Influence of Transportation on the use of the Land: Viabilization Potential of Soybean Production in Legal Amazon Due to the Development of the Transportation Infrastructure

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ABSTRACT

The Brazilian Government has been proposing large investment projects aiming to improve transportation infrastructure of the Central-West and North regions. These projects intend explicitly to develop the delivery system in the Central-West, which stimulates the soybean expansion to Northern areas. However, basic infrastructure (energy and transportation, mainly) in these new areas are important bottlenecks for commercial agriculture, such as soybean. Even some technical question marks are remaining, once wet weather, poverty of soil and lack of adequate soybean varieties could reduce the viability of soybean in the Legal Amazon. There is, also, a potential for conflicts between the desire to produce commercial crops and the preservation of the largest tropical forest in the world. This paper intends to help in this discussion as well as in the analysis of geo-referenced data from Legal Amazon, using a Geographic Information System (GIS) and an optimization model based on the von Thünen's ring theory, incorporating a linear programming model developed to find out where in the Legal Amazon the soybean crop would be economically viable. The results obtained show that the soybean production area tends

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to grow significantly in regions close to a well developed infra-structure of transports and in agriculture/pasture areas or over the cerrados. The direct impact on the rainforest tends to be small. The maps resulted from this paper were compared to other mapped data (such as type of vegetation, type of soils, among others) and can help in developing public policies for a sustainable development of the Amazon.

Key words: logistics, soybean, Legal Amazon, Geographic Information System

1 Introduction

The Brazilian grain production in the past decades has been moved to areas further and further away from the great Southeastern and Southern centers of the country. The technical viabilization of the commercial production at the cerrado regions and the new roads set up in the Central-West region have led the commercial agriculture, especially soybean, to change significantly the Central-West region landscape, and is the development pivot in that region.

The growing importance of the Central-West region as an agricultural pole provided the viabilization of the corridors towards the North of the country which, despite not being new, just recently began to be given more attention in the view of private investments and projects planned by the federal government.

This has been effectively carried out in regions where the transportation infrastructure allows the exportation of grains through the North (case of the Carajás railway and Madeira River waterway). In the 1998 season, according to data by Caffagni (1999), 860 thousand tons were delivered through these two corridors, 370 thousand through the Madeira River and 490 thousand through the Itaqui port (MA).

The change in the soybean delivery direction obviously originates from a cost reduction in transportation caused by two basic factors: i) use of multimodals and ii) distance reduction to the foreign port.

The multimodals allows minimization of transport unit costs because it uses the combination of several modals as an exclusive alternative to road transportation currently prevailing in the country, while the distance reduction up to the final destination occurs since the agriculture has increasingly developed towards northern regions.

Traditionally, soybean has been directed to Southern and Southeastern states since those regions are where the crusher plants, the export ports and a great deal of the grain storing and commercialization infrastructure are located. Some soybean, however, ends up returning to the North in order to be exported to Europe and Asia. With the investments in ports (i.e. Itacoatiara, AM, and Itaqui, MA) and in delivery systems in the North region of the country the soybean travels only the South-North route, thus reducing the total course.

This way, several investors have been interested in incorporating areas of the Amazon region to the productive process, for those are the ones with lower prices and shorter distances to the export ports as currently observed in the regions of Sinop (MT), Sapezal (MT), Santarém (PA), Paragominas (PA), Itacoatiara (AM), Humaitá (AM) and some areas in Roraima.

These areas, however, have a precarious basic structure, deficient in energy and transportation sectors, in addition to the technical viability itself, still to be questioned.

Also, a potential conflict is observed with the intention to preserve the world's greatest rainforest and respect native and community lands and national parks. Policies to make the North region development viable are then required, without surpassing the society's environmental interests or the rights of the traditional Amazonian populations.

This paper intends to contribute in this discussion through a model pointing the potential impact of these new transportation corridors in the development of soybean in Legal Amazon.

2 Main transportation infrastructure improvement projects in Legal Amazon

Lício & Corbucci (1996) describe with further details some of the planned corridors conducting the production to the North. In this case only those counting on governmental investments are reported: i) the Northwest Corridor; ii) the Central-North Corridor; iii) the Northeast Corridor; and iv) the Central-East Corridor.

The first corridor corresponds to road BR 163/364 (connecting Cuiabá to Porto Velho), the Madeira River and the Amazon River. This is the waterway of the Madeira River currently and traditionally being used by the region's population. The destination is the Itacoatiara port, where a private grain terminal operates, loading the ships destined to the European market. According to calculations by Lício and Corbucci (1996), delivery through this route would save, in long term, US$ 44.50/t, when currently US$ 23.50/t are saved.

The Central-North Corridor is made up of two axis: I) Tocantins River – North-South railway – Carajás railway and ii) Araguaia River (up to Xambioá or Conceição do Araguaia) – road (Xambioá – Estreito or Conceição do Araguaia – Estreito) – North-South railway – Carajás railway. Currently, in this corridor, only the railway part runs, while the transportation by the Araguaia River is about to start operating. However, this corridor has undergone problems in order to totally be taken into effect, since the rivers run through restricted access parts like native reserves. In current conditions, this corridor presents cost reduction in the order of US$ 16.00/t, while costs could be reduced to US$ 47.00/t should all work required (total investment of US$ 222,6 million) be carried out (Lício & Corbucci, 1996).

The Central-North Corridor tends to be the major one in terms of the country's agricultural production development. Braga et al. (1997) estimated that its influence area – ready for grain production with no legal hindrance (such as native reserves, national parks and legal reserve areas) – is approximately 40 million hectares, including the states of Goiás (Northwest), Mato Grosso (East), Piauí (South), Maranhão (South) and the entire state of Tocantins. Considering that 45 million hectares of the cerrado were used in 1995 (Braga et al., 1997, quoting Macedo, 1995[4]), the impact of this corridor on the geography of the Brazilian production is observed to be quite significant.

The Northeast Corridor is more significant to the domestic market, especially for grain supply in the Northeastern region. It is composed mainly by the São Francisco River and by the Northeast transportation network and allows Bahia- and Minas-originated grains to reach the Northeastern market with more advantage than importing from Argentina, currently the main corn supplier to this region.

Another corridor arousing an issue is that involving the waterway of rivers Juruena, Teles Pires and Tapajós. This corridor encompasses road BR 163, from the northern state of Mato Grosso to Itaituba (PA), and Tapajós River to Santarém (PA); this course can also be executed entirely by road up to Santarém (PA).

The total paving of this road had a very strong political support and there are little restrictive actions, which can speed up the work. In 1999 and 2000 a pool of entrepreneurs and politicians of Northern Mato Grosso transported over 100 trucks loaded with soybean through this corridor, unloading them in Itaituba (PA) and through waterways until Santarém. Their motivation is to save approximately R$ 2.00/bag, even with the various investments still required (A Gazeta newspaper, 1999).

Another export corridor at the Central-West region, discussed by Marques & Caixeta Filho (1998), is the Ferronorte. In this case, the delivery direction is the same as the current one (Central-West – Southeast), however, the transportation from the Central-West to the Santos port is done only by railway, with no need for transshipment. This railway has undergone several interruptions during its construction due to debt

[4] Macedo, J. **Prospectives for the rational use of the Brazilian Cerrados for food production**. Planaltina. EMBRAPA – CPAC, 1995. 19 p.

payment, however, in 1998 the railway construction was retaken at full speed, reaching the municipality of Alto Taquari (MT) simultaneously with the conclusion of the road-railway bridge over the Paraná River (connecting Ferronorte and the railway network of the state of São Paulo). The initial project is designed to reach Cuiabá and further on, Porto Velho, Uberlândia and Santarém. Marques & Caixeta Filho (1998), quoting data of the Ferronorte project, report that the savings expected for freight from Inocência to Santos (portion already completed) is of R$ 20.00/t. In Rondonópolis it would reach R$ 27.00/t and in Cuiabá R$ 32.00/t.

Another important project is the paving of road BR 174, connecting Manaus and Boa vista and Boa Vista to the border with Venezuela. It is already in an advanced development stage (94% of the 910 km have been already paved) and will provide Brazil with a way out to the Caribbean, through Puerto Ordáz port, at the Orinoco River. In addition, it allows the exportation of soybean from Roraima to Venezuela, which does not produce grains and has been paying prices quite high for the American agricultural products.

In addition to these projects, supported by the federal government, there are others with regional importance.

One of them is the Capim River, which has been navigated for some time to transport kaolin from southeastern Pará. Nevertheless, the Paragominas region has undergone a substantial growth in grain production and already counts on using this river to transport grains both for export, through Vila do Conde port, and to access Belém's market (which imports 90% of its corn from other states).

The road BR 242 will be the connection of Northern Mato Grosso and Primavera do Leste and Canarana/Água Boa. This way, the access to the industries of the Rondonópolis region and to the Araguaia waterway will be made viable for the soybean produced in Sorriso, Sinop, Nova Mutum and Lucas do Rio Verde.

The road BR 401 is the interconnection between Boa Vista and the Guyana and is being paved from the Brazilian side until the border with that country. This road is to connect Roraima and the Caribbean through the Georgetown port, with a course of approximately 500 km, 300 km less than the Venezuelan option. In addition, together with road BR 156 in Amapá, this road will provide a connection between Boa Vista and Macapá, crossing the Guyanas and Suriname, a corridor named as Arco Norte.

This paper, however, considers only the projects under more discussion (therefore with higher chances of coming true): i) Tocantins-Araguaia waterway; ii) paving of road BR 163 (Cuiabá-Santarém); iii) Ferronorte to Cuiabá; iv) conclusion of the lock in Tucuruí; v) Juruena-Teles Pires-Tapajós waterway; vi) adaptation of the ports of Santarém, Vila do Conde and Santana for soybean exportation; vii) Branco e Negro River waterway; viii) Capim waterway; ix) paving of road BR 401; x) paving of road BR 242; xi) paving of road BR 174; xii) Madeira River waterway (already operating).

3 Material and Methods

The model used in this analysis is a set of maximization equations of the net revenue based on the work accomplished by Stone (1998) for the logging sector. This work uses the approach created by Johann Heinrich von Thünen, in 1826 (quoted by Barlowe, 1965) implying that the use of the land of a given region would be determined by the competition between the possible agricultural activities. In von Thünen's model the factors to determine whether a given activity would be more competitive in a certain area would be its consumer's market price and the concerning transportation cost. A detailed explanation of von Thünen's theory as well as a list of presuppositions used in his model are available in Ferreira (1989).

Thus, the mathematical structure of the model is:

$$Max \qquad \sum_i R_i = \sum_j (E_{ij} p_j) - CP_i - E_{ij} f_t k_{tij} \qquad (1)$$

subjected to

$$\sum_i E_{ij} \le C_j \tag{2}$$

$$E_{ij} = 0, \tag{3}$$

$$CP_i = Q_{iz} p_{xz} + Q_{iz} f_t k_{tix} + CO_i + \frac{Q_{ic} p_{xc} + Q_{ic} f_t k_{tix} + CC_i}{n_i} + \frac{CA_i}{m_i} \tag{4}$$

$$\sum_j E_{ij} \le Pt_i \tag{5}$$

$$\sum_i E_{ij} \le D_j \tag{6}$$

$$R_i \ge 0 \tag{7}$$

$$E_{ij} \ge 0 \tag{8}$$

where:

i = index associated to the producing locality;

j = index associated to the soybean demander (exporting port or agroindustry);

t = index associated to the transportation modals (road, railway, waterway and port);

z = index associated to the input supplier;

c = index associated to the limestone supplier;

R_i = net revenue obtained with soybean for each locality i, in R$;

E_{ij} = production of locality i destined to demander j, in tons;

p_j = soybean price paid by demander in j, R$ / tons;

CP_i = cost of soybean production in locality i, in R$ / 100 ha;

f_t = transportation moment for modal t, R$ / tons km;

k_{tij} = distance run in modal t from locality i to demander j, in km;

C_j = maximum annual transportation capacity to destination j, in tons;

Q_{iz} = amount of input z demanded at locality i, in tons;

p_{xz} = price of input z at seller x, in R$ / tons;
k_{tix} = distance run at modal t from seller x to locality i, in km;
CO_i = sum of operational costs for soybean production in i, in R$ / 100 ha;
Q_{ic} = amount of limestone required at locality i, in tons;
p_{xc} = price of limestone at seller x, in R$ / tons;
CC_i = sum of the limestone application costs at locality i, in R$ / 100 ha;
n_i = number of years between two limestone applications in i;
CA_i = cost of area clearing in locality i, in R$ / 100ha;
m_i = number of years expected for investment return regarding area clearing;
P_{ti} = soybean production in i, in tons;
D_j = soybean demand in j in tons.

Equation (1) represents the maximization of the net revenue of each locality i, and is achieved by adding the net revenues from each demanding j. Equation (2) depicts the restriction of some modals as to the maximum transported load. This parameter is especially limiting for waterways for they have a lower operational capacity than the other modals. For areas facing technical hindrances such as a relief that makes the mechanization unviable, or a legal hindrance, as native reserves and conservation units, the model assumes the soybean production to be zero. This restriction is depicted in equation (3).

Equation (4) shows the method to be used to calculate the production cost of each locality i. It should be composed of the purchasing ($Q_{iz}*p_{xz}$) and input transportation costs ($Q_{iz}*f_t*k_{tix}$), operational costs (CO_i), limestone application and transportation costs ($Q_{ic}*p_{xc} + Q_{ic}*f_t*k_{tix} + CC_i$, in this case divided by the n_i years in which the effects of soil liming remain) and area opening cost (CA_i, divided by the years expected for investment recovery, m_i). The area-clearing cost is only relevant for not deforested regions and should be distinguished by the vegetation type (cerrado/capoeira and primary forest). The production limit to each locality i is given in equation (5). This limit will be calculated as the productivity of a certain locality multiplied by the standard area used by this model (100ha).

Equation (6) represents the demand restriction. In the case of exporting ports, this restriction is not active, for Amazonia is supposed to have comparative advantages for exporting over other Brazilian and foreign markets. In addition, the populational growth and, accordingly, the meat consumption growth, have made market experts to forecast an expansion of the international soybean market (Pavan, 1997; GEIPOT, 1999; Sugai et. al., 1998; Roessing, 1998; and USDA and ABIOVE's projections). Thus, the soybean demand is assumed to be perfectly flexible. However, crushing plants are already available and some have been planned for the region, likely to influence some localities for soybean production. In this case, the demand considered is the installed capacity of each plant.

At last, equations (7) and (8) represent the positivity restrictions for the endogenous variables of the model, meaning that neither the net revenue (R_i) nor each locality's production (E_{ij}) can be negative. They are also the main determinants of the limits of the economical reach of soybean in Amazonia.

The data used in this model has been collected in the field during a trip in the months of September and October 1999, in a course going through 8 states observing the main localities of soybean development and transportation infrastructure in Legal Amazon. This data was entered into a Geographic Information System (GIS) database, and shown spatially, as well as the results. The maps used were supplied by the Instituto do Homem e do Meio Ambiente da Amazônia (IMAZON).

Overall, the works using optimization together with a GIS combine a programming language to the geo-referenced database, as observed in Cao et al. (1999), Bouman et al. (1999), Stoms et al. (1998), Qiu et al. (1998), George et al. (1997), Begur et al. (1997), Walsh et al. (1997), Nevo and Garcia (1996), Taher and Labadie (1996), Brusven et al. (1995), Vadas et al. (1995) and Xiang (1993). This strategy is still necessary, for a great deal of GIS software, such as ArcView (used in this work), fails to incorporate any internal optimization routine.

Thus, a specific calculation method (quite simple mathematically) was developed for this model, using the software tools only. This approach was chosen due to the simplicity of the mathematical structure and by the difficulty in transposing ArcView data to any other software because of the database size, since each map contains over 8 million cells (2,584 x 3,331 cells). The limit of columns of an electronic worksheet in only 256 columns, which makes the transposition of data similarly to Stone (1998) unviable.

So the calculation procedure developed for this work is composed of three phases: i) elaboration of maps of input and soybean prices; ii) elaboration of a net revenue map, and iii) incorporation of restrictions.

A base scenario was created, considering every transportation alternative planned for Legal Amazon as completed, except for paving of road BR 163. Additionally, this scenario does not consider climate and relief limitations; it allows only 35% of the area of each cell to be used with soybean; price, cost, freight and productivity data are based on those observed in 1999. Further details of this procedure and data are available in Costa (2000).

4 Results

The results of this work show that the soybean tends to reach a quite significant area in the Amazon, especially nearing the transportation network. New infrastructure projects tend to even make the deforestation of the Amazon forest viable in some regions. This is specially true next to the Itacoatiara and Santarém ports and in Northern Mato Grosso (Fig. 1).

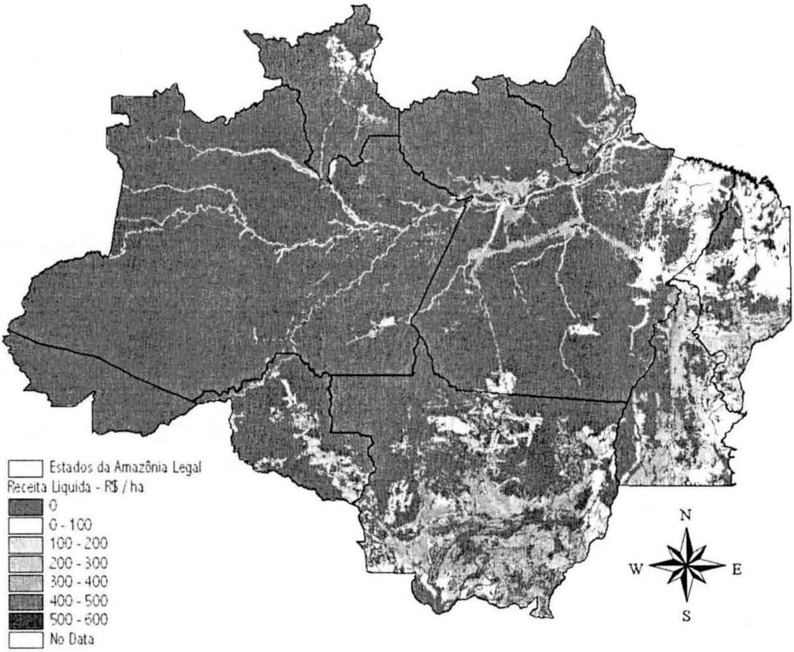

Figure 1. Areas with positive net revenues for soybean planting in Legal Amazon considering the base scenario.

As to the corridors, the more important ports in terms of production delivery will be São Luís (Itaqui/Ponta da Madeira) and Paranaguá (through Ferronorte), which are currently also the main destinations of soybean in Amazonia (Table 1). These two corridors include an area with plenty of paved roads and has a railway (with a higher transportation capacity than the waterways) as the central axis. Santarém and Vila do Conde are also significant, for in addition to the waterways composing its central axis, they are also provided with a road infrastructure, which is currently under precarious conditions (in the model these routes are considered in better conditions). The other corridors have a reduced importance, especially due to the limited waterway transportation.

One should emphasize that the two poles of soybean crushing agroindustries in Mato Grosso, Cuiabá and Rondonópolis are not considered in the solution in that their prices were not competitive with the Paranaguá price after the Ferronorte conclusion. Nevertheless, the prices in these poles are actually known to follow the elevation, for the crushing companies and the grain exporting ones are the same. Thus, whether to crush or export is a choice of the company's strategy and, probably, a significant volume of soybean must be destined to Cuiabá and Rondonópolis even after the Ferronorte completion.

Table 1. Amount of soybean transported and area of influence of each port or agroindustry of Legal Amazon.

Corridors	Production	%	Area	%
São Luís (MA) – port	31,905,285	37%	12,013,645	39%
Paranaguá (PR) – port	28,672,125	33%	9,270,555	30%
Santarém (PA) – port	13,206,092	15%	4,681,285	15%
Vila do Conde (PA) – port	7,699,369	9%	2,825,970	9%
Caracas (Venezuela) – agroindustry	1,655,462	2%	679,490	2%
Itacoatiara (AM) – port	1,299,298	2%	475,055	2%
Santana (AP) – port	1,292,092	2%	479,010	2%
Vilhena (RO) – agroindustry	60,030	0%	18,270	0%
AMAZONIA	85,789,753	100%	30,443,280	100%

Source: research results

As to the states, Mato Grosso will be consolidated as the main soybean producer of the region and maybe of Brazil, with a very significant difference in comparison with the other states (Table 2). On a second block, Pará, Maranhão and Tocantins have quite similar participation and compose a nearly continuous belt East of the Amazon region. Pará also presents an important producing region at the axis along road BR 163, although less important in comparison with the Eastern state. The other states will be much less significant concerning soybean production.

Table 2. Participation of each state of Legal Amazon in the soybean production and in the soybean-planted area

State	Production (t)	%	Area (ha)	%
Mato Grosso	36,612,789	43%	11,994,430	39%
Pará	14,175,147	17%	5,340,405	18%
Maranhão	14,171,673	17%	5,286,085	17%
Tocantins	12,075,482	14%	4,674,180	15%
Rondônia	3,812,185	4%	1,261,400	4%
Amazonas	2,234,088	3%	832,895	3%
Roraima	1,433,042	2%	596,015	2%
Amapá	1,026,950	1%	382,375	1%
Acre	-	0%	-	0%
AMAZONIA	85,541,356	100%	30,367,785	100%

Source: research results

Since the model explicitly disregards the hydric limitation, Sombroek, 1999 data (digitized by Imazon) was overlapped to verify that the larger part of the areas is suitable to agriculture, with annual rainfall lower than 2,000 mm (Table 3). However, for a significant part (21.98% of the result area), doubts remain as to the technical viability, for the rainfall is high enough to cause a severe disease attack, which can make production unviable. Only 1.46% of the area was considered unviable due to the water excess and 19.21% undergo severe drought risks. The localization of these areas are depicted in Costa (2000).

These results were obtained through 1991deforestation data, and from this date until now over 13 million hectares have been deforested (especially forests and transition vegetation), notedly in Rondônia, Northern Mato Grosso and in Pará (INPE, 2000). Thus, the results presented can be different as these areas have higher probability of being incorporated to the solution.

Table 3. Total area scoped in the base scenario for each range of annual rainfall

	Planted area	%
Unviable (> 2.800 mm annually)	443,380	1.46%
Uncertain (between 2.000 mm and 2.800 mm annually)	6,676,565	21.98%
Adequate (< 2.000 mm)	12,942,580	42.62%
Drought risk (3 months with less than 10-mm rainfall)	5,835,480	19.21%
No data	4,469,850	14.72%
AMAZONIA	30,367,855	

Source: research results

In order to verify the sensibility of the model to the parameters used, a few simulations were elaborated over the base scenario data, with a 10% increase in road freights, considering paving of road BR 163 (Cuiabá – Santarém) and increase of the capacity of railways and waterways.

Table 4 shows that the paving of road BR 163 tends to have a quite significant impact on the advance of soybean into the forest, for this project will allow the access to little developed areas in Mato Grosso, Pará and Amazonas.

This table also shows that the variation of the freight values generates a general reduction of the planted area in approximately 2 million hectares. Pará, Tocantins and Maranhão, which have a great deal of the production delivered by railways (Carajás) undergo a relatively lower impact than states like Roraima and Amapá, which base transportation on the road modal. Mato Grosso has a significant impact due to the long extensions run by the soybean to reach a railway (Ferronorte) or a port (Santarém).

Table 5 shows that the increase in the capacity of the main railways and waterways fails to generate any increase in the planted area, nor soybean production in Legal Amazon. This happens because the regions where these transportation routes are located are also provided with roads, which deliver the production exceeding the capacity of the waterways or railways. The exception is the Madeira River waterway, in which the road option is unviable, so the enlargement of the transportation capacity provides an increase of the planted area in its influenced region.

Table 4. Comparison between the results of planted area in the base scenario and in the scenario considering paving of road BR 163.

	Base Scenario (ha)	%	Paving of BR 163 (ha)	%	Variation of freight values (ha)	%
Mato Grosso	11,994,430	39%	16,016,840	44.44%	11,194,400	39.52%
Pará	5,340,405	18%	6,898,045	19.14%	5,336,450	18.84%
Maranhão	5,286,085	17%	5,285,630	14.67%	5,284,090	18.65%
Tocantins	4,674,180	15%	4,676,035	12.98%	4,622,380	16.32%
Rondônia	1,261,400	4%	1,261,050	3.50%	1,120,945	3.96%
Amazonas	832,895	3%	922,460	2.56%	749,490	2.65%
Roraima	596,015	2%	595,700	1.65%	17,780	0.06%
Amapá	382,375	1%	382,375	1.06%	-	0.00%
Acre	-	0%	-	0.00%	-	0.00%
Amazonia	30,367,785	100%	36,038,135		28,325,535	100%

Source: research results

Table 5. Variation of the production and area per corridor in relationship to the base scenario, considering the increase of the transportation capacity of the Carajás railway and waterways

	Carajás 20 million t / year		Carajás 30 million t / year		Waterways	
Corridors	Prod.	Area	Prod.	Area	Prod.	Area
Caracas	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Itacoatiara	0.00%	0.00%	0.00%	0.00%	130,90%	118,16%
Paranaguá	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Santana	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Santarém	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
São Luís	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Vila do Conde	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Vilhena	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Source: research results

However, although not influencing significantly the expansion of the soybean-planted area, the waterways and railways generate a significant reduction in costs (and accordingly an increased net revenue) in a quite significant area, as shown in Table 6. The data presented indicate that the Carajás railway impacts from 3.6 million hectares to 6.9 million hectares with the capacity enlargement. In the case of the waterways, the increase is even higher, causing a increased net revenue of about 7 million hectares.

Table 6. Total area with changed net revenue due to the increased transportation capacity of the routes.

	Carajás 20 million t / year	Carajás 30 million t / year	Waterways
Areas with changed net revenues (ha)	3,614,030	6,873,965	7,015,190

Source: research results

5 Conclusions

The completion of the infrastructure projects planned by the federal government and by private companies tends to generate a quite stressed impact on the Brazilian soybean production, once little exploited areas will be given access and made economically viable.

Mato Grosso is to be consolidated as the region's main agricultural state (and perhaps the country's), although a large growth should be observed in states of Pará, Maranhão and Tocantins. The remaining states tend to have a much less important participation due to their productive and logistic deficiencies.

With regard to the corridors, most important ones should be the ones leading to the Itaqui port (São Luís – MA) and Ferronorte (destination Paranaguá). Both corridors have a railway as a main axis. Santarém (PA) and Vila do Conde (PA) should also deliver significant productions, however, they are road-based (Santarém also receives soybean through waterway Teles Pires – Juruena – Tapajós but its capacity limits the transportation of more substantial productions).

One should also consider that the results do not take into account the approximately 13 million hectares deforested after 1991, which tend to be occupied more easily due to the lower costs for setting up a soybean crop. Thus several areas neglected in the solution can actually be viable today.

Another limitation of this work was disregarding the relief, since no mapped data capable of being used in a SIG were found. Thus several very steep areas may have been included in the solution, overestimating the results. Overall, however, most areas presented in the results are not restricted to mechanization.

The results of this paper also allow determining the main factors affecting the soybean expansion in Amazonia, and can be summarized as follows:

* Port closeness

* Higt productivity
* No-forest areas
* Areas next to waterways or railways
* Areas provided with a good road system.

Therefore, should the traditional evolution of the agricultural frontier remain observed in Amazonia, soybean will tend to expand, for such expansion stimulates the advance in stock-raising over the forest. This advance generates deforested areas which are likely to be used by soybean in the future as well as new areas of production, thus supporting the process indefinitely.

By placing the Amazon in a larger market scope, the region is observed to have a high developing potential. The production costs are usually lower than in regions like Rio Grande do Sul, São Paulo or even some regions in Argentina and U.S.A. This means that if the soybean enters the market and forces a drop of international prices, other regions of Brazil and the world are very likely to suffer an impact, thus generating a more intense migration of production towards the Central-West and North of Brazil. Signs of this trend can already be observed such as the announcement of a few investments in soybean crushing in the North of the country (Ceval in São Luis and Sorriso, Cargill in Santarém and Grupo Maggi in Itacoatiara) in a period in which the crushing capacity in Southern Brazil and some regions of the U.S.A. has reduced.

On the other hand, the technical viability of soybean in humid regions is still uncertain and can make soybean less attractive to regions originally covered by the Amazon Forest. The consolidation of Legal Amazon as a soybean-producing pole is still uncertain for it depends partially on the government investments mentioned in this paper and partially on technological development. However, companies have shown a very clear attitude implying that Legal Amazon is quite competitive regarding the other producing centers of the world.

So an adequate planning of land use in Amazonia is essential for a responsible use of natural resources without causing negative impacts to the environment or to the local population.

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