Expanding global commodities trade and consumption place the world's primates at risk of extinction

Alejandro Estrada [Corresp., 1], **Paul A Garber** [Corresp., 2], **Abhishek Chaudhary** [3]

[1] Field Research Station Los Tuxtlas, Institute of Biology, Mexico City, Mexico

[2] Department of Anthropology, University of Illinois at Urbana-Champaign, Urbana, Illinois, United States

[3] Department of Civil Engineering, Indian Institute of Technology, Kanpur, Kanpur, India

Corresponding Authors: Alejandro Estrada, Paul A Garber
Email address: aestradaprimates@gmail.com, p-garber@illinois.edu

As a consequence of recent human activities. populations of approximately 75% of the world´s primates are in decline, and more than 60% of species (*n*= 512) are threatened with extinction . Major anthropogenic pressures on primate persistence include the widespread loss and degradation of natural habitats caused by the expansion of industrial agriculture, pastureland for cattle, logging, mining, and fossil fuel extraction. This is the result of growing global market demands for agricultural and non-agricultural commodities. Here we profile the effects of international trade of forest-risk agricultural and non-agricultural commodities, namely soybean, oil palm, natural rubber, beef, forestry products, fossil fuels, metals, minerals, and gemstones on habitat conversion in the Neotropics, Africa, and South and Southeast Asia. Total estimated forest loss for these regions between 2001 and 2017 was *ca*179 million ha. The average percent of commodity-driven permanent deforestation for the period 2001-2015 was highest in Southeast Asia (47%) followed by the Neotropics (26%), South Asia (26%) and Africa (7%). Commodities exports increased significantly between 2000 and 2016 in all primate range regions leading to the widespread conversion of forested land to agricultural fields and an increase in natural resource extraction. In 2016, US $1.1 trillion of natural-resource commodities were traded by countries in primate range regions. The Neotropics accounted for 41% of the total value of these exports, Southeast Asia f 27%, Africa 21%, and South Asia 11%. Major commodity exporters in 2016 were Brazil, India, Indonesia, Malaysia and South Africa, countries of high primate diversity and endemism. Among the top 10 importers were China, the US, Japan, and Switzerland.Primate range countries lag far behind importer nations in food security and gross domestic product per capita, suggesting that trade and commodity-driven land-use have done little to generate wealth and well-being in primate habitat countries.Modeling of land-use and projected extinction of primate species by 2050 and 2100 under a business as usual scenario for 61 primate range countries

indicate that each country is expected to see a significant increase in the number of species threatened with extinction.To mitigate this impending crisis, we advocate the “greening” of trade, a global shift towards a low-meat diet, reduced consumption of oil seed, diminished use of tropical timber, fossil fuels, metals, minerals and gemstones from the tropics, accompanied by a stronger and sustained global resolve to regulate and reverse the negative impacts of growing unsustainable global demands and commodity trade on income inequality, and the destruction of primates and their habitats.

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Alejandro Estrada[1], Paul A. Garber[2], Abhishek Chaudhary[3]

[1]Institute of Biology, National Autonomous University of Mexico (UNAM), Mexico City, Mexico

[2]Department of Anthropology, University of Illinois at Urbana-Champaign, Urbana, IL, USA

[3]Department of Civil Engineering, Indian Institute of Technology (IIT) Kanpur, India

ABSTRACT

As a consequence of recent human activities. populations of approximately 75% of the world´s primates are in decline, and more than 60% of species (n = 512) are threatened with extinction . Major anthropogenic pressures on primate persistence include the widespread loss and degradation of natural habitats caused by the expansion of industrial agriculture, pastureland for cattle, logging, mining, and fossil fuel extraction. This is the result of growing global market demands for agricultural and non-agricultural commodities. Here we profile the effects of international trade of forest-risk agricultural and non-agricultural commodities, namely soybean, oil palm, natural rubber, beef, forestry products, fossil fuels, metals, minerals, and gemstones on habitat conversion in the Neotropics, Africa, and South and Southeast Asia. Total estimated forest loss for these regions between 2001 and 2017 was *ca* 179 million ha. The average percent of commodity-driven permanent deforestation for the period 2001-2015 was highest in Southeast Asia (47%) followed by the Neotropics (26%), South Asia (26%) and Africa (7%). Commodities exports increased significantly between 2000 and 2016 in all primate-range regions leading to the widespread conversion of forested land to agricultural fields and an increase in natural resource extraction. In 2016, US $1.1 trillion of natural-resource commodities were traded by countries in primate-

range regions. The Neotropics accounted for 41% of the total value of these exports, Southeast Asia f 27%, Africa 21%, and South Asia 11%. Major commodity exporters in 2016 were Brazil, India, Indonesia, Malaysia and South Africa, countries of high primate diversity and endemism. Among the top 10 importers were China, the US, Japan, and Switzerland. Primate range countries lag far behind importer nations in food security and gross domestic product per capita, suggesting that trade and commodity-driven land-use have done little to generate wealth and well-being in primate habitat countries. Modeling of land-use and projected extinction of primate species by 2050 and 2100 under a business as usual scenario for 61 primate-range countries indicate that each country is expected to see a significant increase in the number of species threatened with extinction. To mitigate this impending crisis, we advocate the "greening" of trade, a global shift towards a low-meat diet, reduced consumption of oil seed, diminished use of tropical timber, fossil fuels, metals, minerals and gemstones from the tropics, accompanied by a stronger and sustained global resolve to regulate and reverse the negative impacts of unsustainable commodity trade on income inequality, and the destruction of primates and their habitats.

Subjects Biodiversity, Conservation Biology, Ecology, Coupled Natural and Human Systems, Natural Resource Management

Keywords International commodity trade, Deforestation, Forest-risk commodity trade, Food security, Sustainable agriculture, Sustainable commodity trade, Agricultural expansion, Primate conservation, Income Equality

INTRODUCTION

Nonhuman primates (primates from here on), our closest biological relatives, are an essential component of tropical biodiversity, contributing to forest regeneration and ecosystem health. Primates play important roles in the livelihoods, cultures, and religions of many societies and offer unique insights into human evolution, biology, behavior, and the threat of emerging diseases. Current information indicates the existence of 512 primate species in 79 genera distributed in 91 countries across the Neotropics, Africa, Madagascar, and Asia. Alarmingly, the populations of about 75% of all primate species are declining and more than 60% of the species are now threatened with extinction (*Estrada et al., 2017*; Fig 1). Major anthropogenic pressures on primate population persistence are land cover changes caused by industrial agriculture, the expansion of pasture for cattle ranching, and increasing logging, mining, and fossil fuel extraction. These activities result in habitat loss and fragmentation, and the disruption of natural ecosystems, caused by the building of dams and mega-dams, and the expansion of road and rail networks for resource extraction, along with the colonization of frontier forests, bushmeat hunting, the illegal trade of primates as pets and for their body parts, and the spread of human and domestic animal-borne infectious diseases. These drivers commonly act in synergy, exacerbating primate habitat loss (including in protected areas) and population decline (*Estrada et al 2017, 2018*). In most primate habitat countries, these pressures arise in the context of an expanding human population with low levels of socioeconomic development, income inequality, political instability, weak governance and the ongoing export trade of agricultural and non-food commodities to international markets (*Estrada et al., 2017, 2018; Li, et al., 2018*).

Insert Fig. 1 about here

69 International commodity trade has become the backbone of many of the world's economies.
70 Each year, trade in just a handful of agricultural and non-food commodities such as soy, palm
71 oil, and minerals drive billions of dollars of investment in both producer and consumer nations
72 (*Henders et al., 2015; Henders et al., 2018; MacDonald et al., 2015*). The volume of food and
73 non-food commodities traded globally has increased by over 60% since the turn of the century,
74 with four trillion US dollars of natural resource commodities traded in 2016 (*Chatham House*
75 *2018;* https://resourcetrade.earth/). The trade of these commodities has had a direct impact on
76 land-use change and environmental and social policies in exporting countries (*Henders et al.,*
77 *2015, 2018*), and in many instances these policies, driven by the over-consumption of a few
78 major importing countries, have had negative conservation consequences (*Gardner et al, 2018;*
79 *MacDonald et al., 2015; Moran, et al., 2016*). The demand for agricultural products and other
80 commodities in importing countries is increasingly being met by global supply chains associated
81 with multinational corporations rather than local producers (*Yu et al., 2013*), a process that
82 weakens the ability of exporting countries to sustainably manage their own natural resources
83 (*Lambin & Meyfroidt, 2011*). Thus, the environmental costs of production have been
84 disproportionately borne by exporting nations, and both exporting and importing countries have
85 become ever more dependent on external and distant resources to satisfy their food and natural
86 resource security needs (*Fader et al., 2011, 2013*; *MacDonald et al., 2015*). Global market
87 demands for forest-risk commodities (e.g., soybeans, palm oil, and hardwoods) have resulted in a
88 process of rapid and widespread industry-driven deforestation, negatively impacting tropical
89 biodiversity, including primates, subdividing single large or continuous populations into small
90 and isolated subpopulations, reducing habitat suitability and gene flow, and limiting the area
91 available for species distribution and population persistence (*Chaudhary & Brooks, 2018;*

92 *Henders, Persson & Kastner, 2015*; *Henders et al., 2018*; *Wich et al., 2014*; *Estrada et al., 2017,*
93 *2018*; *Li et al.,* 2018). Today, commercial agriculture at local and global scales is the most
94 significant driver of deforestation worldwide (*Hosonuma et al., 2012*).
95
96 Clearly, trade is a vital component of food security and all countries are dependent on the global
97 food trade. Approximately 25% of all the food produced for human consumption crosses
98 international frontiers (*D'Odorico & Laio, 2014*). Trade helps food security by providing a
99 safety measure against oscillations in domestic food supply and by stabilizing prices (*World*
100 *Bank, 2015*). Yet, trade dependence also means that all countries are vulnerable to shifts in the
101 trade policies of food-exporting nations, and to the disruption of supply chains associated with
102 political instability, catastrophic weather events, trade wars, and export bans (*Bettina, 2015*).
103 Because the international trade of commodities is widespread and growing, and land conversion
104 permanently alters natural habitats, effective primate conservation requires a comprehensive
105 understanding of the local, regional, and global impacts of consumption on biodiversity and
106 environmental sustainability (*Chaudhary & Brooks, 2017; Chaudhary & Mooers, 2018*). Primate
107 conservation research to date has ascertained these impacts in terms of general threats (*Estrada*
108 *et al, 2017., 2018*), but has yet to document how specific international trade flows of
109 commodities from primate harboring nations are involved in the degradation and loss of primate
110 habitats.
111
112 The goals of this manuscript, therefore, are to examine the environmental impacts of the
113 international trade of essential agricultural and nonagricultural commodities on primate habitats
114 and population persistence in the major regions of the world that harbor wild primates: the

Neotropics, Africa (for the purposes of this manuscript, we include Madagascar as part of Africa), South Asia, and Southeast Asia. We also document the Global Food Security Index (FSI) and the Gross Domestic Product per Capita (GDPPC) for exporter and importer countries and discuss their relationship to consumer nation driven international trade.

SURVEY METHODOLOGY

We collected and integrated information from several international databases. First, using information from the Global Forest Watch database for the period 2001 to 2017, we profiled forest loss (loss of >30% canopy cover) and commodity-driven deforestation (2001 to 2015) for primate-range countries. Commodity driven deforestation refers to permanent conversion and total clearing of forest to nonforest land for the purpose of agricultural (e.g. oil palm, soybeans, natural rubber; *Henders et al., 2015*; *Curtis et al., 2018*) or cattle (beef) production. The extraction of other commodities, such as land-based fossil fuels and ores, also results in forest loss and degradation due to the clearing of vegetation, and in the pollution of air, soil, and water. (*Alvarez-Berrios & Aide, 2015*; *Asner et al., 2013*; *Global Forest Watch, 2018*). Terminology used here for forest loss and commodity-driven deforestation is from Global Forest Watch (2018) and from *Curtis et al.*, 2018. Commodity production was profiled for 20 primate-range countries in the Neotropics, 35 in Africa, six in South Asia and 14 in Southeast Asia (see Fig. 1).

Second, using Chatham House's international trade database, resoucetrade.Earth, we documented, for most countries in each primate-range region, the trade exports in 2016 of four agricultural commodities that contribute to forest fragmentation, degradation and habitat loss: soybeans, oil palm, natural rubber, and beef products (*Curtis et al., 2018*; *Henders et al., 2015*), and four nonagricultural forestry products: fossil fuels, metals, minerals, and gemstones. We

selected these eight commodities because they are among the most commonly traded worldwide (*Beckman et al., 2017*; *Clapp, 2016*; *European Commission, 2013*; *FAO, 2015, 2018*; *MacDonald et al., 2015*; *resourcetrade.Earth, 2018*). For a list of all the commodities examined on resourcetrade.Earth see Text S1. Given the negative effects of these commodities on natural ecosystems, we identified the countries that were the major exporters in each primate-range region in 2016, as well as the consumer nations that were the major importers of these commodities. Commodities terminology follows UNComtrade (https://comtrade.un.org) and resourcetrade.Earth (https://resourcetrade.earth/).

Third, agricultural and nonagricultural trade is principally an economic exchange, where food or non-food products are provided by exporting nations to importing states in exchange for revenue (*Anderson, 2010*). This exchange can be examined in monetary value (US$) or mass traded (e.g., tonnage). We used monetary value as increases in value are strongly correlated with increases in the volume of commodities sold to importing countries as well as with the revenues generated by exporting countries (*MacDonald et al., 2015*). Value also can be viewed as a general measure of the footprint of importing countries on land-use practices in primate-range countries. Value similarly allows for a direct assessment of the magnitude of trade flows and can be correlated with other economic indicators such as GDP (*MacDonald et al., 2015*). With this in mind, we estimated the total revenue generated by the trade of commodities in 2016 by countries in each of the primate-range regions, and compared this to the revenue reported for 2000.

We also assessed trends in the expansion of land area used to cultivate soy, oil palm, and natural rubber trees between 1960 and 2016 in the Neotropics, Africa, South Asia, and Southeast Asia,

using information from FAOSTATS (Statistical division of the Food and Agriculture Organization of the UN; http://www.fao.org/faostat/en/#compare). Similarly, we analyzed growth in the number of cattle produced between 1960 and 2016 in primate-range regions, based on data available in the same database, and compared this to the growth in exports of beef by primate-range nations. Complementary information on commodity trade was obtained from the International Trade Centre (http://www.intracen.org/itc/market-info-tools/trade-statistics/), the UNComtrade database (https://comtrade.un.org) and the FAO trade database (http://www.fao.org/faostat/en/#compare). Because the international trade in agricultural products influences human food security across primate-range countries and regions, we examined the Global Food Security Index 2018 (FSI) of The Economist Intelligence Unit Limited (https://foodsecurityindex.eiu.com/) for each primate-range commodity exporter country, and for importer nations. The FSI defines food security as the state in which people at all times have physical, social, and economic access to sufficient and nutritious food that meets their dietary needs for a healthy and active life. This framework is based on the internationally accepted definition established at the 1996 World Food Summit (http://www.fao.org/WFS/). The FSI uses three central pillars of food security— affordability, availability, and quality and safety, and ranges from 0 (lowest food security or highest food insecurity) to 100 (highest food security; see Text S3). We obtained, from the World Bank, Gross Domestic Product per Capita (GDPPC) values for 2017 for primate-range exporting countries and for importer countries (https://data.worldbank.org/indicator/NY.GDP.PCAP.CD) and used these as indicators of the economic standing of primate-range commodity exporting countries compared to countries importing these products. Each of the agencies that we used as sources of data specify in their portals the constraints of the data they present. We consider that, although in some cases the

185 numbers reported may have varied in their level of accuracy, the patterns and trends within and
186 between each country or region are reliable with high confidence.
187
188 To illustrate international trade flows of commodities exported by primate-range regions and
189 countries we developed Sankey flow diagrams by using the open access software SankeyMatic
190 accessible in http://sankeymatic.com/build/. In these diagrams we used the accumulated value in
191 $US as a general indicator of the footprint of importing nations. Important to consider in this
192 assessment is the magnitude of the revenue accrued by each country that exports commodities.
193
194 **Modeling the current and future (2050 & 2100) risk of extinction**
195 We calculated the number of primate species currently threatened with extinction in each
196 country, and compared this to the expected number of additional primate species in each country
197 that will be threatened with extinction by 2050 and 2100 as a result of land use changes
198 associated with forest-risk trade commodities. We examined six alternative scenarios. We used
199 the approach presented by Chaudhary & Mooers (2018) that links the countryside species-area
200 relationship (SAR) model (*Chaudhary and Brooks, 2017*) with the current (2016) and future
201 (2050 and 2100) global gridded maps generated by the six RCP-
202 SSP combination scenarios (RCP 2.6 SSP-1, RCP 4.5 SSP-2, RCP 7.0 SSP-3, RCP 3.4 SSP-4,
203 RCP 6.0 SSP-4, and RCP 8.5 SSP-5), available from the most recent land use harmonization
204 (LUH2) dataset (http://luh.umd.edu/data.shtml: Table S9). We also allocated the total number of
205 primate species threatened with extinction to 10 individual human land use types in the LUH2
206 database, taking into account each species' ability to utilize each of these altered habitats (IUCN,

2015) and to identify the major land use drivers threatening primate species in each country (*Chaudhary & Mooers, 2018*). See Text S4 for details on the methodology used.

COMMODITY-DRIVEN DEFORESTATION

Data from the Global Forest Watch database on forest cover loss (>30% canopy cover) and commodity-driven deforestation for the period 2001 to 2017 show that both forest loss and commodity-driven deforestation were widespread in countries in the four primate-range regions (Table 1, Fig. 2). The Neotropics was the region with most forest loss (83.5 million ha) followed by Southeast Asia with 54.3 million ha (Table 1). Africa ranked third with 38.5 million ha, and South Asia fourth with 1.9 million ha (Fig. 2, Table 1). Total estimated forest loss for these regions over this 15-year period was 178.8 million ha, with an annual rate of forest cover loss of 10.52 million ha/yr (Table 1). The average percent of commodity-driven permanent deforestation for the period 2001–2015 was highest in Southeast Asia (47%) and lowest in Africa (7%) (Fig. 2, Table 1).

Insert Table 1 about here

Globally, the primate-range countries with the highest percentage of commodity-driven deforestation relative to total forest loss for the period 2001–2015 were Malaysia (91% of 7.3 million ha), Paraguay (90% of 5.5 million ha), Indonesia (89% of 24.4 million ha), Argentina (82% of 5.2 million ha), Bolivia (70% of 4.5 million ha), and Brazil (66% of 51 million ha) (Fig. 2, Table 1, Fig. S1). Many of these countries have high primate diversity. In the Neotropics, Brazil (the primate-richest country with 117 species) stands out among the top five commodity

producing countries in the region due to the disproportionate amount of forest loss during 2001–2017 (Fig. 2). In Africa, the DRC, with 49 primate species, experienced the greatest amount of deforestation, mainly due to shifting agriculture and the extraction of forestry products (Fig. 2). The DRC was followed by Madagascar, Mozambique, Angola, Ivory Coast, and Tanzania (Fig. 2). While shifting agriculture was a dominant cause of deforestation in Africa, several countries in this region were heavily involved in the production of export commodities (e.g., Madagascar, Ivory Coast, Liberia, Nigeria Uganda, Kenya, Equatorial Guinea, and Rwanda among others) (Fig. 2, Table S1). During the period 2001–2017, Madagascar deforested more land (3.7 million ha) than all mainland African countries except for the DRC. Twenty-seven per cent of forest loss in Madagascar was due to commodity deforestation (Fig. 2). This is consistent with a recent study based on remote sensing indicating that between 2001 and 2015, 27% of global forest loss (>30% canopy cover) worldwide was attributed to deforestation through permanent land use change for commodity production. The remaining loss was attributed to forestry (26% was due to natural forests being cut down and trees being planted for wood-based products), shifting agriculture (24%), and wildfires (23%) (*Curtis et al., 2018*). Over the last 3–4 decades, industrial agribusiness and industrial logging have been producing wood products for global rather than local markets (*Rudel et al., 2009*), with the result that commodity-driven agriculture and logging are, currently, the most significant human-induced drivers of forest loss and forest degradation worldwide (*Hosonuma et al., 2012*). Notwithstanding corporate pledges, the rate of commodity-driven forest loss has not lessened and, in order to end deforestation, companies will need to eliminate five million hectares of converted forest from supply chains each year (*Curtis et al., 2018*).

Insert Fig. 2 about here

INTERNATIONAL COMMODITIES TRADE

Growth of commodity exports by countries in primate-range regions

Trade data show that, between 2000 and 2016, agricultural and nonagricultural commodity exports increased by a factor of two to four for primate-range countries, suggesting a global trend in the growth of market demands, higher production of commodities, and an expanding land use footprint by importing nations (Fig. 3A). These data also indicate that, in both 2000 and 2016, a significant share of these imports was purchased by countries in the G-20 group (Fig. 3A). In 2016, for example, primate -range regions exported US$ 1.1 trillion in natural resource commodities. The G-20 group took 60% of commodity exports by countries in the four primate-range regions. This is consistent with the fact that, in 2016, demand from G-20 countries accounted for over half of all of the world's resource imports (https://resourcetrade.earth/) and emphasizes the disproportionate land use footprint of a few consumer nations. A list of countries in the G-20 group can be found in Table S2.

In 2016, countries in all primate regions were commodity exporters, but the relative importance of particular commodities varied from region to region. In the Neotropics, the commodity groups most commonly exported were agricultural products, metals and minerals, and fossil fuels (**Fig. 3B**). In Africa, metals and minerals and fossil fuels were the predominant exports. In both South Asia and Southeast Asia he principal exports were fossil fuels and agricultural products, with forestry products also a commonly exported commodity in Southeast Asia (**Fig. 3B**). The total value of exported commodities by the four regions in 2016 was US$1.1 trillion. Clearly, global market demands for commodities are an important source of income for the economies of primate-range countries. This has come at the cost of the permanent conversion of natural habitats into anthropogenic landscapes, causing the loss of biodiversity and significant declines

277 in primate populations (**Fig. 2**) (*Chaudhary and Brookes, 2017*; *Chaudhary & Mooers, 2018*;
278 *Estrada et al., 2018*).

279 Insert Fig. 3 about here

280 **Trade in commodities leading to permanent deforestation**

281 *Regional patterns*

282 Below, we profile the international trade of soybeans (*Glysine max*), palm oil (*Elaeis guineensis*),
283 and natural rubber (*Hevea brasiliensis*) that results in permanent deforestation. We also examine
284 beef production, a major driver of the conversion of forests to pasture. Data, from
285 resourcetrade.Earth, on the international trade in these four commodities, indicates exponential
286 growth (US bn) between 2000 and 2016, and this has differentially affected permanent
287 deforestation across primate range regions (**Fig. 4**). For example, in both 2000 and 2016,
288 soybeans dominated exports in the Neotropics. This region was also the principal exporter of
289 beef during that period (**Fig. 4**). Southeast Asia was the leading exporter of palm oil and rubber
290 in both 2000 and 2016. The other primate range regions contributed smaller volumes to the trade
291 in these commodities (**Fig. 4**).

292

293 Insert Fig. 4 about here

294 *Expansion of land area for production of agricultural commodities between 1960 and 2016*

295 Data from FAOSTATS show that the production of soybeans in the Neotropics and Southeast
296 Asia has steadily increased since 1960. In 2016, soybean production involved almost 74 million
297 ha of land in primate range countries, of which some 80% was in the Neotropics, particularly
298 Brazil and Argentina (**Fig. 5A**). In 2016, some 15 million ha of land in Southeast Asia were
299 devoted to palm oil production (about 20 million ha worldwide). The conversion of forested land
300 for the production of palm oil in Southeast Asia has increased steadily since 1970 (**Fig. 5B**).

Overall, soybeans and oil palm have become increasingly important not only as food products for humans and domestic animals, but also for biofuel production (*Koh & Ghazoul, 2008*). In 1960, 4 million ha worldwide were devoted to the cultivation of natural rubber. By 2016, this had increased to 11.4 million ha, with Southeast Asia accounting for about 78% of the total (**Fig. 5C**).

Insert Fig. 5 about here

Trade flows in 2016 of agricultural commodities resulting in permanent forest loss

Soybeans

In 2016, a total of US$48.72 bn in soybeans was exported by primate-range countries (this involved almost 74 million ha of land), of which 92% were exports by Brazil and Argentina, two countries in the Neotropics (**Fig. 6A**). Brazil, with 117 primate species, was the second largest producer of soybeans in the world (the US was the top producer, *USDA, 2018*), and contributed approximately 80% of the soybean crop exported by primate-range countries (https://globalforestatlas.yale.edu/amazon/land-use/soy). In Brazil, 30% of deforestation between 2000 and 2010 was driven by global demand for soybean and beef exports (*Karstensen, Peters & Andrew, 2013*). While direct deforestation for soybean production in the Amazon has remained low, it has become progressively common in the *Cerrado* region of Brazil (*Beckman et al., 2017*; *Gibbs et al., 2015*), where 28 primate species are found (*IUCN, 2018*). Other primate rich countries that are significant exporters of soybean are Argentina, Bolivia, and Paraguay. Most deforestation in Bolivia has been in the Amazon basin where expansion of soybean agriculture has intensified and where 24 primate species occur (*Estrada et al., 2017*; *Muller et al., 2012*; *Zales et al., 2019*). Other countries in Africa, South Asia, and Southeast Asia contributed lesser amounts to the international trade in soybeans (**Fig. 6A**). China led the import market in 2016 (**Fig. 6B**), followed by India, the Netherlands, and Vietnam. Much smaller amounts of soybean

were purchased by countries in South Asia, Southeast Asia, and Africa (**Fig 6B**). Soymeal is used for livestock feed (*Delgado, 2005*; *Mielke & Mielke, 2018*) and soy oil (a derivative of soymeal production) is used by the food industry to produce soy sauce, cooking oil, miso, soy milk, soy curd, tempeh, and tofu products. It is also used in the production of detergents, cosmetics, and various industrial chemicals (*Casson, 2003*; *USDA-FAS, 2018*).

Insert Fig. 6 about here

Oil palm

The total accumulated value of exports of palm oil by primate-range nations in 2016 was US$15.42 bn, with 95% of the production from Indonesia and Malaysia (**Fig. 6C**). Clear-cutting for wood and to establish oil palm plantations are common patterns in these two countries (*Henders et al., 2015*). With 56 species, Indonesia is the primate richest country in Southeast Asia. Malaysia has 20 primate species (*Estrada et al., 2017*). Oil palm imports from Southeast Asia were purchased, in 2016, principally by India, China, the US, Italy, and Germany (**Fig. 6D**). Primate-range countries in the other regions contributed smaller amounts to the palm oil trade. Data from FAOSTATS show that cultivation of oil palm has expanded greatly in Southeast Asia from 5.5 million ha in 2000 to 15 million ha in 2016 (**Fig. 5**). Growing global demand for oil palm products is a major cause of rapid decline in the remaining populations of the Critically Endangered Sumatran and Bornean orangutans (*Pongo abelii* and *Pongo pygmaeus*, respectively) and a serious risk for the Endangered or Critically Endangered chimpanzees, bonobos, and gorillas in Africa, because a large proportion of extant populations are found outside protected areas (*Grasp & IUCN, 2018*; *Lanjouw et al., 2015*; *Linder, 2013*; *Vijay et al., 2016*; *Wich et al., 2014*). Projections of land-cover change indicate that the Bornean orangutan, for example, is expected to lose 15 to 30% of its remaining habitat by 2080, mainly due to

deforestation and oil palm plantations (*Wich et al., 2014*; *Struebig et al., 2015*; *Vijay et al, 2016*). Moreover, given the growing global demand for palm oil, which is expected to convert some 400 million ha of African forest to monoculture by the year 2050, population decline and habitat loss is projected to threaten over 40 species of African primates (*Strona et al., 2018*). The oil palm, native to West Africa, is now cultivated in large-scale plantations across the tropics. It is used in several commercial products including cooking oil, soap, cosmetics, and margarine (*USDA-FAS, 2018*).

Natural rubber

The total accumulated value of exports of natural rubber by top exporter primate-range countries in 2016 was US$11.1 bn and the most important primate-range region for supplying natural rubber to global markets was Southeast Asia, with Thailand and Indonesia contributing to 76% of the total value of exports (**Fig. 7E**). Major importing countries were India, China, and the US (**Fig. 7F**). Exports of rubber from Southeast Asia went from 4.3 US$ bn in 2000 to almost 11 US$ bn in 2016, a reflection of the dramatic expansion of rubber plantations over the past several decades (**Fig. 5**). In 1960, four million ha worldwide were devoted to rubber cultivation and, by 2016, the area of land converted to rubber plantations had reached 11.4 billion ha, with Southeast Asia accounting for approximately 78% (**Fig. 5**). Deforestation due to the establishment of rubber plantations in South Asia and China has severely affected populations of threatened primates such as the Vulnerable Bengal slow loris (*Nycticebus bengalensis*), the Endangered western hoolock gibbon (*Hoolock hoolock*), the Endangered Phayre's langur (*Trachypithecus phayrei*), the Critically Endangered northern white-cheeked crested gibbon (*Nomascus leucogenys*), and the Critically Endangered Hainan gibbon (*Nomascus hainanus*) (*Fan et al.,*

371 *2014*; *Mazumder et al., 2014*). Even protected areas are at risk due to the expansion of rubber
372 plantations. Between 2005 and 2010, over 2500 km^2 of natural tree cover and 610 km^2 of
373 protected areas were converted to rubber plantations across Southeast Asia (*Ahrens et al., 2015*).
374 Growing global market demands for natural rubber are driving both industrial-scale and
375 smallholder monocultures of this commodity, with >2 million ha established in the last two
376 decades, mostly in Southeast Asia and southwest China, including the primate-rich province of
377 Yunnan (*Li et al. 2018*). It is estimated that an additional eight million ha of rubber plantations
378 will be required to meet world demand by 2024 (*Warren-Thomas et al., 2015*). Global demand
379 for natural rubber also has increased rapidly in the past decades, with 70% of global consumption
380 used for tires. Rubber is the most rapidly expanding tree crop in mainland Southeast Asia
381 (*Warren-Thomas et al., 2015*).

382 Insert Fig.7 about here

383 *Beef*

384 The total accumulated value of exports of beef by top exporter primate range nations in 2016 was
385 US$13.2 bn. The most important primate-range region supplying beef to global markets in 2016
386 was the Neotropics. In both the Neotropics and South Asia, beef exports increased significantly
387 between 2000 and 2016 (**Fig. 4**). Trade flows show that beef exports in the Neotropics were
388 dominated by Brazil, Mexico, Argentina, and Paraguay, accounting for 63% of beef exports from
389 this region (**Fig. 7G**). In 2016, China, the Russian Federation, and Egypt were the top importers
390 of beef from the Neotropics, suggesting that these countries drive the destruction and conversion
391 of large areas of forested land in this region (**Fig. 7H**). In South Asia, India was the major beef
392 exporter, accounting for 95% of exports (**Fig 7G**). Imports of South Asian beef went principally
393 to Egypt, Malaysia, Saudi Arabia, and the UAE (**Fig. 7H**). As a result of internal and global

394 demands for beef, cattle stocks have been growing rapidly since 1980 in both the Neotropics and
395 Africa, and at a slower rate in South Asia and Southeast Asia. However, collectively in these
396 four primate regions, cattle stocks have grown from 527.7 million head in 1960 to 1 billion head
397 in 2016 (**Fig. 5**), with concomitant increases in pasture placing many primate populations at risk
398 (*Estrada et al., 2017*).

399 Insert Fig. 8 about here

400 **Trade in nonagricultural commodities leading to forest degradation**

401 The international trade in forestry products (e.g., lumber and charcoal), land-based fossil fuels,
402 metals and minerals, and gemstones from primate-range regions is a major driver of forest
403 degradation and loss (*UNComtrade, 2018*). Trade data indicate that the export of these
404 commodities grew substantially between 2000 and 2016 (**Fig. 9**). The Neotropics and Southeast
405 Asia were major exporters of forestry products, while Southeast Asia and the Neotropics
406 dominated exports of fossil fuels. Major exporting regions of metals and minerals were the
407 Neotropics and Africa, while major exporters of gemstones and pearls were South Asia and
408 Africa (**Fig. 9**).

409 Insert Fig. 9 about here

410 **Trade flows in 2016 of nonagricultural commodities resulting in forest degradation**

411 *Forestry products*

412 The total accumulated value of exports of forestry products by the top exporting primate-range
413 nations in 2016 was US$21 bn. Trade flow data show that while all four of the primate-range
414 regions exported forestry products, the Neotropics and Southeast Asia were the greatest
415 exporters (Fig. 10A). In the Neotropics, the top exporter of forestry products in 2016 was Brazil,
416 and the top importer nations were China and the US, followed by Italy, Germany, and Japan
417 (Fig. 10B). Top exporters of forestry products in Southeast Asia were Indonesia and Malaysia,

418 followed by Thailand and Vietnam (Fig. 10A). China, Japan, and South Korea were the top
419 importers of forestry products from Southeast Asia (Fig. 10B). Major importers of forestry
420 products from Africa were China, India, Belgium, and France (Fig. 10B). In addition, the total
421 accumulated export of wood from the Congo Basin countries—which have some 60 primate
422 species—to China doubled between 2001 and 2015, with a concomitant increase in the loss of
423 tree cover (*Fuller et al., 2018*). Global demand for tropical forestry products (e.g., timber) has
424 increased over the past several decades. This has led to an expansion of logging activities
425 creating a potent economic incentive for road building in otherwise forested and hard to access
426 areas in primate-range regions (*Malhi et al., 2014*). Data from FAOSTAS show that harvesting
427 industrial non-coniferous roundwood increased by an order of magnitude between 1960 and
428 2016 (from 34 million m^3 in 1960 to 286 million m^3 in 2000 to 389 million m^3 in 2016, Fig. S2),
429 in response to the ever-increasing worldwide demand for tropical timber. Complex
430 environmental and economic drivers surround the trade of tropical timber and deforestation. For
431 example, US demand for Chinese-made furniture positively correlated with Chinese timber
432 imports from the Congo Basin, suggesting that the US demand for furniture motivates the
433 harvest of timber by Chinese commercial businesses (*Fuller et al., 2018*). Although some
434 primate species—orangutans (*Pongo*), for example—can survive temporarily in logged forests,
435 they and other primate species such as chimpanzees (*Pan troglodytes troglodytes*) and gorillas
436 (*Gorilla gorilla gorilla*) are adversely affected, and their long-term persistence in these degraded
437 habitats is unlikely (*Meijaard et al., 2012*; *Voigt et al., 2018*; *Morgan et al., 2018*). Logging
438 reduces canopy cover and forest undergrowth, and consequently humidity. The drying of the
439 subcanopy and undergrowth increases tree mortality and the likelihood of ground fires, affecting
440 the regeneration of the large tree species that provide food, resting sites, and refuge for primates

441 (*Alisjahbana & Busch, 2017*; *Lewis, Edwards & Galbraith, 2015*; *Peres, 1999, 2001*; *World*
442 *Bank, 2016*). Moreover, the influx of hunters, miners, and settlers has led to the pollution of
443 streams and an increase in bushmeat hunting (*Remis et al., 2012*).
444
445 *Fossil fuels (coal, gas, oil)*
446 The total accumulated value of exports of fossil fuels by the top exporting primate-range nations
447 in 2016 was US$258 bn (Fig. 10). Fossil fuel exports increased markedly in the Neotropics,
448 mainland Africa, and Southeast Asia between 2000 and 2016 (Fig. 9). In the Neotropics,
449 Venezuela, Colombia, and Mexico (Fig.10C) were the leading exporting nations. The leading
450 importer nations were the US, China, and India (Fig. 10D). In mainland Africa, exports of fossil
451 fuels in 2016 were greatest in Nigeria and Angola, and major importers were China, India, and
452 the US (Fig. 10C). In Southeast Asia, Indonesia and Malaysia were the main exporters of fossil
453 fuels, with China, Japan, Singapore, and South Korea being the major importers (Fig. 10D). In
454 South Asia, India was the largest producer of fossil fuels and the major importers were Singapore
455 and the US (Fig. 10C, D). Global demand for oil and natural gas is expected to grow between
456 30% to 53% by 2035, and primate-rich areas such as the Amazon, Malaysia, and Borneo will be
457 severely affected (*Finer et al., 2015*). Oil and gas concessions in the western Brazilian Amazon
458 and in forested areas of Colombia, Ecuador, Perú, and Bolivia, already cover about 733,414 km^2
459 (*Finer et al., 2015*). At the time of writing, 327 oil or gas blocks, covering some 108 million ha,
460 are projected or are being explored in the Amazon Basin (*Bebbington et al., 2018*). In many
461 cases, these potential energy fields have considerable overlap with protected areas, and currently
462 exploited oil and gas infrastructure tends to be found on land where biodiversity, species
463 richness, and range rarity are high (*Hartford et al., 2017*). This exacerbates the negative effects
464 that fossil fuel extraction have on primate populations. Human societies are largely dependent on

fossil fuels (coal, oil, and natural gas), which has contributed to increased carbon in the atmosphere and to climate change. The land-based extraction of fossil fuels, similar to the negative impact of the harvesting of forest products, results in decreased biodiversity and increased accessibility for settlements, logging, hunting, and agriculture, all resulting in primate habitat loss and pollution (*Hartford et al., 2017*; *Finer & Orta-Martinez, 2010*).

Insert Figure 10 about here

Metals and minerals

The total accumulated value of exports of metals and minerals by the top exporting primate-range nations in 2016 was US$204 bn (Fig. 11E, F). The Neotropics was the leading primate region exporting metals and minerals (US$85.6 bn), followed by Africa (US$54.5 bn), Southeast Asia (US$35.0 bn), and South Asia (US$19.8 bn) (Fig. 11E). Of the countries in the Neotropics, Brazil, Peru, and Mexico were the major exporters of metals and minerals. In Africa, South Africa dominated metal and mineral exports (Fig. 11E). Major exporters in Southeast Asia were Indonesia, Thailand, and Malaysia (Fig. 11E). Pakistan, India, and Afghanistan were major exporters in South Asia (Fig.11E). In 2016, China was the primary importer of metals and minerals from the Neotropics, Africa, Southeast Asia and South Asia. Other leading importers were the US, Switzerland, Japan, South Korea, and India (Fig. 11F). The mining of metals and minerals is a persistent threat to primates and their habitats. Mining contributes to habitat destruction, fragmentation, deforestation, and the poisoning and pollution of soil and ground water (*Alvarez-Berrios & Aide, 2015*; *Garcia et al., 2017*). In Brazil, 126 mining dams are currently at risk of failing. In one case, dam failure poisoned hundreds of kilometers of the Rio Doce, from the upper reaches to the sea, with a toxic mud of iron-ore tailings (*Garcia et al., 2017*). Added effects are extensive tree mortality on the borders of both small and large mines,

488 the establishment of camps and frontier towns, the construction of access roads, rail, and trails,
489 the construction of mining dams, and hydro-power/waterway developments (*Alvarez-Berrios &*
490 *Aide, 2015*; *Asner et al., 2013*; *Global Forest Watch, 2018*). Mining stimulates human migration,
491 resulting in illegal logging and the colonization of forested areas, with the consequent increase in
492 bushmeat hunting and illegal primate trade (*Alamgir et al., 2017*; *Butt et al., 2013*; *Laurance et*
493 *al., 2015*).
494
495 In eastern DRC, unprotected areas of high animal and plant biodiversity overlap with areas that
496 are rich in minerals (*Edwards et al., 2014*). Increased global demand for surface deposits of
497 conflict minerals such as tantalum, coltan, and gold has resulted in the expansion of illegal
498 mining camps in several national parks in the DRC. Widespread bushmeat hunting in these areas
499 has devastated populations of Grauer's gorillas, eastern chimpanzees, and other primate species
500 (*Plumptre et al., 2015*; *Spira et al., 2017*). Illegal gold mining in Madagascar by itinerant miners
501 has impacted many forests inhabited by lemurs (*Duffy, 2007*). In the Philippines, mining of gold,
502 nickel, and copper on Dingaan Island has endangered the survival of tarsiers (*Carlito syrichta*)
503 (*Brown et al., 2014*). In Ghana, mining-induced hunting and logging have caused the decline of
504 primates such as the Dwarf galago (*Galagoides demidoff*), Bosman's potto (*Perodicticus potto*),
505 and the Mona monkey (*Cercopithecus mona*) in forest reserves adjoining mine sites (*Erasmus et*
506 *al., 2018*). Gold mining in Indonesia is a major threat to the Endangered proboscis monkey
507 (*Nasalis larvatus*) (*Meijaard and Nijman, 2000*) and to Bornean orangutans and the Endangered
508 Bornean gibbons (*Hylobates muelleri*) (*Garcia et al., 2017*; *Lanjouw, 2014*). Pressure to expand
509 mining as a result of global market demands has resulted in mining concessions covering 160
510 million ha, some 21%, of the total area of the Amazon basin (*Bebbington et al., 2018*). If these

511 concessions are mined, they will have a devastating impact on primate populations and
512 biodiversity.

513 Insert Fig. 11 about here

514 *Gemstones and pearls*

515 The total accumulated value of exports of gemstones and pearls by the top exporting primate-
516 range nations in 2016 was US$45 bn (Fig. 11). India, Botswana,Thailand, Angola, and Namibia
517 were top exporters of gemstones (Fig. 11G). China, the US, Belgium, and the UAE were major
518 importers (Fig. 11H). Mining for gemstones such as diamonds, emeralds, and sapphires is
519 accompanied by forest degradation, influxes of people, frontier settlements, road building,
520 bushmeat hunting, and the disturbance of protected areas similar to that caused by the mining of
521 metals and minerals (*Duffy, 2007*). Illegal gem mining coupled with logging in national parks
522 poses a threat to the Endangered fork-marked dwarf lemur (*Phaner pallescens*) in Madagascar,
523 and to the needle-clawed galagos (*Euoticus elegantulus*) in Cameroon (*Nomuh Forbanka, 2018*).
524 Illicit sapphire mining by itinerant miners in Madagascar has had a negative impact on the
525 survivorship of lemurs (e.g., the Endangered ring-tailed lemur, *Lemur catta*), even in protected
526 areas (*Duffy, 2007*; *Gould & Sauther, 2016*). Many primate range countries are among the most
527 important world producers of diamonds (e.g., Guyana, Brazil, Sierra Leone, Botswana,
528 Tanzania), emeralds (e.g., Brazil, Zambia, Pakistan), sapphires (e.g., Pakistan, Sri Lanka,
529 Madagascar), rubies (e.g., Pakistan, Myanmar, Thailand), jade (e.g., Myanmar), and other
530 colored gemstones (*Shortell & Irwin, 2017*). Only a small fraction of the cutting, polishing, and
531 processing of gemstones are conducted in the countries where this resource is extracted (*Shortell*
532 *& Irwin, 2017*). The world production and trading of gemstones is dominated by a small set of
533 international corporations including Rockwell Diamonds, Gem Diamonds, Lucara, Rio Tinto,

534 Petra Diamonds, and De Beers (https://www.petragems.com/education/top-ten-diamond-
535 companies-in-the-world-/), and monies generated by the gem trade are rarely used to support
536 economic development in primate-range countries (*Howard, 2016*).
537
538 **Top primate-range, commodity-exporter countries and top importer countries of these**
539 **commodities**
540 Our examination of the 2016 trade flows of the eight major commodity groups indicates that 55
541 primate habitat countries were exporters, and 42 countries were importers (Figs. 10, 11; Table
542 S3, S4). Among the top 10 exporting countries, Brazil, India, Indonesia, Malaysia, and South
543 Africa accounted for 50% of the accumulated value of commodity exports in 2016 (Fig. 12A:
544 Table S3). Just 10 importer countries accounted for 95% of the imported value (US$455 bn) of
545 commodities from those 55 primate-habitat countries (Fig. 12B; Table S4). Among the major
546 importers in 2016, China and the US combined, accounted for 58% of the imported value of
547 these commodities. However, China was by far the single major importing nation, purchasing
548 over twice the amount of commodities purchased by the US (Fig, 12B). In this regard, along with
549 the US, China's emergence as an economic superpower has resulted in a devastating
550 environmental footprint that is driving deforestation and biodiversity loss in primate-habitat
551 countries (Ascensão et al., 2018).
552 Insert Fig. 12 about here
553 **Revenues generated by commodity-exporting, primate-range countries in 2016**
554 In 2016, US$4.4 trillion of natural resource commodities were traded by the world's countries
555 (resourcetrade.Earth, 2018) and 25% (US$ 1.1 trillion) were commodities traded by countries in
556 primate-range regions. The Neotropics accounted for 41% of the total value of these exports,
557 Southeast Asia for 27%, Africa for 21%, and South Asia for 11% (Fig. 13A). Trade data from

558 resourcetrade.Earth indicate that these export revenues increased significantly between 2000 and
559 2016 (Fig. 13A). International trade is a critical source of revenue for primate-range countries
560 and, assuming that an increase in the Gross Domestic Product per Capita (GDPPC) has a positive
561 effect on food security, political stability, education, and health, we expect that it would favor
562 primate conservation. For example, primate-range countries with a GDPPC of <10,000 US$ in
563 2018 had a higher percent of IUCN threatened-primate species than countries with a GDPPC of
564 >10.000 US$ (Fig. 13B. Table S5).

565 Insert Fig. 13 about here

566 **Modeling the current and future (2050 and 2100) risk of primate species' extinction due to**
567 **agriculture**

568 As of 2016, the greatest number of primate species threatened with extinction (i.e. Vulnerable,
569 Endangered, or Critically Endangered according to the IUCN Red List) are in Madagascar,
570 Brazil, Indonesia, China, Vietnam, and Colombia (Table 2). In Madagascar and Southeast Asian
571 countries such as Vietnam, Laos, and China, over 80% of the primates are threatened with
572 extinction. Primate-habitat countries differ widely in the degree to which particular
573 anthropogenic drivers have resulted in species decline (Table 2). In Table S9, we aggregated 10
574 human land use patterns of the LUH2 dataset into three broad categories: forestry (defined as any
575 human use of forested land), grazing (defined as pasture or rangeland for commodity
576 production), and agriculture (defined as any crop production), for the top 15 primate-richest
577 countries in the world. At the time of writing, forestry is the major threat to primate species in
578 Peru, Cameroon, Indonesia, Laos, Malaysia, India, and Myanmar. In contrast, the conversion of
579 forest into pasture for grazing, principally for cattle and pig production, is the major threat to
580 primate species in Madagascar, Brazil, Colombia, and China. Among all land use patterns,
581 agricultural activities are the greatest or second greatest threat to primate species in Indonesia,

582 Brazil, Vietnam, Laos, Malaysia, India, Nigeria, Myanmar, Thailand, Cameroon, and Cambodia
583 (see Table S9 for all results per land use type).

584 Insert Table 2 about here

585 The business-as-usual future scenario RCP 4.5 SSP-2 (*Fricko et al. 2017*) assumes continued
586 development along historical patterns such that meat and food consumption converge slowly
587 towards higher levels, trade is largely regionalized, and crop yields in low-income regions catch
588 up with high-income nations. In the model, land use changes, however, are incompletely
589 regulated, with continued deforestation (although at a declining rate) between 2016 and 2050.
590 Each primate-habitat country is expected to see an increase in its number of threatened species
591 (Table S8). This includes 13 newly threatened species in Madagascar (100% of species
592 threatened) and 12 newly threatened primate species in Brazil (44% of species threatened) (Fig.
593 14). Land use changes by the end of the century are expected to result in six of the 15 primate-
594 richest countries having 100% of their primate species threatened with extinction by the year
595 2100, and three additional countries having over 80% of their primate species threatened with
596 extinction (Fig. 14, Table S8). On a more positive note, we found that the most ecofriendly
597 climate change mitigation scenario, coupled with a sustainable socioeconomic trajectory RCP2.6
598 SSP-1 (Van *Vuuren et al. 2017*) which is defined as the world shifting towards a sustainable
599 path, characterized by healthy diets, low waste, reduced meat consumption, increasing crop
600 yields, and reduced tropical deforestation, is expected to limit land use changes such that over
601 the next 30 years (e.g. by 2050), no additional primate taxa will become threatened with
602 extinction (Table S8). The scenario will require significant changes in human behavior and land
603 use practices.

604 Insert Fig. 14 about here

605 **TRADE AND FOOD SECURITY**

606 Trade is a critical factor in food security and provides an income for approximately 30% of the
607 world's active workforce (Clapp, 2015). While some countries lack the natural capital to produce
608 enough food because they are restricted by land, climate, soil, political instability, or technology,
609 other countries produce more food than they require. Open trade policies allow the free flow of
610 food from countries with excesses to countries with deficits and, therefore, are expected to
611 enhance world food security (Lamy, 2011, 2012; OECD, 2013; World Bank, 2012). The
612 Economist Intelligence Unit's 2018 Food Security Index (FSI) ranges from 0 (lowest food
613 security) to 100 (highest food security) (Text S2). In 2018, the mean value of the FSI, available
614 for 43 of the 55 primate-range country commodity exporters was 49.0 (range 27.0 [Madagascar]
615 to 69.2 [Argentina]) (Fig. 13A; Table S6). For the top 10 exporters, the mean FSI was 57.0
616 (range 38.0 [Nigeria] to 68.0 [Brazil]). In contrast, the mean value of the FSI for the top 10
617 commodity importer countries was 76.0 (range 50 [India] to 86 [Singapore]) (Fig. 15A; Table
618 S7). Clearly, primate-range countries that are exporters of commodities lag behind importer
619 nations in food security. These major importing nations tend to capture large volumes of export
620 commodities from primate-range countries with limited positive effects for the exporting
621 countries. This difference is underlined by the disparity in the 2017 GDPPC between these two
622 groups of countries (Fig. 15B).

623 Insert Fig. 15 about here

624 It is expected that trade helps food security by providing a safety net against oscillations in
625 domestic food supply and by stabilizing prices (*World Bank, 2015*). Trade dependence, however,
626 also means that countries are vulnerable to shifts in the trade policies of both food-importing and
627 food-exporting nations, including tariffs and trade bans (Bloomberg, 2017). Importantly, the
628 interconnectedness of global trade and supply chains creates a risk that the storage and transport

infrastructure that governs international trade might collapse (*Bettina, 2015*)—such as when political and physical bottlenecks restrain the flow of food, water, and energy (*Bloomberg, 2017*). Political conflict is one of the main drivers of food insecurity, disrupting not only food production and distribution but also transport (*World Bank, 2015*). Shifts in market prices also have important consequences for consumers. For example, as China pays more for soybeans, whether in response to tariffs on US imports or to broaden its import profile, other consumers will pay more as well (*Reuters, 2017*). For low-income households around the globe that already spend most of their income on food, abrupt cost increases produced by higher import duties, or by unexpected shifts in trade flows, can have a significant negative impact on health, food security, the spread of disease, and political stability (*Bettina, 2015*).

CORRUPTION AND ILLEGAL FOREST CLEARING FOR COMMERCIAL AGRICULTURE

Factors that negatively impact human communities, also negatively impact policies and practices of environmental sustainability, and often result in habitat degradation and loss of biodiversity. One such factor is corruption. Information from the 2018 Corruption Perceptions Index (CPI) of Transparency International (https://www.transparency.org) in which 0 = most corrupt and 100 = least corrupt, showed that commodity exporters in primate-range countries were, on average, more corrupt (average CPI of 33.1; range:18.0 – 68.0; Table S6) than importer countries (average CPI of 52.8; range 20.0 – 85.0; Table S7). Income inequality is often directly associated with corruption. For example, between 2001 and 2015 the richest 10% of Brazilians accounted for 61% of total economic growth (*Oxfam, 2019a*). Similarly, wealth inequality in Indonesia is so extreme that the four richest men in the country have more wealth than the combined total of

652 the poorest 100 million people (*Oxfam 2019b*). Both Indonesia and Brazil are ranked as the first
653 and third primate-richest countries in the world, and increased corruption and income inequality
654 is projected to result in high levels of environmental degradation, deforestation, and increased
655 rates of primate extinctions (*Estrada et al., 2018*).
656
657 A recent report by Forest Trends indicates that since the start of the 21st century, illegal forest
658 clearing for commercial agriculture and related exports has continued at an alarming rate in
659 tropical regions (https://www.forest-trends.org/). This has resulted in high conservation costs. It
660 is projected that unless governments ensure that forested land converted for production is
661 acquired legally and sustainably, deforestation will continue to increase in regions where little
662 commercial agriculture had previously existed, such as the Congo Basin (*Lawsom et al., 2014*).
663 Governments that curb political freedom, free speech, a free press, and citizen rights and choices
664 inevitably also have free license to engage in large-scale environmental destruction. The most
665 recent (2019) evaluation by Freedom House, an independent watchdog group, shows that in
666 many countries in Africa, South Asia, Southeast Asia and the Neotropics, individual freedoms
667 have declined precipitously in the last 13 years (*Freedom House, 2019*), and this is likely to
668 result in a further decline in laws governing environmental and primate protection (Fig. 16).
669 Insert Fig. 16 about here

670 **CONCLUSION AND CLOSING COMMENTS**

671 The production of commodities such as soybean, palm oil, natural rubber, and beef has direct and
672 indirect impacts on biodiversity and primate population persistence because plantations are
673 primarily large-scale, commercial monocultures that require complete clearing of natural
674 vegetation. In addition, the use of pesticides and herbicides serve to eliminate remaining native

675 biodiversity, and diminish the likelihood of habitat restoration (*Fearnside, 2001*; *Laurance,*
676 *2007*; *WWF, 2010*). The extraction of hardwoods, minerals, land-based fossil fuels, and
677 gemstones in undisturbed areas causes extensive forest degradation and forest loss. It also results
678 in the construction of transportation networks and other infrastructure projects that open large
679 and once remote forests to population migration, illegal logging, bushmeat hunting, and the
680 illegal pet trade, critically impacting primate and other animal populations (*Alamgir et al., 2019*;
681 *Estrada et al., 2017*; *Latrubesse et al., 2017*; *Plumptre et al., 2015*; *Spira et al., 2017*; *Timpe &*
682 *Kaplan, 2017*; *Winemiller et al., 2016*; *WWF, 2006*). Unfortunately, a projected massive
683 expansion of transportation networks has been proposed as part of China's Belt and Roads
684 Initiative. This will involve some 60 counties in Africa and Asia through a large-scale expansion
685 of roads and rails in order to create a set of economic corridors designed to expand future global
686 trade. This will result in permanent environmental damage, impacting primates and biodiversity
687 by increasing agricultural production, the extraction of raw materials, as well as the construction
688 of dams and other large infrastructure projects, causing habitat reduction and fragmentation and
689 increased human-primate conflict (*Ascensão et al., 2018*; *Estrada et al., 2017*; *MERICS, 2019*).
690
691 Furthermore, global dietary changes towards greater meat consumption and greater dependence
692 on vegetable oils as a result of improved living standards will encourage many primate-range
693 countries to convert additional forested land into monocultures to meet national and global
694 market demands (*Gouel & Houssein, 2017*; *Kastner et al., 2012*; *Tilman & Clark, 2014*). In order
695 to achieve the goals of primate habitat conservation, it is imperative to decrease the world's
696 demand for agricultural products (e.g. oil seeds, natural rubber, sugar cane) and the consumption
697 of meat and dairy products (*Machovina et al., 2015*; *Stehfest et al., 2009*; *Willet et al., 2019*). It is

698 estimated that the world will need to convert an additional seven million ha of forested land in
699 the tropics to oil palm in the next few years to meet projected demand increases (*Lawsom et al.,*
700 *2014*). Per capita meat-consumption is growing globally and it is anticipated to increase in the
701 approaching decades with an expanding human population, rising incomes in most regions of the
702 world (*Henchion et al., 2014*), and the rapid emergence of a global middle class (1.8 – 4.9 billion
703 by 2030; *Kharas, 2017*). Trade evidence suggests that land conversion for the production of
704 forest-risk commodities has expanded rapidly in primate-range regions, placing primate
705 populations at greater risk (Fig. 6; *Chaudhary and Brooks, 2017*). For example, a study that
706 modeled agricultural expansion and primate distributions for the end of the 21st century found
707 that 68% of the area currently occupied by primates will be turned over to agricultural use,
708 affecting 75% of primate species worldwide (*Estrada et al., 2017*). A country level analysis
709 under a 'worst-case' scenario (e.g. expected increase in conversion of forested land to
710 agricultural production) indicated that by the year 2100, the spatial distribution of primates in
711 Brazil will be reduced by 78%, 72% in Indonesia, 62% in Madagascar, and 32% in the DRC
712 (*Estrada et al., 2018*). Combined, these four countries account for approximately 64% of all
713 primate species. In a second study using the same modeling approach, the most 'optimistic'
714 scenario (e.g. strong and effective legislation to protect primates and their habitats) predicted a
715 51% reduction in the geographical range of primates in China by the year 2100 (China has 25
716 primate species) and an 87% reduction under a 'worse case' scenario (*Li et al., 2018*). Such
717 extensive land conversion will not only increase the susceptibility of primate species at risk of
718 extinction, but it will exacerbate the effects of climate change and cause severe disruption to
719 local human communities through extreme weather events such as increasingly severe storms,

floods, and drought, leading to the high probability of a refugee crises (*Estrada et al., 2017, 2018*; *Henders et al., 2018*).

Unless a way is found to promote environmental protection by "greening" trade (*Neumayer, 2001*; *Henders et al., 2018*), primate habitat loss and population decline will continue unabated. Since the export of food and nonfood commodities may threaten local food security, human safety, and political stability (*FAO, IFAD & WFP, 2015*), a balance needs to be achieved that promotes a reduction in global market demands and takes into consideration the needs of primate-range countries to develop their internal economies, to ensure food security for their expanding human populations, and to protect their biodiversity (Estrada et al., 2017). It has been suggested that corporations marketing products that contain tropical forest-risk commodities should add environmental costs to products so that there is a continuous renewal of resources dedicated to improving conservation and restoring natural habitats (*Butler & Laurance, 2008*). From our analysis of forest-risk commodity trade data it is notable that while 55 primate-range countries were identified as exporters of these commodities in 2016, 95% of the exports were purchased by only 10 importing nations, suggesting an unsustainable pattern of over-consumption, particularly by China and the US. Action taken by importing countries, such as environmentally-friendly policies—for example, banning illegal timber purchases by the EU (*EU, 2010*), the EU resolution on palm oil production and deforestation (*EP, 2017*), and the Amsterdam Declaration to remove deforestation from food and non-food commodity chains (*Amsterdam Declaration, 2015*)—embody important and constructive "green" changes that need to be adopted by the US, China, and other major importers of forest-risk commodity products from primate-range regions (Fig. 17).

743 Because demand for products by more affluent and more developed nations can lead to
744 detrimental environmental pressures in primate-rich and resource-rich regions, countries that are
745 major importers of agricultural and natural resource products from primate-range nations must
746 become active sponsors of, and contributors to, habitat conservation efforts in exporting
747 countries. Sponsoring an increase in land devoted to protected areas, contributing to improved
748 conservation management, promoting community-managed forests, and strict adherence to laws
749 and policies that integrate forest protection and commodity production, are all essential actions
750 that can support biodiversity and the people who live in primate-habitat countries (*Estrada et al.,*
751 *2017*; *Porter-Bolland et al., 2016*; *Sharif & Saha, 2017*) (Fig. 13). Importing countries could also
752 actively support the regeneration of agricultural land and pasture to secondary forests as an
753 important conservation measure (*Chaudhary & Brown, 2017*). In short, a stronger worldwide
754 effort at regulating the negative impact of unsustainable commodity trade in primate-range
755 regions is critically needed (*Henders et al., 2018*). Because the world's agricultural production
756 and supply chains are controlled by a relatively small number of international corporations (e.g.,
757 Cargill, Monsanto, BASF, Dow, Syngenta, and DuPont) that are chartered in consumer nations
758 that produce food in the global south and then exported to other countries for processing and
759 consumption (*EcoNexus, 2013*), ethical responsibility needs to be borne by these corporations.
760 The rise of industrial agriculture (including beef production) has been closely linked to the global
761 seed and agrochemical industries, and this has led to a multitude of environmental problems
762 including the degradation and destruction of ecosystems, a major decline in insect biodiversity,
763 the expanded use of polluting and toxic agrochemicals, and the loss of agricultural biodiversity
764 that threatens sustainable agriculture (*Clapp, 2017, 2019; Sánchez-Bayo & Wyckhuys, 2019*). A
765 similar situation has accrued over decades with the extraction and trade of fossil fuels, where a

766 few corporations including ExxonMobil, Chevron, Shell, BP, ConocoPhillips, Peabody
767 Energy, Consol Energy, and Arch Coal have controlled oil and gas production and distribution
768 worldwide, and disproportionately contributed to the devastating effects of climate change (UCS,
769 2018). The mining of metals and minerals is also dominated by a few companies among which
770 the most dominant are Fresnillo, AngloAmerican, Newmont Mining, Barrick Gold, Coal India,
771 and China Shenhua Energy (https://www.miningglobal.com/top10/top-10-mining-companies-
772 world).
773 By 2050, the global population is projected to increase from 7.5 billion to 9.3 billion and
774 estimates are that food production will need to increase from the current 8.4 billion tonnes to
775 almost 13.5 billion tonnes a year (*FAO, 2014*). Much of this growth in the human population will
776 take place in primate-range countries , where populations are projected to increasing from 5.1
777 billion to 7.3 billion (Fig. S7A in *Estrada et al., 2017*). A major sustainability challenge is to
778 meet global nutritional needs through a healthier diet, and to provide food security for the
779 world's human population while reducing the environmental impacts of the burning of fossil
780 fuels, deforestation, desertification, climate change, and water and air pollution (*Davila &*
781 *Dyball, 2018*; *Willett et al., 2019*). Achieving that level of production from a depleted natural
782 resource base will require an expanded and accelerated effort to transition to sustainable
783 agriculture to ensure world food security, to provide economic opportunities, and to protect the
784 ecosystem services on which agriculture depends (*FAO, 2014*; *FAO, 2017*, *2018, 2019*; *Willett et*
785 *al., 2019*).
786 Insert Figure 17 about here
787 Although the goals of commodity-driven exporting countries may be to improve their economies
788 and to meet the nutritional and socioeconomic needs of their populations, despite considerable

789 year-to-year increases in revenue derived from agricultural and nonagricultural exports in
790 primate-range regions, millions of their citizens remain poor, undernourished, and
791 undereducated, and lack access to quality healthcare (*World Bank, 2018*; *Willett et al., 2019*).
792 Given the rapid pace and large scale at which native forests have been cleared in most primate-
793 range countries, promoting "sustainable intensification" of agriculture on already cleared land
794 would increase production and may help to forestall further land conversion (*Carlson et al.,*
795 *2018*). In addition, connecting farmers who are small landholders with international commercial
796 agricultural entities, may also bring direct economic benefits to the rural poor, as long as their
797 land is protected from debt or confiscation (*Goldsmith & Cohn, 2017*). However, intensification
798 of agriculture that increases yields will not reduce global hunger while a small number of
799 consumer nations distantly located from production areas continue to over-consume and waste
800 food and other commodities. There needs to be a sustained global effort to increase food security
801 in areas of the world where the hungry live, using eco-effective methods that encourage the
802 sustainable productivity of multiple ecosystem services, reduce greenhouse gas emissions, and
803 protect natural biodiversity (*Chaudhary & Mooers*, 2018; *Keating et al., 2010*; *Smith et al.,*
804 *2019*). There is compelling evidence that greater powers of decision making by eco-friendly
805 agricultural practices owned by small landholders who are sensitive to local markets and
806 conditions, rather than profit maximizing large-scale industrial agribusiness, is key to food
807 security in developing nations (*Runting et al., 2015*; *Tscharntke et al., 2012*).
808
809 There is no doubt that additional research is required to examine the role of local and global
810 market demands on primate conservation, including studies to evaluate the extent to which the
811 reduction of land for purposes of agricultural conversion and nonfood resource extraction benefit
812 local human and nonhuman primate communities. Given the crises that we face, applying

economic tools to consumer nations, such as taxes on consumption and on agricultural resources, accompanied by investment in sustainable agri-environmental production and sustainable nonfood resource extraction, are viable alternatives to mitigate the negative impacts of global market demands and of the international commodity trade in primate habitats (*Estrada et al., 2017, 2018*; *Larrosa et al., 2016*). Our assessment on the international commodity trade and over-consumption by a small number of consumer nations suggests that conservation success requires a set of internationally agreed sustainable approaches to land productivity and to natural resource extraction to ensure food security, alleviate poverty, and mitigate forest loss and degradation (*FAO, 2019*). It also underlines the need for a stronger global resolve to regulate the negative impact of unsustainable commodity trade on primate habitats and biodiversity. Such global resolution needs to be matched by a reduction of the world's per capita demand for forest-risk food and non-food commodities from primate-range regions. Primates and their habitats are a vital component of the world's natural heritage and culture. As our closest living relatives, nonhuman primates deserve our full attention, concern, and support for their conservation and survivorship.

ACKNOWLEDGEMENTS

We thank Anthony B Rylands for constructive comments on an early draft of the manuscript. Paul A. Garber is forever grateful to Jennifer A. Garber, Sara A. Garber, and Chrissie McKenney for inspiring him to redirect his efforts to protecting the world's threatened primate populations. Alejandro Estrada is thankful to Erika and Alex for always supporting his interests in primate research and conservation. We are grateful to Dr. Sarah Bologna for her very useful edits on a final version of this article.

ADDITIONAL INFORMATION AND DECLARATIONS

Funding

No funding was used for the preparation of the manuscript

Grant Disclosures

A.C. was funded by the Initiation Grant of IIT Kanpur, India (project number 2018386).

Competing Interests

No competing interests are declared

Author Contributions

Alejandro Estrada conceived and designed the experiments, performed the experiments, analyzed the data, contributed reagents/materials/analysis tools, prepared figures and/or tables, authored or reviewed drafts of the paper, approved the final draft.
Paul A. Garber conceived and designed the experiments, performed the experiments, analyzed the data, contributed reagents/materials/analysis tools, prepared figures and/or tables, authored or reviewed drafts of the paper, approved the final draft.
Abhishek Chaudhary conceived and designed the experiments, performed the experiments, analyzed the data, contributed reagents/materials/analysis tools, prepared figures and/or tables, authored or reviewed drafts of the paper, approved the final draft.

Data Availability

The following information was supplied regarding data availability:
The research in this article did not generate any data or code.

Supplemental Information

Supplemental information for this article can be found online at

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Table 1(on next page)

Deforestation per year (loss of >30% tree-canopy cover) based on remote sensing for the period 2001 to 2017 for the four primate range regions under consideration.

Also shown is the rate of forest loss for each region and the average percent of permanent forest loss caused by commodity-driven forest loss for 2001 to 2015. Shown at the bottom is the total loss in millions of ha for the four regions. Regions are ranked by the magnitude of tree-cover loss between 2001 and 2017.

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Region (n = countries)	Tree cover loss 2001–2017 (million ha)	Rate (n = 17 years) (million ha/yr)	Average % commodity-driven deforestation per region 2001–2015
Neotropics (n = 20)	83.5	4.91	26
Southeast Asia (n = 12)	54.3	3.19	47
Africa (n = 35)	38.5	2.29	7
South Asia (n = 7)	1.9	0.11	26
Total (2001–2017)	178.8 million ha	Four regions 10.52 million ha/yr	

Note: Based on remote sensing, Global Forest Watch has classified five principal causes of forest loss in the world: forestry (26%); shifting agriculture (24%); wildfire (23%); commodity-driven deforestation and urbanization (27%). The last two are consider as drivers of permanent deforestation. Deforestation is measured by GFW as loss of >30% tree canopy cover (*Curtis et al., 2015*; *GFW, 2018*; www.globalforestwatch.org).

Table 2:
Top 15 countries with the greatest number of primate species threatened with extinction (2016).* The total number of primate species threatened with extinction (#threatened) are allocated to the negative effects of conversion of forested land for purposes of forestry, grazing, and agriculture (see *Chaudhary & Mooers, 2018* for additional details).

Country	# species	# threatened	% threatened	% threatened due to Forestry	% threatened due to Grazing	% threatened due to Agriculture
Madagascar	103	90	87	13	76	10
Brazil	116	39	34	15	46	27
Indonesia	56	38	68	43	11	43
Vietnam	22	19	86	37	6	52
Colombia	37	18	49	21	64	11
China	25	20	80	30	46	18
Laos	18	15	83	51	7	37
Malaysia	20	14	70	52	4	40
India	22	12	55	44	5	41
Myanmar	17	11	65	59	3	34
Nigeria	26	11	42	27	31	35
Peru	44	11	25	21	38	20
Thailand	18	11	61	31	5	58
Cambodia	10	9	90	30	9	56
Cameroon	32	9	28	38	18	37

***The number of primate species per country and IUCN status was taken from *Estrada et al., 2017*, except for those of China which was taken from *Li et al 2018*.

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Myanmar	17	11	65	59	3	34
Nigeria	26	11	42	27	31	35
Peru	44	11	25	21	38	20
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Figure 1

Numbers in black indicate species richness in the main regions where primates are naturally found: the Neotropics, Africa (mainland Africa and Madagascar), south Asia and southeast Asia.

The country colors indicate the number of species in each country. In Africa, Madagascar stands out with its rich and endemic primate fauna (the lemurs). Source of information: Estrada et al., 2017 and A. B. Rylands, IUCN SSC Primate Specialist Group,pers. comm., February2019. Note: the range of *Papio hamadryas* extends from mainland Africa into Asia with small populations present in Saudi Arabia and Yemen (IUCN RedList, 2019).

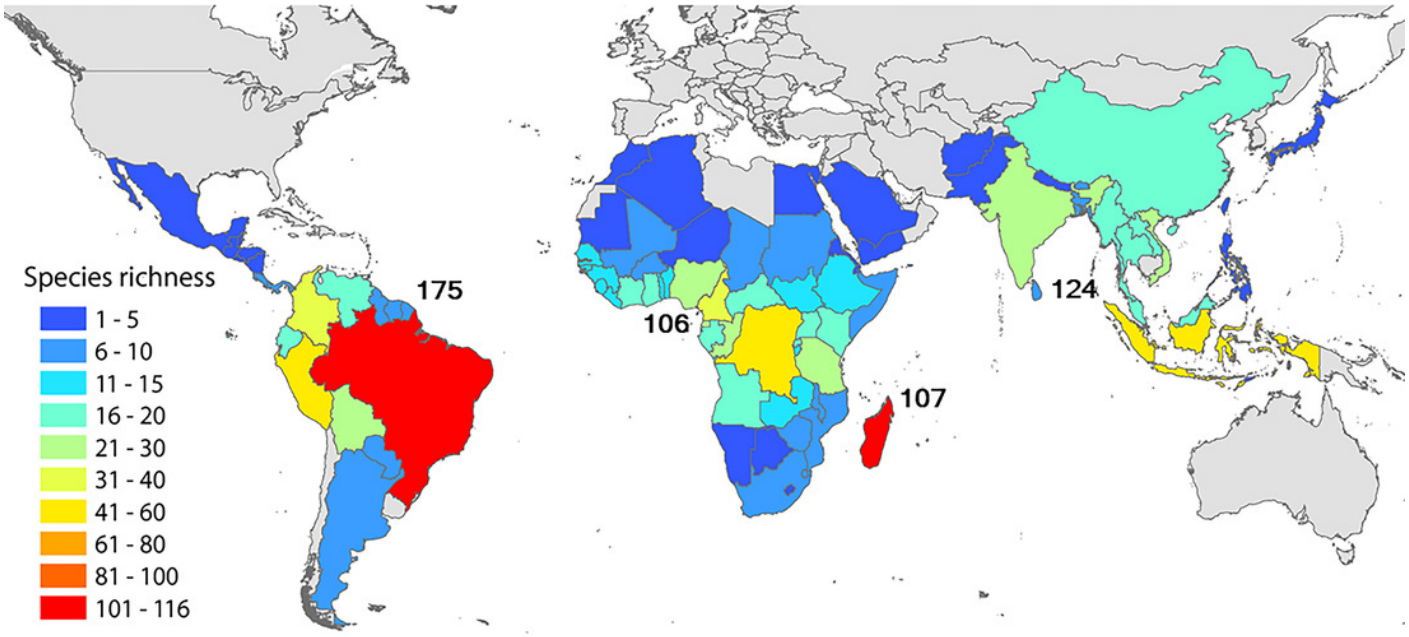


Figure 2

Forest loss (reduction in >30% tree canopy cover) for 2001−2017 (orange bars) and percent of commodity-driven forest loss (permanent deforestation) for 2001−2015 (blue area).

Primate range countries in the Neotropics, Africa (includes Madagascar), South Asia and Southeast Asia based on remote sensing information from Global Forest Watch (www.globalforestwatch.org).

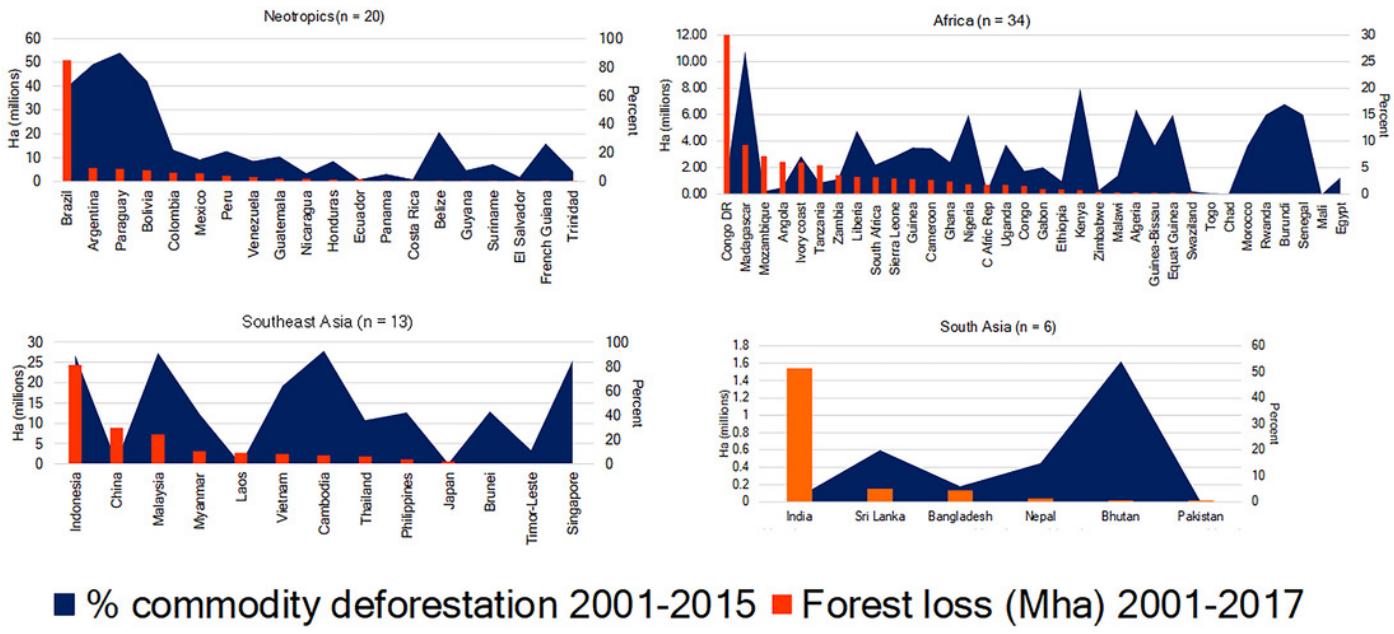
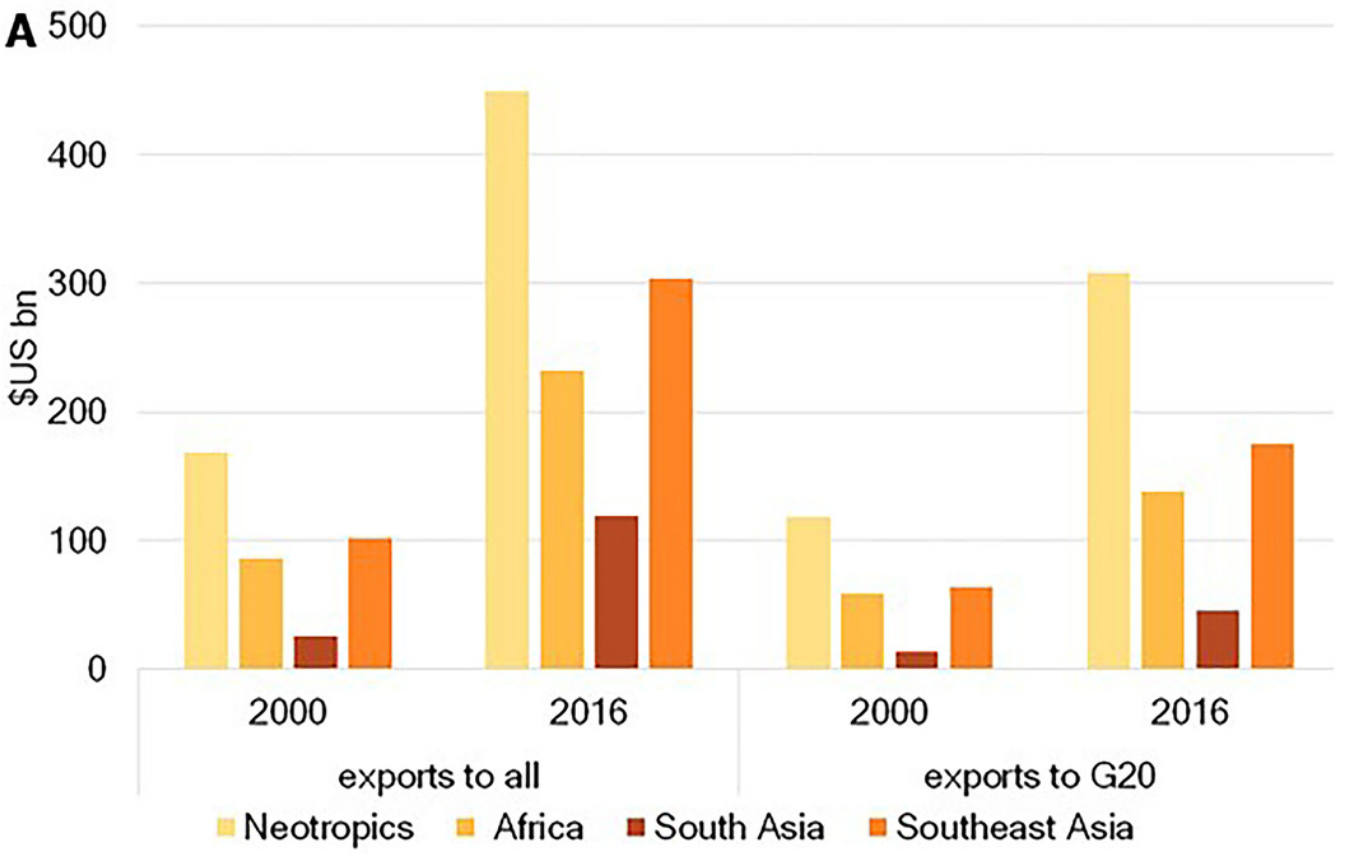


Figure 3

Commodity exports.

(A) Growth of commodity exports between 2000 and 2016 by countries in primate-range regions. Exports refer to all trading parterns (left side of figure) and to countries that comprise the G-20 group (right side of figure). Source: resource trade.earth of Chatham House. **(B) Commodities exported in 2016 by countries in each primate range region.** Source: resource trade.Earth of Chatham House. Beef is considered an agricultural commodity as its large-scale production requires the conversion of large areas of forest pasture. A breakdown of these commodities into their component products can be found in resourcetrade.Eart of Chatham House (https://resourcetrade.earth).


A
500
400
300
200
100
0
$US bn
2000
2016
2000
2016
exports to all
exports to G20
Neotropics
Africa
South Asia
Southeast Asia

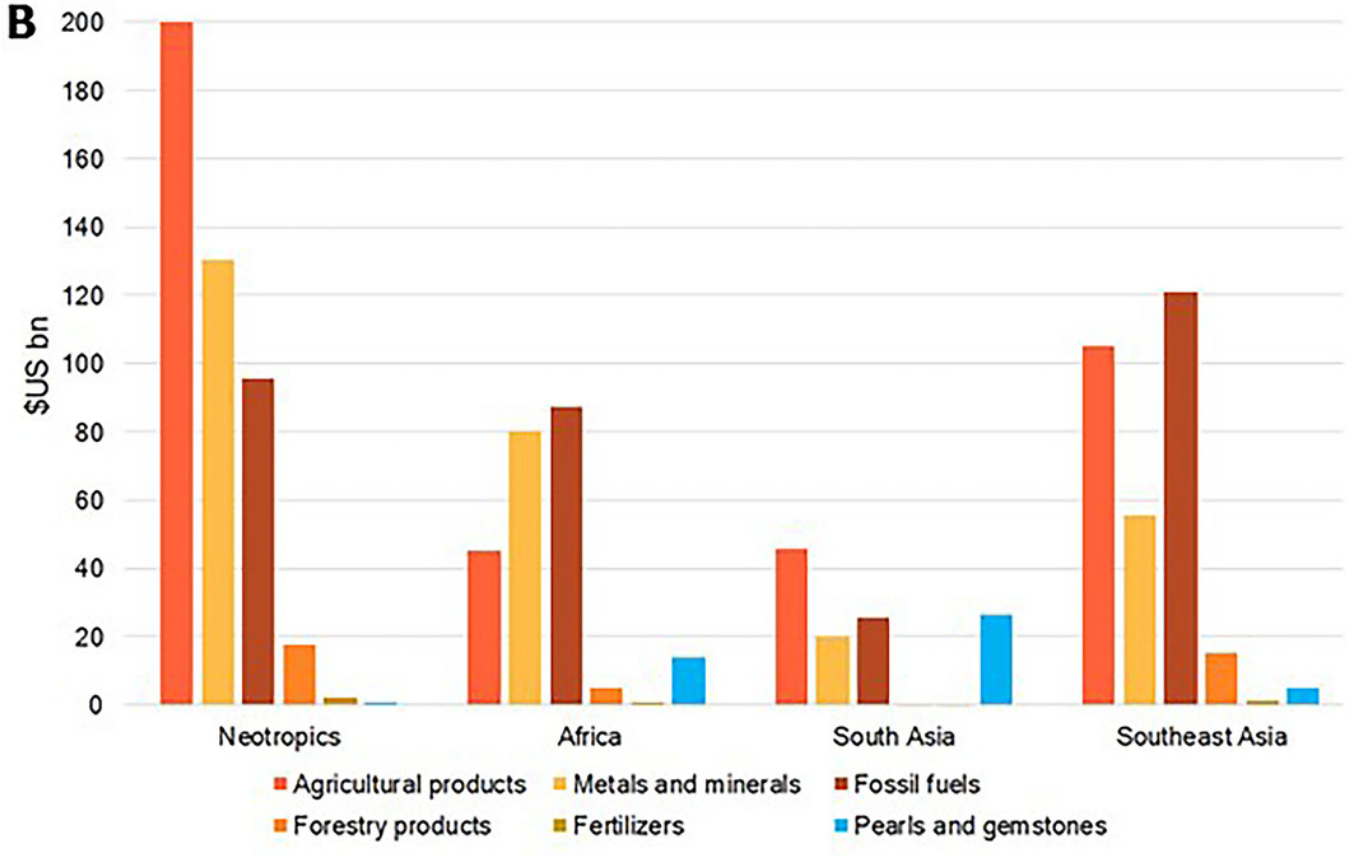

B
200
180
160
140
120
100
80
60
40
20
0
$US bn
Neotropics
Africa
South Asia
Southeast Asia
Agricultural products
Metals and minerals
Fossil fuels
Forestry products
Fertilizers
Pearls and gemstones

Figure 4

Growth in the export of four commodities that led to permanent deforestation in primate-range regions between 2000 and 2016.

Other regions in (A) and (D) refer to Africa, South Asia and Southeast Asia and in (B) and (C) to the Neotropics, Africa, and South Asia. Source: resource trade.Earth of Chatham House.

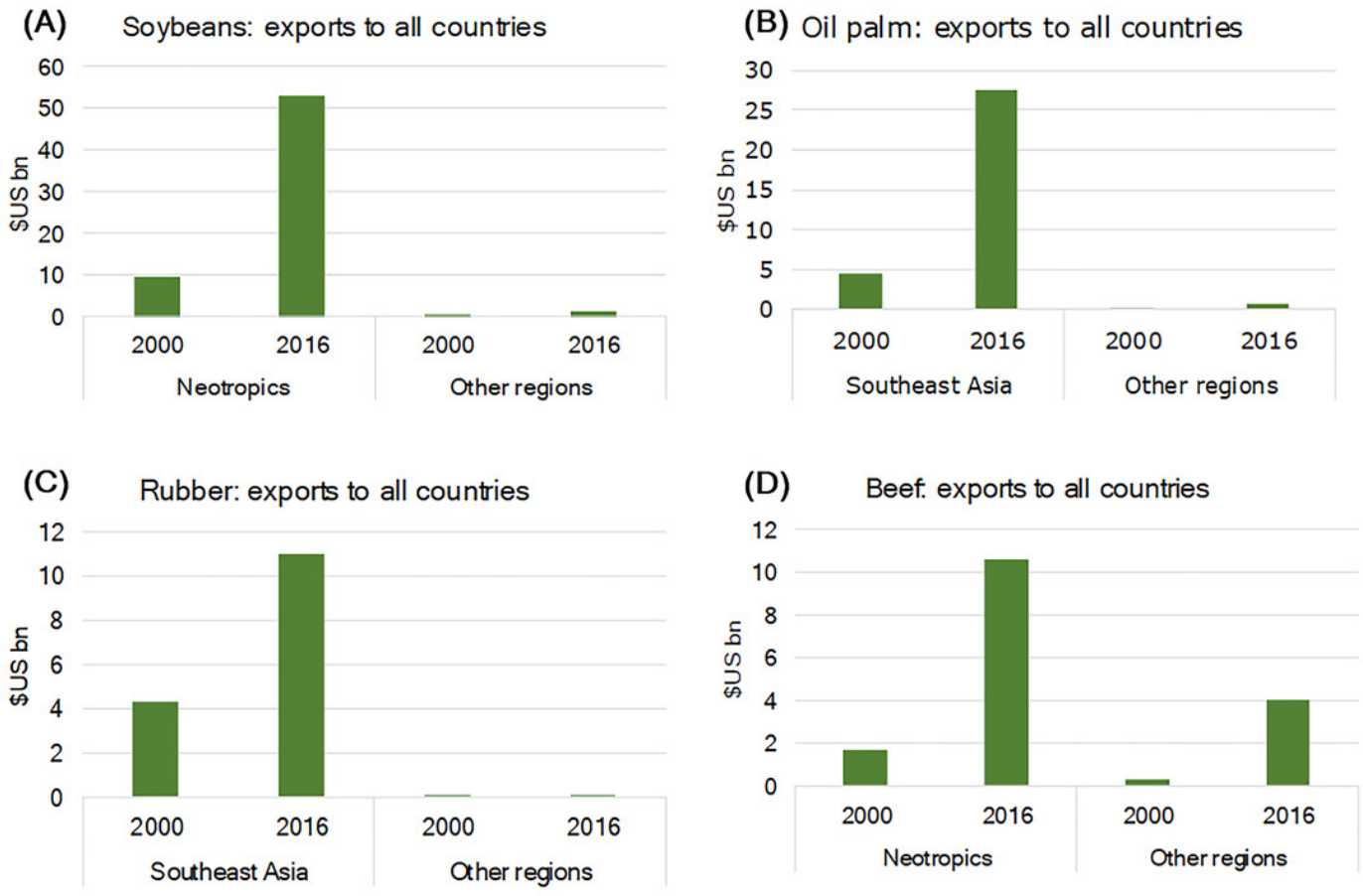


Figure 5

Increase in the area of land dedicated to the production of four selected agricultural commodities.

These increases led to permanent deforestation in primate-range regions between 1960 and 2016. Source: FAOSTATS 2018.

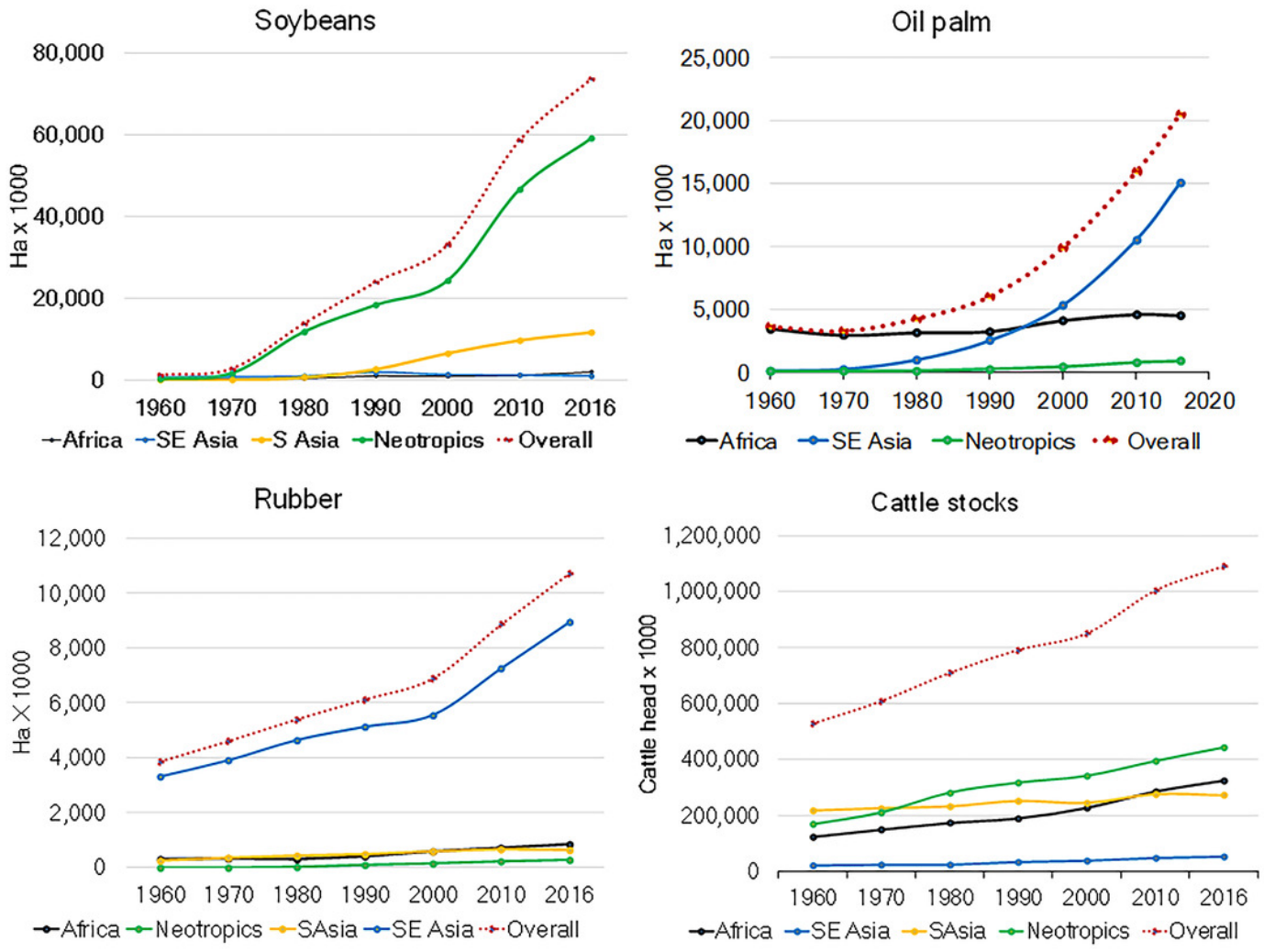


Figure 6

Trade flow diagrams for the top exporter and importer countries of four commodities that resulted in permanent deforestation in each primate-range region in 2016. Soybeans (A, B), Oil Palm (C, D).

Numbers on the flow diagrams indicate the amount in US$ bn of trade for each country. For exports and imports, the trade flows show on the left the accumulated US$ bn for each region and for the countries involved. The width of the connecting flows is proportional to the value exported or imported. Source of trade information resourcetrade.Earth of Chatham House.

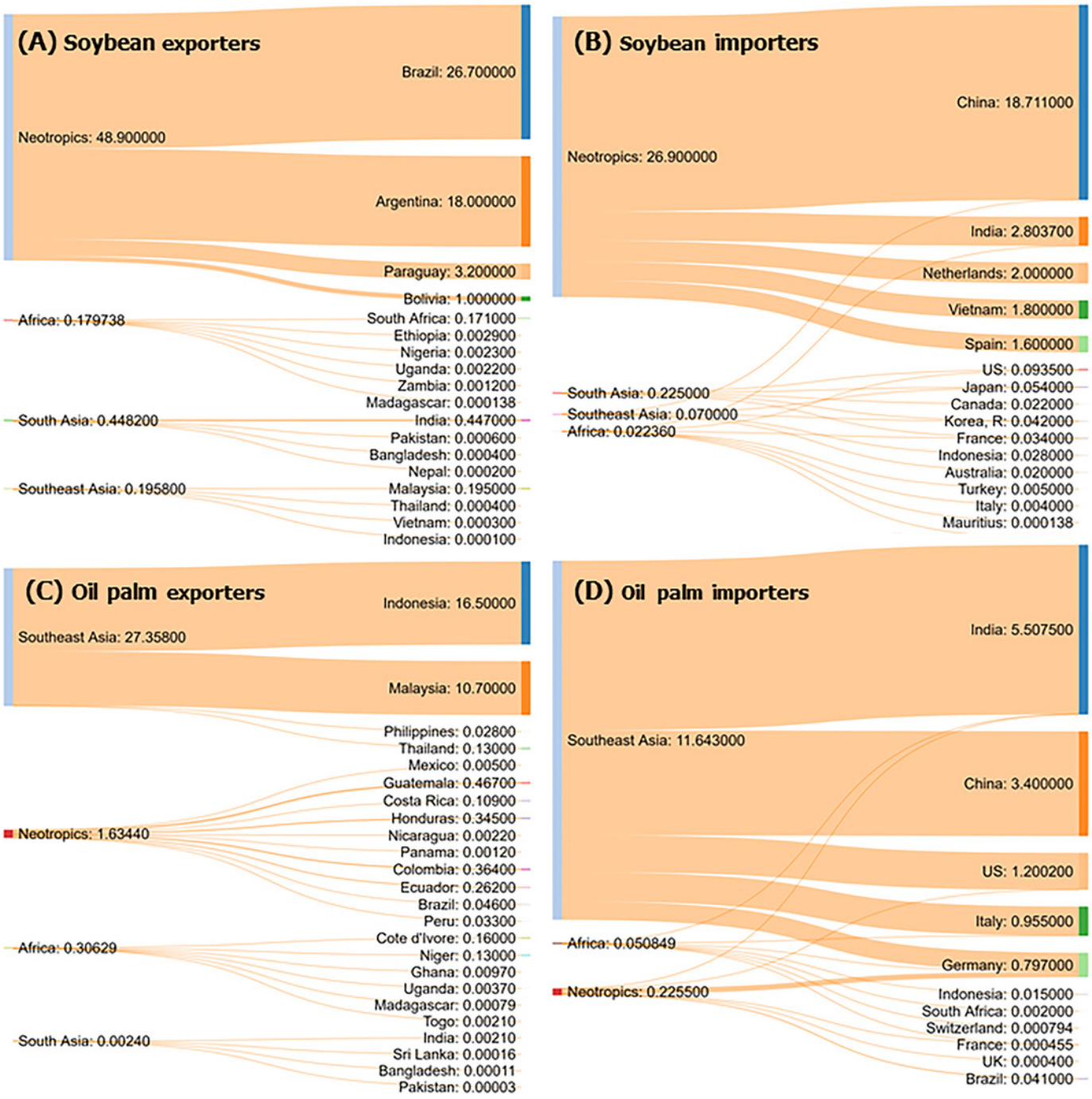
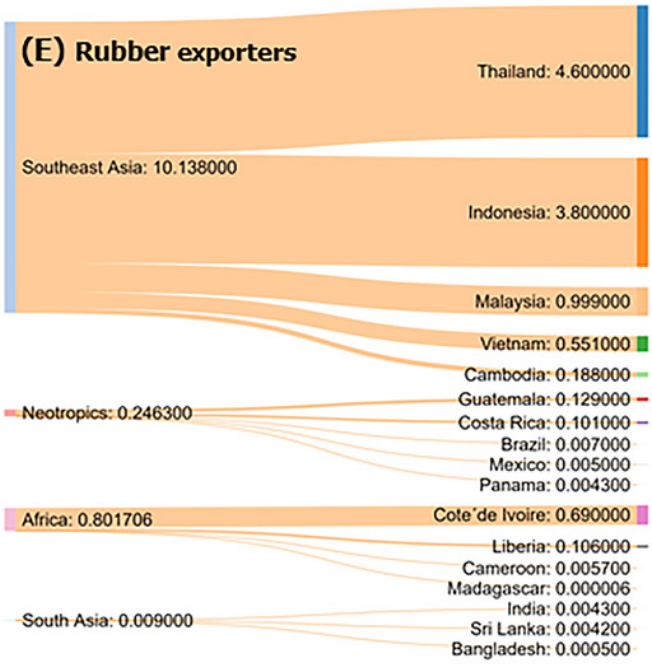
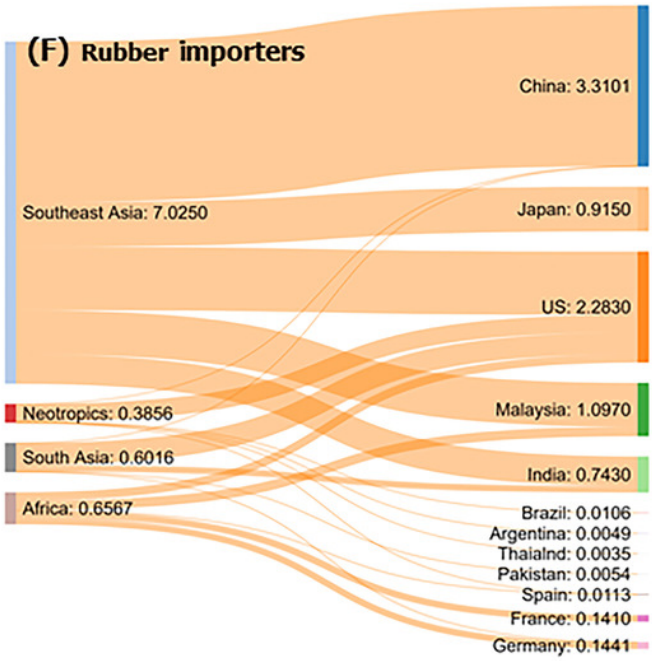

(A) Soybean exporters
Neotropics: 48.900000
Africa: 0.179738
South Asia: 0.448200
Southeast Asia: 0.195800
Brazil: 26.700000
Argentina: 18.000000
Paraguay: 3.200000
Bolivia: 1.000000
South Africa: 0.171000
Ethiopia: 0.002900
Nigeria: 0.002300
Uganda: 0.002200
Zambia: 0.001200
Madagascar: 0.000138
India: 0.447000
Pakistan: 0.000600
Bangladesh: 0.000400
Nepal: 0.000200
Malaysia: 0.195000
Thailand: 0.000400
Vietnam: 0.000300
Indonesia: 0.000100
(B) Soybean importers
Neotropics: 26.900000
South Asia: 0.225000
Southeast Asia: 0.070000
Africa: 0.022360
China: 18.711000
India: 2.803700
Netherlands: 2.000000
Vietnam: 1.800000
Spain: 1.600000
US: 0.093500
Japan: 0.054000
Canada: 0.022000
Korea, R: 0.042000
France: 0.034000
Indonesia: 0.028000
Australia: 0.020000
Turkey: 0.005000
Italy: 0.004000
Mauritius: 0.000138
(C) Oil palm exporters
Southeast Asia: 27.35800
Neotropics: 1.63440
Africa: 0.30629
South Asia: 0.00240
Indonesia: 16.50000
Malaysia: 10.70000
Philippines: 0.02800
Thailand: 0.13000
Mexico: 0.00500
Guatemala: 0.46700
Costa Rica: 0.10900
Honduras: 0.34500
Nicaragua: 0.00220
Panama: 0.00120
Colombia: 0.36400
Ecuador: 0.26200
Brazil: 0.04600
Peru: 0.03300
Cote d'Ivore: 0.16000
Niger: 0.13000
Ghana: 0.00970
Uganda: 0.00370
Madagascar: 0.00079
Togo: 0.00210
India: 0.00210
Sri Lanka: 0.00016
Bangladesh: 0.00011
Pakistan: 0.00003
(D) Oil palm importers
Southeast Asia: 11.643000
Africa: 0.050849
Neotropics: 0.225500
India: 5.507500
China: 3.400000
US: 1.200200
Italy: 0.955000
Germany: 0.797000
Indonesia: 0.015000
South Africa: 0.002000
Switzerland: 0.000794
France: 0.000455
UK: 0.000400
Brazil: 0.041000

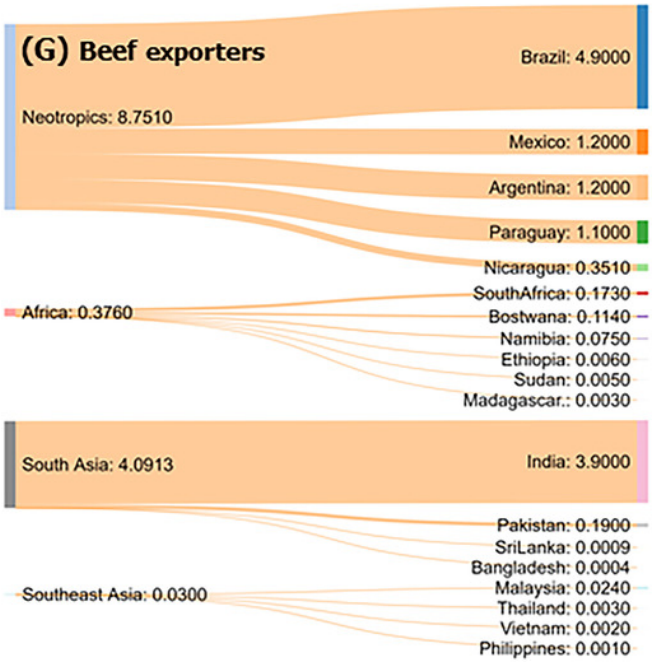
Figure 7

Trade flow diagrams for the top exporter and importer countries of four commodities that resulted in permanent deforestation in each primate-range region in 2016. Natural rubber (E, F) and beef (G, H).

Numbers on the flow diagrams indicate the amount in US$ bn of trade for each country. For exports and imports, the trade flows show on the left the accumulated US$ bn for each region and for the countries involved. The width of the connecting flows is proportional to the value exported or imported. Source of trade information resourcetrade.Earth of Chatham House.


(E) Rubber exporters
Thailand: 4.600000
Southeast Asia: 10.138000
Indonesia: 3.800000
Malaysia: 0.999000
Vietnam: 0.551000
Cambodia: 0.188000
Guatemala: 0.129000
Neotropics: 0.246300
Costa Rica: 0.101000
Brazil: 0.007000
Mexico: 0.005000
Panama: 0.004300
Africa: 0.801706
Cote´de Ivoire: 0.690000
Liberia: 0.106000
Cameroon: 0.005700
Madagascar: 0.000006
India: 0.004300
South Asia: 0.009000
Sri Lanka: 0.004200
Bangladesh: 0.000500


(F) Rubber importers
China: 3.3101
Japan: 0.9150
Southeast Asia: 7.0250
US: 2.2830
Malaysia: 1.0970
Neotropics: 0.3856
South Asia: 0.6016
India: 0.7430
Africa: 0.6567
Brazil: 0.0106
Argentina: 0.0049
Thailnd: 0.0035
Pakistan: 0.0054
Spain: 0.0113
France: 0.1410
Germany: 0.1441


(G) Beef exporters
Brazil: 4.9000
Neotropics: 8.7510
Mexico: 1.2000
Argentina: 1.2000
Paraguay: 1.1000
Nicaragua: 0.3510
SouthAfrica: 0.1730
Africa: 0.3760
Bostwana: 0.1140
Namibia: 0.0750
Ethiopia: 0.0060
Sudan: 0.0050
Madagascar.: 0.0030
South Asia: 4.0913
India: 3.9000
Pakistan: 0.1900
SriLanka: 0.0009
Bangladesh: 0.0004
Southeast Asia: 0.0300
Malaysia: 0.0240
Thailand: 0.0030
Vietnam: 0.0020
Philippines: 0.0010

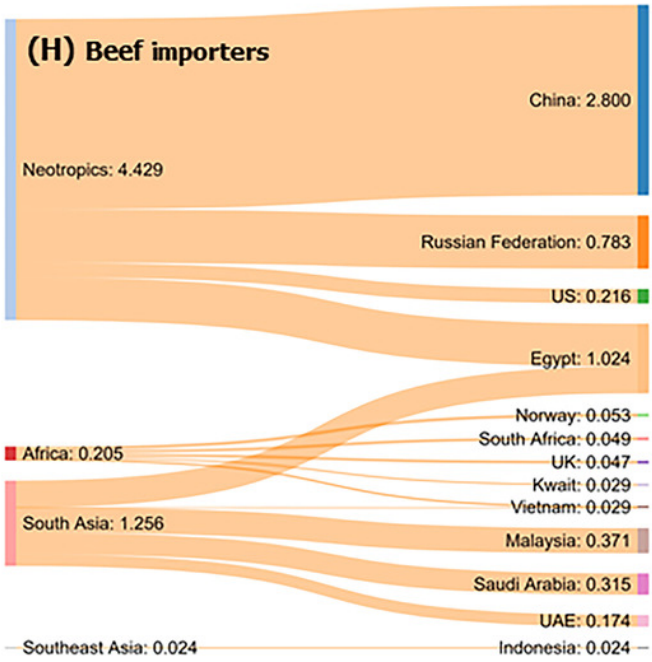

(H) Beef importers
China: 2.800
Neotropics: 4.429
Russian Federation: 0.783
US: 0.216
Egypt: 1.024
Norway: 0.053
South Africa: 0.049
Africa: 0.205
UK: 0.047
Kwait: 0.029
Vietnam: 0.029
South Asia: 1.256
Malaysia: 0.371
Saudi Arabia: 0.315
UAE: 0.174
Southeast Asia: 0.024
Indonesia: 0.024

Figure 8

Photos of selected forest-risk commodities in primate range regions.

Photo credits include the following: (A) forest converted to soy fields in Brazil (photo credit: R. Butler), (B) pulp and paper plantation in Indonesia (photo credit: R. Butler) , (C) Deforestation for natural rubber production in Laos (photo credit: R. Butler). (D) Oil palm plantation in Costa Rica (photo credit: R. Butler), (E) Industrial logging in Malaysia (photo credit: W. F. Laurance.. (F) Gold mining in Peru (photo credit: R. Butler).

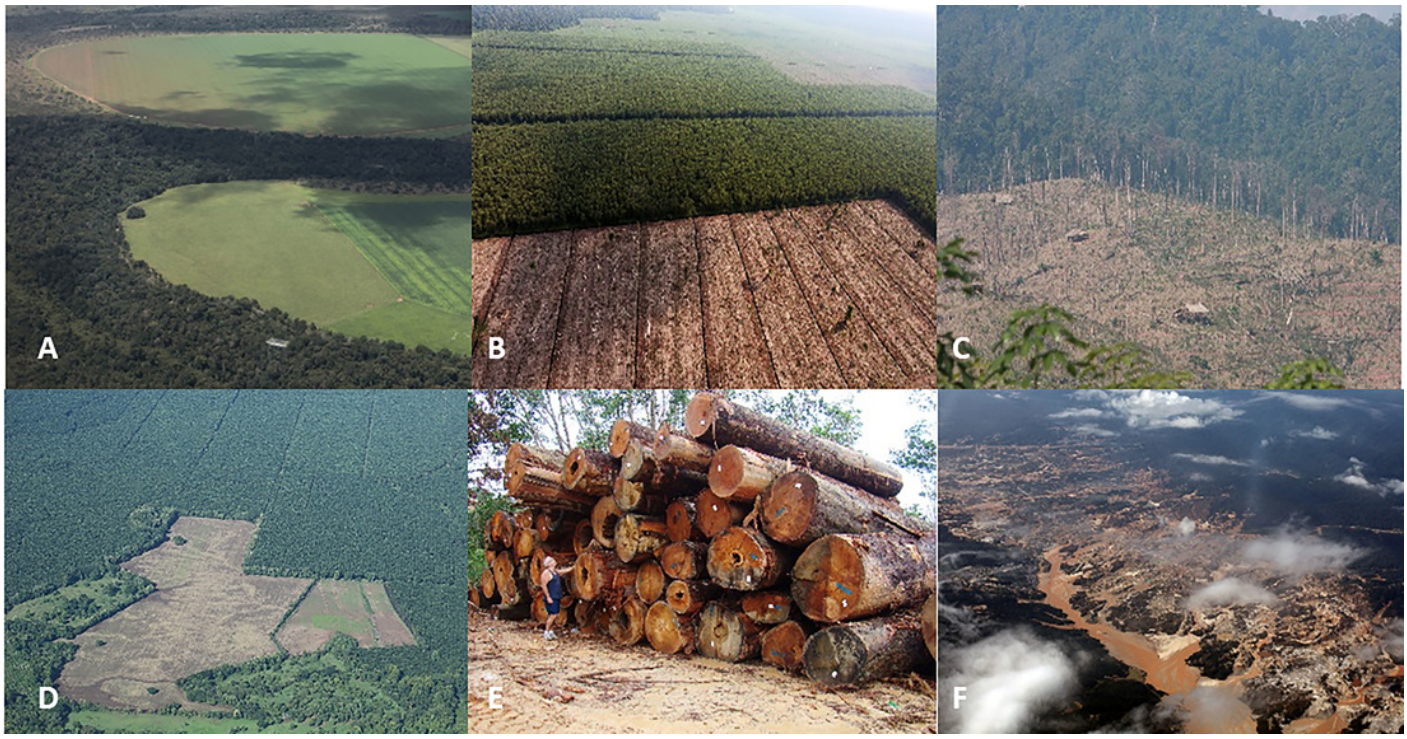


Figure 9

Growth in the export value of four commodities that resulted in forest degradation and forest loss in primate-range regions between 2000 and 2016.

Source of data: resourcetrade.Earth of Chatham House.

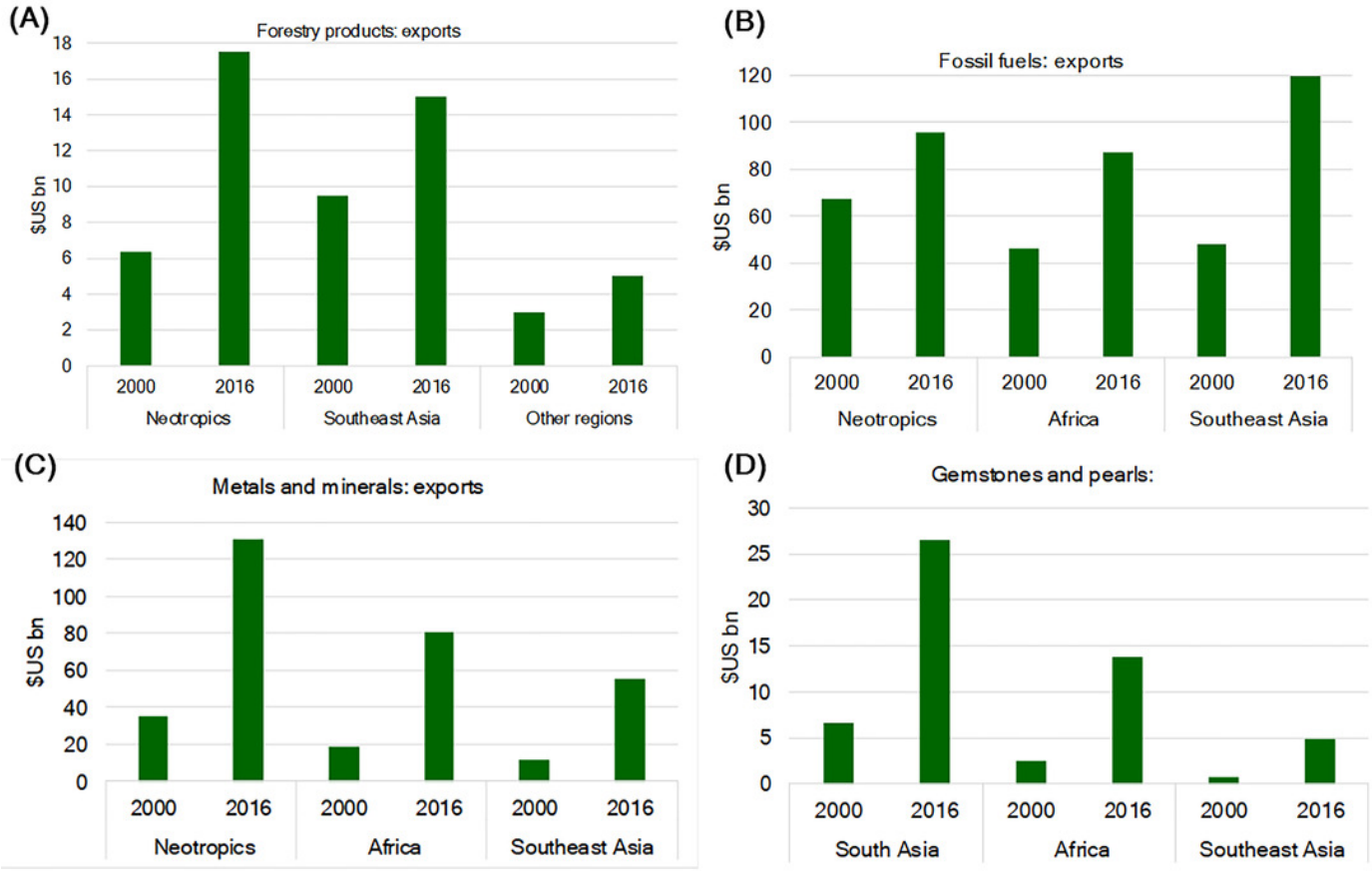


Figure 10

Trade flow diagrams of four commodities for the top exporter and importer countries and primate range regions that resulted in forest degradation in 2016. Forestry products (A, B), fossil fuels (C, D).

We show only the top exporting and importing countries in each region. Numbers on the flow diagrams indicate for each country, the amount in US$ bn involved in trade. For exports and imports the trade flows also show on the left the accumulated US$ bn for each region and for the countries involved. The width of the connecting flows is proportional to the value exported or imported. Source of trade information resourcetrade.Earth of Chatham House. Flow diagrams were built with the software SankeyMatic accessible at http://sankeymatic.com/build/.

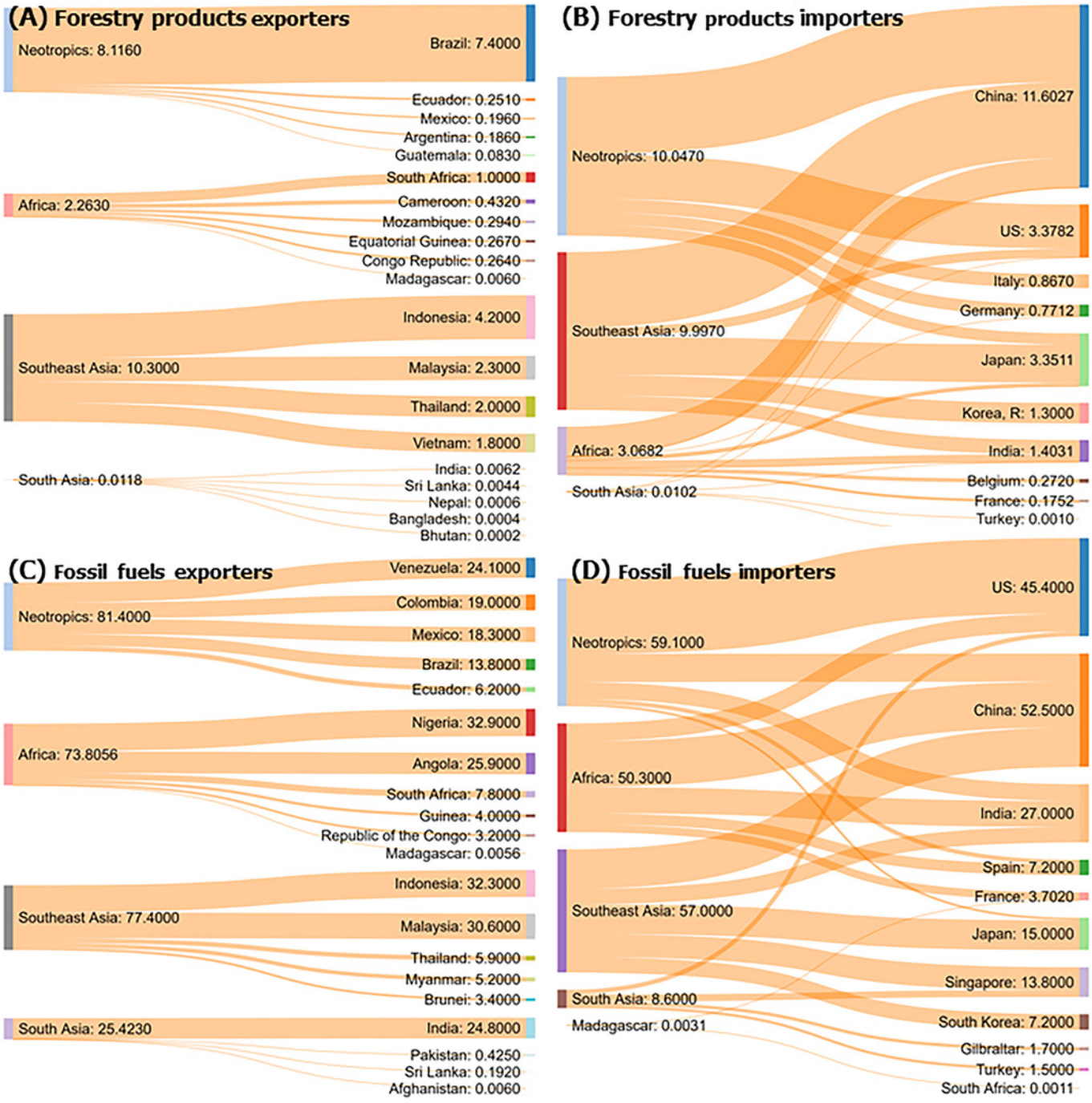
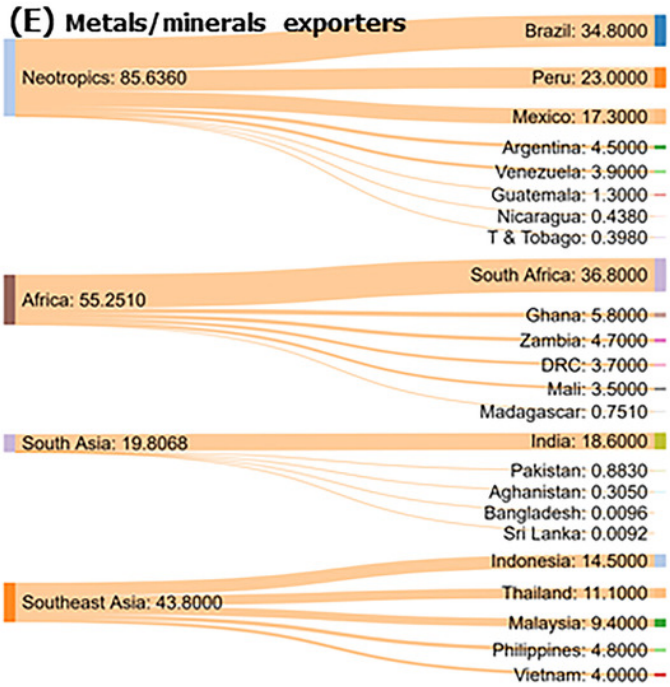
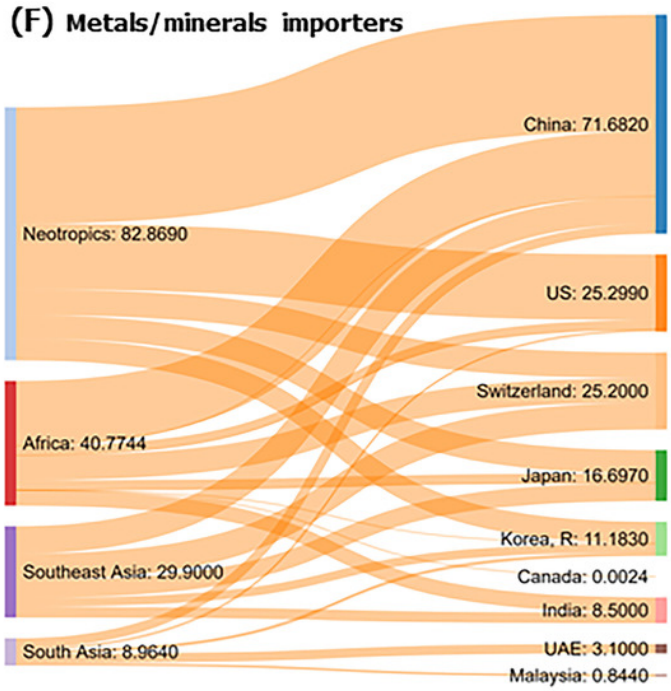

(A) Forestry products exporters
Neotropics: 8.1160
Brazil: 7.4000
Ecuador: 0.2510
Mexico: 0.1960
Argentina: 0.1860
Guatemala: 0.0830
Africa: 2.2630
South Africa: 1.0000
Cameroon: 0.4320
Mozambique: 0.2940
Equatorial Guinea: 0.2670
Congo Republic: 0.2640
Madagascar: 0.0060
Southeast Asia: 10.3000
Indonesia: 4.2000
Malaysia: 2.3000
Thailand: 2.0000
Vietnam: 1.8000
South Asia: 0.0118
India: 0.0062
Sri Lanka: 0.0044
Nepal: 0.0006
Bangladesh: 0.0004
Bhutan: 0.0002
(B) Forestry products importers
Neotropics: 10.0470
Southeast Asia: 9.9970
Africa: 3.0682
South Asia: 0.0102
China: 11.6027
US: 3.3782
Italy: 0.8670
Germany: 0.7712
Japan: 3.3511
Korea, R: 1.3000
India: 1.4031
Belgium: 0.2720
France: 0.1752
Turkey: 0.0010
(C) Fossil fuels exporters
Neotropics: 81.4000
Venezuela: 24.1000
Colombia: 19.0000
Mexico: 18.3000
Brazil: 13.8000
Ecuador: 6.2000
Africa: 73.8056
Nigeria: 32.9000
Angola: 25.9000
South Africa: 7.8000
Guinea: 4.0000
Republic of the Congo: 3.2000
Madagascar: 0.0056
Southeast Asia: 77.4000
Indonesia: 32.3000
Malaysia: 30.6000
Thailand: 5.9000
Myanmar: 5.2000
Brunei: 3.4000
South Asia: 25.4230
India: 24.8000
Pakistan: 0.4250
Sri Lanka: 0.1920
Afghanistan: 0.0060
(D) Fossil fuels importers
Neotropics: 59.1000
Africa: 50.3000
Southeast Asia: 57.0000
South Asia: 8.6000
Madagascar: 0.0031
US: 45.4000
China: 52.5000
India: 27.0000
Spain: 7.2000
France: 3.7020
Japan: 15.0000
Singapore: 13.8000
South Korea: 7.2000
Gibraltar: 1.7000
Turkey: 1.5000
South Africa: 0.0011

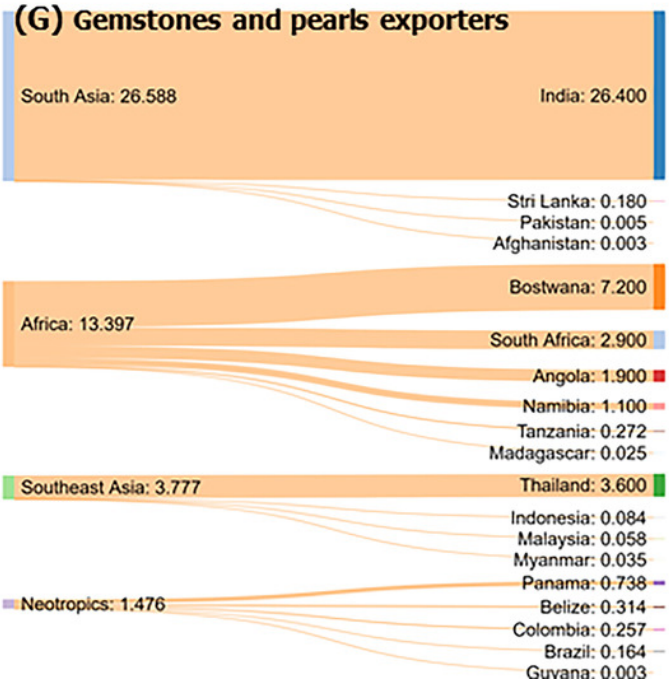
Figure 11

Trade flow diagrams of four commodities for the top exporter and importer countries and primate range regions that resulted in forest degradation in 2016., Metals and minerals (E, F) and gemstones and pearls (G, H).

We show only the top exporting and importing countries in each region. Numbers on the flow diagrams indicate for each country, the amount in US$ bn involved in trade. For exports and imports the trade flows also show on the left the accumulated US$ bn for each region and for the countries involved. The width of the connecting flows is proportional to the value exported or imported. Source of trade information resourcetrade.Earth of Chatham House. Flow diagrams were built with the software SankeyMatic accessible at http://sankeymatic.com/build/.


(E) Metals/minerals exporters
Neotropics: 85.6360
Brazil: 34.8000
Peru: 23.0000
Mexico: 17.3000
Argentina: 4.5000
Venezuela: 3.9000
Guatemala: 1.3000
Nicaragua: 0.4380
T & Tobago: 0.3980
Africa: 55.2510
South Africa: 36.8000
Ghana: 5.8000
Zambia: 4.7000
DRC: 3.7000
Mali: 3.5000
Madagascar: 0.7510
South Asia: 19.8068
India: 18.6000
Pakistan: 0.8830
Aghanistan: 0.3050
Bangladesh: 0.0096
Sri Lanka: 0.0092
Southeast Asia: 43.8000
Indonesia: 14.5000
Thailand: 11.1000
Malaysia: 9.4000
Philippines: 4.8000
Vietnam: 4.0000


(F) Metals/minerals importers
Neotropics: 82.8690
Africa: 40.7744
Southeast Asia: 29.9000
South Asia: 8.9640
China: 71.6820
US: 25.2990
Switzerland: 25.2000
Japan: 16.6970
Korea, R: 11.1830
Canada: 0.0024
India: 8.5000
UAE: 3.1000
Malaysia: 0.8440


(G) Gemstones and pearls exporters
South Asia: 26.588
India: 26.400
Stri Lanka: 0.180
Pakistan: 0.005
Afghanistan: 0.003
Africa: 13.397
Bostwana: 7.200
South Africa: 2.900
Angola: 1.900
Namibia: 1.100
Tanzania: 0.272
Madagascar: 0.025
Southeast Asia: 3.777
Thailand: 3.600
Indonesia: 0.084
Malaysia: 0.058
Myanmar: 0.035
Neotropics: 1.476
Panama: 0.738
Belize: 0.314
Colombia: 0.257
Brazil: 0.164
Guyana: 0.003

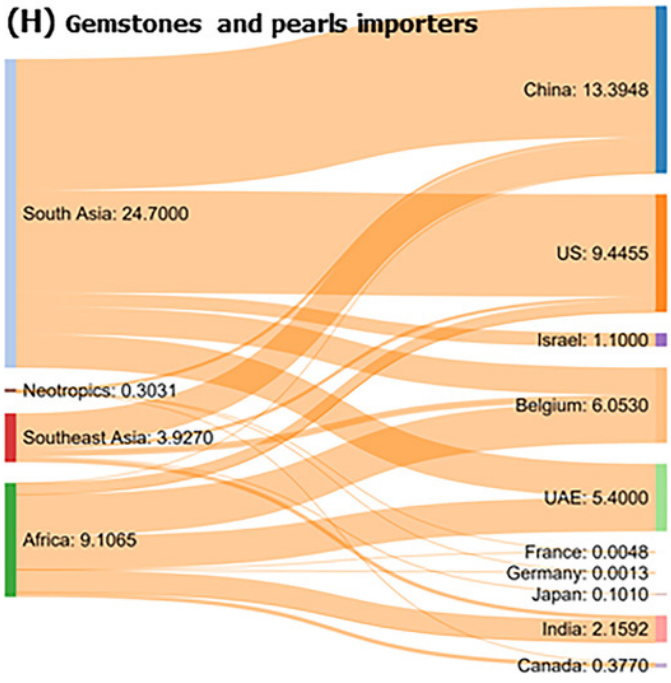

(H) Gemstones and pearls importers
South Asia: 24.7000
Neotropics: 0.3031
Southeast Asia: 3.9270
Africa: 9.1065
China: 13.3948
US: 9.4455
Israel: 1.1000
Belgium: 6.0530
UAE: 5.4000
France: 0.0048
Germany: 0.0013
Japan: 0.1010
India: 2.1592
Canada: 0.3770

Figure 12

A) Top 10 primate range exporters and (B) top 10 importers of forest-risk commodities in 2016.

These 10 exporting countries comprise all or part of the ranges of some 250 primate species (Table S5). Source of data: resourcetrade.Earth of Chatham House.

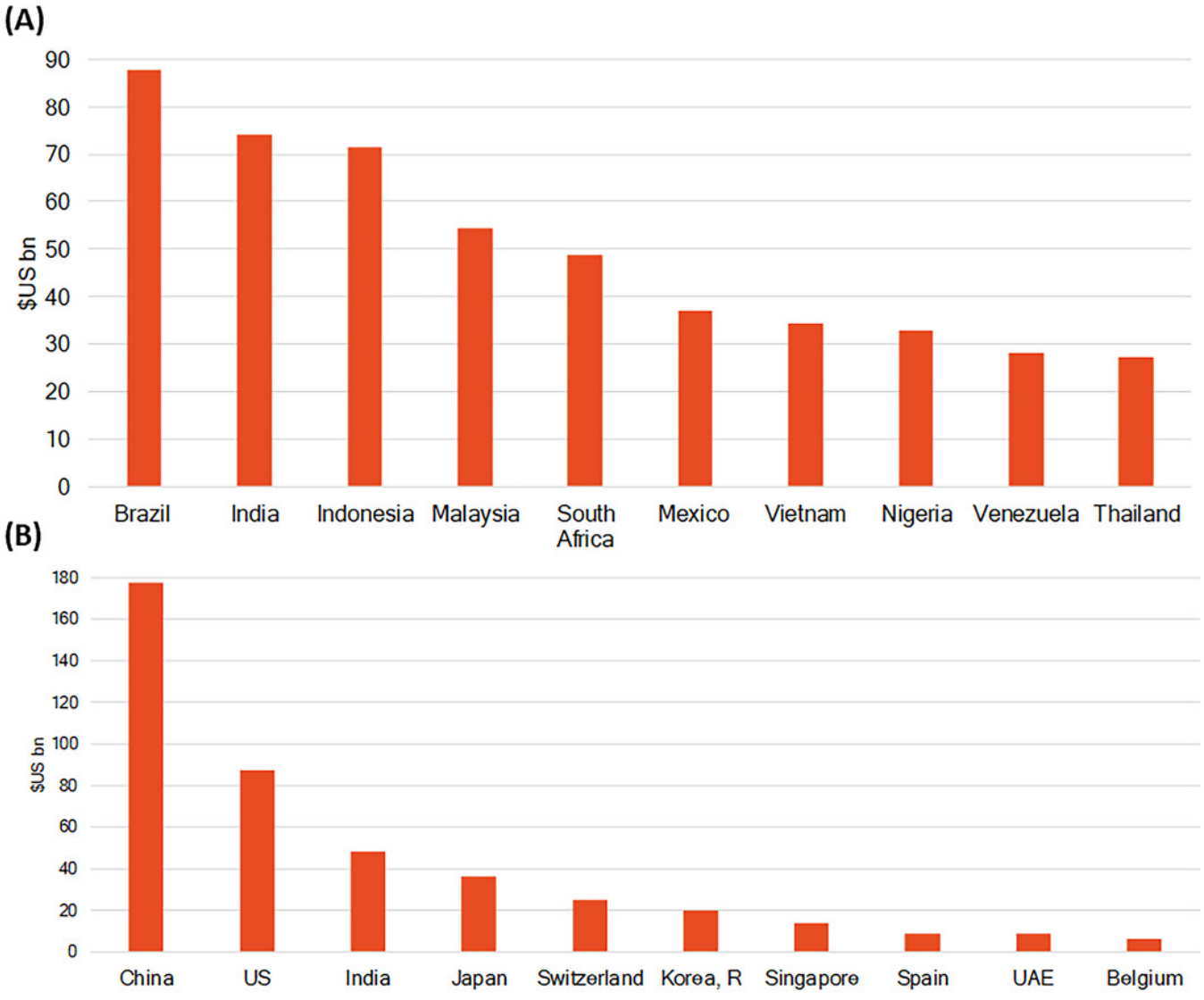


Figure 13

(A) Estimated revenues generated by exports of natural-resource commodities by nations in primate-range regions in 2016.. (B) Average percent of primate species threatened and GDPPC US$10,000 for countries in primate range regions in 2016.

The numbers in parenthesis next to the name of each region refer to the number of countries involved in each GDPPC class. Source for GDPPC is World Bank, 2018. Source for threatened species is Estrada et al., 2017. Source of trade data: resource trade. Earth of Chatham House

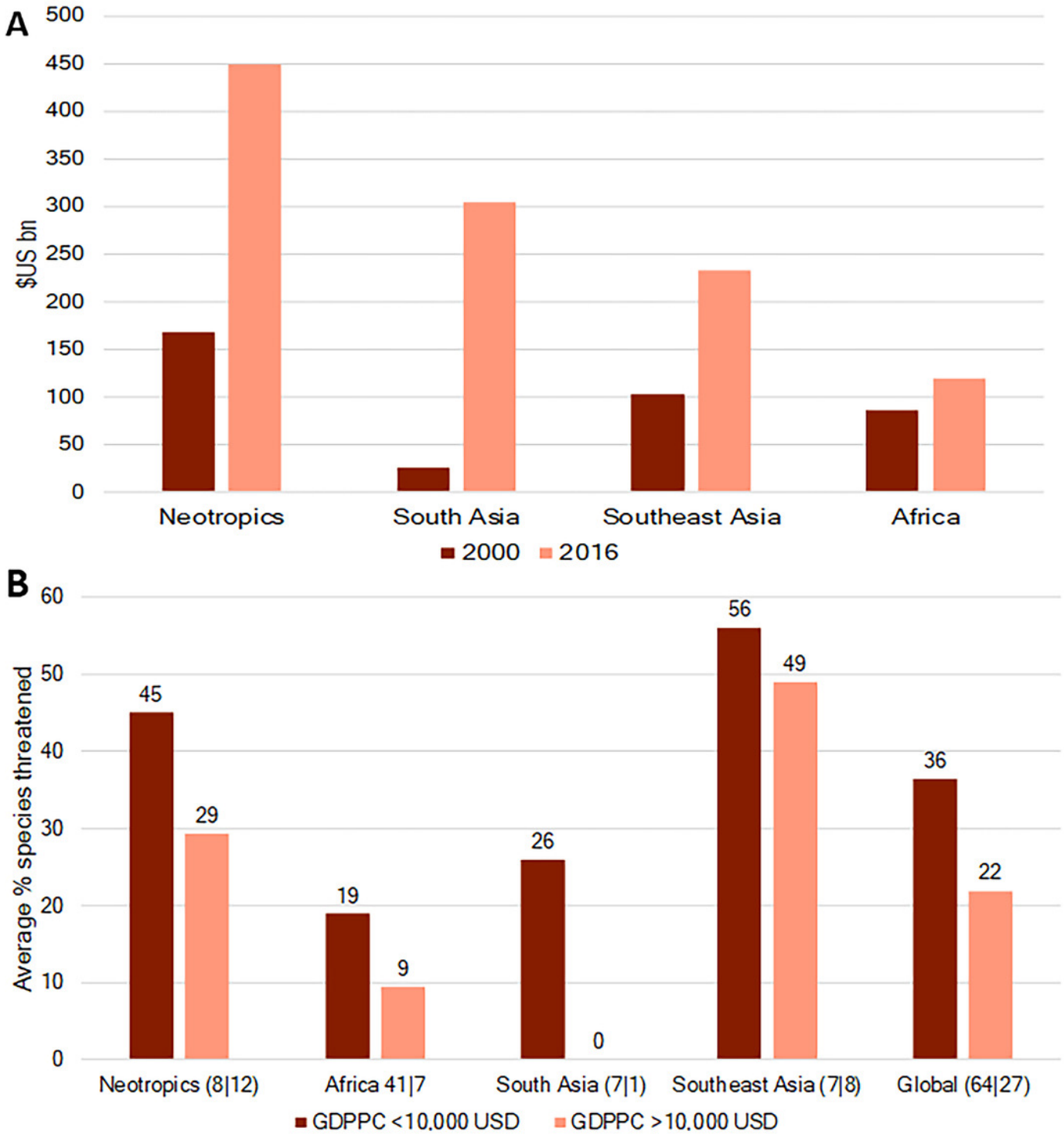

A
500
450
400
350
300
250
200
150
100
50
0
$US bn
Neotropics
South Asia
Southeast Asia
Africa
2000
2016
B
60
50
40
30
20
10
0
Average % species threatened
45
29
19
9
26
0
56
49
36
22
Neotropics (8|12)
Africa 41|7
South Asia (7|1)
Southeast Asia (7|8)
Global (64|27)
GDPPC <10,000 USD
GDPPC >10,000 USD

Figure 14

Percent of primate species currently threatened with extinction(2016) and the percent projected to be threatened with extinction due to commodity driven land use changes by 2050 and 2100 under a business-as-usual scenario (RCP 4.5 SSP-2). Data are present

SeeTable S8 for the projected fraction of primate species threatened with extinction in 61 primate habitat country's under all six future scenarios and Table S9 for the contribution of each of the 10 human land use types to the total number of species threatened with extinction.

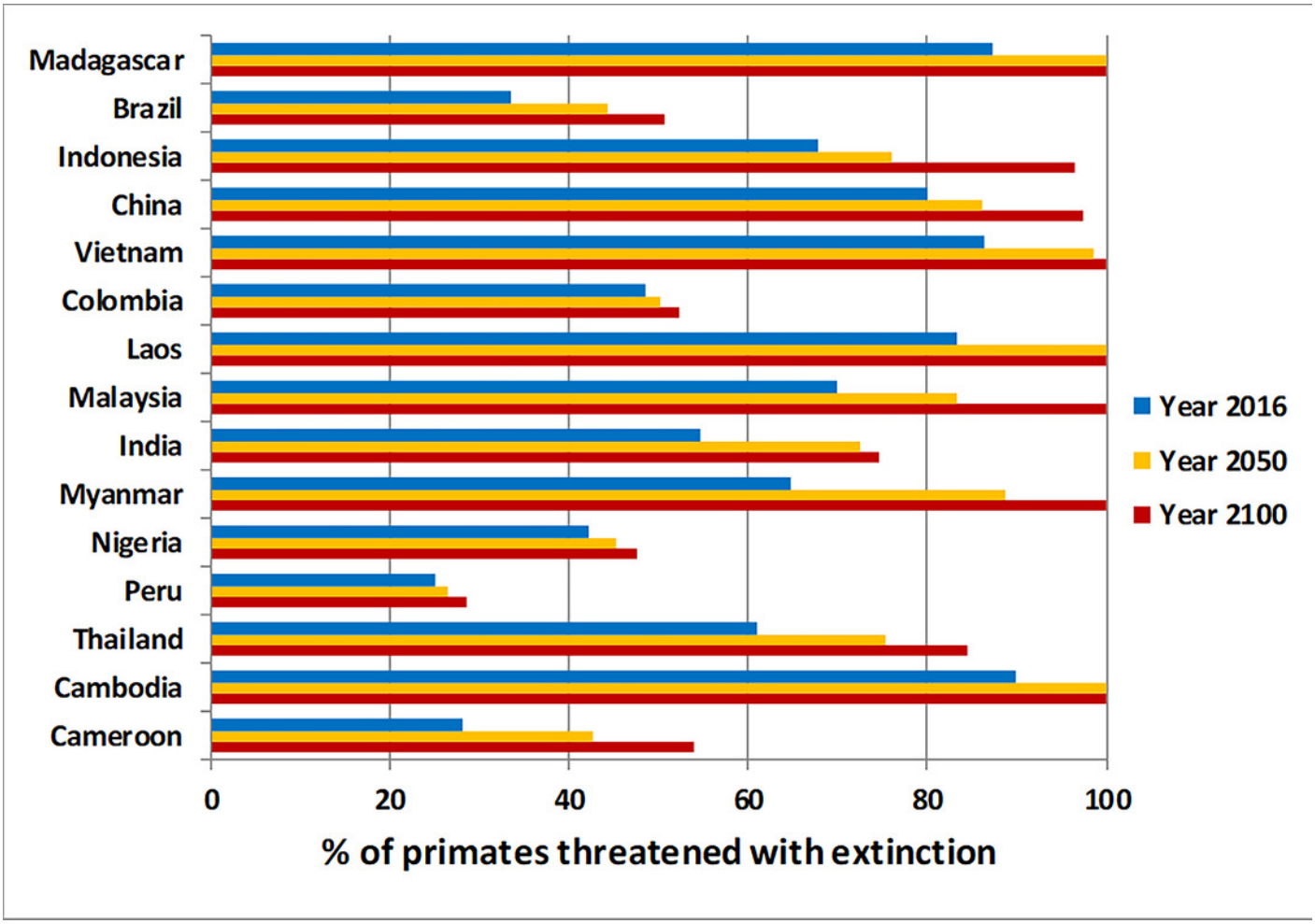
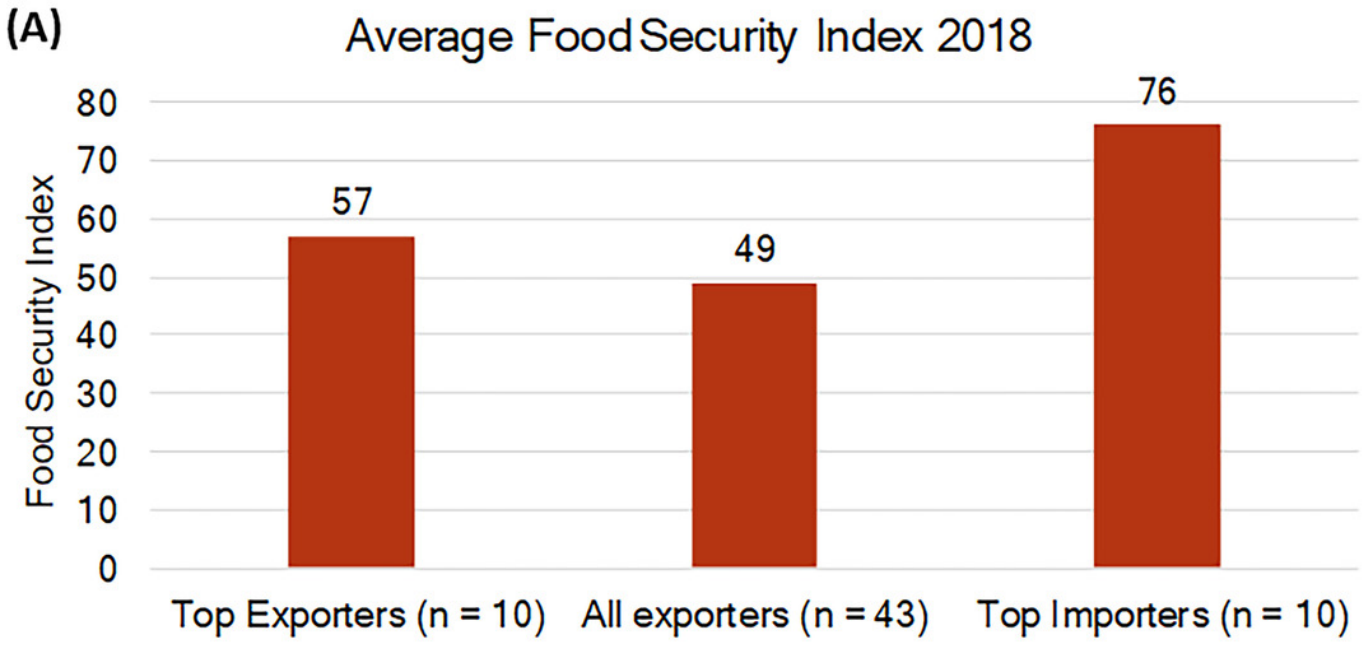


Figure 15

Food Security Index and GDPPC in exporting and importing countries involved in forest-risk commodities trade.

(A) Comparison of the average value of the Food Security Index (FSI: 0 lowest to 100 highest) between top commodity exporting primate-range countries and top commodity importing countries in 2016. (B) Average GDPPC for 2016 for the top primate-range commodity exporting countries and the top importer countries in 2016. FSI 2018 from The Economist Intelligence Unit Limited (https://foodsecurityindex.eiu.com/). GDPPC 2017 from the World Bank (https://data.worldbank.org/indicator).


(A)
Average Food Security Index 2018
Food Security Index
80
70
60
50
40
30
20
10
0
57
49
76
Top Exporters (n = 10)
All exporters (n = 43)
Top Importers (n = 10)

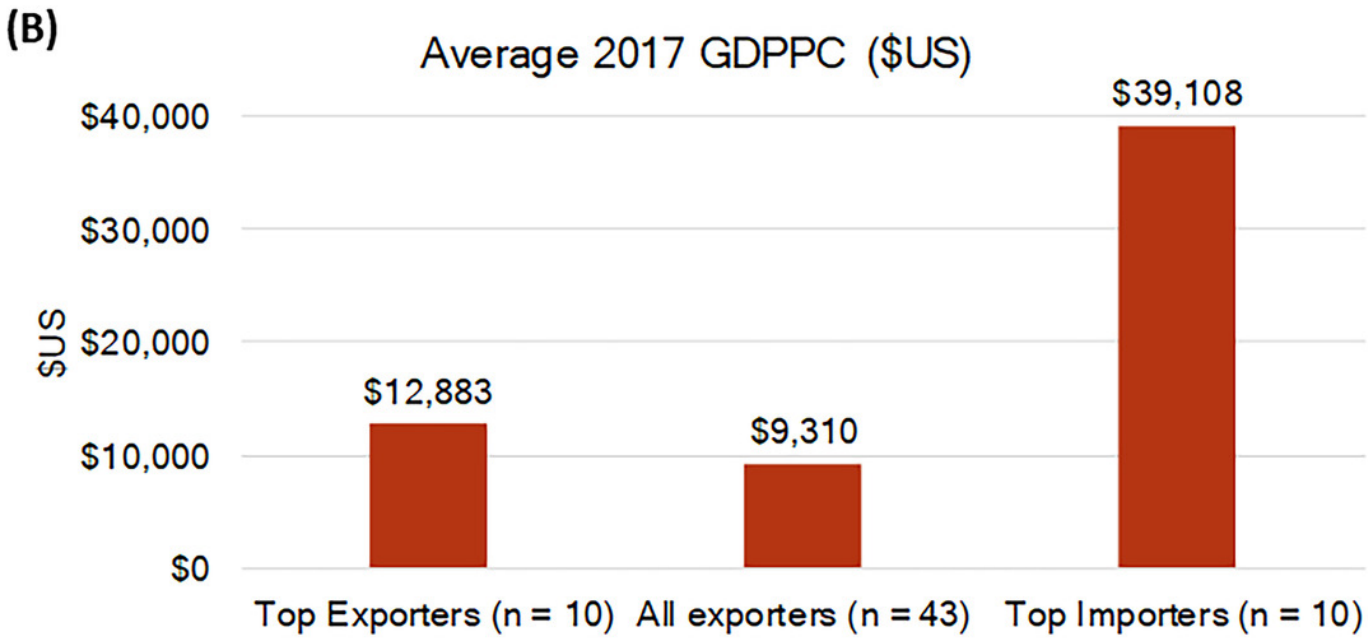

(B)
Average 2017 GDPPC ($US)
$US
$40,000
$30,000
$20,000
$10,000
$0
$12,883
$9,310
$39,108
Top Exporters (n = 10)
All exporters (n = 43)
Top Importers (n = 10)

Figure 16

Photos of selected primate species impacted by forest loss and degradation resulting from production of forest-risk commodities. Also shown is their IUCN conservation status.

Photo credits include the following: (A) Bornean orangutan (*Pongo pygameus*), Borneo. Status: CR (photo credit: R. Butler), (B) Western gorilla (Gorilla gorilla), Gabon. Status: CR (photo credit: R. Butler), (C) Indochinese Lutung ((*Trachypithecus germaini*), Cambodia. Status: EN (photo credit: R. Butler), (D) white-headed langur (*Trachypithecus poliocephalus*, China. Status: CR (photo credit P. A. Garber), (E) Black-and-white ruffed lemur (*Varecia variegata*), Madagascar. Status: CR (photo credit: S. Johnson), (F) Skywalker hoolock gibbon (*Hoolock tianxing*), China. Status: CR (photo credit: P-F Fan). EN= endangered, CR= critically endangered

Figure 17

Diagram summarizing key aspects of international commodities trade and primate conservation.