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THE IMPACTS OF THE FOOD-FEED-FUEL COMPETITION ON BRAZILIAN FOOD SUPPLY

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ABSTRACT

The impact of the so-called "food-feed-fuel competition" on hunger has been a major concern worldwide. In addition, the environmental impacts caused by increases in the production of meat made supplying food even more challenging. As few studies have dealt with this issue in Brazil, this paper aims to evaluate the country's nutritional situation since 1995, focusing on the effects of producing animal feed and biofuels on both the domestic availability of food and the role of Brazil as a food supplier to foreign countries. We estimate the quantity of nutrients produced in the country, compare them with the necessities of Brazilians and estimate the population that could be fed by means of Brazilian exports. The results indicate that despite the food-feed-fuel competition, the supply of food has increased and has been sufficient to nourish all Brazilians plus an even larger number of foreigners. As food availability is adequate, the large number of Brazilians still exposed to undernourishment reflects the limited access to food by low-income consumers. We also conclude that Brazil could contribute even more to feed foreigners if policies were implemented aiming to induce farmers to produce a different sort of products.

keywords: Food-feed-fuel competition; Food Security; Nutrition.

RESUMO

Os impactos da "competição alimentos-ração-combustíveis" sobre a fome têm sido preocupação mundial, assim como os impactos ambientais causados por aumentos na produção de carne. Como poucos trabalhos têm lidado com esta questão no Brasil, propomos aqui avaliar a situação nutricional do país desde 1995, enfocando os efeitos da produção de ração e combustíveis sobre a disponibilidade alimentar e sobre o papel do Brasil como supridor mundial de alimentos. Assim, estimamos a produção de nutrientes do país, comparamos a mesma com as necessidades dos brasileiros e estimamos a população que poderia ser alimentada pelas exportações brasileiras. Os resultados indicam que a oferta alimentar tem crescido e é suficiente para alimentar os brasileiros e um número ainda maior de estrangeiros. Como a disponibilidade alimentar é suficiente, a existência de fome reflete o acesso limitado aos alimentos por parte dos consumidores de baixa renda. Concluímos também que o Brasil poderia contribuir ainda mais com a alimentação mundial se houvesse políticas visando induzir os agricultores a produzirem uma gama diversa de produtos.

Palavras-chave: competição alimentos-ração-combustíveis; segurança alimentar; nutrição.

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INTRODUCTION

Hunger is a major preoccupation worldwide. Though the Global Hunger Index indicates that the levels of hunger in developing countries have decreased 25% from 2000 to 2015, estimates suggest that around 800 million people are still affected by hunger across the globe (VON GREBMER et al., 2015; FAO; IFAD; WFP, 2015), a situation that can be even more severe in the future as the world's population is projected to reach 9.6 billion people by 2050 (FAO, 2009a). Likewise, has this issue been a great concern in Brazil, as estimates indicate that 52 million Brazilians still face some degree of undernourishment (BRASIL, 2014a). The challenge is, therefore, to respond to an enormous and growing demand for food both domestically and globally.

A first difficulty to ensure adequate food availability refers to the types of foods that will be demanded and produced in the future, since some authors warn that if today’s typical diets continue, it will be impossible for supply to meet demand without large increases in greenhouse gas (GHG) emissions (GARNETT, 2014a; GARNETT, 2014b; BAJZELJ et al., 2014; GARNETT, 2015). In this regard, Garnett (2011) alerts that the expected increase in the consumption of foods of animal origin in the future might undermine the mitigation of GHG emissions achievable through technological and managerial innovations.

Beyond their impact on climate change, different agricultural products have distinct impacts on nutrient supply. As was first highlighted by Yotopoulos (1985), the increase in meat consumption by high-income individuals has intensified the use of grains for animal feed and has reduced the availability of nutrients for humans. In addition, the increase in crop-based biofuels production can impact food supply negatively (BANERJEE, 2010; BANERJEE, 2011). Both issues are central in Brazil, since the country is the second largest producer of soybeans and corn (USDA, 2015) – the two main products used for animal feeding –, has a large area occupied by pasture where grass-fed cattle herds are raised (STEIGER, 2006), and is also the second largest producer of (sugarcane based) ethanol fuel (EIA, 2015).

Few studies have been done on food availability in Brazil and all have used data up to the first half of the 1990’s (AGUIAR, 1998; CARVALHO FILHO, 1995). Regarding the expansion of the ethanol sector, some studies have analyzed its impacts on food prices and land use (AMARAL; PEDUTO, 2010; MELO; LIMA, 2010; SILVA; FREITAS, 2008; SIMAS, 2010), but none has evaluated how the growth of this sector has affected food availability. Aiming to fill this gap, this paper evaluates the nutritional situation in Brazil since 1995, focusing on the effects of producing animal feed and biofuels on domestic food availability and on the role of Brazil as a food supplier to foreign countries.

The paper is organized in five sections, including this introduction. The next section presents the main concepts and issues regarding food security. After that, we describe our database and our empirical methods. Then, we present and discuss our results. Finally, in the last section, we draw our conclusions.

BACKGROUND: THE DETERMINANTS OF FOOD SECURITY

Food security is the crucial concept behind hunger and malnutrition. The 2009 Declaration of the World Summit on Food Security says that "food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food, which meets their dietary needs and food preferences for an active and healthy life" (FAO, 2009b). Based on that definition, FAO identifies four food security dimensions (FAO; IFAD; WFP, 2013; FAO; IFAD; WFP, 2014; LOCKE; HENLEY, 2014): **availability**, **access**, **utilization** and **stability**. "Availability" refers to the quantity, quality and diversity of food at hand for consumption. "Access" is associated to the fact that people need to own the food products in order eat them, what depends on economic (income, prices, etc.) and physical (transportation, storage facilities) factors. The other two dimensions are "utilization", which is related to the conditions necessary to better utilize the foods (such as sanitary conditions), and "stability", which refers to the persistence of food provision.

Income distribution and education are the most important variables affecting the food security dimensions (AGUIAR, 1998; MUSGROVE, 1987). Income disparities prevent food access by the poor, as well as affect the choice of products to be produced. Regarding education, it is supposed to reduce income inequalities, as well as to allow individuals to choose healthier and more sustainable diets.

Given the four dimensions of food security, the nutritional level of a population will depend on the balance between requirements and availability of nutrients. If the requirements are larger than the availability, the country will be facing malnutrition or even hunger. If, on the other hand, the availability is larger, the country will have food surplus.

As we have pointed out, Yotopoulos (1985) identified animal feed as a threat to food security and called this phenomenon "food-feed competition". The basic idea is that income increases in developed countries, as well as in emergent countries (REGMI; MEADE, 2013), raise meat consumption, what expands the demand for grains to produce animal feed. Consequently, the supply of grains for human consumption decreases and food prices rise, causing food shortages in developing countries. Metaphorically, the food-feed competition can be thought as a competition for food between (low-income) humans and livestock. Beyond the competition for food there is a competition for land: as most of the cattle herds are grass-fed in most countries, including Brazil (STEIGER, 2006), large amounts of land are occupied by pasture instead of food crops.

Another threat to food security comes from the fuel sector: the "food-feed-fuel competition" (BANERJEE, 2011; von BRAUN, 2007; DONG, 2007; HLPE, 2013). Owing to concerns about high oil prices and carbon dioxide emissions from fossil fuels, many countries have launched policies aiming to replace fossil fuels with biofuels. Consequently, food crops and biofuel crops started to compete for natural and financial resources. Despite that, Locke and Henley (2014) highlight the lack of consensus on how the crop-based biofuels production impacts food security, as some authors say that resources used to grow food products will be switched to biofuels production, reducing food supply and increasing prices, while others argue that the interest in biofuels will attract more investment to agriculture in general, increasing the supply of food crops as well. So, the evaluation of the impacts of biofuels on food availability requires a case by case analysis (HLPE, 2013). Particularly about Brazil, Nogueira and Capaz (2013) infer that despite the large amount of land used for biofuels production, this sector has not had remarkable impact on food production.

As we have already said in the introduction, the impact of different diets on the environment is an additional concern affecting food security, as the agricultural systems emit large quantities of GHG (GARNETT, 2011) such as carbon dioxide (due to fossil fuels use at different segments in the agri-food chains), methane (mainly from enteric fermentation in ruminant livestock) and nitrous oxide (from soil management and fertilizers use). In particular, many studies have highlighted the huge impact of meat production on climate change, such as FAO (2006) crediting to livestock 18% of global GHG emissions, what made Garnett (2014a) assert that "the lower the meat content of the diet, the lower the environmental impacts" (p.18). On the other hand, many authors, such as Silva et al. (2016), argue that it is possible to raise meat production without increasing GHG emissions by adopting new technologies and increasing productivity in livestock production. Though the possibility of mitigating GHG emissions through new technologies is very welcomed, efforts also need to be done in the demand side since it is almost unthinkable to feed 9.5 billion people using today's typical diets. This issue is crucial to Brazil indeed, since the country is one of the major producers (FAOSTAT, 2017) as well as one of the largest consumers of meat (OECD, 2017).

EMPIRICAL PROCEDURES AND DATA SOURCES

We follow the procedure used by FAO, IFAD and WFP (2013), FAO, IFAD and WFP (2014), and Kumar (1989), among others, and estimate per capita macronutrient availability. A limitation of such approach is that it does not take into account food access. Despite that, this method allows us to verify whether the quantity of food available for consumption is sufficient to nourish the country’s population.

Data

This study covers the period from 1995 to 2013 and deals with the main products consumed in Brazil: rice, beans, wheat, cassava, sugar, banana, soybeans, corn, milk, eggs, chicken, beef and pork. So, our measurement actually underestimates Brazil's nutrient intakes because in addition to these products, Brazilians eat several other vegetables and fruits rich in calories as well as other foods rich in protein (e.g. fish, peas).

To measure food availability, we use data from the Food Balance Sheets (FAO, 2001; FAO, 2015) on quantities of calories and protein available for human consumption at domestic level for every product, leaving out both the amount processed for non-human uses (manufacturing, animal feed, seeds, and waste) and the exports of food.

For the requirement of calories, we consider 2,000 kcal per capita daily following the recommendation of the Food Guide for Brazilian Population published by Brazilian Health Ministry (BRASIL, 2008). For protein, as BRASIL (2008) has no recommendation about it, we consider 51 g of protein per capita daily, the mean requirement for men and women above 18 years old according to Otten et al. (2006).

CONAB (2015) is the source of production data necessary to carry out the simulations for all products except cassava, for which the data source is IBGE (2015). To simulate the effects of ethanol production we use data on production of sugarcane and ethanol, and sugarcane acreage, provided by UNICADATA (2015a) and UNICADATA (2015b).

Procedures

We start our analysis identifying the share of every food product in the country’s availability of calories and protein. Then, we compare the availability with the requirements of nutrients, from 1995 to 2013, in order to assess the domestic nutritional situation. After that, we estimate the population that could be fed by means of Brazilian exports. In order to do that, we first convert the exports into quantities of calories and protein, and then we divide the result by per capita intake recommendations. Our estimates consider the content of all agricultural exports, including those products that are predominantly used for animal feeding (soybeans and corn). Therefore, our estimates indicate the population that could potentially be fed by all Brazilian exports of calories and protein.

After the analysis of the current situation, we simulate what could have happened between 1995 and 2013 under three different scenarios:

- *Scenario 1 – only human food is produced*. This scenario considers that humans would have used all protein and calories contained in the products destined for animal feeding. In addition, we assume that pasture land would have been converted into cropland. As references, Sparovek et al. (2011) and Alkimin, Sparovek and Clarke (2015) estimated the pasture land that would have either moderate or high suitability to agricultural production, reaching a total of 61 million hectares in the former study, and 50 million hectares in the latter, when infrastructure and resources availability were also taken into account[1]. Therefore, we assume in our simulation that 50 million hectares of grassland could be transformed into cropland keeping Brazil's average productivity.

- *Scenario 2 – food crops are produced instead of ethanol*. In this scenario we assume that the area used to grow sugarcane for ethanol fuel production would have been assigned to grow food products.

- *Scenario 3 – neither ethanol nor animal feed are produced*. This scenario is a fusion of the previous two.

The first step to build the three scenarios is to calculate yields of calories and protein per hectare considering the average share of each food product of plant origin (rice, beans, wheat, cassava, soybeans and corn) in Brazilian harvests between 1995 and 2013. Then, to simulate scenario 1, we used these yields to convert 50 million hectares of pasture into cropland and then into calories and protein.

In scenario 2, we estimate the area occupied by sugarcane destined for ethanol production considering that one metric ton (t) of sugarcane originates 85 liters of ethanol (NOVA CANA, 2015). Dividing the annual production of ethanol by 85, we find the quantity of sugarcane (in metric tons) used to produce ethanol every year. Then, we divide the quantities of sugarcane by its productivity to find the area used only to produce ethanol. After all, supposing that this area would have been used to grow food crops, we calculate the quantity of calories and protein that could have been produced.

[1] According to Alkimin, Sparovek and Clarke (2015), there would be 36 million hectares of grassland with high suitability and 14 million hectares with moderate suitability for agricultural production, considering physical (soil and climate) as well as socioeconomic and infrastructure attributes.

As a final word, it is important to bear in mind that the scenarios used in our simulations stand for extreme circumstances and not direct recommendations. There might be certain effects that can make these scenarios unviable or undesirable. For instance, replacing ethanol fuel by gasoline would increase GHG emissions by automobiles, affecting global warming. Moreover, extinguishing the sector of animal production would generate conflicting effects, since on the one hand the emissions of GHG would reduce, but on the other hand the incomes of many who are dependent on animal and meat production would be harshly reduced (BRASIL, 2014b). Despite such limitations, our three scenarios reflect situations that could be in some measure pursued.

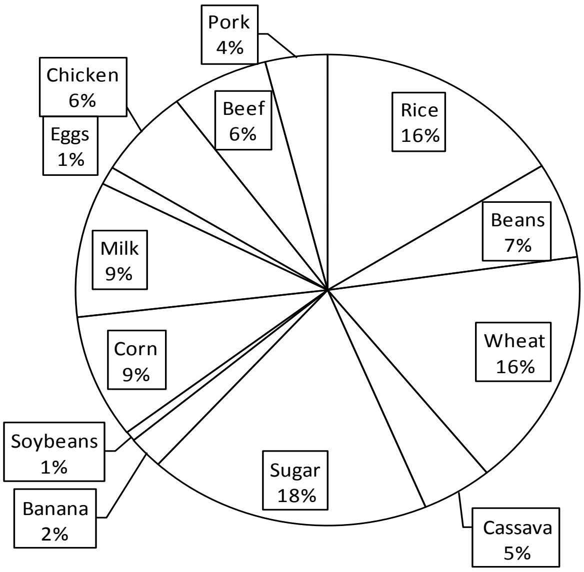
RESULTS

In this section, we report and analyze the results following the sequence described in the previous section. First, we present the share of each product in the provision of calories and protein. Then, we contrast the provision of nutrients with the biological requirements. After that, we present our estimates on the foreign population that could have been sustained by Brazilian exports. Finally, we report and analyze the simulations for three scenarios.

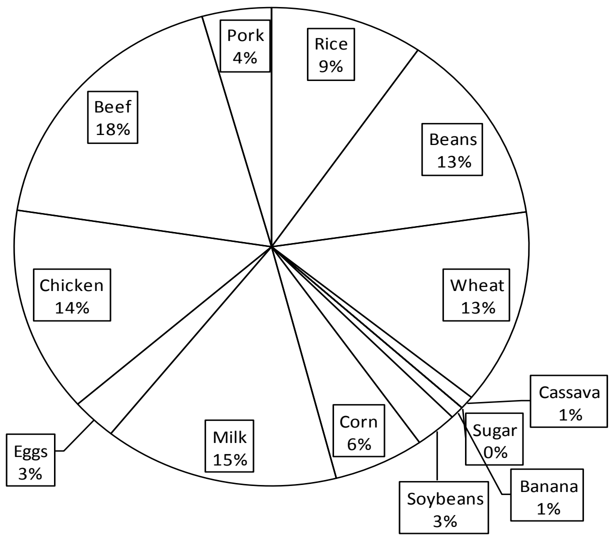
Analysis of food products

Half of the calories available for consumption in Brazil comes from only three products (sugar, rice and wheat), and two thirds come from five products, including corn and beans (Figure 1(a)). Regarding protein, Figure 1(b) shows that meat is responsible for more than a third of it. Adding milk and eggs, we have more than half of the total protein availability, what suggests that, under the current circumstances, restricting the consumption of products of animal origin would greatly reduce the provision of protein to Brazilians. Thus, despite the wide range of products eaten in Brazil, the intake of calories and protein are mainly based on only a few products.

The food products consumed in Brazil have different characteristics. Some are mostly destined for the domestic market and for human consumption, such as rice, beans and banana, all with more than 80% of their productions used by humans. Cassava is also mainly destined for the domestic market, but only a third of its production is used as human food (half goes to animal feed). Sugar is predominately used as human food, but more than half of its production is exported. Regarding soybeans and corn, Brazil has increased its exports of both, so that less than half of the soybeans production and around two-thirds of the corn production have been available in the domestic market. In addition, given that both products are primarily destined for animal feeding, less than 10% of the domestic availability of both products are used as human food. The great exception among the foods of plant origin is wheat because this product is mostly imported (almost 70% of the total availability come from abroad) as well as destined for human food (90% of the total availability are consumed by humans).



(a) Calories



(b) Protein

Figure 1. Average share of each food product in the provision of calories and protein in Brazil, 1995-2013, in percentage

Source: Elaborated by the authors based on Food Balance Sheets (FAOSTAT).

About the foods of animal origin, which have had significant increases in production over the last two decades, all have at least 80% destined for human consumption. The increases in milk production allowed a reduction in the share of imports in the domestic availability of this product from 17% to 3%, between 1995 and 2013. Meat production has also increased considerably as well as has exports, which reached, in 2013, more than 30%, 15% and 20% of the productions of chicken, beef and pork, respectively. Despite the increase in the share of exports, the domestic per capita availability increased for all products, with increments ranging from 14% (beef) to 97% (chicken), between 1995 and 2013.

Nutritional situation

Data reported in table 1, columns 2 and 3, show that the availability of nutrients exceeds the requirements the whole period. Comparing the first with the last five-year period, the difference between availability and requirements of calories rose from 8% to 17%, while for protein the increase was from 34% to 59%. The surplus of protein has been higher than the surplus of calories due to Brazil's remarkable production of meat and other foods of animal origin, such as milk and eggs. Beyond availability, the numbers presented in table 1 reflect stability, one of the FAO dimensions of food security, as the provisions of both calories and protein have always been above 100% of the requirements. Thus, the food-feed-fuel competition has not precluded Brazilians from having sufficient quantity of food.

Our results suggest that neither lack of availability nor instability is causing undernourishment in Brazil. Due to its impressive production of meat, Brazil has been able to provide more nutrients than necessary to feed its citizens, despite using grains to produce animal feed and cropland to grow sugarcane and raise cattle. The most plausible cause for malnutrition in the country is lack of access to food by low-income citizens, as it has already been argued by Amaral and Peduto (2010), Carvalho Filho (1995) and Hoffmann (1994).

Brazilian contribution to feed foreigners

The number of people who could be sustained by Brazilian exports has increased substantially through time (Figure 2), in such a way that the calories exported by Brazil in 2013 would have been sufficient to feed a population twice as large as Brazil's population and, regarding protein, a population 3.5 times larger.

Figure 2 also reflects the rise in Brazilian exports of meat and other foods of animal origin over the last 20 years. In 1995, the exports of Brazil could have sustained 42 million people based on calories and 49 million people based on protein, but in 2013, 380 million people could be sustained in terms of calories and 691 million people in terms of protein. The population that could be fed through Brazilian exports increased 801%, considering calories, and 1,293%, considering protein. Consequently, over the last two decades Brazil has become a major provider of food, especially foods rich in protein, to the rest of the world.

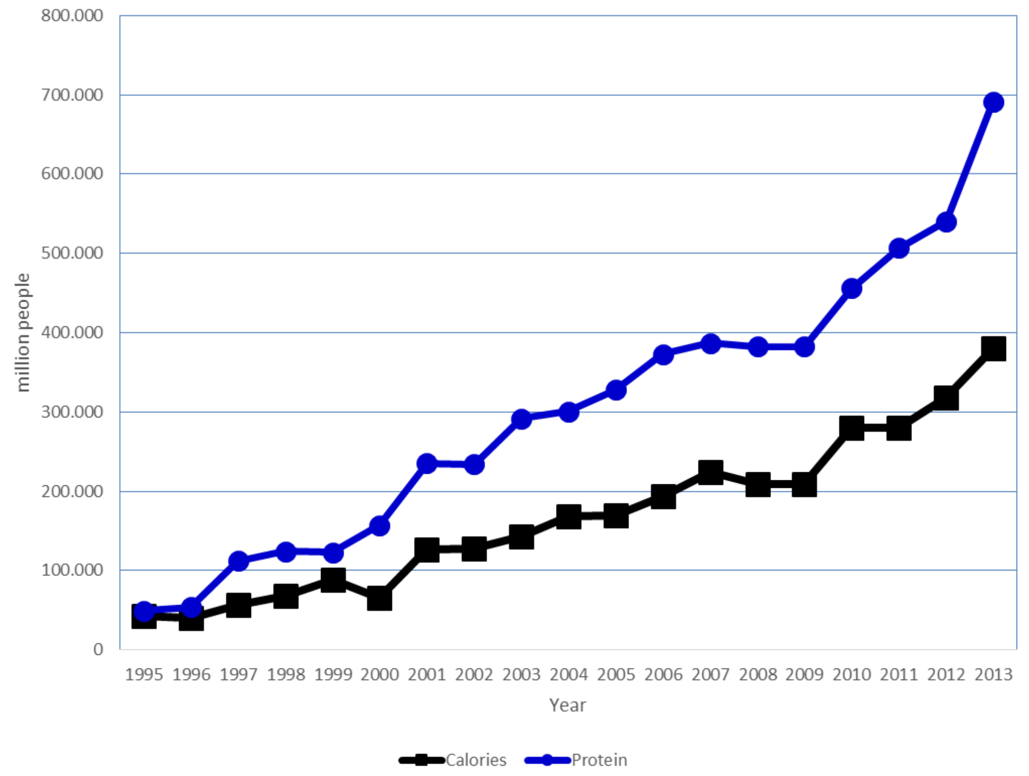


Figure 2. Population that could have been fed in terms of either calories or protein by means of Brazilian agricultural exports, 1995-2013, in million people

Source: Elaborated by the authors based on Food Balance Sheets (FAOSTAT).

Scenarios privileging human food

This section analyzes the potential effects of three scenarios on food availability. Admitting, initially, that the whole production of grains plus the quantity of crops that could be cultivated in 50 million hectares currently occupied by pasture were available for human consumption (scenario 1), food availability would be much larger (table 1, columns 4 and 5) than in the situation reported in columns 2 and 3. On average, calories availability would have reached 574% of the necessities of all Brazilians, while for protein it would achieve 255%.

Table 1. Degree of accomplishment of nutrients under the real situation and under three scenarios (without production of animal food, without production of ethanol fuel, and without both), 1995-2013, in percentage

Year	Real Situation		Scenario 1: Without Animal Food		Scenario 2: Without Ethanol Fuel		Scenario 3: Without Both	
	Calories	Protein	Calories	Protein	Calories	Protein	Calories	Protein
1995	108%	129%	626%	265%	134%	136%	735%	333%
1996	110%	137%	623%	272%	136%	145%	733%	346%
1997	108%	132%	607%	259%	134%	140%	715%	328%
1998	109%	133%	596%	254%	135%	141%	705%	325%
1999	106%	137%	587%	254%	129%	143%	688%	324%
2000	105%	137%	581%	254%	126%	143%	679%	322%
2001	106%	137%	579%	255%	126%	143%	678%	325%
2002	107%	140%	566%	247%	127%	146%	664%	317%
2003	114%	146%	564%	248%	134%	152%	669%	325%
2004	114%	145%	564%	249%	135%	151%	669%	323%
2005	113%	143%	559%	247%	134%	149%	665%	322%
2006	113%	145%	555%	247%	136%	152%	661%	322%
2007	113%	147%	554%	249%	138%	154%	662%	325%
2008	114%	152%	574%	269%	144%	161%	686%	346%
2009	114%	152%	574%	269%	151%	163%	693%	348%
2010	116%	157%	547%	249%	151%	167%	664%	328%
2011	118%	161%	549%	254%	155%	172%	668%	334%
2012	117%	160%	549%	255%	152%	170%	665%	333%
2013	118%	164%	551%	260%	153%	173%	667%	339%
Average	**112%**	**145%**	**574%**	**255%**	**138%**	**153%**	**682%**	**330%**

Source: estimated by the authors using data provided on Food Balance Sheets (FAOSTAT), UNICADATA, CONAB and IBGE (2015).

The increases in scenario 2 (columns 6 and 7 of table 1) are moderate compared with the current situation (columns 2 and 3), as the eradication of ethanol production would deliver between 2.7 million hectares (in 1995) and 4.5 million hectares (in 2013) to crop production. In scenario 2, the availability of calories and protein would have exceeded the requirements by 38% and 53%, respectively, while in the current situation the surpluses would be 12% and 45%. It is worth mentioning that such small effect of biofuels production had already been identified by Enciso et al. (2016) in a global study.

The third scenario (columns 8 and 9 of table 1), which comprises the other two, shows a little larger availability of nutrients than scenario 1. This occurs because the amount of land used to produce ethanol is much smaller than that used to produce animal feed: the pasture land converted into cropland is more than 11 times larger than the land occupied by sugarcane for ethanol production in 2013.

Although the third scenario has a higher provision of nutrients, two reasons made us to choose scenario 1 to dimension the population that could be fed by Brazilian exports. First, scenario 1 would be more sustainable than scenario 3, as far as the exclusive use of fossil fuel in the latter would imply higher emissions of carbon dioxide. Second, the difference in terms of nutrient availability between scenarios 1 and 3 is fairly small.

Using scenario 1 to illustrate the potential of Brazil to nourish foreigners, table 2 indicates that in 2013, after satisfying the necessities of Brazilians, around 900 million people could have been fed in terms of calories and near 320 million in terms of protein.

Table 2. Population that could be fed by calories and protein exported by Brazil if only human food of plant origin were produced (Scenario 1), 1995-2013, in million people

Year	Considering calories (million people)	Considering protein (million people)
1995	852	267
1996	860	282
1997	847	265
1998	841	261
1999	838	264
2000	840	268
2001	848	273
2002	836	263
2003	844	269
2004	853	273
2005	854	274
2006	857	276
2007	863	283
2008	909	324
2009	909	324
2010	873	291
2011	884	304
2012	892	308
2013	903	321

Source: estimated by the authors using data provided on Food Balance Sheets (FAOSTAT), UNICADATA, CONAB and IBGE (2015).

The fact that tree times more people could have been fed with calories than with protein is owing to the products that would not be produced in scenario 1, as neither animal feed nor foods of animal origin would have been produced.

It is also worth mentioning that the estimates reported in table 2 are only indications of how many people could have been fed under scenario 1, as far as we use foods typically eaten in Brazil, which are not necessarily eaten abroad. If Brazil had increased its production of food crops aiming to export, other sort of products would probably have been produced. Even so, the population that could have been fed would probably be similar to our estimates.

Concerns regarding greenhouse gases emissions

As the discussion reported in this paper highlights, the world faces the Herculean task of increasing food availability without raising GHG emissions. An effective way to raise nutrients' availability for human consumption is converting areas of pasture used to raise livestock into croplands, as nutrient (especially calories) production per area of land is greater for crops than for livestock. So how would this conversion affect GHG emissions?

Though the estimations vary according to the technology used to grow crops or to manage pastures, the highest loss of soil's carbon stock capacity occurs due to deforestation, despite the land's destiny afterward[2]. Therefore, considering that the scenarios simulated in this article imply no further deforestation but only conversion to a different use of areas already deforested in the past, the impact on carbon sink capacity of the soils might not be very large and even a gain is possible, especially considering that most of the country's grassland is still poorly managed.

In order to quantify the impact of the change of land use on GHG emissions, we used emission data provided by Brazilian Ministry of Science, Technology and Innovation (BRASIL, 2014c), as well as the global warming potential (GWP) to have all emission in CO_2 equivalent. First, we calculated the emissions of nitrous oxide in 50 million hectares of pasture, the proportional emission from manure management and the enteric emissions of methane from livestock to estimate the reduction in GHG emissions for ceasing livestock production in the referred area. Then, we estimated the increase in emissions for introducing crops. We only considered the products for which the government (BRASIL, 2014c) provides emissions data (rice, beans, cassava, corn and soybeans), maintaining the same proportion they have in Brazil's agriculture. As the

[2] Fujisaka et al. (1998), for instance, analyzing the effects of forest conversion on annual crops and pastures in the Amazon area (Rondônia state) found that the carbon stocks of forest plots are 199.8 t ha^{-1}, while croplands store 76.1 t ha^{-1} and grasslands 28.3 t ha^{-1}.

government does not provide data on carbon dioxide emitted from energy used in the production process, we restricted our analysis of crop emissions to nitrous oxide emitted from soils and methane emitted in rice production. Consequently, we are somehow overestimating the reduction of GHG emissions due to land use change because energy emissions are probably greater for crops than for livestock production.

As table 3 reports, soil's GHG emissions would be lower for crops than for pasture despite the high level of emissions due to rice cultivation. When we add the enteric emissions of methane from livestock, the balance becomes even more favorable to crops. Replacing grassland for cropland would allow a net reduction of 74 million metric tons of equivalent CO_2, what suggests that increasing nutrient production and reducing GHG emissions are goals that can be pursued concomitantly.

Table 3. Estimated GHG emissions that would occur in 50 million of hectares used either as pasture (with livestock production) or as cropland (in t of CO_2 equivalent)

Emission sources	Emissions in t of CO_2 equivalent		
	Cropland	Pasture	Variation
Nitrous oxide from soil use	8,790,196	24,219,451	-15,429,255
Manure management		5,872,828	-5,872,828
Methane emissions from rice production	10,566,530		10,566,530
Methane emission in livestock production		63,316,293	-63,316,293
TOTAL	**19,356,726**	**93,408,572**	**-74,051,846**

Source: estimated by the authors using data provided by BRAZIL (2014c) and IBGE (2007).

CONCLUSIONS AND IMPLICATIONS

Our analysis shows that despite the so-called food-feed-fuel competition, Brazil's food availability has been sufficient and has grown steadily since the 1990's. Furthermore, we can presume that the provision of food is even higher than our estimates suggest because we have left out many products consumed in the country. Consequently, the incidence of malnutrition in Brazil is not caused either by food availability or by food instability, being probably the result of lack of access to food by low-income citizens living in an environment of unequal distribution of income.

Despite that, the effect of the food-feed competition cannot be ignored in a global perspective. Increases in income and a remarkable reduction in worldwide poverty for the last few decades have disseminated a new pattern of food consumption and production based on meat and dairy products, with two major consequences: first, increasing amounts of land have been destined to produce animal feed products; and second, high emissions of GHG. Although the adoption of new technologies might help to mitigate GHG emissions, the concerns about hunger will continue.

To overcome hunger, more nutrients need to be produced for human consumption. In this direction, our results also indicate that Brazil has a huge potential to supply increasing quantities of food using the country's current agricultural land in a more effective way in terms of nutrient production. Our results show that Brazil not only can supply much more nutrients than it does today, but also, can reduce GHG emissions substantially. Naturally, incentives would be necessary to direct the agricultural systems to a new pattern. If producing animal feed and foods of animal origin remains more rewarding than producing food crops, farmers will continue producing the same. Therefore, public policies regarding trade, as well as consumer education about the consequences of their consumption habits, would be necessary to persuade the food system to change.

Finally, future research could refine our study by including other nutrients, other food products or even by evaluating the nutritional situation regionally, as well as analyze diets under the perspective of both health and sustainability. Moreover, simulations of policies aiming to induce consumption and production of healthy and sustainable diets would be very helpful.

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