Balance between food production, biodiversity and ecosystem services in Brazil: a challenge and an opportunity

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Abstract: Brazil has a unique position in the world. It is one of the few countries that can be one of the most important producers of food, fiber and biofuel and at the same time maintain its mega biodiversity endowment and vital ecosystems services properly running. This is a challenge that only can be achieved by recognizing the importance of agribusiness sector to the Brazilian economy, but also that ecosystems have limits and we should not endless expand agriculture in the name of "development". Ecosystem services have to be recognized also as a "development" to be kept for the next generations. Agriculture only exists where ecosystems are able to maintain its basic functioning. Therefore, a well preserved nature it is the most precious asset of agriculture.
Keywords: *agriculture, ecosystem services, food production, biodiversity, Brazil.*

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Resumo: O Brasil encontra-se em uma posição privilegiada diante do mundo. É um dos únicos países que pode ao mesmo tempo ser um importante produtor de alimentos, fibras e biocombustíveis e manter sua mega biodiversidade relativamente intacta e serviços ambientais vitais funcionando apropriadamente. Este é um desafio enorme que pode ser obtido através do reconhecimento da importância que o setor agropecuário brasileiro tem para o país, mas ao mesmo tempo reconhecendo também que os ecossistemas têm limites naturais e não devemos expandir nossa fronteira agrícola indefinidamente em nome do "desenvolvimento". Os serviços ambientais prestados pelos ecossistemas devem ser valorizados e também reconhecidos como um tipo de "desenvolvimento" a ser mantido para as próximas gerações. A agricultura somente existe onde os ecossistemas são capazes de manter suas funções básicas de funcionamento. Portanto, o maior capital da agricultura é a natureza minimamente preservada.
Palavras-chave: *agricultura, serviços ambientais, produção de alimentos, biodiversidade, Brasil.*

Introduction

The rise of Brazil, Russia, India, and China (the Big Four, also known as BRICs) as emerging markets in the past few years is not only changing the face of global economics and politics, but also shaping the use of global resources (Scott-Kennel & Salmi 2008). Brazil, with its favorable climatic conditions and relatively small population, has emerged in the global scenario mostly as an important food producer while it is still claims a position of significance for its vast natural resources and mega biodiversity. However, Brazil is now at a turning point where agricultural development must continue together with environmental protection. If not, Brazil is likely to come to increasing scrutiny as agricultural development is associated with devastation of remaining natural resources and growing risk of climate change because of deforestation in the Amazon. Unlike developed countries that had the opportunity to develop their agricultural and industrial sectors without the same degree of environmental awareness, Brazil needs to develop ways to overcome the challenges that appear to make accelerated growth and sustainability incompatible.

Material and Methods

Here we describe the transformation of Brazilian agriculture in the last decades, the environmental consequences of such development, and discuss the unique position that the country is in the world for promoting sustainable development. In a near future Brazil could be one of the first countries to reach a satisfactory status of development, while preserving its phenomenal biodiversity and important ecosystem services.

Results and Discussion

The model for agricultural development in Brazil is the same model used in developed countries, which is based on few crops and high technology (World Bank 2008). As a result, while the agricultural area in Brazil has expanded significantly in the past few decades, agriculture has become more intensive and productivity higher for several crops. We exemplify this accelerated growth by selecting the temporal variability of covered area and production of soybean, corn, sugar cane from the early 60s to present times (Figure 1).

By far pasture is still the main agricultural land use in Brazil, occupying an area of approximately 200 million hectares. Yet, pasture had the lowest expansion in the past 40 years in comparison to the crops mentioned above and, of the total area of expansion, 50% occurred in the Amazon region (Figure 1a). The area of deforestation in the Amazon reached approximately 70 million ha, increasing 400% since the first assessments of deforestation done in 1978 (Figure 2a). Moreover, the number of cattle also increased during the past decades, but at a faster rate than pasture area. In the 60s, there were approximately 56 million cattle heads in Brazil and today this number is almost four times as large. In contrast to cattle ranching in the US, where cattle is mainly fed corn and soybeans in intensive managed systems (CAFOS), cattle in Brazil is mostly grass feed and unconfined, so an increase in the number of cattle heads resulted greatly in increasing the carrying capacity of pastures in Brazil, which almost doubled in the last 40 years. We speculate that this increase was due to a combination of factors such as genetic improvements on grasses used in pastures, better selection of cattle, and on the overall management of the cattle ranches.

Between 1961 and 2007, the soybean area in Brazil increased almost 8,000% from only 0.24 million ha to approximately 20 million ha in 2007 (Figure 1b). During the same period, production increased more than 20,000%, from 0.27 to approximately 60 million Mg of grains (Mg = 10^6 g = 1 t). In the last decades, there was also a

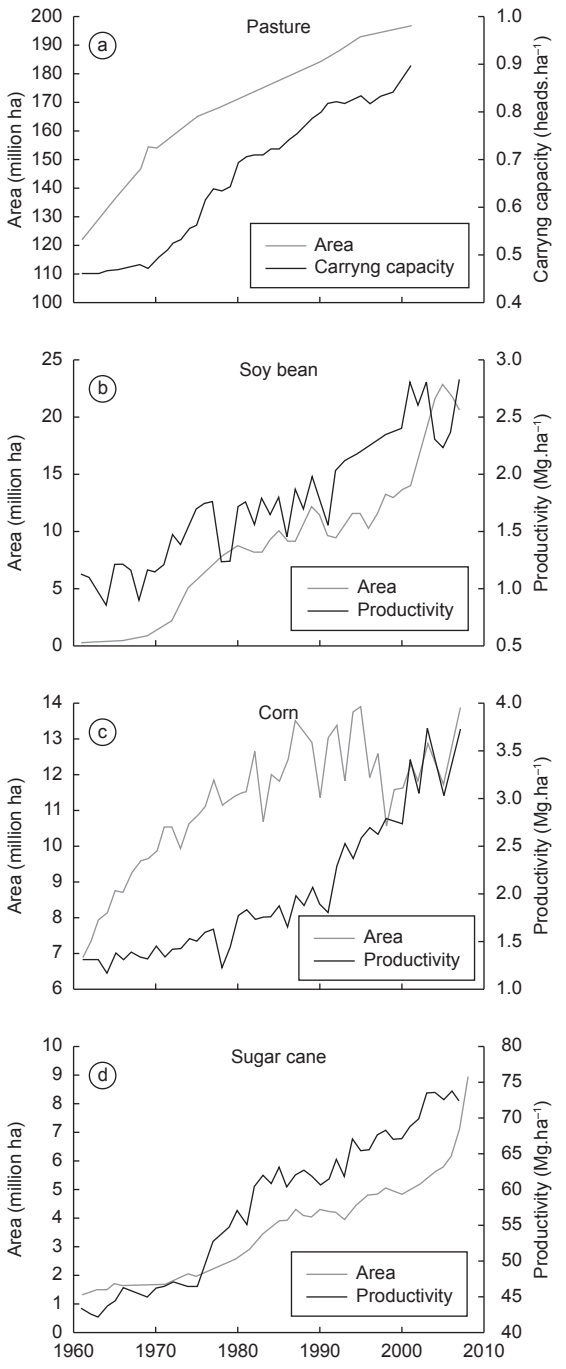

Figure 1. Annual variability of a) pasture area and carrying capacity, and area and productivity of: b) soybean, c) corn and d) sugar cane.

Figura 1. Variabilidade anual de a) área coberta com pastagens e lotação. Área e productivade de b) soja, c) milho e d) cana de açúcar.

significant increase in soybean productivity from only approximately 1 Mg.ha^{-1} (Figure 1b). Soybean cultivation started in the south of Brazil, in the State of Rio Grande do Sul (approximately 32° S), in the early 60s. In the last 40 years, soybean crops started expanding towards the Equator by first taking the Cerrado region, which is the Brazilian tropical savanna, and now reaching the Amazon as deep as the parallel 2° S. Therefore, Brazilian soybean is now cultivated

in an area that stretches along a latitudinal swath of 30°. At the same time, the area planted with corn increased approximately 100%, from approximately 7 million to 13 million ha, which is a modest expansion compared to that of soybeans (Figure 1c). On the other hand, production increased almost four times as much as the crop area, again indicating a tremendous increase in productivity and the intensification of agriculture (Figure 1c).

The area planted with sugarcane started to expand in the middle 70s with the onset of a Brazilian government program called Pro-Álcool, which was conceived for energy security purposes (Macedo et al. 2008). However, in recent years (~2002) the sugarcane industry and crop area went through an unprecedented new expansion, which was boosted by the biofuel fever. For instance, in the past two years alone, sugar cane area increased from approximately 6 to almost 9 million ha, while in the middle 70s sugarcane plantations occupied only 2 million hectares (Figure 1d). Furthermore, the increase in productivity of sugar cane was one of the most impressive in the history of the country, going from approximately 40 $Mg.ha^{-1}$ in the 60s up to approximately 80 $Mg.ha^{-1}$ in the last decade (Figure 1d).

As the result of such increases in agricultural land cover and production, the availability of food and energy to the Brazilian population increased by 40% in spite of a tremendous population growth. In the last 40 years, the number of people in Brazil increased from 75 to 184 million (Figure 2b).

The productivity increase observed in the last decades can be attributed to several factors. Unquestionably, the use of new crop varieties, and better and more efficient land management practices, such as crop rotation and no till, were important factors. However, a more intensive use of fertilizers and agrochemical products played a major role. Since 1960, the consumption of potassium fertilizer in Brazilian crops increased 6,000%; while the consumption of nitrogen and phosphorus increased 4,000% and 2,500%, respectively (Figure 2c). Although these are spectacular increases that amount to more than 8.5 Tg of fertilizer used in 2007 (Tg = 10^{12} g = 10^{6} t), the average use of fertilizer per hectare in Brazil is still well below the average for developed countries (Martinelli et al. 2006). The use of agrochemicals (insecticide and herbicides) also increased 300% since the 90's (Figure 2d). Recent estimates showing data on agrochemical use from 2008 show that Brazil has became the largest market for agrochemical in the world (O Estado de São Paulo 2009a). Unfortunately, according to a survey conducted by *Instituto Brasileiro de Geografia e Estatística*, more than half of the rural properties in the country (1.4 million properties) apply agrochemicals without using proper handling procedures (IBGE 2009). Hence, the increase in the use of agrochemicals can also have a negative impact if it harms the environment and human health.

The expansion of the agricultural frontier in Brazil was achieved largely by replacing the natural vegetation of important biomes like the Cerrado and the Amazon forest by crops. Also, most of the Brazilian Atlantic forest, for instance, was replaced by crop fields and urban areas centuries ago (Branstom & Oliveira 2000). However, the boldest example of natural vegetation conversion is seen in the Amazon region, where deforestation rates are among the highest in the world. In the late 70s, the area of deforestation in the Amazon was less than 16,000,000 ha. Last year (2007) the total deforested area was more than 70,000,000 ha (INPE-DETER 2009).

Due to the vastness of the Amazon forest in Brazil, the deforestation area represents approximately 14% of the 500 million ha Brazilian Legal Amazon, which is a relatively small percentage in contrast with the ~75% of Cerrado that has been replaced by crops and urban land (Machado et al. 2004). The contrast is even more dramatic when we compare with the devastation of the Atlantic forest, which has

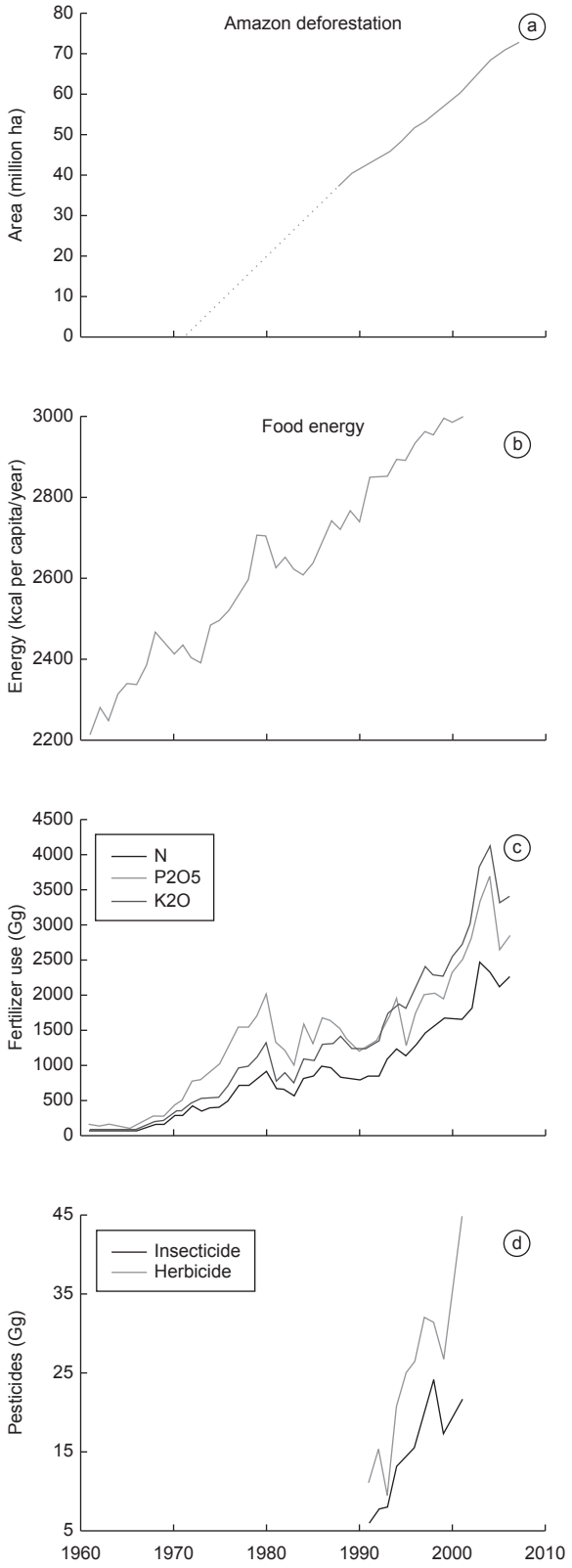

Figure 2. Annual variability of: a) deforested area in the Brazilian Legal Amazon, b) food energy available per capita, c) fertilizers consumption, d) agrochemical consumption.

Figura 2. Variabilidade annual de: a) área desmatada na Amazônia Legal Brasileira; b) Energia calórica disponível por habitante; c) consume de fertilizantes; d) consume de agroquímicos.

had 93% of its original area (almost 130 million ha) converted into agricultural or urban land use (SOS MataAtlântica 2008). As a result, the number of endangered animal species in Brazil has increased from 44 in 1963 to 206 in 1986, and to approximately 630 species in 2004 (Biodiversitas, 2008). The number of plant species facing the risk of extinction is even higher, with the last estimate listing more than 1,500 species (Biodiversitas 2008). However, in spite of such losses, the mega biodiversity of Brazil is still largely intact and need to be preserved for future generations.

Agrobusiness is a key sector of the Brazilian economy (World Bank 2008). In the last 15 years, the average share of the country GDP provided by the agribusiness sector was 25% (CEPA-ESALQ 2009), which is typical for countries with transition economies, where agriculture is vital to development (Bravo-Ortega & Lederman 2005). Even after acknowledging that the benefit to society has not been equally distributed (Ferreira et al. 2006), the agricultural sector, especially related to biofuel production, is considered to be a positive force as it helps promote rural development and close the gap between urban and rural incomes (De Ferranti et al. 2005).

However, despite the economic advancements associated with intensive agriculture, it is crucial that we realize that the agricultural frontier in Brazil cannot advance indefinitely. Continuous expansion will not only jeopardize the mega biodiversity of Brazilian flora and fauna, but also vital functions that ecosystems provide to sustain the same agricultural systems that are so important for the Brazilian economy. For instance, the Amazon forest is well known for its capacity to generate rain, not only through forest evapotranspiration (Ramos da Silva et al. 2008), but also by emitting isoprene to the atmosphere, which helps in the formation of water droplets that generate more rain (Claeys et al. 2004). Part of the rainfall generated locally in the Amazon is exported to other regions of Brazil like the Cerrado (Nobre et al. 1991), for instance, where extensive areas planted with soybeans in the last decades rely on this rain produced in the Amazon to thrive. In other words, we can say that a pig in China that is feed with soybeans from central Brazil (Naylor et al. 2005) depends also on Amazon rain water. Actually, different climate models have predicted that if deforestation in the Amazon reaches a certain threshold, there will be a significant decrease in rainfall not only in the Amazon but also in other areas of the country (Oyama & Nobre 2003).

On the bright side, Brazil already has the legal apparatus to protect vital ecosystems and the services they provide. For instance, a recent federal law has banned sugar cane cultivation in environmentally sensitive regions of Brazil like the Amazon and Pantanal. Another important law requires that Brazilian farmers preserve riparian forests along streams and rivers to create permanent preservation areas (PPA). Furthermore, every farmer is required to preserve an area of original vegetation in their land that is proportional to the size of their property. The required area varies regionally, but for the most part it is 20%. In the Cerrado and Brazilian Legal Amazon, the proportions are 35% and 80%, respectively. The enforcement of such laws is still weak throughout the country, and most of the rural properties do not have any protected area. However, while law enforcement is under intense debate in the country right now, the revision of some aspects of these laws, especially with regard to small farmers who are often left with an area too small for crops, will help in the implementation.

The rationalization used in Brazil for continuing the devastation of natural resources for the sake of advancing the economy is based on the assumption that increased productivity in agriculture will eventually make it unnecessary to continue expanding horizontally at the agrarian frontier. However, at the present rate, the expansion of agriculture in Brazil is likely to jeopardize vital ecosystem functions and the mega biodiversity that support the very system that has helped the country fight persistent poverty and economic stagnation in the past few years – the agriculture. While successful and productive agriculture needs basic ecosystem services such as consistent supply of rain and water, and a rich gene pool, we are pushing ecosystems to their limits of providing such services, especially now that the effects of global warming are increasingly more evident.

According to Eduardo Assad from the Brazilian Agency for Agriculture and Animal Husbandry (pers. comm., 2009) the mega biodiversity of Brazil potentially contains the source of genes that can help agricultural varieties become adapted to new climatic conditions. Therefore, conservation is also an activity that generates wealth (M. Bustamante 2009, O Estado de São Paulo 2009b).

If stakeholders and the Brazilian society as a whole understand that ecosystems have limits in terms of carrying capacity and ability to provide important functions, Brazil will have a great chance to continue to develop and, at the same time, keep its biodiversity endowment almost intact to provide valuable resources to many generations to come. Few developed countries in the world have had this opportunity while in development, therefore, the time for Brazil to act is now and not tomorrow.

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