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# Are forest transitions associated with the international trade of agricultural *commodities*?

Camila Espezio de Oliveira [I]
Leandro Reverberi Tambosi [II]
Adriane Calaboni [III]
Paulo Antônio de Almeida Sinisgalli [IV]
Helene Mariko Ueno [V]
Alexandre Toshiro Igari [VI]

***Abstract:*** Critics of the forest transition theory suggest that it occurs through the displacement of agricultural production abroad while exporting countries suffer agricultural expansion and deforestation. Other studies refute the idea of international trade as the main connection between the occurrence of the forest transition in importing countries and the advance of agricultural frontiers and deforestation in producing countries. Considering this divergence, we assessed whether international trade in agricultural commodities is associated with forest growth in importing countries and deforestation in exporting countries. Data on exports and imports of soy and palm oil among the leading countries in this market were confronted with their historical variation of forest cover between 1990 and 2020. The results suggest that global soy and palm oil markets significantly connect the exporting regions to importing countries that undergo forest transition.

***Keywords:*** Forest Transition; Deforestation; Forest gain; Land use change; Commodities trade.

[I] *Sustainability Post-graduate Program, University of São Paulo, São Paulo, SP, Brazil.*

[II] *Center for Engineering, Modeling and Applied Social Sciences, Federal University of ABC, Santo André, SP, Brazil.*

[III] *Center for Engineering, Modeling and Applied Social Sciences, Federal University of ABC, Santo André, SP, Brazil.*

[IV] *Environmental Science Post-graduate Program, University of São Paulo, São Paulo, SP, Brazil.*

[V] *Sustainability Post-graduate Program, University of São Paulo, São Paulo, SP, Brazil.*

[VI] *Sustainability Post-graduate Program, University of São Paulo, São Paulo, SP, Brazil.*

**São Paulo. Vol. 26, 2023**

*Original Article*

**DOI:** http://dx.doi.org/10.1590/1809-4422asoc0094r1vu2023L3OA

## Introduction

The Forest Transition Theory (FTT) states that forest stocks predictably change with the economic development of societies (MATHER, 1992; WALKER, 1993). After a period of continuous reduction of forest cover, there is a turning point towards a predominance of forest expansion (MATHER, 1992; WALKER, 1993; FARINACI et al., 2013). The first stage of economic development would rely on agriculture commodities expansion, which would promote massive deforestation. In the following stages, industry and services dominate the economy, and urbanization processes attract the rural population to the cities. Massive migration to urban areas would contribute to a labor shortage in the countryside and would ultimately increase agricultural production costs. In this scenario, production would concentrate in the more productive areas, and marginal areas would be released for native vegetation regrowth (MATHER, 1992; WALKER, 1993; RUDEL et al., 2005; XU et al., 2007; RUDEL et al., 2009; RUDEL et al., 2010; SILVA et al., 2016; RUDEL et al., 2020). The labor shortage would also boost agricultural mechanization, producing better results in the flatter and well-drained areas. Mechanization then fosters the abandonment of less suitable agricultural areas (MATHER, 1992; WALKER, 1993; RUDEL et al., 2005; RUDEL et al., 2009; PFAFF; WALKER, 2010; RUDEL et al., 2010; KLEPEIS et al., 2013; CALABONI et al., 2018). FTT also acknowledges that forest gains reflect government efforts regarding environmental conservation (MATHER, 1992; WALKER, 1993; RUDEL et al., 2005; RUDEL et al., 2009; RUDEL et al., 2020).

FTT offers simplistic and empirically testable pathways connecting native vegetation change to drivers such as farm labor, agricultural technology, and biophysical features of the rural lands at national and subnational scales (RUDEL et al., 2005; XU et al., 2007; SILVA et al., 2016; CALABONI et al., 2018; RUDEL et al., 2020). However, the effects of broader-scaled phenomena on national and subnational Forest Transitions (FT) are only partially estimated. Transference of commodities production to countries where agriculture is more competitive (facilitating countries) could release land for forest regrowth in FT countries (MEYFROIDT; LAMBIN, 2009; RUDEL et al., 2020). The transference of agricultural production from Europe and North America to tropical places intensified after 1970, while FT took place in temperate and developed countries (RUDEL et al., 2020).

Globalization of agricultural commodities markets stresses the comparative advantages of producer countries and fosters specialization and international division of economic activities. Comparative advantages, as institutional, social, and environmental issues, are drivers for the global allocation of agricultural activities and their associated environmental degradation (ABDULLAH; HEZRI, 2008; GRAU; AIDE, 2008; RUDEL et al., 2009; PFAFF; WALKER, 2010; WICKE et al., 2011; HOSONUMA et al., 2012; ANGELSEN; RUDEL, 2013; MEYFROIDT et al., 2013; IMAI et al., 2018). Therefore, the production of agricultural commodities usually migrates from less productive countries, under more restrictive labor and environmental policies, to others where legal, social, and biophysical conditions are more favorable to agricultural activities.

This phenomenon is known as Land-use Spillover, a situation in which land use

changes in one location affect the land use in other areas. The most common form of spillover is the leakage caused by regulations on land use, such as environmental conservation policies, which trigger changes in local, regional, or even transnational land use, according to their comparative environmental restrictions (MEYFROIDT; LAMBIN, 2009; LAMBIN; MEYFROIDT, 2011; MCCAY; RUDEL, 2012; ANGELSEN; RUDEL, 2013; MEYFROIDT et al., 2013; WARMAN; NELSON, 2016; MEYFROIDT et al., 2018; PENDRILL et al., 2019).

Exports of agricultural commodities are pivotal to the economy of countries with extensive forested areas, such as Brazil and Indonesia, which are among the world's major exporters of soybeans and palm oil, respectively (HELFAND; REZENDE, 2001; FAO, 2003; RADA; VALDES, 2012; MEYFROIDT et al., 2013; HENDERS et al., 2015; SAHIDE et al., 2015). Furthermore, Brazil and Indonesia account together for 36% of global forested area, 61% of gross deforestation in the humid tropics between 2000 and 2005, and almost half (44%) of the world's deforestation attributed to the expansion of agriculture, livestock, and forestry (MEYFROIDT et al., 2010; PENDRILL et al., 2019).

However, Meyfroidt et al. (2010) emphasize that global trade of agricultural commodities would not be the primary driver of the significant international land-use shifts. Policies aimed at forest conservation, reforestation, agricultural intensification, and land use planning may also contribute to the occurrence of FT phenomenon (ABDULLAH; HEZRI, 2008; IZQUIERDO et al., 2008; MEYFROIDT; LAMBIN, 2009; ANGELSEN; RUDEL, 2013; MEYFROIDT et al., 2013; JADIN et al., 2016; ASHRAF et al., 2017; GONZÁLEZ-VAL; PUEYO, 2017). The socio-ecological contexts in which FT has taken place in recent decades have changed drastically, so major changes have also occurred in the determinant factors of change in forest cover around the globe (IGARI; TAMBOSI, 2016; LEITE et al., 2020; RUDEL et al., 2020).

In Brazil, for example, part of the dynamics of land use may be connected to the effectiveness in imposing legal control over land use (IGARI; TAMBOSI, 2016). The first Brazilian Forest Code dates to 1934 (Federal Decree 23,793) and aimed at protecting native vegetation in areas with an essential environmental role from the expansion of agriculture. In 1965, Federal Law 4,471 was enacted, containing more explicit and clear criteria for conserving and rationalizing native vegetation on rural properties (BRANCALION et al., 2016; IGARI; PIVELLO, 2011). Federal law 12,651 of 2012, which replaces the 1965 Forest Code, modifies and undermines general norms for protecting natural vegetation, facilitating, in some cases, deforestation. Another critical point is the enactment of laws that stimulate international trade, like Brazilian complementary Law nº 87 of 1996, which ends the collection of tributes from exported goods.

As well as Brazil, Indonesian legislation also supports the protection of forests. Law 18 of 2013, for example, aims to prevent forest destruction, eradicate forms of degradation, establish public participation, increase international cooperation, obtaining financing for restoration projects, among other issues directly related to reversing illegal logging in the country. The Indonesian government points out the country's accelerating economic development efforts, which includes agricultural commodities production, as

the main cause of the accelerating negative impacts on the environment. This situation increases the need for political efforts to minimize environmental impacts and risks (INDONESIA, 1997).

As one of the major importer countries in the world, China also struggles to mitigate the problems of forest loss through specific public policies, such as the 'Grain for Green' after the Yangtze and Yellow River floods in 1998 (RUDEL et al., 2020), and the Natural Forest Conservation Program (NFCP), which aimed mainly at protecting and restore natural forests (ZHANG; UUSIVUORI; KUULUVAINEN, 2000). The NFCP had significant importance to the gain of forests in China between 2000 and 2010. However, the source of forest goods and other agricultural products may have been transferred to other parts of the world, "thus, China's conservation policy may be exacerbating forest degradation (through legal and illegal logging) in other regions" (VIÑA et al., 2016, p. 4).

The dispute between explanatory frameworks regarding the weight of international commerce on land use changes in exporters (facilitating countries) and importers (FT countries) of agricultural commodities demands empirical broad-scaled evidence for clarification of this trade-mediated FT phenomenon. In the present study, we used 31 years of nationally compiled data to assess the relationship between the forest cover changes and the international commerce of agricultural commodities (soybean and palm oil), aiming to verify if exporter countries presented forest reduction and importers underwent forest cover increase. We converted their trade (kg per year) to equivalent production area (ha) to evaluate the joint association between soybean and palm oil on land use. This approach is also replicable in future studies encompassing a broader set of agricultural commodities and timeframes.

## Material and Methods

This study relies on trade data from the United Nations Commodity Trade Statistics Database (UN COMTRADE database) and forest cover data gathered from the "Global Forest Resources Assessment (FRA)" issued by the Food and Agriculture Organization of the United Nations (FAO). The UN COMTRADE database compiles the annual global data of exports and imports of agricultural commodities. We focused our analysis on the global trade of two commodities, soybean and palm oil, which are the main export products of tropical countries with large forest cover. These exports also present significant participation in the world market, as well as a historical growth trend and, consequently, a substantial potential for even more expansion of planted areas (DEFRIES et al., 2006; LAMBIN; MEYFROIDT, 2010; CARLSON et al., 2012; KARSTENSEN et al., 2013).

FAO publishes, in 5- or 10-year intervals, the "Global Forest Resources Assessment" which summarizes the gains and losses of forest cover and the mainland uses around the world. One caveat regarding the FAO forest database: FAO reports include planted forests for commercial use in their definition of forest area, which is questionable, considering the marked diversity contrast between forest monocultures and native forests, especially

in biodiversity-rich tropical countries. The forest data in this study came from the FRA 2020 report, which assessed the status and trends of forest resources from 1990 to 2020. Data were compiled by hundreds of experts worldwide, involving the collaboration among many partner organizations, increasing methodological synergies among reporting processes and improving data consistency (FAO, 2020).

**Time horizon**

The study covered the period from 1990 to 2020, which comprises the intensification of global deforestation (ANGELSEN; RUDEL, 2013; PAGNUTTI et al., 2013; KEENAN et al., 2015), as well as the liberalization of international commerce that succeeded the Uruguay round and the emergence of the World Trade Organization (WTO). Trade liberalization fostered the expansion of soybeans and palm oil global trade after the 1990s (GONZÁLEZ-VAL; PUEYO, 2017).

On the other hand, the 1990s were also marked by substantive environmental advances from the United Nations Conference on Environment and Development (ECO 92). Global commitments as Agenda 21, Convention on Climate Change, and Convention on Biological Diversity were settled. Those international agreements fostered regional and domestic environmental policies which favored forest recovery and conservation (MATHER, 2007; MEYFROIDT; LAMBIN, 2009; RUDEL et al., 2009; ANGELSEN; RUDEL, 2013; JADIN et al., 2016).

In 2015, during the 21st Conference of Parties (COP), United Nations members signed the 2030 Agenda, which states that its signatories would strengthen sustainable development actions in various sectors, represented by 17 Sustainable Development Goals (FREY et al., 2020). Each one of the signatory countries has set its own targets to achieve the goals (NDCs), and a substantial number of countries proposed to meet its GHG emissions reduction targets by accelerating carbon sequestration through forest expansion (RUDEL et al., 2020).

Some importing nations, for instance, France, Italy, Japan, Spain, and the United Kingdom have possibly experienced long-term FT before 1990, as shown by Walker (1993). However, they were included in the dataset because we understand that they might still be experiencing the FT and, as importers of palm oil and soybean, they would encourage crop expansion in exporter nations.

The broad time horizon is also suitable for incorporating the lag times of forest losses and gains dynamics. The 31-year timeframe would be suitable to capture much of the possible forest gains and losses to reflect the intensification of international trade of agricultural commodities and the effects of the rise of national and regional government efforts for environmental conservation.

### Characterization of leading exporters and importers

The leading exporter and importer countries of soybeans and palm oil from 1990 to 2020 were identified in the UN COMTRADE database. The exporter and importer countries were incorporated in the dataset according to descending market share until the bottom limit of 0.5% of the total global exports or imports was reached. We have withdrawn countries that presented less than 27 years (90%) of trade data in the 1990-2020 period (31 years). Selected countries are presented in Table 1.

**Table 1 – Main exporters and importers of Soybeans and Palm oil between 1990 and 2020 and their respective average share (%) in the world market**

| | Main exporters | Main importers |
|---|---|---|
| **Soybeans** | USA (49%), Brazil (29.7%), Argentina (8.8%), Paraguay (4.3%), Canada (3%), Netherlands (1.3%) | China (48.8%), Japan (5.7%), Netherlands (5.25%), Germany (5%), Mexico (4%), Spain (3.8%), Thailand (2%), Indonesia (1.9%), Republic of Korea (1.7%), Italy (1.6%), Turkey (1.3%), Portugal (1.2%), Argentina (1%), United Kingdom (1%), Malaysia (0.8%), France (0.8%), Brazil (0.6%), Israel (0.5%), USA (0.5%) |
| **Palm oil** | Indonesia (46.3%), Malaysia (41.6%), Netherlands (3.1%), Guatemala (0.8%), Germany (0.7%), Colombia (0.8%), Thailand (0.6%), Singapore (0.5%) | India (29.9%), China (24.8%), Netherlands (9.7%), Malaysia (5.8%), Germany (5.6%), Italy (4.8%), Spain (4.2%), USA (4.2%), Japan (3.5%), United Kingdom (3.1%), Turkey (2.7%), Egypt (2.6%), Singapore (2.2%), Republic of Korea (2%), Saudi Arabia (1.8%), France (1.7%), Uganda (1.1%), Denmark (0.9%), Australia (0.8%), Brazil (0.7%), Sweden (0.6%) |

Source: Oliveira et al., 2023.

### Data analysis

To assess the relationship between the international trade of agricultural commodities and the forest cover change in importer and exporter countries, we used linear regressions between the relative forest variation (response variable) and the historical trend of the trade balance (explanatory variable).

The forest cover variation in each country was standardized according to the following proceeding: [(forest cover in 2020 – forest cover in 1990) / forest cover in 1990], to avoid a possible bias derived from countries with large forest extension. The normalized variation of small absolute values can show large relative variation, which actually is not significant to the analysis. Then, countries that presented less than 1 million hectares of forests in 1990 were withdrawn from the dataset.

The trade balance (exports – imports) of soybeans and palm oil (in kg) was cal-

culated for each country and each year in the period from 1990 to 2020. To integrate trade balances of both commodities in each country, the information on commodities trade in kg was converted to the equivalent cultivated area (in ha). The conversions took as reference the annual average productivity data (kg/ha) of each country, available in FAO's database (2022), for both soybeans and palm oil. For countries that did not have declared productivity data (Argentina, Australia, Canada, Denmark, Egypt, France, Germany, India, Italy, Japan, Malaysia, Netherlands, Portugal, Republic of Korea, Saudi Arabia, Singapore, Spain, Sweden, Turkey, Uganda, United Kingdom, USA) we used the average world productivity in the conversion. The conversion of trade balance in kg to the equivalent area in ha allows estimating the increase of cultivated area to supply the increase of trade balance in the period or, conversely, the decrease of the cultivated area as a response to trade balance reductions.

To generate our explanatory variable, we used the linear regression slope to estimate the historical trade balance trend for each country. The regression was based on the annual trade balance (exports-imports in equivalent ha) as a function of the study period years, with 1990 as the year zero and 2020 as the year 30. The slope (b) of the linear regression is given by equation (1), which represents the average increase (if positive) or decrease (if negative) of the trade balance from 1990 to 2020. The value of slope b was standardized for each country (divided by the average trade balance in the period) to avoid eventual bias from major exporting or importing countries in the trade dataset.

$$(1)\ b = \frac{\Sigma\,(x-\underline{x})\,(y-\underline{y})}{\Sigma\,(x-\underline{x})^{2}}$$

In order to avoid small absolute values that can show sizeable relative variation, which is irrelevant to the analysis, countries with less than 100,000 equivalent ha of average trade balance from 1990 to 2020 were withdrawn from the dataset. The combined exclusion criteria - small absolute values of forest cover or trade balance - resulted in 21 selected countries for data analysis.

We then created linear models for the forest cover variation as a function of the historical trend (slope) in the commodities trade. R-squared was used to evaluate the goodness-of-fit of the linear models (LEGENDRE; LEGENDRE, 1998). The statistical significance (p-value) was then estimated from 10,000 randomizations of the response variable (MANLY, 2006), utilizing the R environment (http://www.r-project.org/). The p values obtained represent the proportion of regressions from the randomizations of the response variable, which present an R-squared value greater than or equal to the value calculated from the original data arrangement in each scenario. The linear regressions with p-value smaller than 0.05 were considered significant.

We preferred to test the significance of the regressions through data randomization instead of regular parametric regressions because of the limited size of the final dataset (21 countries), which would hinder traditional statistical analysis. The methods are suitable

for further inclusion of commodities, and the study can be expanded to larger datasets in which parametric regressions could be undertaken. This research, however, aims to present the analysis results in a more limited and controlled dataset.

Since the initial choice of the commodities was influenced by their potential effect on land use in Brazil and Indonesia, data analysis applyed two scenarios: 1) with all 21 countries; 2) excluding Brazil and Indonesia from the analyzed countries group. The second scenario evaluates the sensibility of the regression to Brazil and Indonesia data. Furthermore, noticing *ex-post* that China contributed with a considerable positive variation of forests and negative trade balance variation, two additional scenarios were created to evaluate possible changes in the results due to the three significant traders (Brazil, Indonesia, and China). The third scenario excluded only China from the regression, and the fourth scenario excluded Brazil, Indonesia, and China simultaneously.

## Results

We found six countries with negative trade balance variation and positive forest variation between 1990 and 2020 (China, Germany, India, Italy, Thailand, Turkey). In these countries, imports grew more than exports, while forest gains were larger than deforestation. Complementarily, 8 countries (Argentina, Brazil, Canada, Indonesia, Japan, Malaysia, Paraguay, Republic of Korea) presented a positive trade balance variation (exports grew more than imports) and negative forest variation, indicating that trade balance growth in these countries is associated to forest loss over the 31 years. The other three countries showed a reduction in trade balance and forest loss (Colombia, Mexico, Portugal). In contrast, the other 4 presented increased trade balance and net forest gains between 1990 and 2020 (France, Spain, United Kingdom, USA) (Table 2).

**Table 2 – Trade balance and forest variation in the 21 leading exporters and importers of soybeans and palm oil between 1990 and 2020. Positive values trade balance = increase in the trade balance in the period. Negative values trade balance = decreases in the trade balance in the period. Positive values forest = gains exceeded forest losses in the period. Negative values forest = predominance of deforestation.**

| Country | Trade balance variation (%) | Forest variation (%) |
|---|---|---|
| Argentina | 1.55 | -18.84 |
| Brazil | 7.29 | -15.67 |
| Canada | 9.56 | -0.39 |
| China | -10.36 | 27.66 |
| Colombia | -3.41 | -8.95 |
| France | 0.41 | 19.51 |
| Germany | -0.06 | 1.05 |
| India | -7.92 | 12.86 |

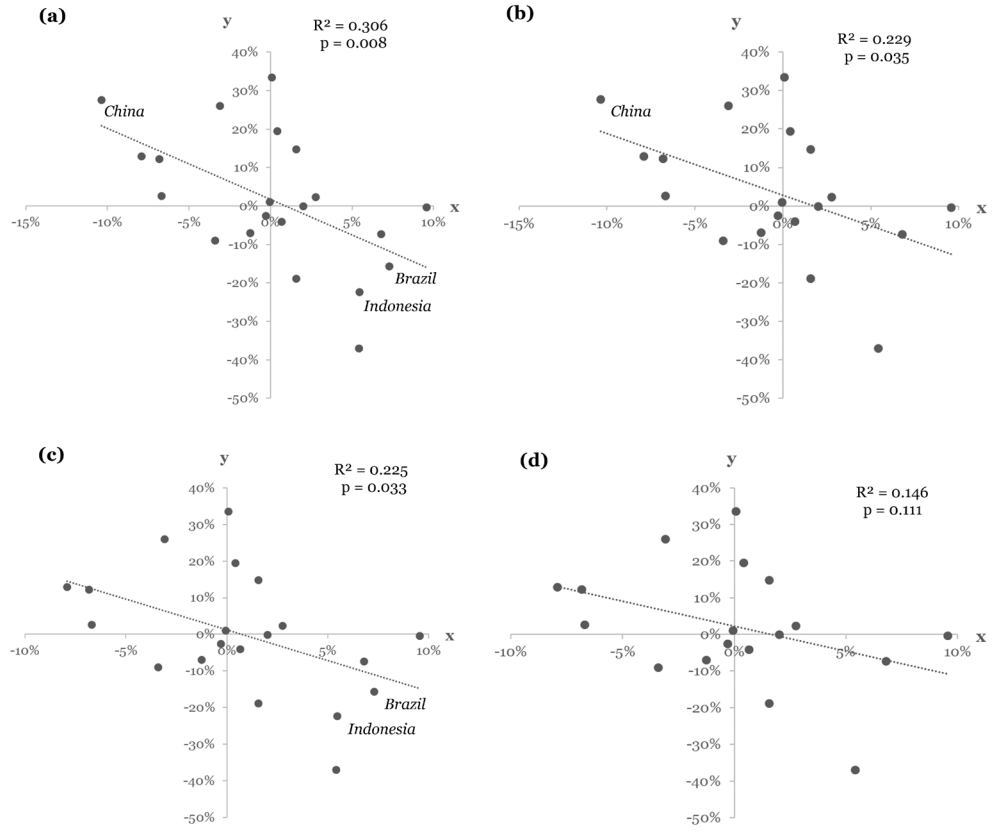
| Country | Trade balance variation (%) | Forest variation (%) |
|---|---|---|
| Indonesia | 5.45 | -22.28 |
| Italy | -3.11 | 26.03 |
| Japan | 1.99 | -0.06 |
| Malaysia | 6.78 | -7.30 |
| Mexico | -1.27 | -6.94 |
| Paraguay | 5.40 | -36.97 |
| Portugal | -0.30 | -2.56 |
| Republic of Korea | 0.66 | -4.03 |
| Spain | 0.06 | 33.56 |
| Thailand | -6.70 | 2.64 |
| Turkey | -6.85 | 12.32 |
| United Kingdom | 1.55 | 14.83 |
| USA | 2.75 | 2.43 |

Source: Oliveira et al., 2023.

The scenario with all 21 countries (Figure 1a) corroborates the proposition that exporters lose forests while importers gain forests ($R^2$=0.306, p=0.008). When the significant exporters, Brazil and Indonesia, are excluded from the analysis (Figure 1b), the pattern of exporters/forest loss and importers/forest gains remain. However, the explanatory power of the regression decreased ($R^2$=0.229, p=0.035). A similar result is observed when only China, the most outstanding importer, is excluded from the analysis ($R^2$=0.225, p=0.033) (Figure 1c).

The fourth scenario, carried out *a posteriori*, left out simultaneously Brazil, Indonesia, and China (Figure 1d) to assess the joint influence of the countries in the analysis. This analysis shows that the results are not significant (p> 0.05). However, even in this scenario, the downward trend of linear regression remains observable.

**Figure 1 – Forest variation (% on the vertical axis) relative to the trade balance variation of soybeans and palm oil between 1990 and 2020 (% on the horizontal axis) in 21 countries (dots). In the y-axis, the positive values indicate a predominance of forest gain, while the negative indicates the predominance of deforestation. In the x-axis, the positive values indicate growth of the trade balance, while the negative indicates a decrease.**




Source: Oliveira et al., 2023

## Discussion

The large-scale production of soybean and palm oil to international markets has been pointed out as the main contribution to tropical deforestation, mainly after 1990 (GRAU; AIDE, 2008; RUDEL et al., 2009; WICKE et al., 2011; HOSONUMA et al., 2012; IMAI et al., 2018; PENDRILL et al., 2019). Countries with expressive agricultural comparative advantages (e.g., availability of fertile soils, water, and suitable climate), such as Brazil and Indonesia, supply the agricultural demand of developed countries through the expansion of production areas at the expense of deforestation of their tropical mega-diverse forests (MEYFROIDT et al., 2013; RUDEL et al., 2020). Brazil and

Indonesia increasingly supply the growth of global demand for soybeans and palm oil, mainly to China and European Union, leading to an increase of agricultural expansion and the consequent loss of forest cover (ARIMA et al., 2011; CARLSON et al., 2012; MEYFROIDT et al., 2013).

Much of the deforested areas do not immediately give way to agricultural areas. Instead, much of Brazilian forests are first converted into extensive pastures, and only after consolidation of land tenure they are converted to capital-intensive agricultural areas, such as soybean production (BARONA et al., 2010; FERREIRA et al., 2015; JADIN et al., 2016; CALABONI et al., 2018). We understand that the 31 years timeframe in this study is broad enough to capture this land use succession.

Linear regression results suggest the occurrence of the phenomenon of international trade-mediated forest spillover, which corroborates the findings of Mather (2007), Grau et al. (2008), Meyfroidt & Lambin (2009), Kastner et al. (2011), Lambin & Meyfroidt (2011), McCay & Rudel (2012), Angelsen & Rudel (2013), Meyfroidt et al. (2013), Pagnutti et al. (2013), Warman & Nelson (2016). The simultaneous withdrawal of Brazil, Indonesia, and China from the dataset in the fourth scenario resulted in non-significant linear regression. Therefore, the global forest leakage is particularly influenced by soybeans trade between Brazil and China, which has intensified since the 2000s, along with commodities trade liberalization (WÜTENBERGER et al., 2006). Brazil then represents a facilitating region for FT in China.

The changes in land use in China were marked by economic development, industrialization, and urbanization (ASHRAF et al., 2017; LU et al., 2021); as well as the enactment of more restrictive environmental policies, contributed to the expansion of forested area and reduction of deforestation (YANG, 2001; MATHER, 2007). The increase in demand for wood and other forest ecosystem services, the increase in urban population, more restrictive environmental policies, and the increase in industrial and service jobs created multiple paths for FT in China (ESTOQUE et al., 2022).

On the other hand, in Indonesia, the rural contribution to economic growth is identified as the primary cause of the accelerating environmental negative impacts (INDONESIA, 1997). The conversion of forests to palm oil plantations is fostered by exports to countries that have undergone radical improvements in their environmental policies, such as India (MATHER, 2007).

China, France, Germany, India, Italy, Spain, Thailand, Turkey, the United Kingdom, and the USA gained forests between 1990 and 2020. Results suggest that some of their FT in this period may have been facilitated by imports of agricultural commodities from exporting countries, such as Argentina, Brazil, Canada, Indonesia, Malaysia, and Paraguay, which have lost forests during this period. Then, our results corroborate the hypothesis that trade globalization facilitates FT in importing countries through displacement of their agricultural production abroad (MATHER, 2007; GRAU et al., 2008; MEYFROIDT; LAMBIN, 2009; ANGELSEN; RUDEL, 2013; KASTNER et al., 2011; LAMBIN; MEYFROIDT, 2011; MCCAY; RUDEL, 2012; MEYFROIDT et al., 2013; PAGNUTTI et al., 2013; WARMAN; NELSON, 2016; RUDEL et al., 2020). The results

of Meyfroidt et al. (2010) also suggest the relationship between FT and the displacement of agricultural production abroad between 1960 and 2007 regarding 12 countries, among which China appears as an FT country, while Brazil and Indonesia are countries which did not undergo FT.

However, countries also present idiosyncratic domestic issues that influence the variation of forests, as the increase of forests associated with local cultural influence and forced outmigration due to armed conflicts (HECHT; SAATCHI, 2007; BRUGGEMAN et al., 2016). Another point is that some countries struggle to comply with the Nationally Determined Contributions (NDCs) of the Paris Agreement, which can result in more restrictive policies for reforestation (RUDEL et al., 2020). Both cases stress that international trade by itself would not explain the complex FT phenomenon completely. As Rudel et al. (2020) pointed out, despite the FT arguably shows a predictable pattern of land use and cover change during economic development, the socio-ecological contexts in which the transitions take place changes over time. Non-intentional FT pathways in which producers abandoned their lands in search of better welfare in the cities are combined with intentional FT pathways where the forest increase occurred through active environmental policies of governments.

Lingchao et al. (2017) analyzed nine developing countries, of which three (China, India, and Vietnam) underwent FT in the 1980s and 1990s, while the others presented forest loss (Brazil, Indonesia, Myanmar, Argentina, Cameroon, and the Central African Republic). In FT countries, there was a rapid reduction in total exports of primary products after the 1980s. On the other hand, non-FT countries experienced a significant decline in native coverage associated with increasing exports of agricultural products in the same period. Our study found that, as shown by Lingchao et al. (2017), Brazil, Indonesia, and Argentina presented a marked decline in forest cover and appeared among the leading exporters of soybean and palm oil. Complementarily, China, and India figured as FT countries since the 1990s and also as the leading importers of these commodities.

On the other hand, the present study identifies some countries that did not reflect the predominant relation between the international trade of commodities and the occurrence of FT or deforestation in the analysis period. France, Spain, the United Kingdom and the USA showed gains in forested areas associated with increased soybeans and palm oil trade balance. Conversely, Colombia, Mexico, and Portugal showed a decline in trade balance and a reduction in forest cover. Other issues drive each country's land use and trade dynamics (MEYFROIDT et al., 2010). Among France, Spain, the United Kingdom and the USA, only USA presents an increase in positive values of trade balance (predominance of exports). The increase in the trade balance in the United Kingdom is due to the values in more recent years being less negative than those of previous years, showing a trend of reduction in imports, although still the imports being larger than exports. France and Spain show subtle changes in the negative trade balance over the years, and the positive trend in the trade balance is negligible compared to the forestry gains over the period (Table 2).

The expansion of agricultural production in the USA is concentrated in the coun-

try's Center-South. Meanwhile, forest gains occur mainly in the North, which suggests a subnational scaled FT–facilitating dynamics (RUDEL, 2001). Large countries such as USA and Brazil can simultaneously show FT and agriculture expansion in different regions (RUDEL, 2001; PFAFF; WALKER, 2010; CALABONI et al., 2018), which could lead to confounding aggregated national patterns. Furthermore, forest gains can coincide with agricultural expansion over non-forest native vegetation. In Brazil and Indonesia, massive deforestation may conceal a subnational FT.

Colombia and Mexico showed a decrease in the trade balance and figured as net importers of the commodities, but these changes were not associated with forest gains. In 2019 Mexico had 33.5% of its area covered by forests and 49% of the land under agricultural use (FAO, 2019a). The main crops in Mexico are sugarcane, corn, and sorghum. Therefore, soybean and palm oil do not play a relevant role in Mexican agriculture, and their imports increase has not avoided substantial forest loss.

Despite figuring as one of the leading exporters of palm oil, Colombia was identified as importing country because the quantity of palm oil exported between 1990 and 2020 (18,944,295 tons) is smaller than the total of soybeans imported by the country (40,307,369 tons) in the same period. The forest reduction in the last decades in Colombia was mainly caused by armed conflict, narcotic plantations, illicit mining, and logging (LANDHOLM et al., 2019). On the other hand, the expansion of palm oil, which represents 1% of the Colombian agricultural area in 2021 (FAO, 2019b; FAO, 2022), occurs mainly in non-forested lands (FURUMO; AIDE, 2017). Between 2002 and 2008, about 56% of the palm oil expansion occurred over pastures, 30% replaced croplands, and the other 16% replaced natural vegetation; that is, nearly 86% of the expansion occurred on previously deforested lands instead of natural areas (FURUMO; AIDE, 2017). Although palm oil is one of the largest crops in the country, deforestation in Colombia cannot be directly associated with the production and trade of this commodity.

Portugal, in turn, showed a decrease in the trade balance in the studied period, reinforcing its role as importing country of soybeans and palm oil, while it also presents a reduction in forest cover. Recent research shows evidence of FT in Portugal until the 1990s when the agricultural area suffered significant reductions, replaced by forest areas (OLIVEIRA et al., 2017; ALVES et al., 2022). After the 1990s, there was an inversion in the expansion of wooded and shrubby areas, and this reduction was mainly related to the large fires in the more central and northern areas of the country (SILVA et al., 2011; OLIVEIRA et al., 2017; ALVES et al., 2022).

Despite the previously discussed exceptions, present evidence corroborates that world agricultural commodity markets connect facilitating regions that provide the agricultural products which make FT possible in importing countries (PFAFF; WALKER, 2010). This effect of environmental leakage occurs when activities are displaced to other regions, recurrently as a way to escape from more restrictive environmental policies. The leakage is perceived in the present analysis through the substantial increase in the soybean trade balance in Argentina, Brazil, and Paraguay and of palm oil by Indonesia and Malaysia, associated with the reduction of forest area in all these countries. India imports

almost 100% of its palm oil from Indonesia and Malaysia. However, the occurrence of FT in India is also attributed to a radical change in environmental policies and much of the forest increase is due to silviculture (MATHER, 2007).

## Conclusions

Results support a significant relationship between the international trade of agricultural commodities and the predominance of forest gains in commodity-importing countries and deforestation in exporting ones. The findings corroborate the proposition that international trade represents a channel for allocating socioenvironmental impacts between regions. Therefore, international trade of agricultural commodities mediates agricultural production and deforestation leakage. Clearly, the leakage should not be seen as a single driver for current levels of deforestation. However, it plays a crucial role in land use changes that reflect the changes in the economic structure of each country.

The aggregated analysis of the international trade of soybeans and palm oil allowed evaluation of their joint facilitating effect of agricultural expansion, mainly in Malaysia, Indonesia, and Brazil, on FT abroad. The aggregated analysis relied on the conversion of trade, usually given in kilograms, to the equivalent in local cultivated areas. This approach allows estimating the combined effect of the trade of many other commodities on land use change. We recommend that future studies investigate, departing from the same methodological approach, if alternative sets of commodities deliver similar results.

## Acknowledgments

This work was carried out with the support of the Coordination for the Improvement of Higher Education Personnel – Brazil (CAPES) – Financing Code 001.

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**Camila Espezio de Oliveira**

✉ camila.espezio.oliveira@usp.br

ORCiD: https://orcid.org/0000-0002-1775-0321

Submitted on: 21/06/2022
Accepted on: 18/04/2023
2023;26:e00941

**Leandro Reverberi Tambosi**

✉ l.tambosi@ufabc.edu.br

ORCiD: https://orcid.org/0000-0001-5486-7310

**Adriane Calaboni**

✉ adriane.calaboni@gmail.com

ORCiD: https://orcid.org/0000-0002-7217-4697

**Paulo Antônio de Almeida Sinisgalli**

✉ psinisgalli@usp.br

ORCiD: https://orcid.org/0000-0001-7822-3499

**Helene Mariko Ueno**

✉ papoula@usp.br

ORCiD: https://orcid.org/0000-0003-2133-9145

**Alexandre Toshiro Igari**

✉ alexandre.igari@usp.br

ORCiD: https://orcid.org/0000-0002-1382-5031

AMBIENTE & SOCIEDADE 25 anos 25 años 25 years

SciELO

# Estão as transições florestais associadas ao comércio internacional de *commodities* agrícolas?

Camila Espezio de Oliveira
Leandro Reverberi Tambosi
Adriane Calaboni
Paulo Antônio de Almeida Sinisgalli
Helene Mariko Ueno
Alexandre Toshiro Igari

***Resumo:*** Críticos da teoria de transição florestal sugerem que ela ocorre através do deslocamento da produção agrícola para o exterior, enquanto países exportadores sofrem expansão da agricultura e desmatamento. Outros estudos refutam a ideia do comércio internacional como principal elo entre a ocorrência da transição florestal nos países importadores e o avanço das fronteiras agrícolas e desmatamento nos países produtores. Considerando tal divergência, buscou-se avaliar se o comércio internacional de *commodities* agrícolas está associado ao crescimento florestal em países importadores e ao desmatamento em países exportadores. Dados das exportações e importações de soja e óleo de palma entre os principais países envolvidos nesse mercado foram confrontados com sua variação histórica da cobertura florestal entre 1990 e 2020. Os resultados sugerem que os mercados globais de soja e óleo de palma conectam significativamente as regiões exportadoras aos países importadores que passam pela transição florestal.

***Palavras-chave:*** Transição Florestal; Desmatamento; Ganho florestal; Mudança de uso da terra; Comércio de *commodities*.

**São Paulo. Vol. 26, 2023**

*Artigo Original*

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SciELO

# ¿Están las transiciones forestales asociadas al comercio internacional de *commodities*

Camila Espezio de Oliveira
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Helene Mariko Ueno
Alexandre Toshiro Igari

São Paulo. Vol. 26, 2023
*Artículo Original*

***Resumen:*** Críticos de la teoría de transición forestal sugieren que ella ocurre mediante el desplazamiento de la producción agrícola al extranjero, mientras que los países exportadores sufren expansión agrícola y deforestación. Otros estudios refutan la idea del comercio internacional como principal vínculo entre la ocurrencia de transición forestal en países importadores y el avance de las fronteras agrícolas y deforestación en países productores. Teniendo en cuenta esta divergencia, buscamos evaluar si el comercio internacional de *commodities* agrícolas está asociado con el crecimiento forestal en los países importadores y la deforestación en los países exportadores. Los datos sobre exportaciones y importaciones de soja y aceite de palma entre los principales países involucrados en este mercado se compararon con su variación histórica en la cubierta forestal entre 1990 y 2020. Los resultados sugieren que los mercados mundiales de soja y aceite de palma conectan significativamente las regiones exportadoras con los países importadores en transición forestal.

***Palabras-clave:*** Transición Forestal; deforestación; aumento forestal; cambio de uso de la tierra; comercio de *commodities* agrícolas.