A Pathway to Energy and Food Security with Biodiesel

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ABSTRACT

The simultaneous rise in commodity prices and the global production of biofuels, between 2007 and 2008, strengthened discussions, which persist currently, about the competition of land use between biofuel production and food production. The objective of this paper is to compare and evaluate the arguments from both sides. The methodology used was an analysis of the relevant and comprehensive reports and manuscripts on the topic, comparing them to the available data from international organizations and agencies. Biodiesel received special attention in this analysis. The conclusion is that hunger and poverty problems are due to structural and historical roots and they do not have a cause-effect relationship with biodiesel production. In fact, the production of biodiesel, under specific regulatory and production conditions, can be a driver of economic development improving energy security and promoting social inclusion in poor countries, which still have land available for agriculture.

KEYWORDS

Food security, Energy security, Biofuels, Biodiesel, Fuel x food.

INTRODUCTION

Between 2007 and 2008 there was a substantial increase in food prices worldwide, raising concerns about the difficulty of feeding a still-growing human population on the planet. The green revolution contradicted the Malthusian prediction providing an increase in food production. Indeed, the amount of food produced on the planet would be enough to feed everyone satisfactorily. However, there is a huge inequality in life conditions [1] and a waste of food, that cause many people to eat less than needed while others have overweight problems. On one hand, there are about 842 million underfed people [2], and on the other hand, there are around 1.4 billion obese people [3], reflecting the problem of distribution of wealth and food in the world. Increases in grain prices can make such inequality worse, and also can threaten more people with lack of accessibility, adequacy and availability of food [4].

Diesel is the basis of the mobility of goods and people. It's price influences commodity prices, as it represents 35% of the road transport operating costs [5].

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Biodiesel, among biofuels, is an alternative to partially replace of mineral diesel, requiring no substantial changes in engines [5]. In addition to helping decrease the mineral diesel consumption, it is an alternative to mitigate GHG emissions, as society is now getting increasingly concerned about the GHG emissions from fossil-fuel combustion. Indeed, biodiesel reduces pollutant emissions such as CO_2, SO_2, particulates and other greenhouse gases [6].

Biodiesel production has been rising on a regular basis since 2005 [7] competing in a market where fossil fuel derivatives dominate. The IPCC's projection that biofuels would reach 3% of the energy supply [8] for transport sector was met in 2011 [9]. Therefore, it seems to be logical to investigate the relationship between the increase in food prices and biodiesel, since food, feed and biodiesel compete for the same oilseeds.

The discussion about the relationship between food prices and biofuel production has become intensified. Biodiesel, in particular, has been criticized as if it had worsened hunger and misery, and had caused land use change, deforestation and species extinction. All these reasons seem to be ethical arguments, in favour of planet health and of the protection of human dignity. However, those arguments have negatively affected the understanding of food and energy security, favouring the oil industry, without discussing the real reasons of hunger and poverty. Major institutions that can influence the global energy policies have incorporated such arguments, resulting in propositions of reducing biodiesel targets. These changes can preclude small farms, especially in developing countries, to participate in the energy market, reducing the possibility of social inclusion and poverty reduction. Some works have already analysed both themes. For example, Gasparatos *et al*. [10] analyse the works related to food security and energy security and conclude that biofuels' effect on food security, particularly at the household and the local level, depends on the socioeconomic context of biofuel production and the policies in place during biofuel production and trade. Kgathi *et al*. [11] suggest that the production of biodiesel in Botswana would encourage farmers to increase food production in idle lands available in the country, instead of increasing the local food commodity prices. Popp [12] states that there is a future for a sustainable biofuels industry, as long as the feedstock production avoids encroaching on agricultural land. This can be achieved by choosing feedstocks that can grow on marginal land or matter such as wastes and residues that do not use up land. Ajanovic [13] said in 2011 that no significant impact of biofuels production on feedstock prices had been observed. Hence, a co-existence of biofuel and food production seems possible especially for second generation biofuels. However, sustainability criteria should be seriously considered. Abbott *et al*. [14] analysed how the increase in the Chinese demand of soybean is affecting food prices in 2011. They suggest three main causes: depreciation of the US dollar, changes in production and consumption standards, and growth in biofuels production. They also recognize the link between oil prices and food commodity prices, even though they focus their analysis on ethanol produced from corn. Koizumi [15] assumed that only non-food-based biofuel and cellulosic-based biofuel do not have a serious impact on food security on a country and sub-country level in China and Japan, because the amount of feedstock used for non-food and cellulose-based biofuels is small. However, the author states the Chinese biofuel production may become a new agricultural investment to promote rural development and to increase income in poor areas.

The purpose of this article, based on updated data, is to confront and analyse arguments and contradictory positions, seeking a balance between them, discussing the real biodiesel role in food and energy security. From those work, none of them analyse food (and hunger), biodiesel production and its feedstock, and mineral diesel. This work aims to cover this gap, bringing in three main contributions. The first is to show that the correlation between food commodity prices and biodiesel production happens because they are linked in the international commodity market, which depend much on oil prices. The second is to show that, besides biodiesel being produced from by-products that do not occupy land at all, there are other choices to produce biodiesel without competing for land assigned for food production. The last is to show evidence of bad distribution of food and income, which can be softened by stimulating the production of biodiesel feedstock in countries at low latitude.

METHODOLOGY

To clarify the relationship between food security and energy security, a careful review was conducted of published articles and reports produced by international organizations, especially those produced after 2008, when the debate was strongly entrenched. Reports and data from international institutions and agencies, such as:

- Food and Agriculture Organization (FAO);
- Organization for Economic Co-operation and Development (OECD);
- World Bank;
- US Department of Agriculture (USDA);
- International Energy Agency (IEA);

were used, besides scientific works.

Indicators and data available on the main issues addressed in those publications were analysed, based on the arguments against and in favour of the cause-effect relationship between biofuels production and commodity prices. As much as possible, the analysis of biodiesel production and the feedstock used were pointed out as the main subject of interest in this work, because ethanol and biodiesel have different feedstock and markets, and they replace different fuels. In addition, alternative ways to produce biodiesel were identified, considering the options for type of land and oilseed used to produce biodiesel.

Quite often, historical series of data before 2008 were required to identify trends and/or correlations between variables. These data were updated and tracked on the available sources. Information and data from institutions with international credibility and universal acceptance were used in order to avoid sectoral biases. Results of quantitative and qualitative studies already conducted and published were searched. However, it does not mean concordance with the results found in such studies.

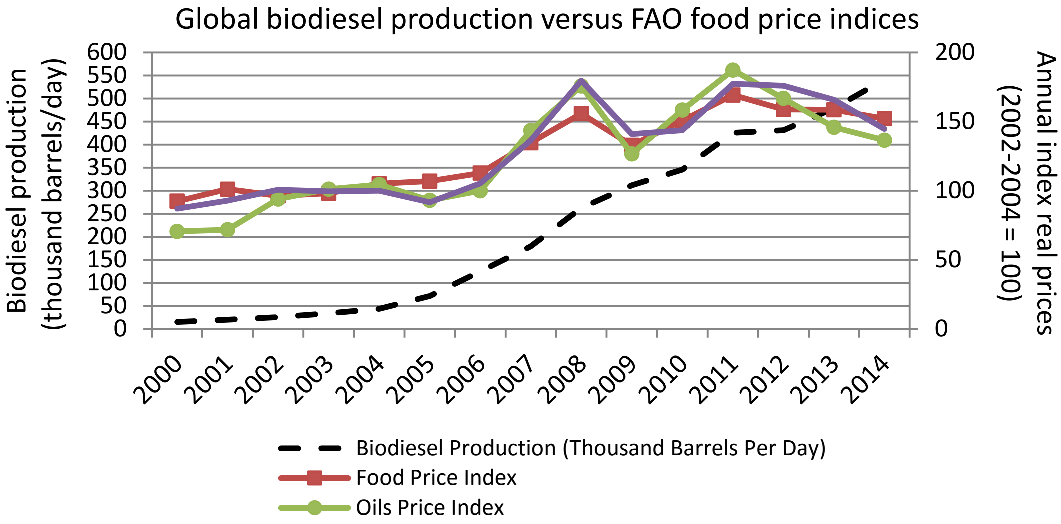
The analysis is based is on the hypothesis that sustainable development is committed to ecological wisdom, social inclusion and economic efficiency, besides being supported by institutional sustainability.

THE IMPACT OF BIODIESEL PRODUCTION ON FOOD SECURITY

Food security means to have access to food of enough quality to ensure good health, access to drinking water, and respect for cultural traditions in food [4].

A sufficient amount of food to feed everyone in the world is produced. However, as the distribution is unequal, part of world population goes hungry. The highest rates of malnutrition [16] coincide with the areas of greatest poverty [17], which are predominantly in some African and Asian regions. Food commodities are the ones that, despite different menus, cultures and geographical locations, are internationally known and consumed [18].

The significant increase in prices of food commodities during 2007-2008 gave rise to studies trying to identify the causes, often taking the analysis back in time to better understanding the phenomenon comparing to other seasons. In Figure 1, it is possible to see together the food prices and biodiesel production.



Obs.: Biodiesel production for 2013 was estimated considering 11% increase [19] regarding to 2012 figures from EIA [20]; biodiesel production for 2014 was estimated considering 13% increase [19] regarding to the estimated production for 2013.
Source: elaborated by authors based on U.S. EIA www.eia.gov [20]; FAO, 2015 [21]

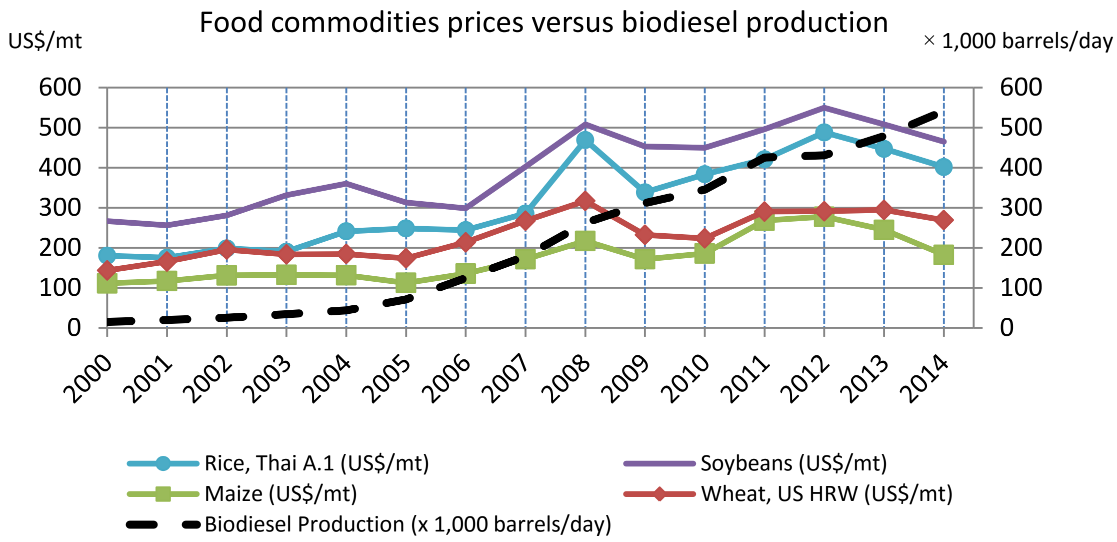
Figure 1. Biodiesel production versus food price indices

According to Mitchell [22], the energy prices in 2005-2008 have caused higher transportation cost, stimulated the production of biofuels and encouraged policy support for biofuels production. Consequently, biofuels production has not only increased the demand for food commodities (for instance maize and soybean), but also led to land use changes. This reduced the production of wheat and other grains, causing a reduction of stocks [22]. The direct result was the weakening of the ability to cope with other events that affect the price of commodities, such as climate change and currency fluctuations. Thus, from 2002 to 2008 the traded food commodity prices increased 130%, led by grains [22]. Especially for biofuel grains, from 2005 to 2008, the prices increased more than this magnitude. For example, maize prices almost tripled while wheat prices increased by 127%. Oils prices have also increased at the same level. The prices of palm oil and soybean, which are used to produce biodiesel[†], increased by up to 200% and 192% respectively [22]. The increase in food prices, especially oilseeds [23], on the international market followed the increase in biodiesel production [24] (Figure 2).

In short, the increase in energy prices had direct and indirect effects on the abnormal increase in commodity prices. The direct effects were on increasing the inputs and transport prices; indirect effects were through encouraging the production of biofuels. The grain production for food and feed was displaced by biofuel production [22]. However, the dynamic was different for each commodity, which led to analyse separately bioethanol from biodiesel. Maize production grew by 70% between 2004 and 2007, not for food production, but ethanol – which today consumes 65% of maize produced in USA [22]. This growth, particularly in the U.S., resulted in a decrease in

[†] Soybean, rapeseed and palm oil are the major feedstock used for biodiesel production, but the proportion between them varies every month. Soybean has been the most used lately in USA, Brazil and Argentina, http://www.eia.gov/biofuels/biodiesel/production/
http://www.anp.gov.br/?pg=73584&m=&t1=&t2=&t3=&t4=&ar=&ps=&cachebust=1421402672874

soybean area, reducing soybean production and, of course, contributing to raise soybean prices between April 2007-2008 [16]. As an exception, Brazilian ethanol – made from sugarcane – did not contribute to the recent increase in food commodity prices, because Brazilian sugarcane production had increased before 2007 and sugar exports have nearly tripled since 2000 [22]. The most important factor for the rapid rise in food prices was the increased production of biofuels in US and EU [22].



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Source: Elaborated by authors based on U.S. EIA www.eia.gov [20]; World Bank – Global Economic Monitor (GEM) Commodities [36]; (mt = metric ton)

Figure 2. Comparison of agricultural commodities prices and biodiesel production

In global road-transport, the use of liquid biofuels accounted for 3% of fuel demand in 2013 [7]. The use of renewable energy has grown in absolute numbers, but not in its contribution to the global energy mix. In 2006 it accounted for 18%, and in 2010 for 16.7% [7]. Nevertheless, investments went from USD 63 billion in 2006 to USD 257 billion in 2011 [19].

According to Cushion *et al.* [25], as production of most biofuel feedstocks are strongly oriented toward exports, the impact of the bioenergy developments can cause general increase in global commodity prices. Biofuel production is causing land use change, soil degradation, deforestation and loss of biodiversity [25]. Moreover, the poor who have to cut their consumption of food, exposing themselves to the risk of malnutrition and malnourishment, felt the greatest effect of the increase of prices [26].

Indeed, the impact of the 2007-2008 price spike on household access to food would have been on two factors: the degree to which the international price was transmitted to domestic markets and how people's incomes and expenditures were affected by domestic price changes, and then how they responded to it [26]. The transmission of the prices to the domestic market can be quite different, depending on the internal trade policy of each country [26]. Therefore, it would be necessary to analyse each case separately.

FAO estimates that the volatility of food prices may continue with the rise of biofuel production because demand for food will increase in economies that are growing faster [27]. The demand for food will probably increase by 60% by 2050, due to the global population growth. It means that the challenges will be bigger in areas with shortages of natural resources, especially in low latitudes of the planet that are already more exposed to climate changes [28]. Furthermore, economic growth means more demand for energy and higher prices for oil; the prices of inputs and transport will rise and, at the end, commodity prices will also rise [22]. Hence, when the price of oil increases, the demand for biofuels also increases [27] affecting the food prices. Here are the ingredients for the intensification of inequalities in distribution of food and income, and also for worsening of the relationship between oil producing countries and oil consuming countries.

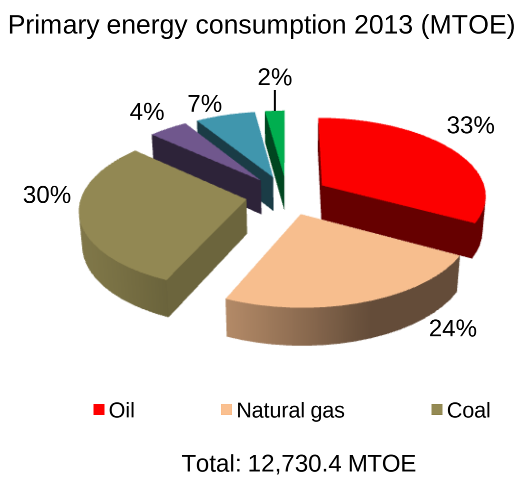
According to FAO, biofuels will be only a small portion of the consumption of fossil energy over the next decade, but will bring much bigger impacts on agriculture and food security, especially for the poorest countries that depend on food imports [29]. Any diversion of land from food production or animal feed to produce biomass for energy will influence food prices since both compete for the same inputs [24].

Therefore, the recommendations are to slow down the replacement targets of mineral diesel by biodiesel, and to reformulate policies for production and use of biofuels, in order to decrease the replacement targets in the United States (US) and European Union (EU). Moreover, Mitchell [22] and Gallagher [23] suggest a land use control system in potential producer countries, which seems to be a strong commercial barrier. The reduction from 20% to 10% was suggested to the Directive 2009/28/EC which stipulates that 20% of consumed energy in transport in 2020 must be renewable [22].

THE ROLE OF BIODIESEL FOR ENERGY SECURITY

Energy security is related to having access to energy sources at reasonable prices for the functioning of the economy. It is directly related to internal and external security of the nations, as energy is essential for transport, communication, production and preservation of food, and health services, among others. Improving energy security involves the diversification of energy sources, mitigating the risks associated with reliance on a single source and promoting economic stability of nations.

The sources of primary energy have been coal, gas, oil, nuclear power, hydroelectricity and biomass. The oil consumption had the highest share, 33% in 2013 [30] (Figure 3). Of these, approximately one-third can be refined into diesel.

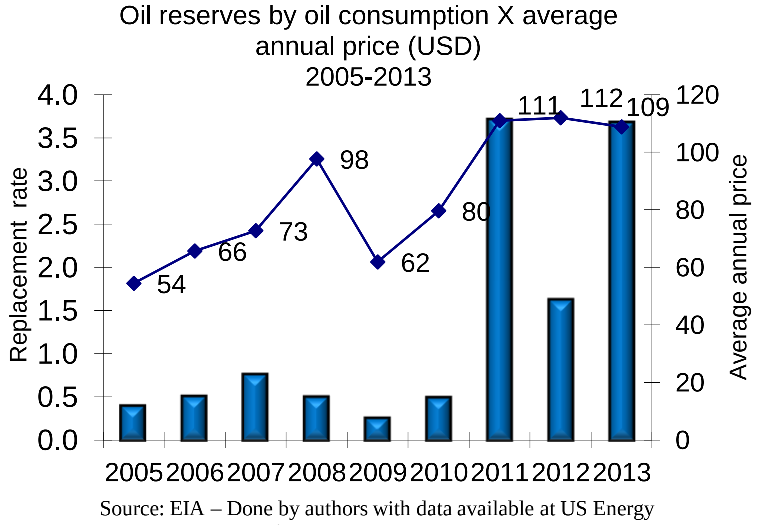


Source: BP statistical review of world energy, 2014 [30]

Figure 3. Global primary energy mix in Millions of Tonnes of Oil Equivalent (MTOE)

The peak of conventional oil production may have already happened, whereas the volume of replenishment has been smaller than consumption. From 2005 to 2010, less than a half barrel, for each one consumed, was added to proven reserves, with clear consequences on oil price volatility (Figure 4). However, in 2011, the high prices of the oil turned economically viable some unconventional petroleum deposits like oil sands and deep water oil. Also, they make viable technologies such as fracking, both in oil shale and conventional wells, increasing the recovery factor from 70% to 90% in the conventional wells [31]. The impact on aquifers, the waste disposal and even the seismic stability of the geological formations exploited with fracking, are not yet very clear and have been subject of discussions, accidents and conflicts. To make things worse, fossil fuels are considered one of the worst culprits of global warming. If all these issues were perceived as threats to the oil industry, it is natural that barriers to the entrance of the substitute products such as biofuels will be created by the oil industry.

Considering the demand side, either by the exhaustion of oil or owing to the continuous rise in price, oil dependence is a constant threat to the economic stability of the countries. That dependence becomes even more critical if we consider that the reserves are concentrated in a few places on the planet and the oil supply involves the internal and regional policy of oil-producing countries. Moreover, the cost of fossil fuel subsidies are economically unbearable, reaching USD 544 million in 2012, which can turn to USD 2 trillion if tax losses are included [32]. In addition to economic aspects, in 2010, there were 6.7 Gt CO_2 emission due to transport sector, with the possibility to double by 2050 [8]. It is estimated that more than 3 million deaths /year occurs due to vehicle pollution [33]. Summing up, the society finances a fuel that brings diseases, death, financial losses [33], welfare decrease, and threats to energy security.



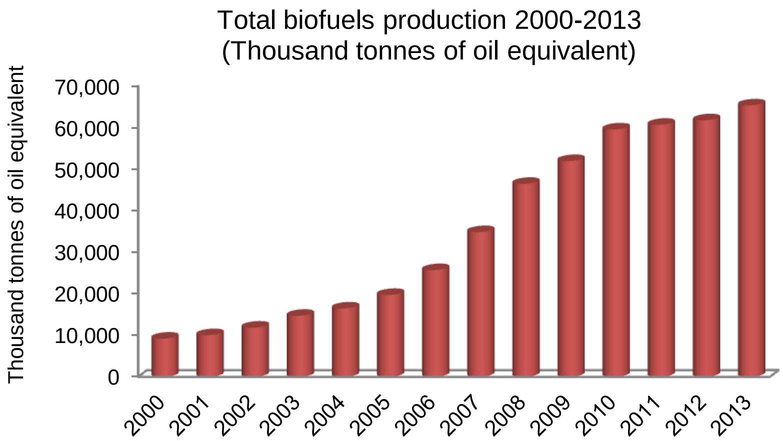
Source: EIA – Done by authors with data available at US Energy Information Administration.
Source: U.S. EIA, www.eia.gov [34]

Figure 4. Number of barrels of oil added to proven reserves for every barrel consumed and the average annual price of oil

Any source of energy that can be a replacement for oil contributes to decrease oil dependency. However, some of the sources depend on seasonal natural resources (hydro, wind and solar energy), others have strong civil opposition (nuclear), and not all of them can be stored.

Biodiesel and other biofuels (bioethanol and biokerosene) are possible replacements to oil: they can be used in transport and also generate electricity. Besides that, comparing to mineral diesel, biodiesel reduces emissions of unburned hydrocarbons, carbon monoxide, sulphates, aromatic compounds and particulate material [6]. Biodiesel decreases almost 15% of CO_2 emissions when it is used up to 20% (B20), reduces SO_2 emissions compared to mineral diesel, and improves injection pump lubrication [9]. Even though biodiesel does not help in reducing NO_x [9], it has unquestionable advantages over mineral diesel, for improving the quality of life in urban centres.

Biodiesel can be produced from castor oil, palm oil, soybean, rapeseed, sunflower, jatropha, thistle seed, seaweed, waste cooking oils and animal fats, among other feedstock. Most of these crops grow easily in tropical and subtropical climates [35], exactly where the poorest countries are, even though it depends on appropriate topographical, climatic and edaphic conditions, and water availability. Anyway, these conditions can be found in various places, unlike oil reserves, which have a specific geological location. All these issues: storage, electricity generation, transport, reduction of pollutant emissions and the possibility of production in various parts of the globe have favoured the increase of biofuel production in the last decade (Figure 5).



Source: BP statistical review of world energy 2014 [30]

Figure 5. Global production of biofuels from 2000 to 2013

Replacing 20% of mineral diesel by biodiesel would help to reduce the reliance on oil and, consequently would enhance the energy security.

ANALYSIS AND RESULTS

Correlations

To make a correlation between the two variables − food prices and biodiesel production, it is necessary to consider all inequality issues that have always existed between the countries, the interest of the countries that produce fossil fuels, and also the consequences of CO_2 emissions and carbon debt. That is, it is not a simple equation. Biofuels are one of several factors leading to rising food prices.

Indeed, finding a relationship between food commodity prices and biofuels production, over a period of several overlapping crises, is extremely difficult due to the complexity involved. Considering, for example, the prices of other commodities in the same period, it is easy to see that there are also strong correlations with the production of biodiesel (Table 1). Taking as an example, the price variation of some metals in Figure 6, it seems the metal prices are correlated to biodiesel production too. Looking closer at the Figure 7, the curves representing biodiesel production and gold prices seem to increase together. Indeed, the Pearson correlation between these variables (Table 1) confirms this closeness. The correlation among the food indices and biodiesel production is as relevant as between the precious metals indices and biodiesel production. It is unlikely, however, that the production of biofuels has influenced all these prices or vice versa. It is more plausible that they are all subject to the same international trade dynamics.

Table 1. Correlation values obtained comparing the price of commodities with biodiesel and crude oil price for the period 2000-2013

Analysed correlation values between variables (2000-2013)		
Analysed indicators commodities	Biodiesel production(EIA)	Crude oil price(BP)
Food price index (FAO)‡	0.954	0.953
Cereal price index (FAO)§	0.920	0.920
Food price index (WB)**	0.959	0.934
Wheat price, US HRW (WB)	0.841	0.909
Maize price (WB)	0.932	0.909
Soybean price (WB)	0.926	0.893
Soybean price oil (WB)	0.862	0.904
Rice price, Thai A.1 (WB)	0.931	0.941
Tin price (WB)	0.949	0.936
Iron ore price (WB)	0.847	0.928
Lead price (WB)	0.795	0.858
Copper price (WB)	0.815	0.918
Platinum price (WB)	0.858	0.925
Gold price (WB)	0.980	0.894
Crude oil price	0.906	1.000

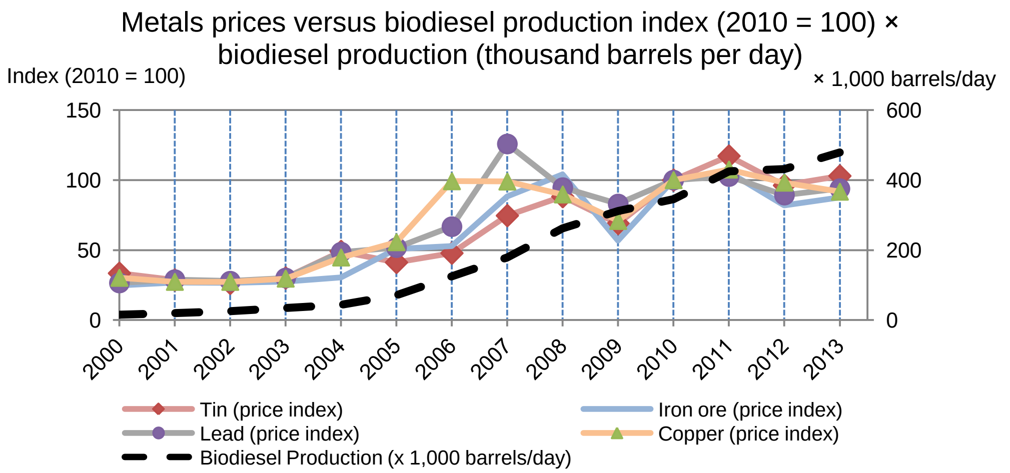
Source: [20, 21, 30, 37]

‡ Consists of the average of 5 commodity group price indices mentioned above weighted with the average export shares of each of the groups for 2002-2004: in total 73 commodity quotations considered by FAO commodity specialists as representing the international prices of the food commodities noted are included in the overall index. Each sub-index is a weighted average of the price of the commodities included in the group, with the base period price consisting of the averages for the years 2002-2004. All indices have been deflated using the World Bank Manufactures Unit Value Index (MUV) rebased from 2010 = 100 to 2002-2004 = 100

§ This index is compiled using the International Grains Council (IGC) wheat price index, itself an average of 10 different wheat price quotations, one maize export quotation and sixteen rice quotations. The rice quotations area combined into three groups consisting of Indica, Japonica and Aromatic rice varieties. Within each variety, a simple average of the relative prices of appropriate quotations is calculated; then the average relative prices of each of the three varieties are combined by weighting them with their assumed (fixed) trade shares. Subsequently, the IGC wheat price index, after converting it to base 2002-2004, the relative prices of maize and the average relative prices calculated for the rice group as a whole are combined by weighting each commodity with its average export trade for 2002-2004. All indices have been deflated using the World Bank Manufactures Unit Value Index (MUV) rebased from 2010 = 100 to 2002-2004 = 100

** Weights used in the World Bank commodity price index: cereals (28.2%) + vegetable oils and meals (40.8%) + other food (31%), where: cereals = maize (40.8%) + rice (30.2%) + wheat (25.3%) + barley (3.7%); vegetable oils and meals = palm oil (30.2%) + soybean meal (26.3%) + soybeans (24.6%) + soybean oil (13.0%) + coconut oil (3.1%) + groundnut oil (2.8%); other food = sugar (31.5%) + meat, beef (22.0%) + meat, chicken (19.2%) + bananas (15.7%) + oranges (11.6%). Index has been deflated using the World Bank Manufactures Unit Value Index (MUV) − 2010 = 100

Looking closer at the variation in prices of food commodities (Figure 2), we can see an abrupt increase between 2007 and 2008 followed by a decrease in 2008 to 2009 and then a rise after 2009, until 2011. Surprisingly or not, for 2013 the curves (biodiesel production and food prices) are decoupling again, as biodiesel production has had a constant growth [36]. Therefore, the variables analysed do not have a strong correlation all the time. If there was a close relationship between biodiesel production and food commodity prices, we would know how to explain all time series since 2005, or even since 2000. Maybe, this is an opportunity for deeper research, but it is not reasonable to make decisions based only on an apparent simultaneous growth.



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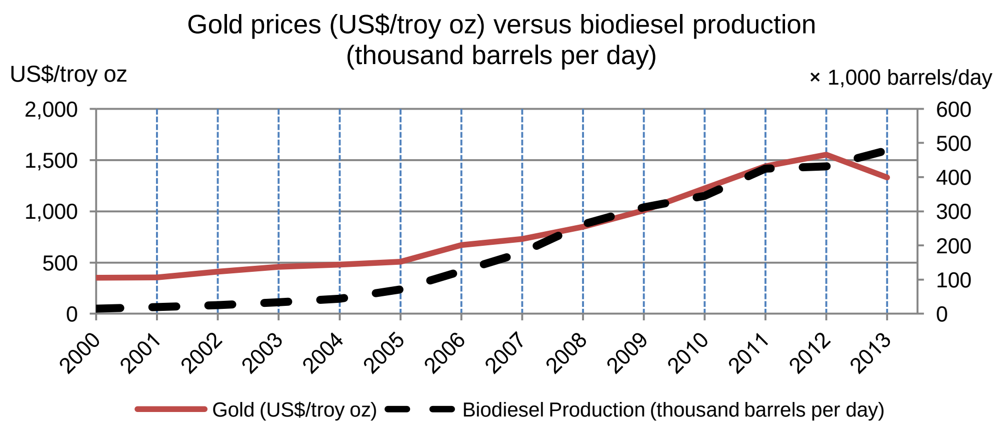
Source: World Bank – Global Economic Monitor (GEM) Commodities [37]; U.S. EIA, www.eia.gov [20]

Figure 6. Metals prices versus biodiesel production



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Source: World Bank – Global Economic Monitor (GEM) Commodities [37]; U.S. EIA, www.eia.gov [20]

Figure 7. Gold price versus biodiesel production

Hochman *et al.* [38] found that the growth in income, changes in meat consumption, and the consequent increase in the demand for feed, also resulted in the spike of corn and soybean prices in 2010/11. The introduction of biofuels led to a 25% increase in the price of corn and soybean in 2011 relative to 2001, while economic growth contributed more than 50%.

Schmitz [39] and Timilsina & Shrestha [40] summarized their analysis, showing that the biodiesel contribution to the increase in food commodity prices can go from 0 to 66%, depending on how the analysis was done (Table 2). The author in [39] realized that most of that analysis did not consider stochastic models, which is more commonly used to analyse time series. This can result in substantial differences, because stochastic models and time series analysis would identify correlation and self-correlations along the time better than regression and econometric analysis.

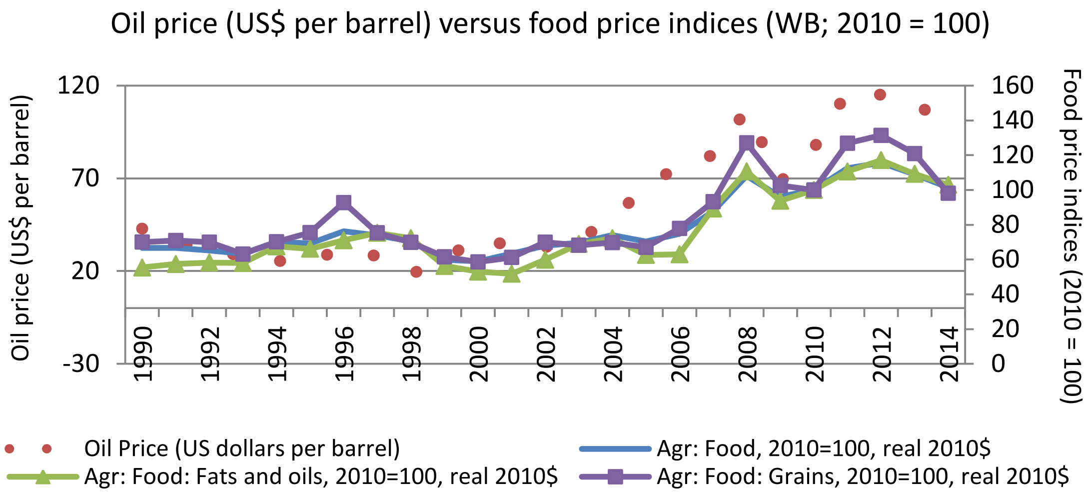
Table 2. The influence of biofuels quantitative analysis on agricultural commodity prices

Authors	Contribution to price rise
Mitchell (2009)	66% between 2002-2008
Rosegrant (2008)	30% between 2000-2007
Wright (2009)	Substantial price effect due to biofuels
USDA (2008)	13-18% between 2007-2008
FAO (2008)	7-15% between 2008-2018
OCDE (2008)	5-12% between 2008-2020
Von Witzke (2011)	0.1-4.6% between 2007-2008
Gibert (2010)	Hardly any effect by biofuels
Baffes & Haniotis (2010)	Hardly any effect by biofuels

Source: partially reproduced from Schmitz [39])

It is likely that common market causes have caused volatility in commodity prices. Gilbert concludes that global warming, oil price volatility transmitted via biofuel demand and index investment in future market might have led to a permanent increase in volatility, in particular in grains price [18]. Mueller *et al*. state that it not possible to reconcile claims that biofuel production was the major factor driving food price increase in 2007/8; but they suggest the cause of rising prices was a speculative bubble related to high petroleum prices (Figure 8), weak US dollar, and increased volatility due to commodity index fund investments [41]. Besides the growing middle class in developing countries and the biofuels production, the financialization of the commodity markets is also important to explain the changes in commodity prices [42], to what Baffes and Haniotis agreed [36]. Trostle points out many factors, namely the declining value of US dollar, rising energy prices, increasing agricultural costs of production, growing foreign exchange holdings and policies adopted by some exporting countries to mitigate their own food price inflation [43]. Indeed, Ajanovic also concluded that biofuels production had no significant impact on feedstock prices [13]. Figure 8 shows the oil price versus food price. It is possible to see that their variation has been quite the same in the last 14 years, which supports the hypotheses that oil price strongly affects all food commodity prices. The correlation can be seen in Table 1.

An analysis of the impact of biodiesel production must take into account the objective, the time considered, the feedstock used, the elasticity of demand and supply on each country [44]. Biodiesel is produced from rapeseed, soybean, palm oil, beef tallow, coconut and so on. When it is produced from a by-product like soybean, beef tallow and rapeseed, the production chain as a whole, will have valued added in. This can make the main product cheaper, or at least, the price of the main product can be more stable due to the value added by the by-product. Producing those feedstocks does not compete with food for land. On the other hand, using palm oil and jatropha can have a distinct effect on the competition with food for land. Even more if the oil is used for food industry, like palm oil. Therefore, the discussion would consider, at least, if the biofuel is produced from a residue and by-product, and if it is produced from a main product and edible oil. Notice that even if the biodiesel is produced from non-edible oil like jatropha or turnip-feed oil, for example, the competition for land may occur, unless marginal land is used. So, all these factors should be considered: if the feedstock is a main product, by-product or residues; the kind of land used and the yield of the oilseeds. The same rationale could be applied to ethanol, which has different feedstocks. Moreover, the competition food versus fuel cannot be settled by global models, mainly because they erase the local differences. A spatial structure of biofuel production, i.e. where and how it is produced and where it is consumed must be also analysed [45]. Summing up, the competition for land between biodiesel feedstock and food, and consequently, the influence on food commodity prices is neither direct nor simply connected.



Source: BP statistical review of World Energy June 2015 [30],
The World Bank – Global Economic Monitor (GEM) Commodities [37]

Figure 8. Oil prices versus food price indices

The role of biodiesel in food security

The amount of food produced on the planet is enough to feed everyone satisfactorily. The 2012/2013 harvests produced 2.415 billion tons of grain[††], which would mean 340 kg per year for each inhabitant of the planet, enough to ensure food security. However, along the food supply chain, food losses reach 1.3 billion tons per year [46]. This lost production occupied 1.4 billion hectares (ha), almost 30% of the world's agricultural land, with a financial cost of USD 750 billion, an environmental cost of 3.3 billion tons of CO_{2eq} emitted and 250 km^3 of potable water consumption [46]. Despite these figures, the number of undernourished people decreased by 26 million in the last two years [2], even with a record increase in biodiesel production. But the malnutrition persists in the poorest and most arid regions such as Sub-Saharan Africa (223 million people) and in East and South Asia (462 million people) [47]. Clearly, there is a distribution problem. On the one hand, there are 842 million people suffering from chronic hunger [2]; on the other hand, around 1.4 billion people are overweight, from which 500 million have severe obesity [3]. In countries like the US and Mexico, more than 31% of the population suffers from generalized obesity with

[††] http://www.fao.org/worldfoodsituation/csdb/en/

serious health problems. The hunger in the world is not related to amount of food produced, nor to the international food prices. There are many causes for the hunger in the world such as lack of investment in agriculture, climate and weather, war displacement, unstable markets, food wastage and poverty trap [48]. The latter is called trap because people can barely get out of it and also because poverty is the cause and effect of hunger. Those causes depend on both internal and external environments. Unstable markets can be related to food prices, but all causes are interconnected and they cannot be seen separately [48]. However, the proportion of undernourished in the developing regions has fallen from 23.3% in 1990 to 12.9% in 2014-2015. It is likely due to the efforts to accomplish the Millennium targets [49], not due to the decrease in international food prices. In conclusion, hunger does have a relationship with poverty and, probably, with how each country is linked to the global market, in central or peripheral position [50]. In this complex and broad context, what would be the role of the biodiesel in the food security?

World biodiesel production of 23.6 million of m^3 (431.3 thousand barrels/day) in 2012 [20] occupied approximately 19.4 million ha (Table 3), less than 0.39% of the 5 billion hectares occupied by agriculture in the world[‡‡]. The most optimistic prognosis of increased biodiesel production states 6% of oil consumption for transport in 2020; i.e. 200 million m^3 of biodiesel according to forecasts on oil demand by OPEC [47]. Assuming a conservative average oilseed yield of 2.2 m^3/ha[§§], 91 million ha would be needed to produce biodiesel by 2020, which correspond to 7% of the area used to produce the total food wasted in 2007, and less than 2% of the total area allocated to agriculture. However, these figures do not consider that most of the feedstock used is by-products, namely soybean, rapeseed and animal fat. For example, North-American biodiesel is produced from 52% of soybean [51], Brazilian biodiesel uses 75% of soybean and 19% of beef tallow [52]; German biodiesel uses 53% of rapeseed as feedstock [53]; and Argentina largely depends on soybean to produce biodiesel, speaking just about the four larger biodiesel producers. Roughly speaking, at least for 45% of the global biodiesel production, the land is used primarily to produce protein for feed and food, not biodiesel. Indeed, in 2014/15, the production of rapeseed and soybean produced 82% of the world's protein meal, counting 241 million metric tons [54]. Going further, it is possible to produce biodiesel without competing by land at all, if we use cooked oils [55, 56], esterified oils [57], or algae [58], for instance. Also it is possible to use some non-edible oils, such as jatropha and castor oil [49], that can be produced in degraded and marginal areas [55, 59], besides some fruit seeds considered as waste [53], which can decrease the total cost of biodiesel [60].

Therefore, the competition for land between the biodiesel and food commodities would be irrelevant. An impact on food commodity prices can hardly be assigned to biodiesel production. On the other way around, to produce one tone of biodiesel, it is necessary to produce about 3.3 tonnes of protein, considering an oilseed (soybean or rapeseed) with 20-30% of oil.

Agriculture faces huge challenges. So, it is necessary to adopt sustainable agricultural practices that take into account the resilience of the ecosystems, and can save fossil energy, nitrogen, phosphorus, water and soil organic matter, and, at the same time, increase productivity. Otherwise, the natural resources will continue to be depleted and, also, the small farmers will be expelled from agribusiness. There are risks

[‡‡] productivity of 2.2 m^3/ha due to: 25% soybean (0.68 m^3/ha), 20% rapeseed (1.31 m^3/ha) and 55% of oil palm (3.1 m^3/ha)

[§§] Weighted average productivity levels of the three main sources of biodiesel: soybean, palm and rapeseed and alternatives for sustainable production of biodiesel related to social, environmental and economic dimensions [5], for which there are suggestions such as strengthening family farming, ecological and agricultural zoning, creation of anti-trust laws and environmental certifications, among others [5]. Moreover, there are about 400 million ha of abandoned and degraded agriculture area in the world that can be used to produce biodiesel feedstock [59], as it has already been done in the Amazon biome using palm oil [62]. Besides that, increasing livestock productivity can also release up to 70 million ha (in Brazil) in the long term [63]. Summing up, restoring degraded land using oilseeds can bring more energy, more food and improve the income, but it requires investments. Thus, there is no doubt we need an integrated analytical perspective to make a "bio-based transition" to a new economy [64].

Table 3. Simulation of the total land used to produce biodiesel, considering the most common feedstock

Feedstock	2013 production [m^3]	Percentage	Yield [m^3/ha]	Land used [ha]
Rapeseed	7,316,000	0.31	1.31	5,584,732
Palm oil	2,832,000	0.12	3.1	913,548
Soybean	6,608,000	0.28	0.68	9,717,647
Others (taking the average yield)	6,844,000	0.29	2.13	3,213,145
Total	23,600,000			19,429,073

Source: elaborated by the authors, taking total production from [20] and percentages from [61]

Biofuels, in particular biodiesel feedstocks, have the potential to incorporate land of little agricultural value [55], restore degraded areas [59], promote crop rotation and soil improvement, besides pest control. Integrating small farmers into the production of biodiesel has led to the revitalization of rural areas [65], improvement of country life [66, 67], access to energy (generation of electricity), increase in income [65] and generation of jobs in rural areas [44, 67]. All these positive results can reduce the vulnerabilities[***] in tropical countries, increase the ability to cope with climate change and improve food security. On a large scale, biodiesel production can improve job creation and technological development, once the issues related to land tenure are solved [44, 65]. If properly integrated, food and energy production may be one of the best alternatives to improve energy and food security at the same time [68].

Another aspect to consider is that high prices may trigger a response in terms of increased agricultural production and employment, which could contribute to reduce poverty and improve food production in the long-term [29], since exporting barriers and price control policies are avoided. These last two issues may worsen and prolong the crisis by blocking price incentives for farmers and preventing them from increasing production. Internal market protection through surcharge on imported biodiesel is already a common practice in the European market. Recently, imported biodiesel was largely banned from that market through a surcharge that did make imported biodiesel (by EU) far more expensive than the one domestically produced in the European Union [69].

Some scenarios forecast the risk of energy scarcity in transport very soon: by 2015-2020, comparing the supply and demand for energy. Moreover, the critical energy constraints have the potential to provoke unexpected abrupt changes in societies and maybe the world political configuration [70].

[***] Social, environmental and economic

Opportunities for developing countries with growing demand for biofuels could be much higher if agricultural subsidies of biodiesel production and trade barriers were removed. Currently, they benefit OECD producers at the expense of developing countries' producers [29]. Hence food commodities and biofuels production are also related to the amount of subsidies and trade barriers, as shown in ethanol production in USA [71]. Taking the cellulosic biofuels as example, the analysis shows that technological development and policies can induce consumption, with less intensive use of land [71]. Also, if they are produced where there is still land available for agriculture, namely South American and African countries, biodiesel can contribute to reduce the global conflicting relationship between food and fuels [71].

To promote sustainable agricultural development to produce oilseeds, it is necessary to ensure biodiesel will contribute to reduce GHG emission, minimizing negative impacts on the environment, especially those related to the land use change [44, 72]. It can be stated that an important and pioneering conceptual path was traced and has been explored by Sachs, such as the "Green Civilization" [73] or "XXI Century Energy Revolution" [74]. Sachs shows that integrated systems of food and energy production can be an approach to promote bioenergy sustainability. Nonetheless, even in such systems, it is possible to see problems, like land use change and slavery for instance, especially in vulnerable regions from the socioeconomic point of view, such as in African [75] and Asian countries [65]. In most cases, there is no doubt that public biofuel policies have a central role in raising the biofuel production, as can be observed in Brazil [66] and Malaysia [76], and promoting a "bio-based" economy [64].

CONCLUSIONS

Despite the efforts spent by those interested in the issue, it has not been possible to ensure that the growing biodiesel production has been such an important cause of the increase in food commodity prices. Demand for food is increasing, the stocks are not. It will easily result in rise of food prices. Moreover, food prices are influenced by a set of conditions, including oil prices. The correlations found and the analysis show the inconsistency of stating that biodiesel production or any biofuel production has been responsible for increasing the food commodity prices. Moreover, those prices did not result in worsening the hunger in the world. World hunger is much older than the biofuel production. It has no relation to the global production of food, or to biodiesel production, or even to the international food prices. It is more likely that hunger does have a relationship with unequal distribution of the food produced, poverty and how each country is linked to the global market.

The competition between food and biodiesel for land can be irrelevant. The wasted food has occupied much more land than the biodiesel crops. Besides, several oilseeds can grow in marginal and degraded land helping to recover land and capture CO_2. Others produce protein (much more than oil) that can be used for food and feed. They can be produced in low latitudes where there are more social and economic vulnerabilities. Therefore, biodiesel can help raise the income of these populations, and consequently, it indirectly improves the access to food.

Nevertheless, the recorded increase of food price in 2007-2008 still reverberates today, strengthening the recommendations for reducing biofuel expansion goals. These positions find adherence in the European Union, the largest independent market for biodiesel. In addition to that, the financial crisis might have aided that important sectors of society supported the revision of mandatory targets. Such decisions have created uncertainties that contaminated all environmental policy. As a result, these changes in the biofuel mandates might have cancelled the vector of sustainable regional development in developing countries, which would have been benefited by the production and exporting of vegetable oil. This feedstock would be destined to the EU to meet the biodiesel market needs and, therefore, help to reach the reduction targets of CO_2 emissions.

The debate brought by the simultaneity between increases in food prices and biofuels production can be seen as a good opportunity to consider food and energy security together. A deeper look into the two issues, and a consistent analysis over history, can reveal a unique opportunity for the developing countries to improve the economic and social situation, since it be well conducted by local governments. The integration of some portion of the poorest populations in agricultural bioenergy production chain can promote social inclusion and enhance the life conditions in the countryside. In addition, biodiesel can help mitigating the effects of global warming and weaken the influence of oil geopolitics in global political instability. This approach is crucial to guide public policies for African, Asian and Latin-American countries, among others, which live with food and energy insecurity simultaneously.

In conclusion, stopping the production of biodiesel will not solve the hunger problem, but will worsen environmental conditions. Biodiesel is ready to be used without changes in the engines, replacing mineral diesel, reducing most of the emissions, and contributing to energy security. It can provide integrated solutions for environment, energy, social security and food in particular, when it is produced from the by product. Maybe it will not be a complete solution, but certainly is already a safe bridge for a new sustainable economy. Of course, as much as other renewable sources, it strongly depends on good policies that can address land tenure, supply and demand needs, R&D support and sustainable production. To leave biodiesel production to the "invisible hand" of the market is to be in favour of the oil industry and condemn a good solution to an early death.

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