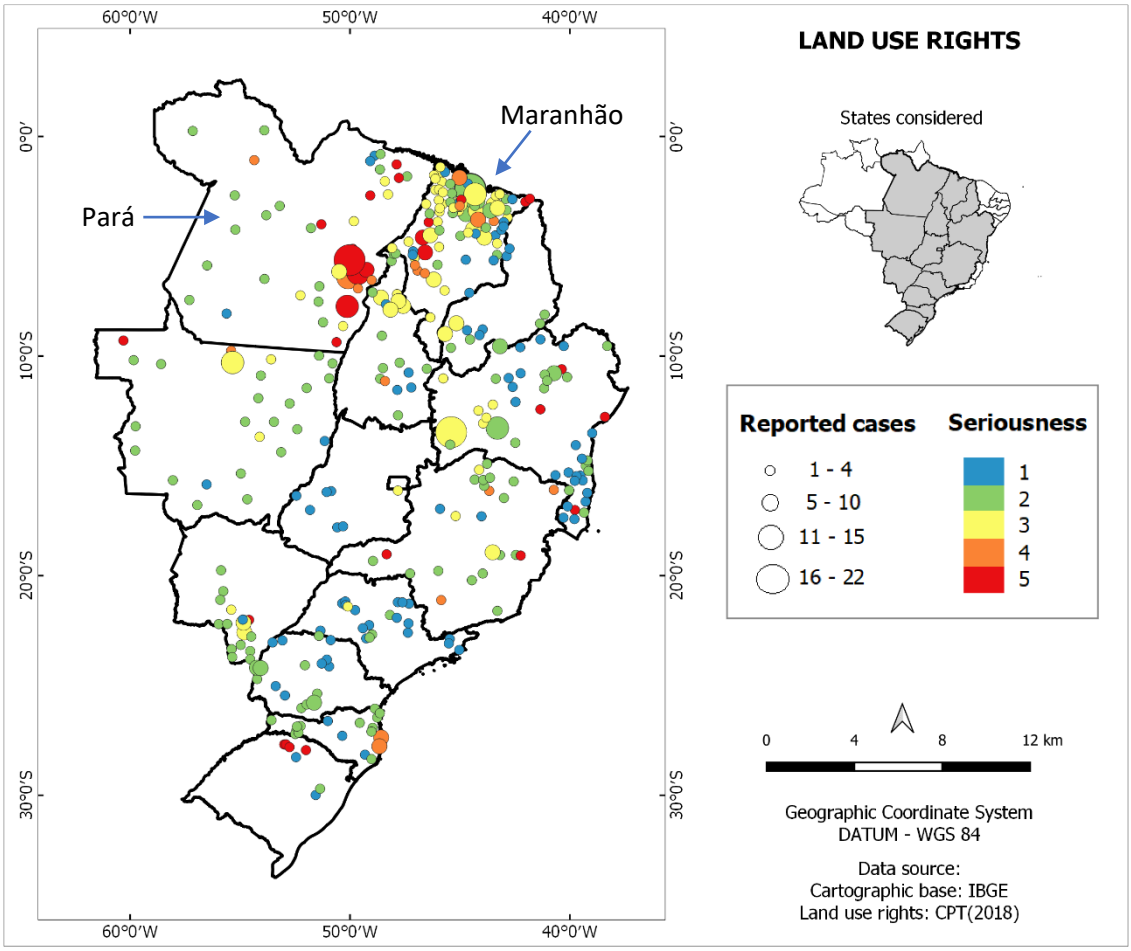
Sources [4-7]

Figure S2. Location of legally protected areas in Brazil. The arrow indicates state of Pará.

3. Reported Violations to Land Use Rights

Figure S3 illustrates the distribution of reported violations of land use rights, based on [8]. The information corresponds to the period 2016-2018. The reported cases are the number of records in each municipality. Severity is a metric defined by the authors of this study, ranging from 1 to 5, corresponding to 1, for example, threats, and 5 to, for example, homicides reported by [8] in association with disputes over land use and land tenure.

In Figure S3 the states of Pará and Maranhão are highlighted. Maranhão had, in the period 2016-2018, more cases notified, in different municipalities, but in the same period Pará had many more cases classified as serious, mainly in the southeast of the state.



Source [8]

Figure S3. Reported violations to land use rights; the states of Pará and Maranhão are highlighted.

4. Maps for Other Crops

Maps, reports and data can be accessed through www.safmaps.com. Moreover, detailed information can be accessed through the following links:

Eucalyptus: http://dx.doi.org/10.17632/ghvrstw7pw

Soybean: http://dx.doi.org/10.17632/jpwggmp9zy

Sugarcane: http://dx.doi.org/10.17632/dp4y36fjw5

Corn: http://dx.doi.org/10.17632/g25wt3t7k5

Some maps, available at the database are presented below, as examples.

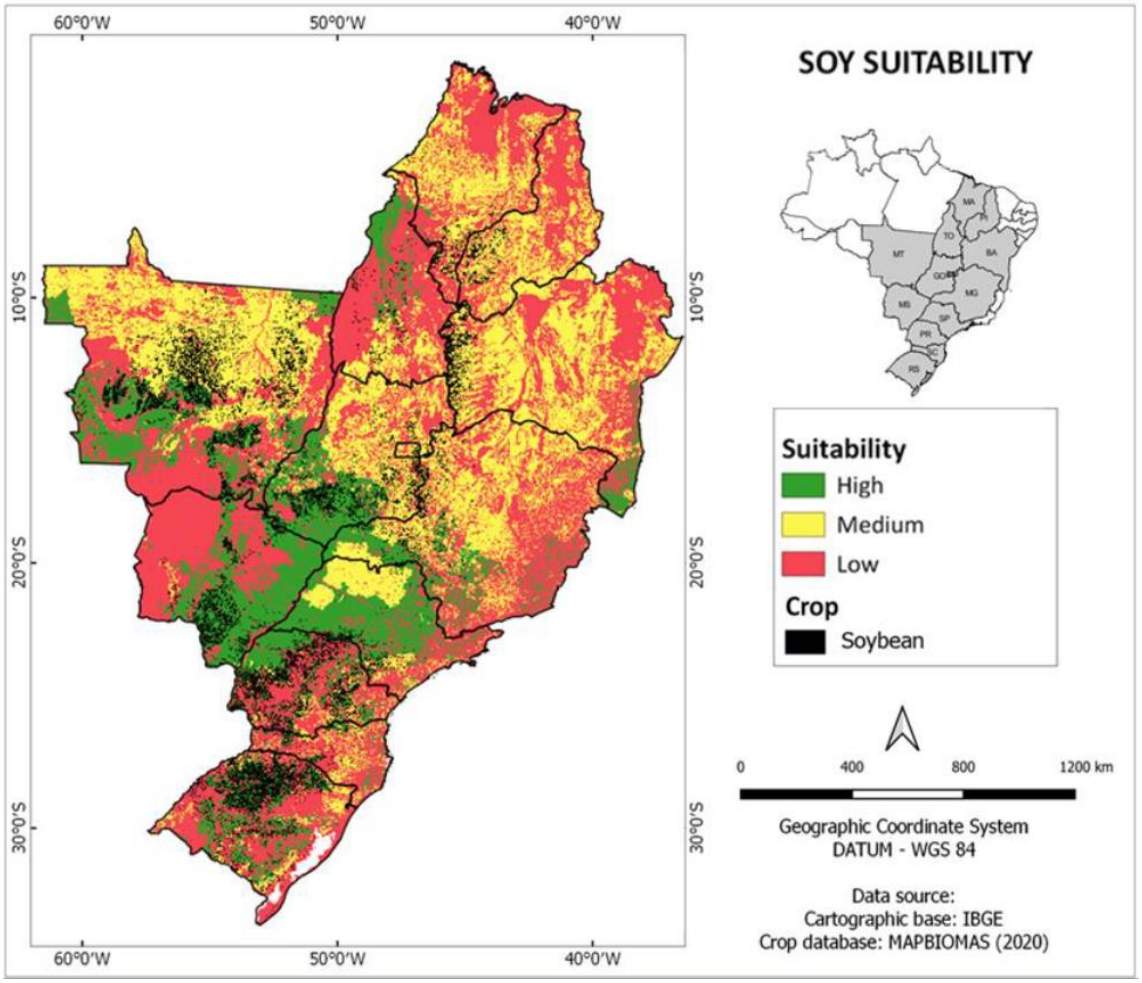


Figure S4. Suitability for soybean production, and validation against registers of cropped area in 2018.

The areas cropped with soybean were identified in the map of land use/land cover for 2018 [9]. It was combined with the suitability map, based on the estimates by the authors. In Figure S4 it can be seen that there is good match between the estimated suitability and the results obtained from land use/land cover map.

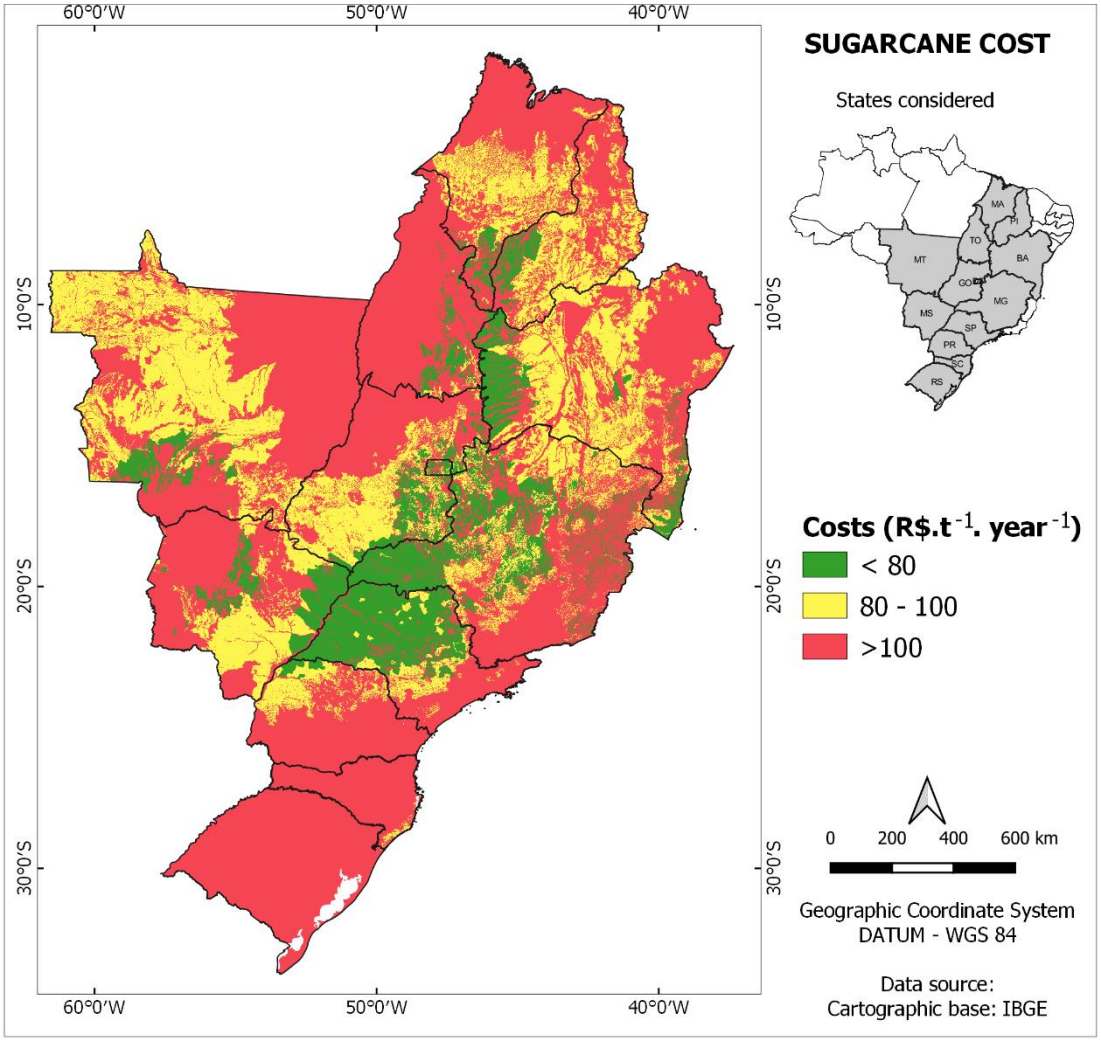


Figure S5. Map of estimated average sugarcane costs, including harvesting and transport to the mill, in a five-year cycle.

Figure S5 shows the distribution of estimated average sugarcane production costs. The estimate is based on a producing cycle of five years. The cost structure and reference values were taken from [1], which shows representative data for five states (SP, PR, MG, GO and MS; i.e. the most important producing states).

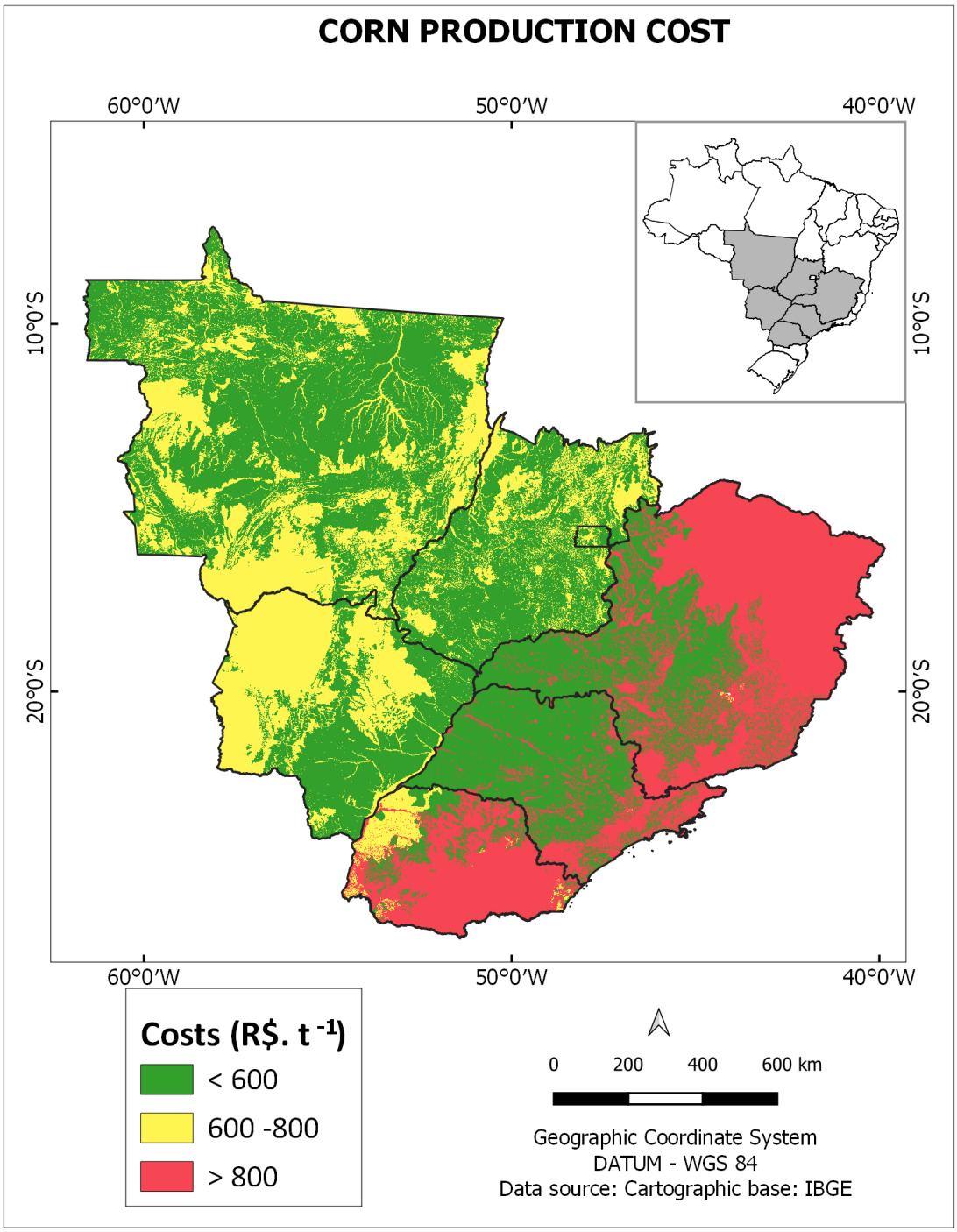


Figure S6. Map of estimated average corn costs, as second crop.

Figure S6 shows the estimated production cost of corn as second crop. The distribution is shown in the six states in which there is potential for corn to be produced in association with soybean. The cost estimate is for transgenic corn. Costs include harvesting, transport to nearby warehouses and storage for one month. Thus, costs reflect the availability of corn at an intermediate point between the harvest and the ethanol unit.

Corn costs are estimated according to the cost structure reported by [1] for five states (MT, MS, GO, SP and PR).

5. Other Parameters

5.1 Heat Content

The assumed heat content of different feedstocks/fuels is presented in the table below.

Table S1. Assumed heat content of different fuels.

Feedstock/Fuel	LHV (MJ.kg^{-1})	Comment	Reference
Wood (dry)	18.07		[10]
Wood (wet)	11,29	With 60% moisture; to be transported	[10]
Soy oil	35.96		[11]
Anhydrous ethanol	28.24		[12]
Jet-fuel	42.80		[12]

5.2 Cost of Transport

The cost of transport of wood (in BRL.t^{-1}.km^{-1}) (2018) is calculated by equation (1), which has been adjusted for different estimates presented by [13]. The values obtained with this function are equivalent to those presented by [14], in BRL.m^{-3}.km^{-1}, for distances between 100 and 140 km, using trucks with a transport capacity of 54 t.

The values obtained by equation (1) were checked with transport costs for different loads, and proved to be adequate. Thus, the function was used for different feedstocks.

$$K = 1.3322 \, . D^{-0.3076} \quad (1)$$

Where K is the cost (BRL.t^{-1}.km^{-1}) and D is the distance (km).

Vassalo [15] states that the transport of liquids by pipeline is 4.5 to 5.7 times cheaper (in \$.t^{-1}.km^{-1}) than the transport by trucks. Here it was used 5.1 for estimating the costs due to the use of pipelines.

From the literature review [16-18], it was observed that the cost ratio of rail/road freight, expressed in US\$.t^{-1}.km^{-1}, varies between 0.31 and 0.74 for distances greater than 1,000 km, with a clearer indication that 0.50 could be used for a preliminary assessment. Here, 0.50 was used.

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