# Is Worldwide Deforestation Associated with Agricultural Commodities Price Fluctuations?

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# Is Worldwide Deforestation Associated with Agricultural Commodities Price Fluctuations?

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1. Motivation
2. Visual
3. Data
4. Method
5. Results
6. Discussion

# Literature

Expansion of commercial **agriculture** for export markets ⇒ a driver of **deforestation** that emerged in the 1980s (Rudel et al., 2009)

Recent deforestation in developing countries linked to trade of forestry & agricultural commodities (Pendril et al., 2019) & correlated with international **agricultural export value per land unit** (Leblois et al., 2017).

Link already unveiled for some **crops** & **regions** (Rubber in Cambodia: Grogan, 2019; Soybean in Bolivia: Fehlenberg et al., 2017 in cross section) or in **meta-analysis** (Busch et al., 2017)

Curtis et al. (2018) spatially attribute deforestation among a classification of drivers, ⇒ **agricultural** as the **major driver of global forest loss** (either commodity driven deforestation or shifting to agriculture) specifically in the Southern hemisphere.

# Literature

- Expanding cropland, pastures and forest plantations responsible of:
  - 70% of total tropical forest loss (2005-2013) in Lawson (2014)
  - 80% in Hosonuma et al. (2012).
  - 60% in Pendrill et al. (2019a)

- Recent focus on imported deforestation around the world:

  ⋆ European commission roadmap for reducing deforestation impacts of products sold in the EU.

  ⋆ France: reflexion about the national strategic scheme to fight imported deforestation has been launched.

  ⋆ US: carbon tax at the borders included in the green new deal.

# Motivation

- Land use changes are known to account for more than 20% of human greenhouse gas emissions
- Forest additionally provides numerous ecosystemic services
- Prices provide incentives to orient agent decisions

**Research questions**:

⋆ To what extent locally identified agricultural expansion reacts to global international demand for commodities?

⋆ Global approach:
$\neq$ between temperate, tropical and boreal forests ?

⋆ Future impacts considering price forecasts ?

- Pushes forward socio-economically focused models of deforestation & improves the predictive capacity of modeling spatial and temporal evolution of global tree cover losses.

# What is new in our approach:

- We provide, to our knowledge, the $1^{st}$ worldwide **robust statistical analysis** of **price shocks** impact on **forest disturbance**

- **Quantification** of **global** deforestation shocks, using recent high resolution data, complementary to existing studies of other disciplines

⋆ Pendrill et al. (2019b) associate historical trade flows to land use change and compute carbon balance of trade flows.

⋆ Barona et al. (2010) look at the specific role of pastures and soybean in Latin America.

⋆ Abman and Lundberg (2020) show that, following the enactment of a regional trade agreement, signatory countries are strongly affected by deforestation.

# What do we find?

Result in brief:

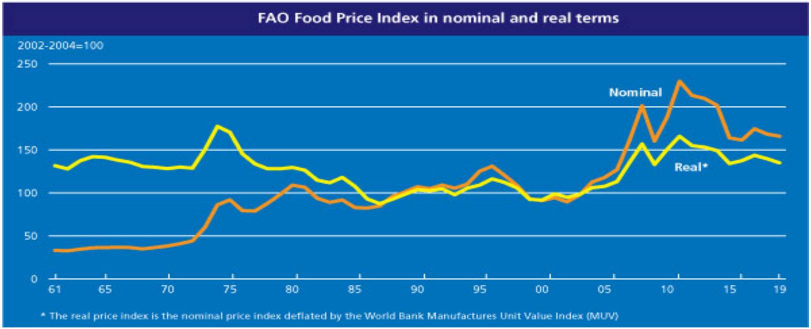
- Large and robust global impact (2001-2018)

- Not only in the tropics, happening mostly after 2007

- Price forecasts (2030) suggest large future impacts

# Prices variations

Figure: Fao food price index

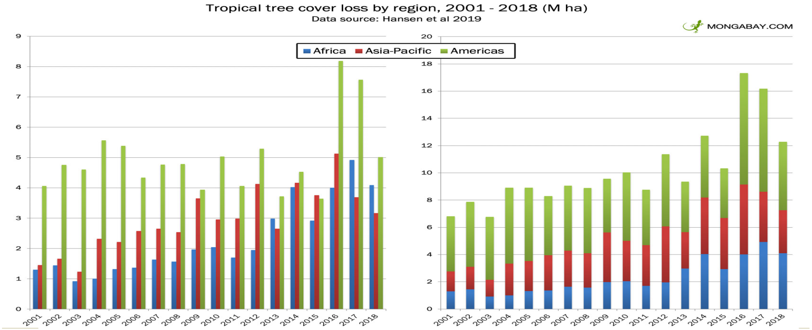



Source: FAO

Specificity of 2006-2013 period, (probably oil prices, increasing costs: inputs such as fertilizers and transport).

# Deforestation variations

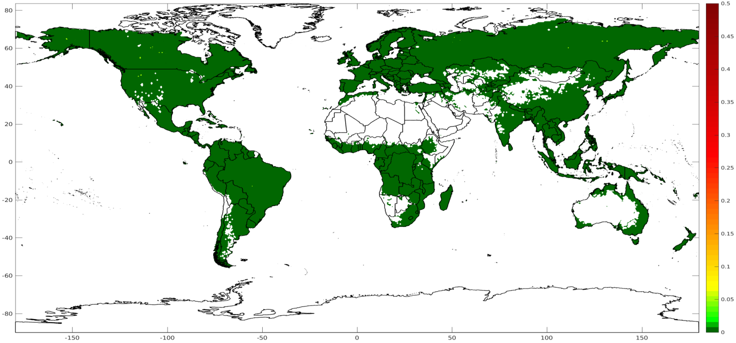
Figure: Tropical Deforestation 2000-2018




Significant ↗ in Africa (2013)
& stable ↗ in Asia-Pacific region
Source: Hansen (2013)

# Deforestation 2001-2018

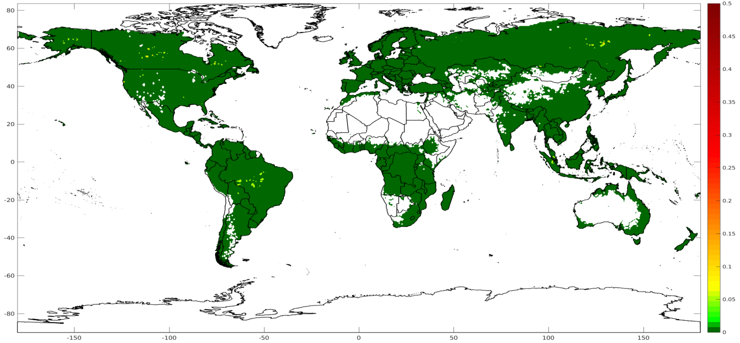
Figure: Accumulated deforestation: 2001




Source: Hansen et al. (2013)

# Deforestation 2001-2018

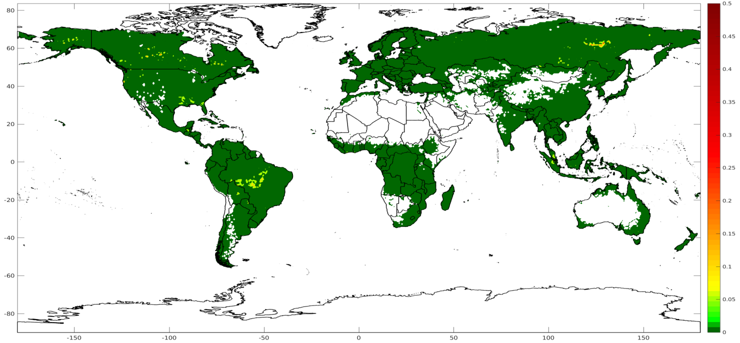
Figure: Accumulated deforestation: 2002




Source: Hansen et al. (2013)

# Deforestation 2001-2018

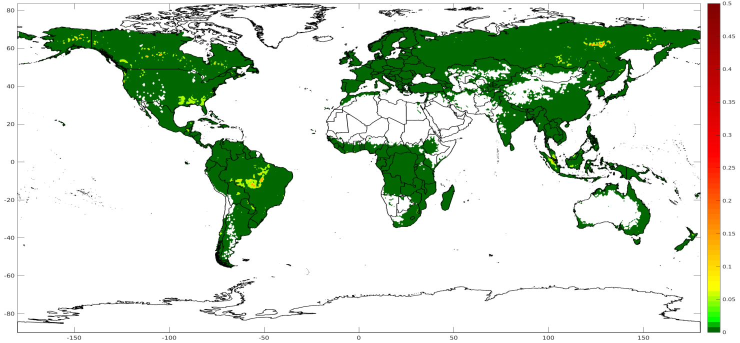
Figure: Accumulated deforestation: 2003




Source: Hansen et al. (2013)

# Deforestation 2001-2018

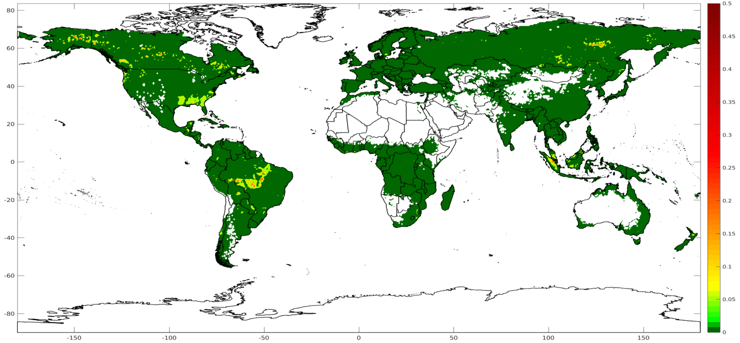
Figure: Accumulated deforestation: 2004




Source: Hansen et al. (2013)

# Deforestation 2001-2018

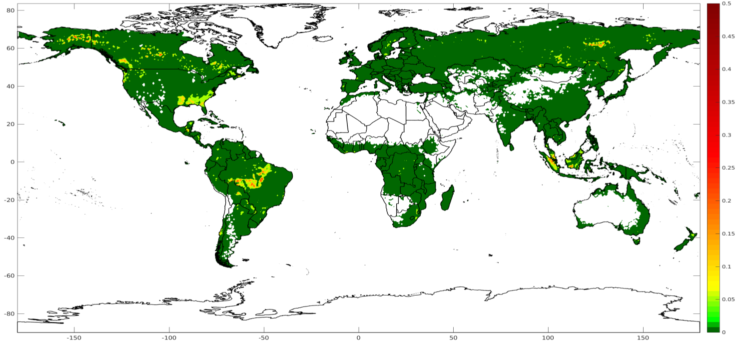
Figure: Accumulated deforestation: 2005




Source: Hansen et al. (2013)

# Deforestation 2001-2018

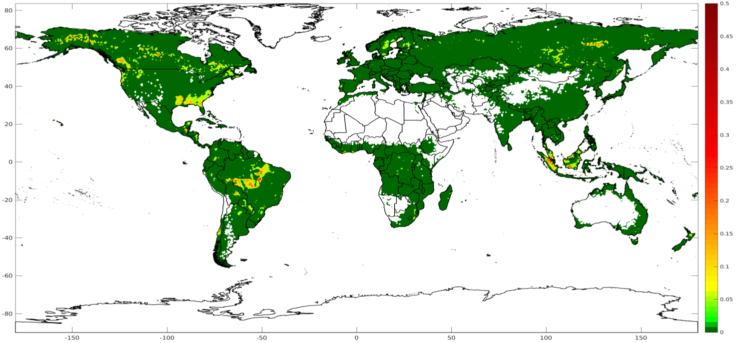
Figure: Accumulated deforestation: 2006




Source: Hansen et al. (2013)

# Deforestation 2001-2018

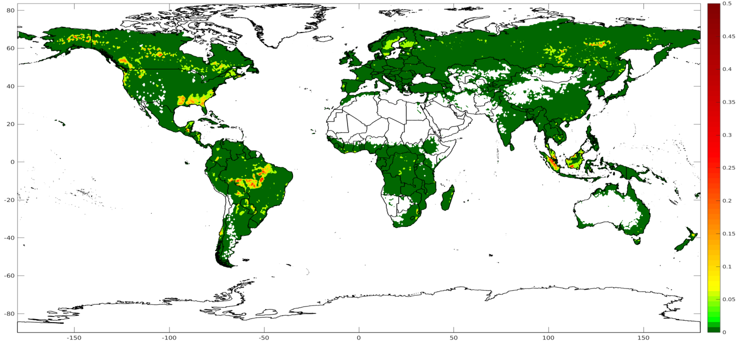
Figure: Accumulated deforestation: 2007




Source: Hansen et al. (2013)

# Deforestation 2001-2018

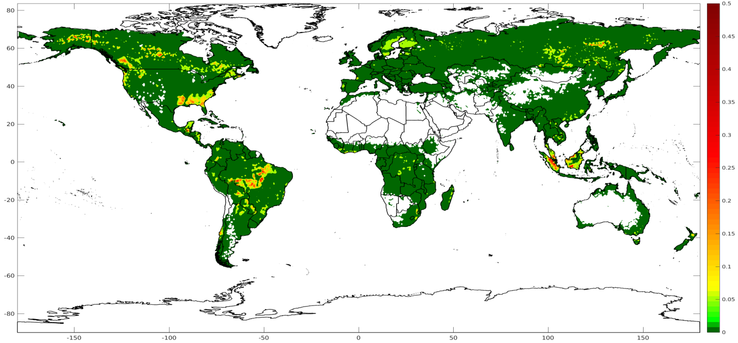
Figure: Accumulated deforestation: 2008




Source: Hansen et al. (2013)

# Deforestation 2001-2018

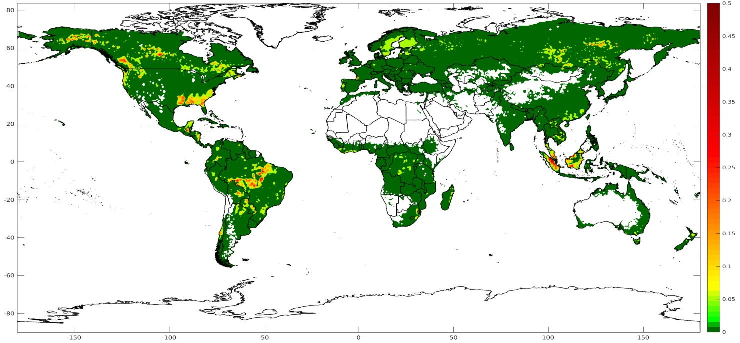
Figure: Accumulated deforestation: 2009




Source: Hansen et al. (2013)

# Deforestation 2001-2018

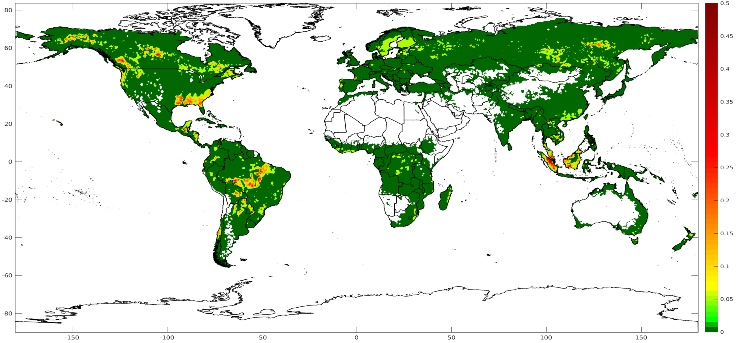
Figure: Accumulated deforestation: 2010




Source: Hansen et al. (2013)

# Deforestation 2001-2018

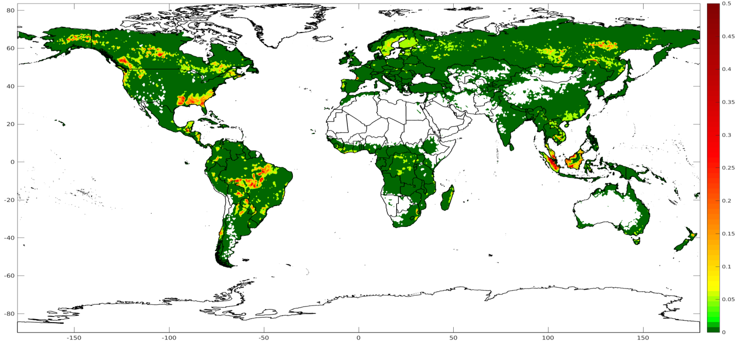
Figure: Accumulated deforestation: 2011




Source: Hansen et al. (2013)

# Deforestation 2001-2018

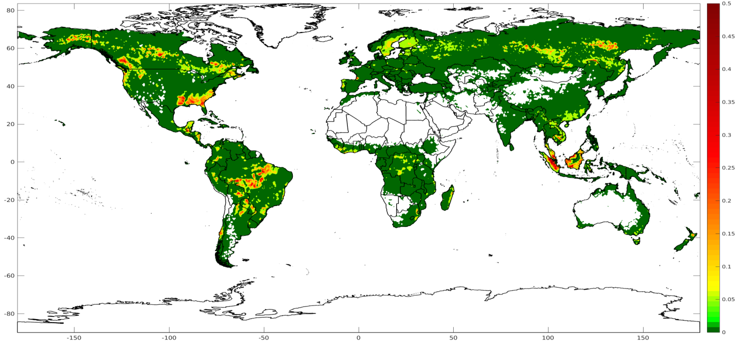
Figure: Accumulated deforestation: 2012




Source: Hansen et al. (2013)

# Deforestation 2001-2018

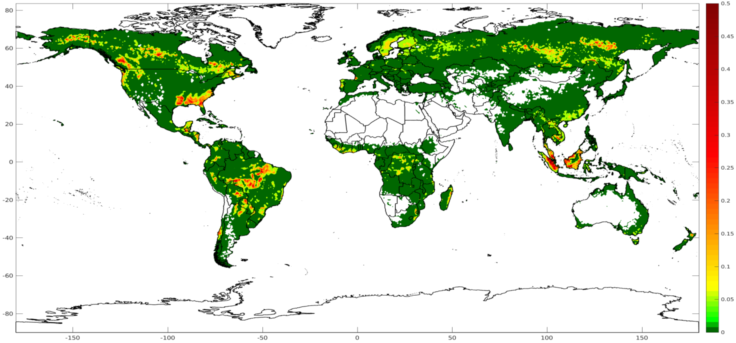
Figure: Accumulated deforestation: 2013




Source: Hansen et al. (2013)

# Deforestation 2001-2018

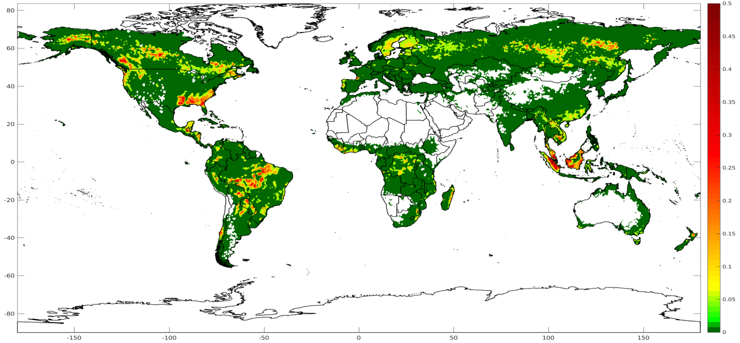
Figure: Accumulated deforestation: 2014




Source: Hansen et al. (2013)

# Deforestation 2001-2018

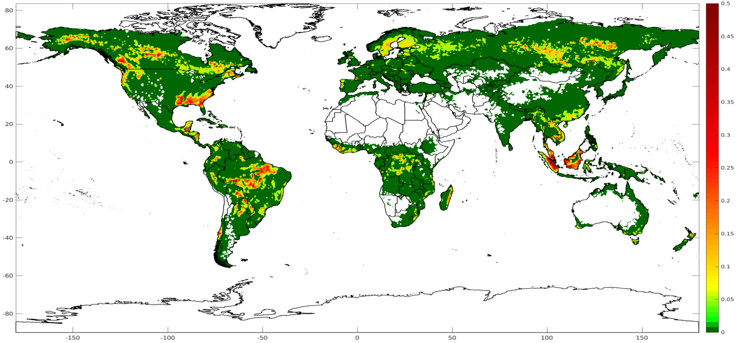
Figure: Accumulated deforestation: 2015




Source: Hansen et al. (2013)

# Deforestation 2001-2018

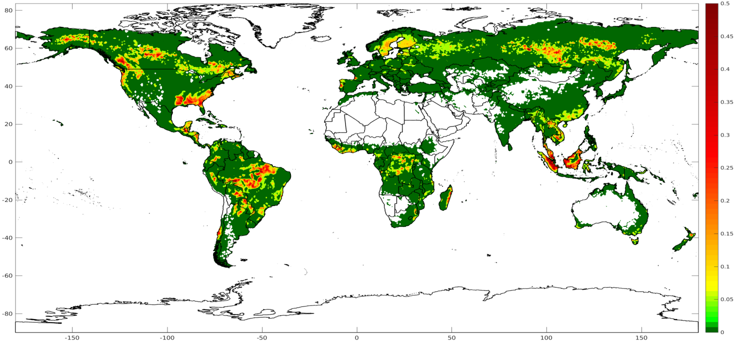
Figure: Accumulated deforestation: 2016




Source: Hansen et al. (2013)

# Deforestation 2001-2018

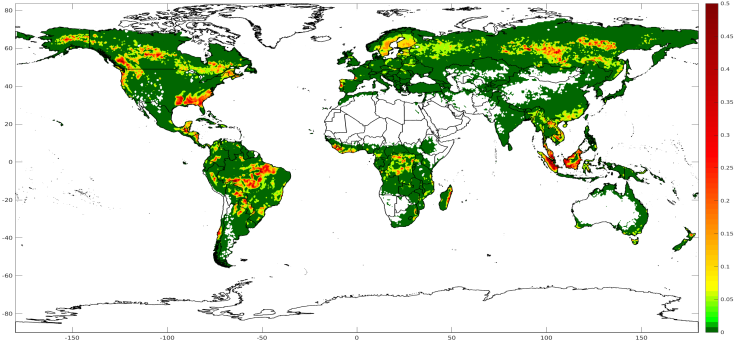
Figure: Accumulated deforestation: 2017




Source: Hansen et al. (2013)

# Deforestation 2001-2018

Figure: Accumulated deforestation: 2018




Source: Hansen et al. (2013)

# Data

Cells $(36,577)$ of $0.5 \times 0.5$ degree over 2001 - 2018 period.

$\rightarrow$ Unit of observation (628,337): cell $\times$ year

For each cell, we use information on:

1. Deforestation
2. Worldwide variations in commodities prices
3. Soil suitability heterogeneity (spatial variations & exogeneous price shocks)

# Deforestation

- Main dataset: Hansen (2013), Deforestation → resolution: ≈30m.

  → Forest defined as 50% of pixels' 2000 forest cover (robust, 25-75%)
  → Deforested pixels (comparing 2018 and 2000 tree cover) by year (highest likelyhood → 2001-2018)

- Baseline variable: count of deforested pixels (30m) by cell (0.5°: ≈55km).

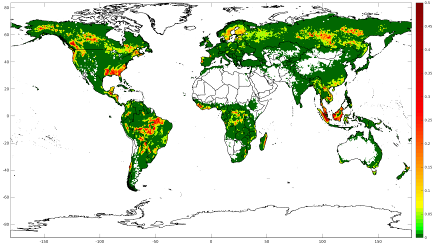



Figure: Cumulative deforestation (2001-2018, share of 0.5° cells)
Source: Hansen (2013)

# Commodity price shocks

Cell-specific (c) time-varying (t) proxy for local agricultural output prices:

$$P_{ct} = \sum_{crop_i=1}^{15} \alpha_c^i . P_t^i$$

# Commodity price shocks

Cell-specific (c) time-varying (t) proxy for local agricultural output prices:

$$P_{ct} = \sum_{crop_i=1}^{15} \alpha_c^i . P_t^i$$

- Annual world prices of commodities: World Bank ($P_t$: index base 100 in 2000)
- Crop (N=42) specialization ($\alpha_c^i$): FAO-GAEZ suitabiliy index under current technology in 2000.
  - → Relative suitability to produce specific crops predicted from soil and climate characteristics
  - → Normalized by the 'total suitability' of the cell
    all crops for which prices available: *banana, barley, cocoa, coconut, coffe, cotton, maize, oilpalm, rice, sorghum, soybean, sugar, tea, tobacco, wheat.*

# Estimation

**Specification #1**: Spikes in commodity prices accelerate deforestation ($\alpha > 0$)

$$\Delta \text{Deforest}_{c,t} = \exp\left(\alpha \ln P_{c,t} + \mu_{t,country} + \eta_c\right) + \varepsilon_{c,t}$$

**Specification #2**: specific relation depending on: distance to ports, spei, tropics, initial forest cover.

- Estimator: (pseudo) Poisson regression model
- Robustness checks: log-log / Standard errors: Conley (1999) allowing for spatial correlation (500km radius) and serial correlation (infinite)
  $1^{st}$ specification robust to country clustering and every robustness check.

**NB**: wood and meat annual international prices controlled for (within year FE)

# Results

Tableau: Drivers of forest disturbances (% for 1 st. dev. of log prices): panel (pseudo) poisson regression, in pixels with 50 % of forests

| | (1) Defor | (2) Defor | (3) Defor | (4) Defor | (5) Defor |
|---|---|---|---|---|---|
| log commodity price | 68.31*** | 35.49*** | 74.19*** | 69.67*** | 69.45*** |
| × tropics | | 28.39*** | | | |
| × boreal | | 30.05*** | | | |
| × dist. to harbor (st. dev. =600km) | | | -30.28*** | | |
| × Drought (spei) | | | | | 12.55** |
| Drought (spei) | | | | 4.88 | -69.26** |
| Observations | 571,602 | 571,602 | 571,602 | 571,602 | 571,602 |
| Cell & year FE | Yes | Yes | Yes | Yes | Yes |
| Country × year FE | Yes | Yes | Yes | Yes | Yes |

effet (percent points) : $exp(\alpha * (st.dev.(X)) - 1) * 100$
Standard errors in parentheses
$^{*}$ $p < .1$, $^{**}$ $p < .05$, $^{***}$ $p < .01$

- Significant commodity driven tree cover losses (68%) (column 1) in tropical, temperate & boreal forests (column 2)
- Souza-Rodrigues (2018) that shows that transport costs play an important role in deforestation decisions.
  $\rightarrow$ We find that the effect of agricultural commodities price variations becomes (slightly) weaker as remoteness increases (measured as the distance to the closest harbor) but it remains positive even for the most remote locations (column 3)
- While a drought does not seem to significantly increase deforestation, it may increase the effect of commodities (uncontrolled fires? Burgess et al., 2019) (columns 4-5).

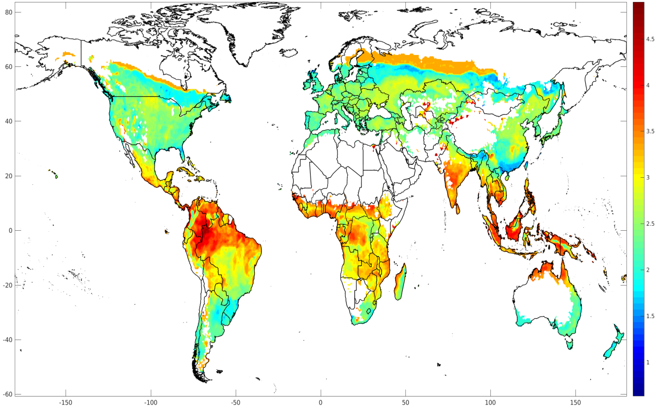



Figure: **Avg.** contribution of agr. commodity price var. to deforestation (2001-18).

⇒ Plotted values are based on the estimates obtained using a panel poisson regression, specification #1, effet (percent points) $exp(\alpha * (log(P) - log(avg.cellP)) - 1) * 100$

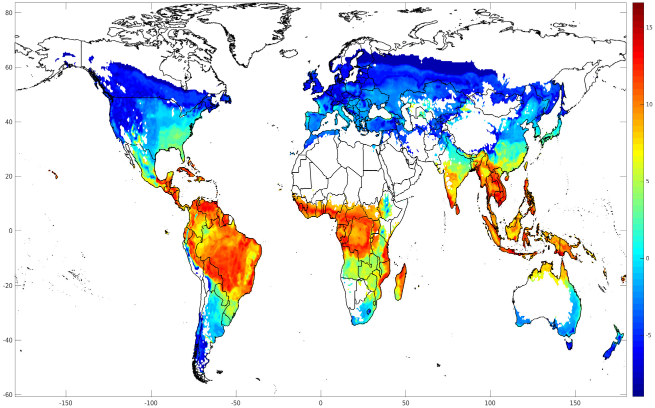



Figure: **Median** of contribution of agr. commodity price var. to deforestation (2001-18).

⇒ Plotted values are based on the estimates obtained using a panel poisson regression, specification #1, effet (percent points) $exp(\alpha * (log(P) - log(avg.cellP)) - 1) * 100$

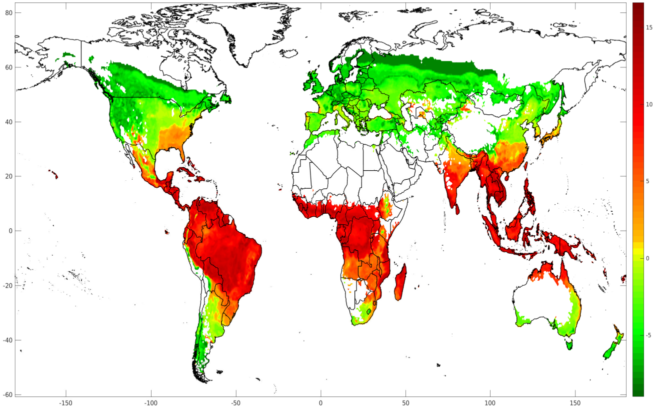



Figure: **Median** of contribution of agr. commodity price var. to deforestation (2001-18).

⇒ Plotted values are based on the estimates obtained using a panel poisson regression, specification #1, effet (percent points) $exp(\alpha * (log(P) - log(avg.cellP)) - 1) * 100$

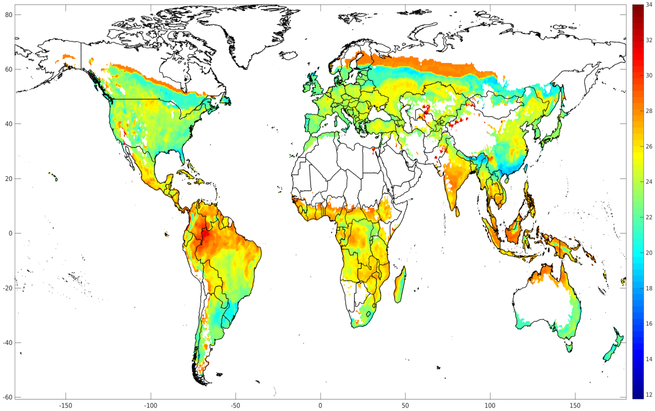



Figure: **St. dev.** of contribution of agr. commodity price var. to deforestation (2001-18).

⇒ Plotted values are based on the estimates obtained using a panel poisson regression, specification #1, effet (percent points) $exp(\alpha * (log(P) - log(avg.cellP)) - 1) * 100$

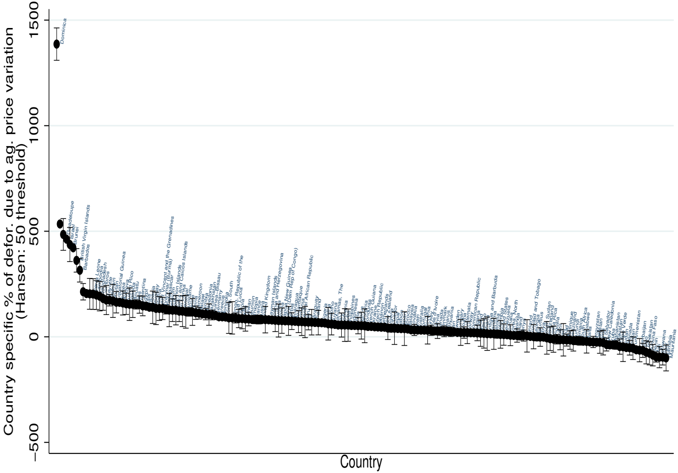



Figure: Effect (%) of agr. commodity price variations to deforestation (2001-2018), by country.

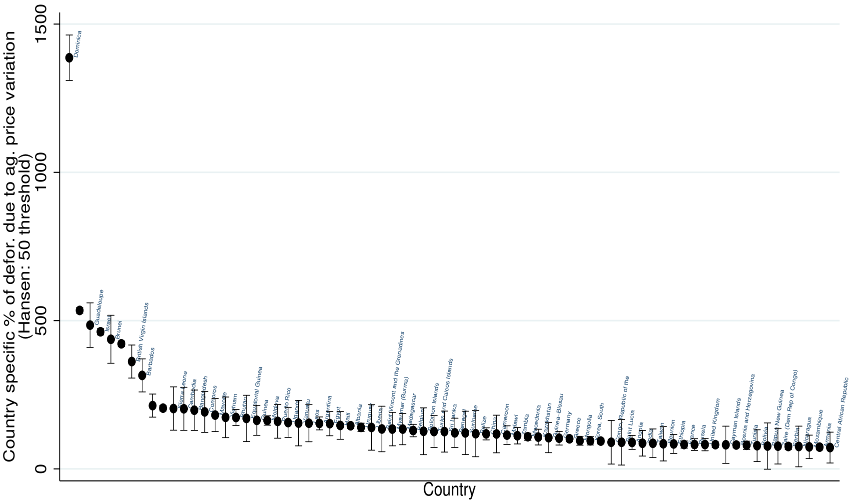



Figure: Effect (%) of agricultural commodity price variations to deforestation (2001-2018), by country (75 largest impacts).

# Deforestation 2001-2018: timing of impacts

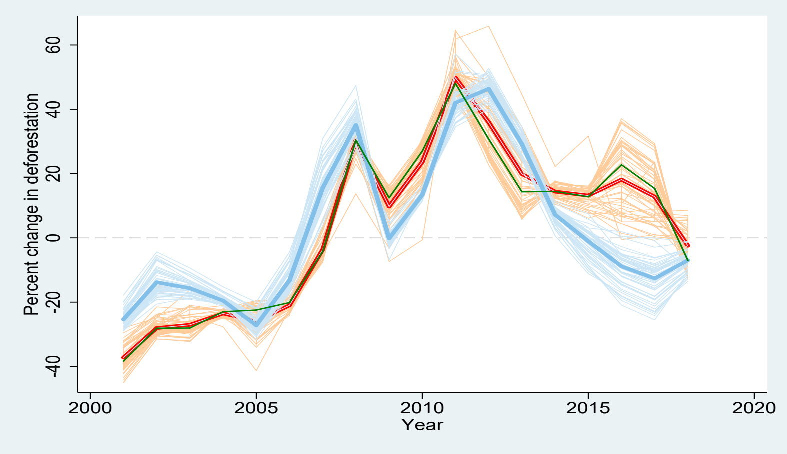



Figure: Contribution of agricultural commodity price variations to deforestation (2001-2018), **by year** and tropical (orange) vs. temperate countries (blue) vs. Bresil (green)

Source: authors calculation of pixel specific annual deforestation shocs driven by agr. commodity price shocks, with country × year & cell fixed effects.

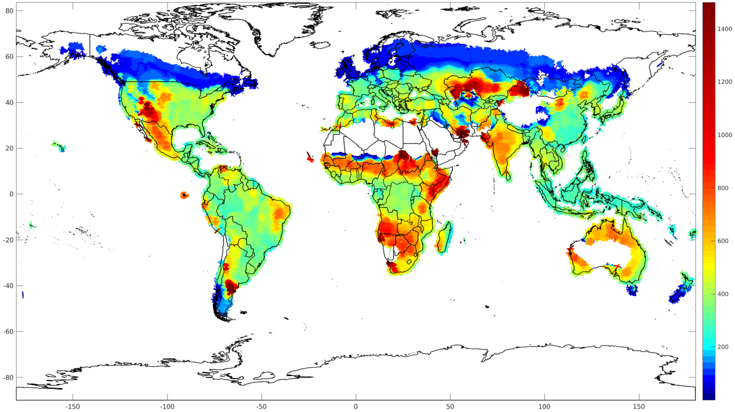



Figure: Contribution of agricultural commodity price variations to deforestation (2030).

Plotted values are based on the estimates obtained using a panel poisson regression, projecting prices by using World Bank price predictions.

# Preliminary results

- Role of agricultural prices

- Boreal and temperate forest biomes seem to be subject to positive (avg.) agr. commodity related deforestation (median impact: negative).

- 3 periods, deconnexion of the northern & the southern hemisphere in the 2000's?

- Large future (2030) impacts, whatever the underlying hypothesis (current trend or WB projections).

Thank you for your attention !

Abman, R. and C. Lundberg (2020): "Does Free Trade Increase Deforestation? The Effects of Regional Trade Agreements," *Journal of the Association of Environmental and Resource Economists*, 7, 35–72.

Barona, E., N. Ramankutty, G. Hyman, and O. T. Coomes (2010): "The role of pasture and soybean in deforestation of the Brazilian Amazon," *Environmental Research Letters*, 5, 024002.

Leblois, A., O. Damette, and J. Wolfersberger (2017): "What has Driven Deforestation in Developing Countries Since the 2000s? Evidence from New Remote-Sensing Data," *World Development*, 92, 82–102.

Pendrill, F., U. M. Persson, J. Godar, and T. Kastner (2019a): "Deforestation displaced: trade in forest-risk commodities and the prospects for a global forest transition," *Environmental Research Letters*, 14, 055003.

Pendrill, F., U. M. Persson, J. Godar, T. Kastner, D. Moran, S. Schmidt, and R. Wood (2019b): "Agricultural and forestry trade drives large share of tropical deforestation emissions," *Global Environmental Change*, 56, 1 – 10.

Souza-Rodrigues, E. (2018): "Deforestation in the Amazon: A

Unified Framework for Estimation and Policy Analysis," *Review of Economic Studies*, 86, 2713–2744.

Variables / controls

→ Annual deflated commodity prices (World Bank, in log)

→ GAEZ (FAO) crop specific suitability for growing (spatial variations)

→ Rainfall Standardized Precipitation-Evapotranspiration Index (spei)

→ Distance to ports (km)

→ Tropics

→ Volatility / lags ?

Tableau: Drivers of deforestation (forest disturbances), in pixels with 50 % of forests

| | (1) Defor | (2) Defor |
|---|---|---|
| log commodity price | 1.282*** | 1.279** |
| | (0.0950) | (0.643) |
| Drought_spei | 0.0477 | -1.180** |
| | (0.0347) | (0.503) |
| DRspei × log commodity price g | | 0.287** |
| | | (0.115) |
| Constant | 5.065*** | 5.078** |
| | (0.369) | (2.498) |
| Observations | 571,602 | 571,602 |
| Cell & year FE | Yes | Yes |
| Country × year FE | Yes | Yes |

Standard errors in parentheses
* $p < .1$, ** $p < .05$, *** $p < .01$

While a drought does not seem to significantly increase deforestation, it may increase the effect of commodities (uncontrolled fires? Burgess et al., 2019).

Tableau: Drivers of tree loss: by geozones, panel (pseudo) poisson regression, in pixels with 50 % of forests

| | (1) Defor 25 | (2) Defor 50 | (3) Defor 75 |
|---|---|---|---|
| Price × Africa | 1.343*** | 1.219*** | 0.963*** |
| | (0.0481) | (0.0488) | (0.0518) |
| Price × Asia | 1.332*** | 1.280*** | 1.172*** |
| | (0.0501) | (0.0489) | (0.0491) |
| Price × Pacific Ocean | 1.423*** | 1.407*** | 1.386*** |
| | (0.215) | (0.216) | (0.221) |
| Price × Indian Ocean | 1.886** | 1.280 | 0.399 |
| | (0.739) | (0.786) | (0.740) |
| Price × Europe | 1.071*** | 0.988*** | 0.873*** |
| | (0.0629) | (0.0627) | (0.0649) |
| Price × North America | 0.518*** | 0.373*** | 0.275*** |
| | (0.0665) | (0.0620) | (0.0580) |
| Price × Central America | 0.790*** | 0.798*** | 0.858*** |
| | (0.116) | (0.116) | (0.117) |
| Price × West Indies | 0.828*** | 0.849*** | 0.900*** |
| | (0.280) | (0.289) | (0.314) |
| Price × South America | 0.227*** | 0.107** | -0.0649 |
| | (0.0505) | (0.0497) | (0.0507) |
| Price × Atlantic Ocean | -0.837 | -0.883 | -1.454 |
| | (1.161) | (1.409) | (1.441) |
| Price × Australasia | 0.225 | 0.633*** | 0.495*** |
| | (0.212) | (0.131) | (0.125) |
| Constant | 6.970*** | 7.297*** | 7.812*** |
| | (0.179) | (0.176) | (0.179) |
| Observations | 587142 | 567,558 | 543,510 |
| Cell & year FE | Yes | Yes | Yes |
| Country × year FE | No | No | No |

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

Tableau: Drivers of tree loss: by continents, panel (pseudo) poisson regression, in pixels with 50 % of forests

| | (1) Def 25 | (2) Def 50 | (3) Def 75 |
|---|---|---|---|
| Price × Africa | 1.344*** | 1.220*** | 0.962*** |
| | (0.0480) | (0.0487) | (0.0518) |
| Price × Americas | 0.383*** | 0.256*** | 0.125*** |
| | (0.0508) | (0.0490) | (0.0483) |
| Price × Asia | 1.378*** | 1.304*** | 1.164*** |
| | (0.0565) | (0.0560) | (0.0578) |
| Price × Europe | 0.509*** | 0.465*** | 0.455*** |
| | (0.0415) | (0.0404) | (0.0409) |
| Price × Oceania | 0.465*** | 0.831*** | 0.723*** |
| | (0.166) | (0.0995) | (0.0939) |
| Constant | 6.918*** | 7.249*** | 7.795*** |
| | (0.177) | (0.175) | (0.177) |
| Observations | 592,290 | 572,382 | 548,154 |
| Cell & year FE | Yes | Yes | Yes |
| Country × year FE | No | No | No |

Standard errors in parentheses
* $p < .1$, ** $p < .05$, *** $p < .01$

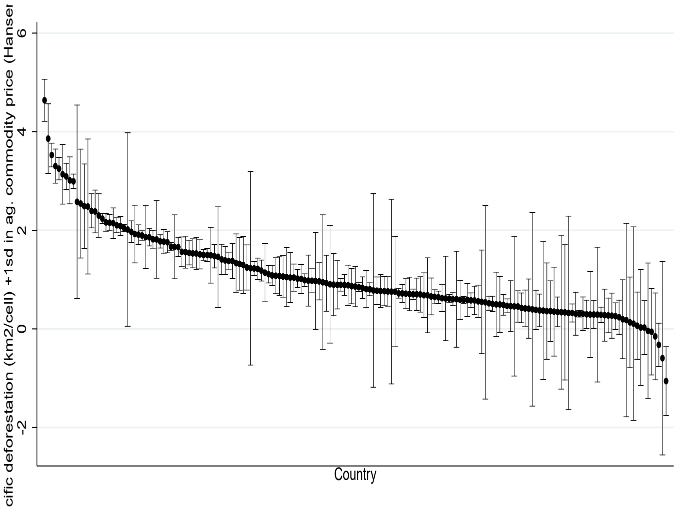



Figure: Contribution of agr. commodity price variations to deforestation (2001-2018), by country.

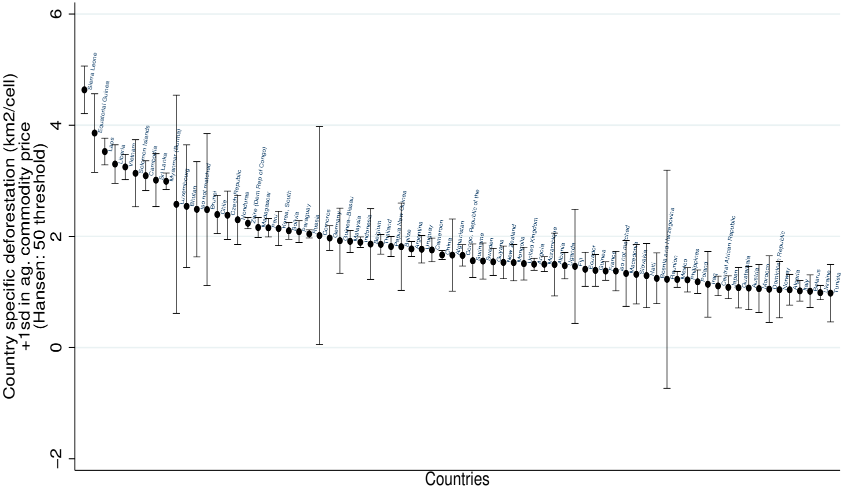



Figure: Contribution of agricultural commodity price variations to deforestation (2001-2018), by country (75 largest impacts).

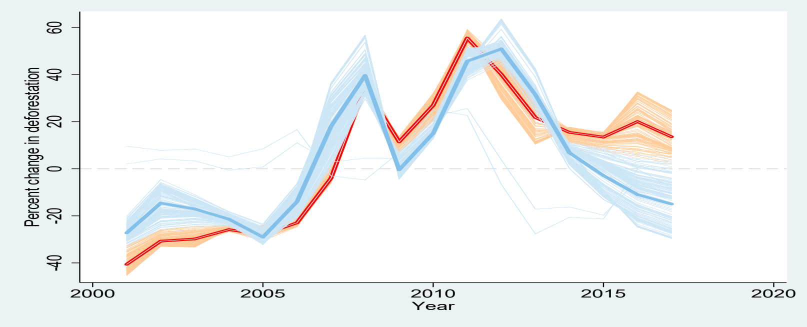
Tableau: Drivers of deforestation: panel (pseudo) poisson regression, in pixels with 50 % of forests

| | (1) Defor 50 | (2) Defor 50 | (3) Defor 50 | (4) Defor 50 |
|---|---|---|---|---|
| Log price index | 1.256*** | | 1.500*** | 1.199*** |
| | (0.0998) | | (0.106) | (0.114) |
| Monthly volatility (price) | 0.0234 | | | |
| | (0.0149) | | | |
| Lag (Log price index) | | 0.477*** | | |
| | | (0.105) | | |
| Lag(Monthly volatility (price)) | | 0.151*** | | |
| | | (0.0156) | | |
| av. Volatility (2 last y) | | | 0.316*** | |
| | | | (0.0233) | |
| av. Volatility (5 last y) | | | | 0.296*** |
| | | | | (0.0652) |
| Constant | 5.130*** | 7.978*** | 3.697*** | 4.853*** |
| | (0.379) | (0.397) | (0.424) | (0.488) |
| Observations | 571,602 | 537,723 | 504,477 | 406,282 |
| Cell & year FE | Yes | Yes | Yes | Yes |
| Country × year FE | Yes | Yes | Yes | Yes |

Standard errors in parentheses
* $p < .1$, ** $p < .05$, *** $p < .01$

# Deforestation 2001-2018

Figure: Deforestation 2000-2018: impact of commodity prices variations, distribution of effect through the period, by latitude (northern hemisphere in blue & southern hemisphere in orange)




Source: authors calculation of pixel specific annual deforestation shocs driven by agr. commodity price shocks, with Country × year and cell fixed effects.