

# A data science and historical global political ecology perspective on the financial system, agriculture and climate: from the trans-Atlantic slave trade to agroecology

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## Abstract

We show that narrative visualisation can contribute to identifying financial, legal, political, trade and other mechanisms capable of serving the diverse needs of practitioners of agroecology (primarily small scale farmers) and advocates of food sovereignty. Using financial and non-financial public information (re)sources such as historical macroeconomic data from the Bank of England and open source software tools, we paint portraits of (a) the trans-Atlantic slave trade and European Empires, (b) 21<sup>st</sup> century large-scale land acquisitions, and (c) traditional farming systems, agricultural biodiversity, and climate change. This triptych of background notes plus autonomous yet complementary cartograms and timelines overlaid with events provides long historical and large geographical lenses for understanding how the web of institutional and social structures of the United Kingdom, Europe, and the United States of America were and remain central to the international political ecology of agriculture, particularly food and fibre. We propose that policies that support, strengthen and scale agroecology can increase financial stability by reducing climate change-related physical, liability and transition risks thereby making macroeconomies more resilient to crises and prepared for adverse shocks. This exploration of human and natural systems affords also a window on the emerging fields of structural one health and planetary health.

## Introduction

Fiscal, monetary, and financial stability are increasingly important objectives of policy makers seeking to influence a nation's economic activity, prevent or mitigate the triggers of financial crises, and cope with, recover from, and reconstruct after adverse shocks. Beyond its responsibility for monetary policy – control and management of the money supply and interest rates, financial stability is a much more prominent aspect of the work of the Bank of England and the central banks of other countries [1, 2]. In February 2015, the Bank launched its *One Bank Research Agenda* (OBRA) [3, 4], a wide-ranging and ambitious framework aimed at transforming and guiding its future research, and as part of a commitment to forging closer ties between policy makers and researchers, published a selection of its structured and unstructured current and historical datasets for the United Kingdom (UK). Seven months later in a speech delivered at Lloyd's of

London, the Bank’s Governor and chair of the international Financial Stability Board Mark Carney warned “climate change is the tragedy of the horizon,” noting that insurers are “anticipating broader global impacts on property, migration and political stability, as well as food and water security” [5]. Thus, “forming a strategic response to the financial risks from climate change helps ensure the Bank can fulfil its mission to maintain monetary and financial stability, both now and for the long term” [6].

In April 2018, individuals from more than 50 central banks and financial supervisory agencies in over 30 countries gathered to discuss how to keep the financial system stable when the climate is changing. At this summit, Carney outlined a taxonomy of channels through which climate risks are transmitted to the macroeconomy: physical risks (“increased frequency and severity of climate- and weather-related events that damage property and disrupt trade”), liability risks (“parties who have suffered loss from the effects of climate change seeking compensation from those they hold responsible”), and transition risks (“a sudden and disorderly adjustment to a low carbon economy”) [7]. These risks have been analysed in terms of the direct affects of hazardous events (for instance, droughts, floods, storms, and sea-level rise) and gradual changes in climatic conditions (for instance, temperature and ocean acidity) on economic outcomes (for example, different components of Gross Domestic Product (GDP) such as trade, investment, and productivity, and sectors of the economy such as agriculture and manufacturing) and critical economic resources (for example, water and human health) [8]. Carney asserted that with early transitions in thinking and action, the tragedy of the horizon can be resolved in an orderly, effective and productive manner [7]. Here, we address this remark in the context of the OBRA themes *Central bank response to fundamental technological, institutional, societal and environmental change* and *Using new data, methodologies and approaches to understand household and corporate behaviour, the domestic and international macroeconomy, and risks to the financial system*.

Macroeconomies are functions of the interplay of human systems (social, cultural, political, economic, legal, financial, scientific, technological, engineering, mathematical, medical and other spheres) and natural systems (the lithosphere, atmosphere, biosphere, and hydrosphere). Formulating policies aimed at making them less vulnerable to crises and shocks requires broad and deep knowledge of the interactions between individuals, institutions, organisations and Earth’s physical, chemical and biological processes over centuries. For instance, the UK’s macroeconomy is the outcome of social relations between the state and national as well as international institutions and structures – not least the government, the Bank, HM Treasury and the International Monetary Fund [9]. As subclasses of macroeconomic policy, fiscal and monetary policies determine and influence agricultural policy: laws and activities relating to domestic agriculture and imports of foreign agricultural products. A keystone of financial stability is the resilience of agriculture, its ability to absorb shocks whilst still maintaining function and its capacity to reorganise following a disturbance. Hence, individually and collectively, central banks stand to benefit from greater information on how and why monetary and fiscal matters are linked to the cultivation and breeding of soil, plants and animals to provide food, feed, fibre, medicines and other products to sustain and enhance life.

Here, we use data from the Bank and elsewhere to paint a broad brushstrokes picture of the financial system, agriculture and climate triad since the turn of the 16<sup>th</sup> century. We illuminate selected social relations within and between the UK, other countries of the “Global North” (the United States of America (USA), Belgium, France, Italy, Portugal, Spain, and the Netherlands) and the land and peoples of the “Global South” (countries in Central America, South America, Africa, and Asia). We describe some of the threads linking the financial system (institutions, agreements and formal and informal actors such as central banks, multilateral treaties, and intergovernmental organisations) with the globalisation and industrialisation of agriculture. Since its establishment in 1694 [10] in the age of mercantilism through the industrial revolution (mid-18<sup>th</sup> to early-19<sup>th</sup> century) and beyond, the Bank’s history is intertwined with that of Parliament, the trans-Atlantic slave trade [11, 12] and the British Empire [13] – times when societies were treated as parts of economies rather than economies being considered parts of societies. Lloyd’s was founded in 1688 at a time when “London’s importance as a trade centre led to an increasing demand for ship and cargo insurance” and that today “develops the essential, complex and critical insurance needed to underwrite human progress” [14]. Sometimes, a slave ship’s captain threw its slaves overboard to drown during a storm in order to collect insurance monies because the vessel’s dead slaves were then claimed as damaged property [15]. After the USA outlawed the slave trade in 1808, people rented to work in mining, manufacturing and other industries

were insured [16].

Typically, global political ecology studies of how the environment is shaped by and shapes economy and society utilise a social science framework and focus primarily on the Global South [17]. For example, soil erosion in Africa has been cast as a legacy of colonial policies of land appropriation more than over-exploitation by small farmers, underdevelopment and climatic factors [18]. The 1970s famine in Northern Nigeria has been traced to the effects of colonialism more than an outcome of drought in the region [19]. An economic power, ecological dynamics and global health lens has been applied to pesticide exposure in Southwestern Ecuador’s banana industry [20]. An historical political ecology perspective has been used to understand the political-economic arrangements that have shaped conservation and management of a wetland in Southern France since the mid-1990s [21].

In contrast, we employ a data science framework that considers the Global North as well as Global South and delves considerably further back in time: a data-driven historical global political ecology approach. Courtesy of the Bank, the UK has a number of extremely long time series for a broad set of macroeconomic and financial variables, some stretching back a millenium. We employ background notes and visual surveys to highlight general trends and illustrate points pertinent to (a) the trans-Atlantic slave trade and European Empires, (b) 21<sup>st</sup> century large-scale land acquisitions and their consequences, and (c) traditional farming systems, agricultural biodiversity, and climate change. Whilst there is growing recognition of the potential of storytelling with (interactive) data visualisations in fields such as journalism, sports, public policy, finance and industrial ecology [22, 23], the use of narrative visualisations in food and agriculture is relatively new. The material needed to reproduce [24–26] our interactive charts and cartograms is freely available here. For details, download this PDF file. For datasets, R code and HTML files, download the files individually or this single zip file. We used the R packages and libraries xts, dygraphs, Leaflet, rworldmap, RColorBrewer, sp, and maptools. Journal publishing platforms and community databases such as PubMed and PMC only permit indexing and syndication of still image files as figure elements for an article. Hence, every Figure in this article is a static representation – an arbitrary snapshot – of an interactive visualisation. In general, a chart portrays two different factors (one plotted on the left vertical axis, the other on the right axis) over time (horizontal axis) and in the context of selected events during this period covered (points or intervals on the horizontal axis). Similarly, a cartogram renders various country- and/or region-specific factors. The full functionality of the dynamic version can be explored by viewing the corresponding HTML file in a web browser.

We combine insights extracted from exploratory data analyses with written and online material to produce a *global* historical, geographical, political, economic, ecological, and agricultural frame for contemporary discussions of fiscal, monetary and financial stability. Quantitative macroeconomic models and forecasts used by governments to assist in the development and evaluation of macroeconomic policy are beyond the scope of this work. Our aim is qualitative inspections of long periods of time (history) in relation to wide swaths of space (geography) that are not intended to be interpreted, inspected, and analysed in minute detail. We hope our integration of a specific collection of heterogeneous data from diverse (re)sources in a particular manner spurs researchers in data science, global political ecology, historical political ecology, global political economy, economic history, banking, insurance, agroecology, international development, public policy and practice, human geography and other fields to devise new questions for further study – including alternative ways to combine, analyse and visualise the datasets we explore.

Based on our data-driven storytelling, we propose that policies, programmes, and strategies which support and scale agroecology can increase financial stability. This transdisciplinary, participatory applied science embedded in a social context [27–36] encompasses a simple set of techniques and productive practices that are not just agriculture but the full diversity of food production, gathering and consumption – knowledge that is the outcome of diverse historical experiences and practices. Agroecology’s benefits include ensuring food sovereignty [37], sustaining and improving human and environmental health [38–40], helping to conserve biodiversity [41, 42], providing sustainable and meaningful livelihoods [43–45], nursing resilient communities [46], mitigating the effects of climate change [47–50], and promoting local and stable economies [51, 52]. These benefits – and many others – are included in the recent UN FAO’s High Level Panel of Experts report *Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food*

*security and nutrition* [53]. Overall, our work can expand the horizon of critical agrarian studies [54, 55], contribute to recent debates on food regime theory [56–60], assist efforts to build strategic alliances among multiple movements whose goal is to advance changes in 21<sup>st</sup> century food systems, and generate insights for the fields of structural one health and planetary health.

## The trans-Atlantic slave trade and European Empires

The 1494 Treaty of Tordesillas [61] and the 1529 Treaty of Zaragoza [62] defined a pattern for exploration and conquest of non-Christian worlds outside Europe by Iberian colonial interests. Whereas the former treaty granted lands to the east and west of the Cape Verde Islands to Spain and Portugal respectively (essentially the Americas and Africa), the latter employed the Moluccan Islands as the basis for recognising Spain’s dominion over the Americas and most of the Pacific whilst solidifying Portugal’s claim to the Indian Ocean and all of Asia. Although other European maritime powers contested the commercial arrangement [63] in the “New World,” irrespective of whether the traders were British, French, Spanish, Portuguese, Dutch, Norwegian, Swedish or Danish in origin [64], humans [65] remained the most attractive commodity in trans-Atlantic trade crossings [66].

Europe, Africa and the Americas were the geographic pillars of the trans-Atlantic slave trade [67] that took place from the 16<sup>th</sup> through to the 19<sup>th</sup> century, a network of routes and an economic system lubricated by humans. Manufactured and luxury goods such as textiles, guns, knives, copper kettles, mirrors and beads from Europe were exported to the west African coast where they were exchanged for enslaved Africans. The slaves were sent forcibly to the New World where their labour underpinned the production of agricultural commodities such as sugar, tobacco, rice, cotton, mahogany and indigo: raw goods whose import by Britain fuelled the country’s Industrial Revolution [68] and satisfied its lifestyle [69]. During 35,000 slave voyages, over 12 million Africans were transported to the Americas [70]. More slaves were imported from Africa into Haiti (Saint Domingue) than into North America [71]. By 1789, the latter was producing 60% of Britain and France’s coffee and 75% of the world’s sugar, Saint Domingue owed its profitability entirely to slavery [72].

During the 16<sup>th</sup> and 17<sup>th</sup> centuries, financial, commercial, legal, and insurance institutions emerged to buttress Britain’s overseas trade and imperial ambitions [10]. Banks and banking were essential in making capital available to and securing profits from the transnational business of enslavement [73] and empire [74]. When set up in 1694, the Bank braced the entire system of commercial credit [13] needed for the trans-Atlantic slave trade. Acknowledging the centrality of slave-grown cotton to the economy of north west England [75] and recognising the importance of Manchester as a commercial centre, the Bank established a branch [76] there in 1826. The plantation slave economy – from slave-trading through slave-ownership to the shipping, trading, finance, and insurance of slave produce – contributed materially to the foundations of 19<sup>th</sup>-century London [77]. Moreover, “slave-owners in aggregate constituted a meaningful source of capital and entrepreneurial endeavour in the development of Britain’s transport infrastructure” [78]. In the early 19<sup>th</sup> century, cotton was a commodity that determined the wealth of nations [79]. In the mid-19<sup>th</sup> century, one of the Bank’s key roles was the provision of last resort lending to commercial banks facing liquidity pressures [80].

The Bank’s Governors [81] were well-placed to facilitate creation of the political and regulatory milieu necessary to (re)orient the performance, structure, behaviour and decision-making of national, regional, and global economies. For instance, Sir John Houblon (1694 – 1697) [82], Sir William Scawen (1697 – 1699) [83], and Sir Francis Eyles (1707 – 1709) [84] were also directors of the East India Company [85], a firm chartered in 1600 that rose to have a near monopoly of the world’s trade, particularly in agricultural commodities such as cotton, silk, indigo dye, salt, saltpetre, tea, and opium [86]. After the hundred year military and administrative rule of large swathes of the Indian subcontinent by this corporation – the “original corporate raiders” [87], the British Crown assumed direct control of India in the mid-19<sup>th</sup> century. Governors turned their gaze not only East but also West: Sir Humphrey Morice (1727 – 1729) [88] was also both a trans-Atlantic slave trader and a Member of Parliament [89].

British slave-ownership was instrumental in transmitting the fruits of colonial slavery [90] to metropolitan

Britain, shaping the country and bequeathing a legacy [91] that reaches into the present [92–94]. The Legacies of British Slave-ownership Project [95] articulates the following legacies: commercial (“evolution of firms receiving slave compensation and their redeployment of slave wealth into other investments”), cultural (“role of British slave-owners as connoisseurs and collectors, as philanthropists and as founders or participants in new cultural and social institutions”), historical (“role of slave-owners and their descendants as writers and historians constructing memories of the slave-trade and slavery”), imperial (“wider circuits of Empire, as investors, administrators and settlers in colonies beyond the slave-colonies”), physical (“physical legacies include country houses, domestic residences and public monuments”), and political (“involvement in national or local politics of any kind”).

The latter part of the 18<sup>th</sup> century saw the rise of abolitionist organisations such as the “Sons of Africa” [96, 97]. Although Parliament finally abolished slavery in the British Caribbean, Mauritius and the Cape in 1833, “in place of slavery the negotiated settlement established a system of apprenticeship, tying the newly freed men and women into another form of unfree labour for fixed terms. It also granted £20 million in compensation, to be paid by British taxpayers to the former slave-owners” [95]. That sum constituted 40% of the British state’s expenditure in 1834 – the modern equivalent of £17 billion [98], the largest government pay-out prior to the bailout of the banks in 2009. The recipients of compensation, clustered overwhelmingly in the southern strongholds of high society, included 100 Members of Parliament (over and above the West India lobby) and 150 Anglican clergymen – “thus did mammon assert its priority over humanity and religion” [99]. Whereas British taxpayers subsidised the British Empire’s scheme for abolition, the slaves in Saint Domingue who emancipated themselves from the French were forced to compensate their former slave owners: payments in service of the Independence Debt imposed by France on Haiti in 1825 continued until 1947 – an amount estimated to be \$21 billion [72, 99, 100].

Consider the Neave Baronetcy [101] created in 1795 for Richard Neave [102], a London Jamaica merchant whose wife, seven children (such as son Sir Thomas Neave [103] and daughter Harriet Trevelyn [104]) and their descendants were claimants and/or financial beneficiaries of slave ownership. Sir Richard Neave was a Director of the Bank for 48 years as well as its Governor (1783 – 1785), a position held later by his son-in-law Beeston Long (1806 – 1808) [105] and grandson Sheffield Neave (1857 – 1859) [106], the latter also a Director for 27 years. Assisted by representatives of the colonial assemblies, the London Society of West India Planters and Merchants (whose chairmen included Sir Richard Neave and Beeston Long) formed the West India Interests which “through publications, depositions before parliament, and direct lobbying of government ministers . . . defended their self-proclaimed right to import African slaves based on constitutional precedent and a right to enjoy the fruits of their fixed property in the colonies” [107]. Founded in 1735, “ten out of fifteen members of one of the most important committees of the Society of Planters and Merchants held seats in the English Parliament” [108]. Today, the Society exists as the West India Committee [109], a registered charity promoting agriculture, trade and manufacturing in the Caribbean and providing services to corporations, institutions, government and other organisations.

Two other examples illustrate the transmission of the benefits of slave ownership across generations. Established six years before the Bank, “when Lloyd’s was a coffee house and nothing more, many advertisements in the London Gazette about runaway slaves listed Lloyd’s as the place where they should be returned. . . . Lloyd’s, like other insurance companies, insured slaves and slave ships, and was vitally interested in legal decisions as to what constituted ‘natural death’ and ‘perils of the sea.’ . . . One of the most distinguished chairmen of Lloyd’s in its long history was Joseph Marryat, a West Indian planter, who successfully and brilliantly fought to maintain Lloyd’s monopoly of maritime insurance against a rival company in the House of Commons in 1810” [108]. Joseph Marryat (1757 – 1824) was a member of the House of Commons (1808 – 1824), chairman of Lloyd’s (1811 – 1824), an Agent for Trinidad (1805 – 1812), an Agent for Grenada (1815 – 1824), and an important figure in the defence of slavery [110, 111]. Likewise, his son Joseph Marryat II (1790 – 1876) was a member of the House of Commons (1826 – 1834), an Agent for Grenada (1831 – 1851), and an individual who resisted moves towards emancipation [112, 113]. Yet, a major recipient of compensation by the British taxpayer was Joseph Marryat & Co, a firm whose partners were Joseph Marryat II and his brother Charles Marryat (1803 – 1884) [114]. The ancestors of David Cameron, UK Prime Minister (2010 – 2016), “were among the wealthy families who received generous reparation payments that would be worth

millions of pounds in today’s money” [115].

The system of plantations pioneered by the Spanish, perfected by the Dutch and adopted eagerly by the English were key to the internationally integrated trading network encouraged, approved, regulated and monitored by Parliament and lubricated by the Bank. Amongst those that thrived within this legal and financial infrastructure were the City of London’s Corporation, Lloyd’s, a host of banking facilities, and (domestic) industries which provided goods for exchange in Africa, equipped the slave plantations of the Americas, and processed and sold the imported slave grown produce [116]. Many of the financial, arts, cultural, religious, educational and other institutions in London [117, 118], Greater Manchester [119], Oxford [120–122], Scotland [123], and elsewhere were founded on the wealth gained from the trans-Atlantic slave trade. That profits trickled back to all levels and sections of British society – government, companies and households – is illustrated by “Dividend Day at the Bank of England” [124], an 1859 painting depicting investors from a broad range of social classes receiving their dividends. In contemporary life, the Empire’s legacy is evident in social structures, public monuments, and art [117, 125, 126].

The advancement of natural philosophy went hand-in-hand with the advancement of England’s commercial and imperial interests [127]. For instance, the conjoined twins of the Royal Society (a scientific academy founded in 1663) and the Royal African Company (a mercantile company founded in 1660) enjoyed a legal monopoly on the transportation of African slaves for many decades [128]. Hans Sloane (1660 – 1753) was a President of the Royal Society, a President of the Royal College of Physicians, a physician to a colonial governor, inheritor of his wife’s Jamaican sugar plantations (estates and income), and the vast collection of natural and artificial rarities from across the world that he acquired with the aid of his wealth became the nucleus of the British Museum, Natural History Museum, British Library and Chelsea Physic Garden [129, 130]. In Victorian Britain, professors and others at University College London – a stone’s throw from the British Museum and the British Library – contributed to developing, establishing and legitimising eugenics [131–133]. The technological tools built to conduct the U.S. Census helped usher in not only the digital age but also eugenics [134].

Echoing Britain, “the slave-based economy generated the profits that allowed the US to industrialize, and also enabled these processes to happen much quicker and much more extensively than could have been done without slavery. The factories and industrial-related employment provided allowed the US to absorb the millions of people immigrating from especially Europe in the late 1800s to early 1900s. Without this capability, emigration from Europe would have been much more limited” [135]. In the USA, the roots of many elite universities and colleges lie in slavery and the large endowments of some are a financial legacy of the slave economy [136] – “the labor of enslaved people actually translates into buildings, endowments, and real hard material resources” [137]. The establishment of the Eugenics Record Office at Cold Spring Harbor Laboratory (New York) in 1910 provided eugenics in the USA scientific credibility and an institutional home [138].

The late 16<sup>th</sup> and early 17<sup>th</sup> century settlement of islands and regions in the Carribean and North American mainland formed the basis of the British Empire [139]. By 1922, this “empire on which the sun never sets” [140] held sway over one-fifth of the world’s population and covered almost a quarter of the Earth’s total land area. In the mid 20<sup>th</sup> century, the collapse of the formal British empire gave birth to a financial empire where the UK managed to retain a significant degree of influence over global flows of money [141, 142]. “Britain structured its economy not around manufacturing and productive sectors, but around finance. City of London banks provided the financing for the Empire and the colonies would pay interest to the City. Britain would create trade agreements with its colonies that would allow them to export a certain amount of their goods to the UK, thus enabling them to pay the interest on their loans. The Empire allowed the financial sector in the UK to take on a role and importance, which financial sectors did not have in other countries” [143]. The movement of wealth that has been illegally earned, transferred, or used across borders (illicit financial flows) has been called “the ugliest chapter in global economic affairs since slavery” [144].

## Visualisations

Our first goal is to provide a spatiotemporal sense of the nature and scale of the trans-Atlantic slave trade. Our second goal is to provide some measure of how the people and places involved, in conjunction with

those that were part of the British Empire, contributed to the economic wellbeing of the UK not only at that time, but laid the foundations for the UK's prosperity in subsequent decades and centuries. We utilised these public (re)sources.

- *A broad set of macroeconomic data spanning almost a millennium released by the Bank* [145]. (1) The contribution of different parts of the industrial and agricultural sectors to GDP. (2) The population of England and Britain.
- *A collection of geographic, imputed voyage and other data drawn from libraries and archives around the Atlantic world on the trans-Atlantic slave trade* [70]. (1) Major sites in the Atlantic rim from where slaves embarked and disembarked. (2) Estimates of the number of captives transported between these regions.
- *Entries in Wikipedia related to British and other European colonial powers*. (1) Possessions and colonies of European countries. (2) The year a former colony or dominion gained its independence from Britain.
- *A comprehensive account of parliamentary politics in England then Britain* [146]. (1) Biographical information on specific members of the House of Commons 1790 – 1820 and 1820 – 1832.
- *The Centre for the Study of the Legacies of British Slave-ownership database* [95]. (1) Biographical information on specific slave owners.

## Timelines and events charts: British economic growth (1270 – 1870) and two distinct labour forces

The left vertical axis of a chart shows data from libraries and archives on the trans-Atlantic slave trade and the Bank, one of the following

- Population of England (1086 – 1870) and Great Britain (1700 – 1870): this quantity is a proxy for the internal workforce; the values shown are overestimates of this labour force because the numbers include more than working age individuals (Fig 1, Fig 2, Fig 3, Fig 4, and Fig 5).
- Estimate of the number of captives transported between major sites in the Atlantic rim (1501 – 1866): this quantity is a proxy for an external workforce; the values shown are underestimates of this labour force because the numbers exclude people from the dominions, colonies, protectorates, mandates and other territories ruled or administered by Britain (Fig 6, Fig 7, Fig 8, Fig 9, and Fig 10).

The right vertical axis of a chart shows data from the Bank, one of the following

- British agricultural production of arable crops (1270 – 1870): data for wheat, rye, barley, oats, and pulses (Fig 1 and Fig 6).
- British agricultural production of livestock products (1270 – 1870): data for milk, beef, veal, mutton, pork, wool, hides, and hay (Fig 2 and Fig 7).
- British industrial production for key industries (1270 – 1870): data for tin, iron, coal, wool/textiles, leather, foodstuffs, construction and printed books (Fig 3 and Fig 8).
- British GDP(O) (1270 – 1870): data for agriculture, industry, services and GDP (Fig 4 and Fig 9).
- Regional trade (1665 – 2015): data for export/import of goods to/from Europe, Africa, Asia, North America including West Indies to 1972, South and Central America, and Australia (Fig 5 and Fig 10).

The events shown along the horizontal axis of a chart are the year a colony or dominion gained its independence from Britain.

The English and British population grew steadily from the mid-16<sup>th</sup> century with the main rise occurring in the 19<sup>th</sup> century, an increase that is related in part to the Public Health Act 1848, legislation on the sanitary

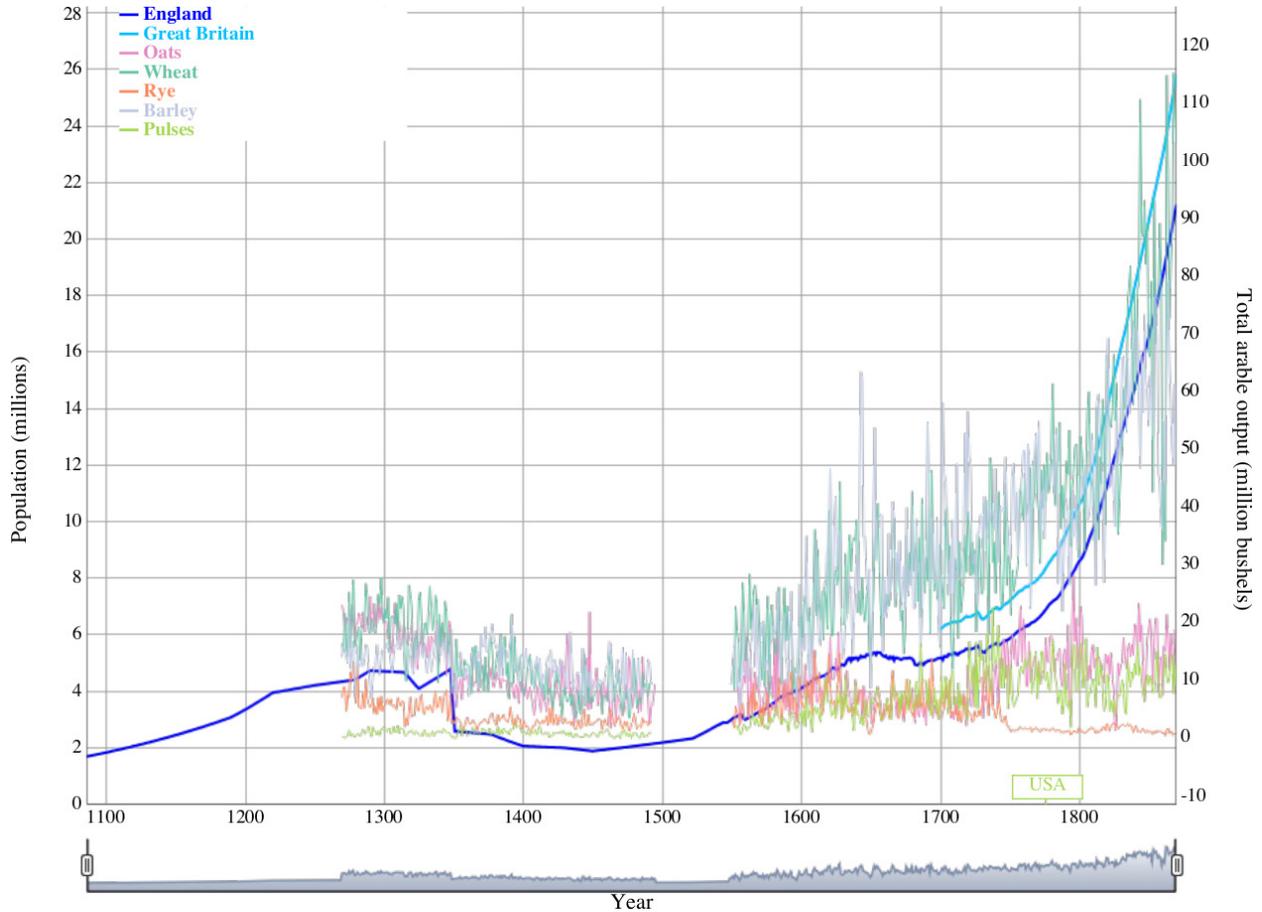


Figure 1: **British economic growth (1270 – 1870) and the “internal” workforce.** Timelines and events chart showing (a) English and British population (millions). (b) English and British agricultural production (arable crops): total output of wheat, rye, barley, oats, and pulses (million bushels). (c) The year a colony or dominion gained its independence from Britain. For the interactive version of this still image, download and open this HTML file in a web browser.

conditions of England and Wales [147, 148]. Below, we discuss charts where this “internal” workforce is shown alongside various macroeconomic factors (Fig 1 – Fig 5). However, the UK’s productivity and GDP was a function also of the labour provided by two “external” workforces. To emphasize this point, Fig 6 – Fig 10 are a parallel set of charts where the size of the domestic population in a given year is replaced by the number of slaves transported during that year. After the American Revolution, the slave population of the South reached over 1.1 million in 1810 and 3.9 million in 1860 [149]. We do not show analogous charts for the second external workforce, the population of the British Empire and its territories.

The increase in output for some arable crops (Fig 1) and livestock products (Fig 2) is due to the growing application of mechanisation in agriculture and, especially in the 18<sup>th</sup> century, the industrial revolution and the urbanisation expanding the demand for primary products. For some key industries in the 19<sup>th</sup> century (Fig 3), the increase in iron output reflects this material’s position at the heart of the industrial revolution. The relatively low levels for natural items such as wool/textiles, leather and foodstuffs indicates the deep integration of the national economy with the global economy, especially the import of raw products, primary goods, and less sophisticated manufactured goods from its colonies and territories. The exportation of manufactured goods and the importation of natural goods are tightly coupled with the industrial dominance

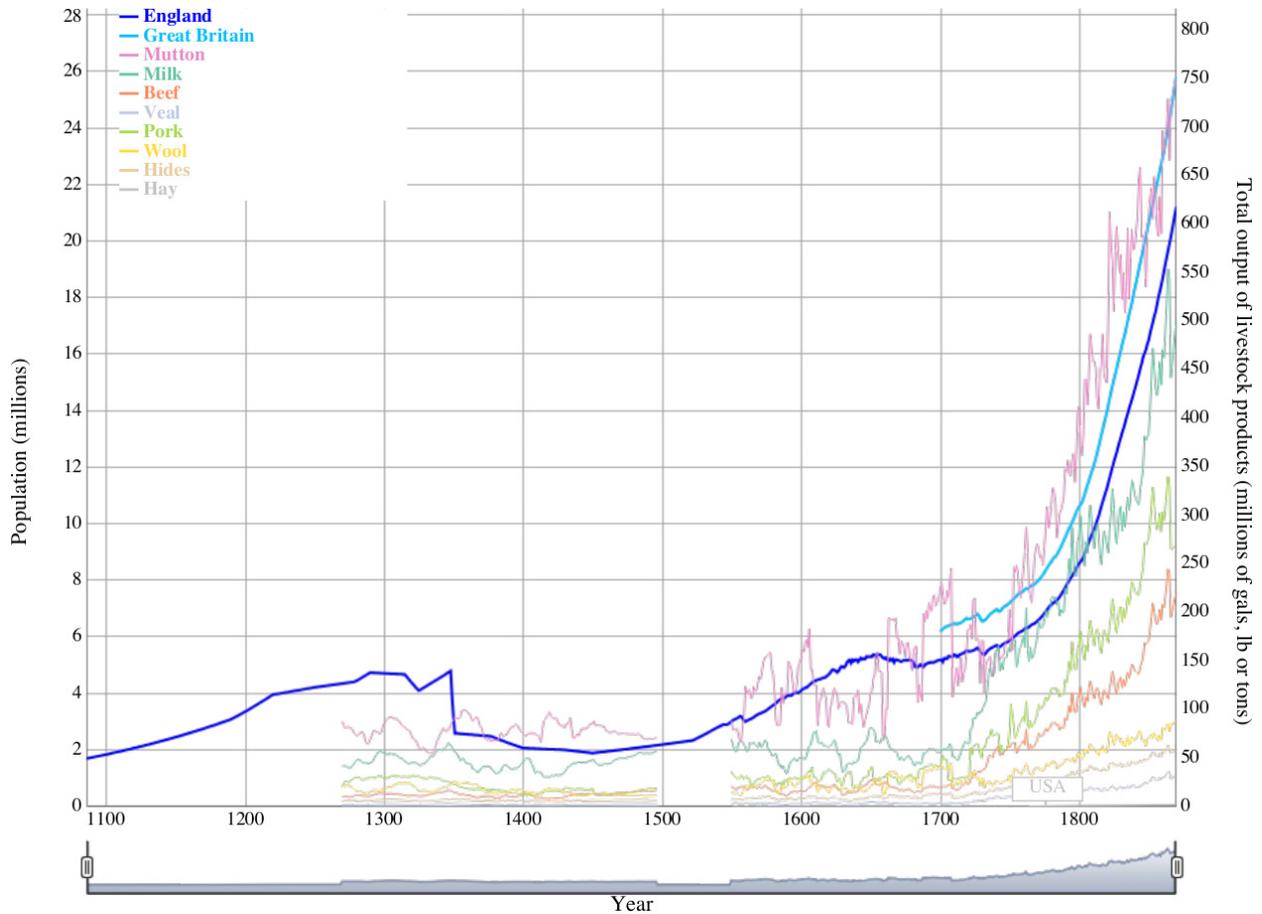


Figure 2: **British economic growth (1270 – 1870) and the “internal” workforce.** Timelines and events chart showing (a) English and British population (millions). (b) English and British agricultural production (livestock products): total output of milk (million gals), beef (million lb), veal (million lb), mutton (million lb), pork (million lb), wool (million lb), hides (million lb) and hay (million tons). (c) The year a colony or dominion gained its independence from Britain. For the interactive version of this still image, download and open this [HTML file](#) in a web browser.

of the empire, the centrality of the financial sector, and the growing power of some British groups and companies – global trade would be impaired or even blocked without insurance schemes for securing the transport of basic products.

The economic patterns established by the UK, including its empire, led to an increasing economic performance (Fig 4). In the 19<sup>th</sup> century, industry provided an ever greater proportion of the real GDP compared to services with agriculture lagging far behind. This reflects the force of the industrial revolution, the increasing national and international prominence of the financial sector, and the empire’s growing dependency on agricultural goods produced overseas by slaves and colonised peoples.

The UK’s trade reveals an empire taking advantage of its global position by favouring one region over another depending on the state of international affairs (Fig 5). In the 18<sup>th</sup> century, most products were sold to other European countries and although Europe remained the leading export destination the following century, its dominance was reduced, in large part by growth to Asia. Import wise, Europe was the UK’s main partner but North America (especially the USA) was almost equally relevant, especially in the early- to mid-19<sup>th</sup> century, decades when the USA was experiencing its own industrial boom. Prior to the declaration

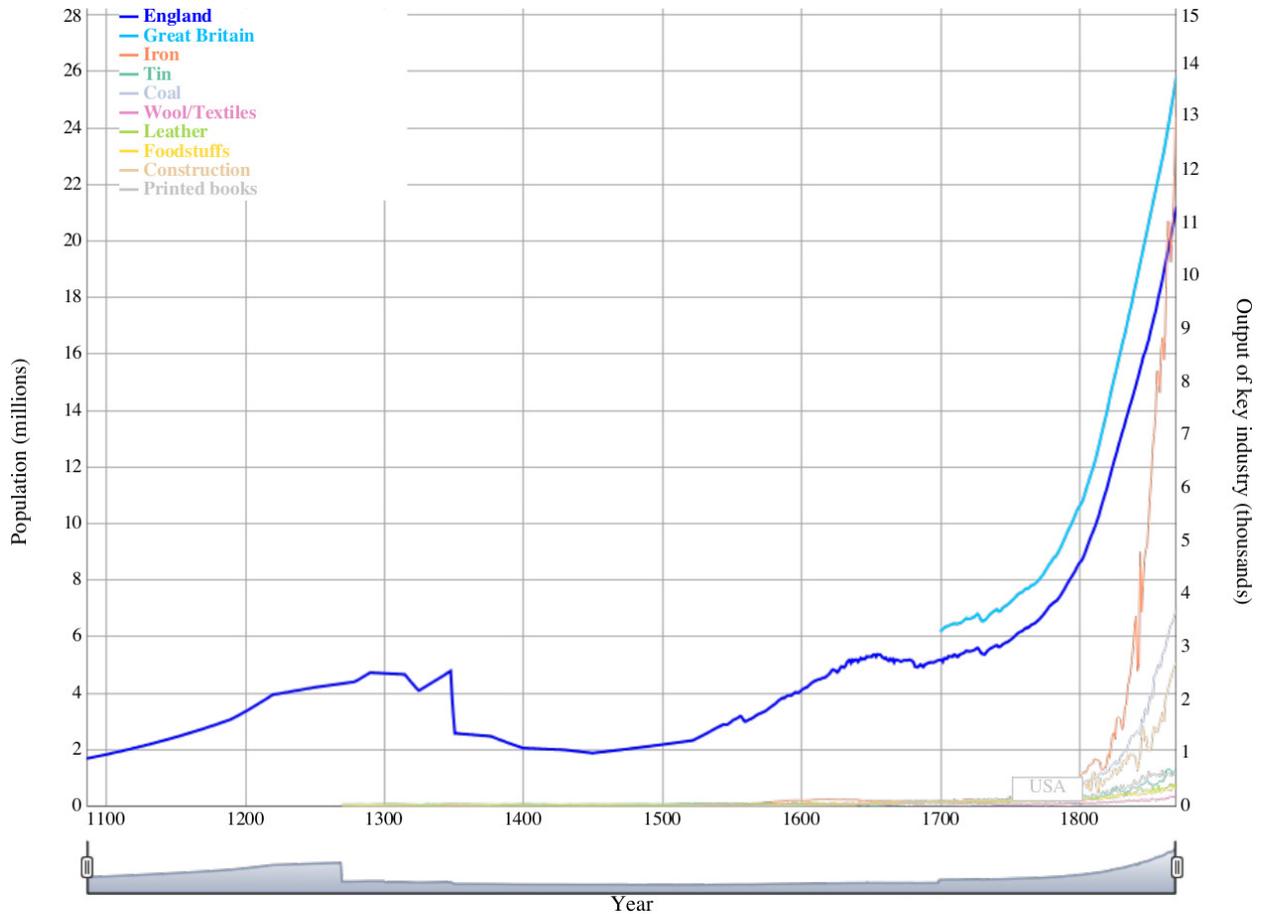


Figure 3: **British economic growth (1270 – 1870) and the “internal” workforce.** Timelines and events chart showing (a) English and British population (millions). (b) English and British industrial production (key industries): output of tin, iron, coal, wool/textiles, leather, foodstuffs, construction and printed books. (c) The year a colony or dominion gained its independence from Britain. For the interactive version of this still image, download and open this [HTML file](#) in a web browser.

of Independence by the USA in 1776, exports to and imports from Europe decreased rapidly whilst trade with North America exhibited the exact opposite trend. Subsequently, there were times when the weight of the USA was smaller than that of Asia. Most of the UK’s international trade could focus on manufactured, more sophisticated products because simultaneously, it had constant access to raw materials imported from Africa, South America, and Australia. In the 20<sup>th</sup> century, Europe regains its status as the UK’s main export and import partner, an economic haven. This reflects a new international order marked by disturbances such as the deep economic crises of the 1930s and two world wars.

Over the centuries, a sort of “fraternity of empires” emerged (Fig 10). Since 1700, Europe has been the UK’s main trade partner but during the apogee of the slave trade, North America reached Europe’s level, even surpassing it in terms of goods imported. This likely reflects the economic and industrial momentum gained by the USA during the 18<sup>th</sup> century as well as complementarities between the two economies in terms of international projection and participation in the global slave trade despite playing different roles: the USA was a massive importer of slave workers whereas the UK was an economic player in the trade.

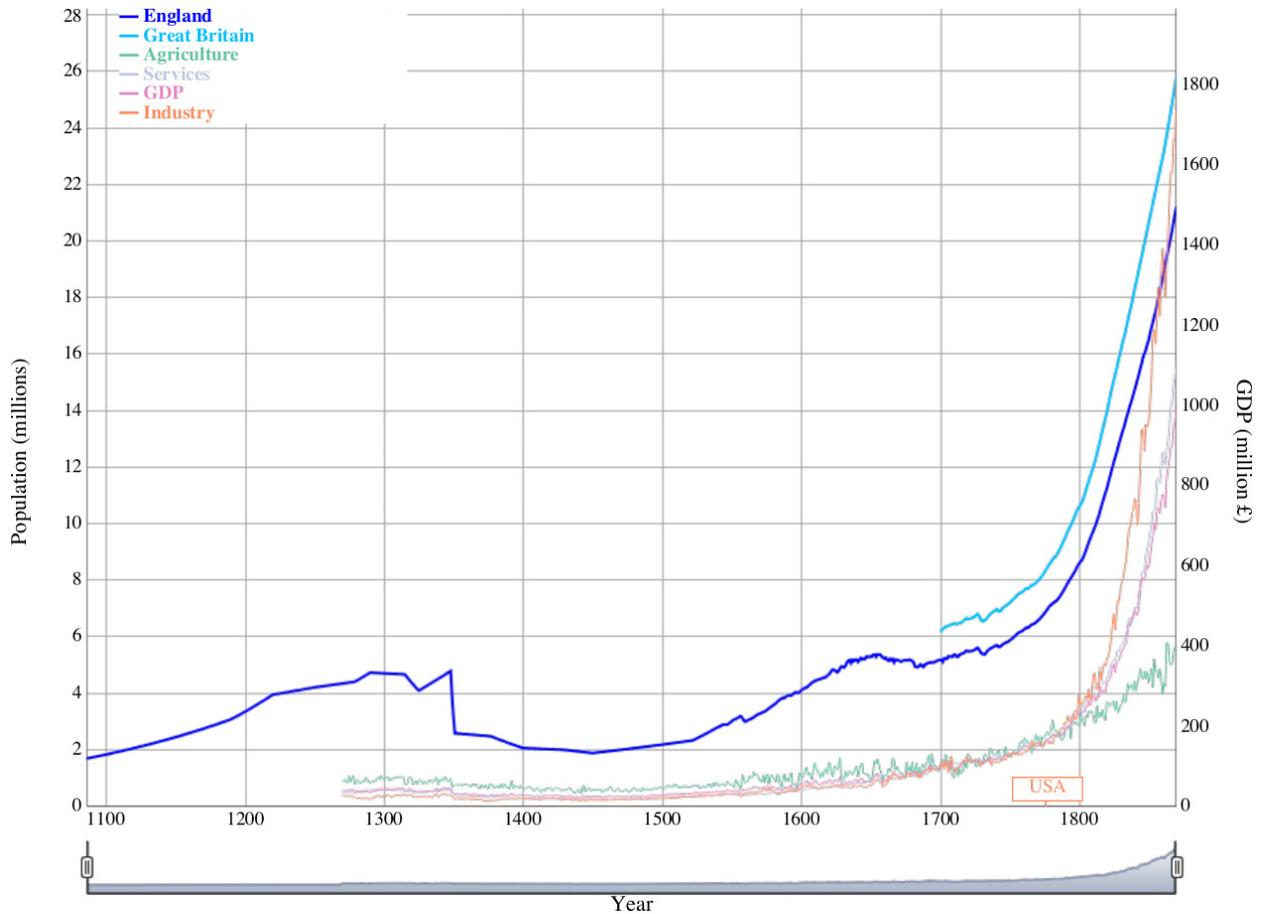


Figure 4: **British economic growth (1270 – 1870) and the “internal” workforce.** Timelines and events chart showing (a) English and British population (millions). (b) English and British GDP(O) (real GDP): agriculture, industry, services, and GDP. (c) The year a colony or dominion gained its independence from Britain. For the interactive version of this still image, download and open this HTML file in a web browser.

## Cartogram: The trans-Atlantic slave trade and European empires

Fig 11 shows the geographic extent of the major coastal regions involved in the trans-Atlantic slave trade and the global reach of European colonial powers. The UK was not the last colonial ruler of most regions that were explored as sources of slave workers, for example, France and Portugal controlled the most intensively exploited areas in the Atlantic Rim. Although the UK remained in the background, it continued to play a major role in the global trade because of its international financial projection. Hence, UK agents could campaign against slavery but still maintain deep connections with the slave trade. Thus, the empire was one of the greatest beneficiaries of the slave trade but could, in parallel, present itself as an opponent of slavery.

## 21<sup>st</sup> century large-scale land acquisitions and their consequences

The objectives of the Bank’s Monetary Policy Committee are reaching the target rate of inflation – mostly by changing the official interest rate known as Bank Rate or the Base Rate – and supporting the Government’s economic objectives [150]. Perhaps the most influential lever the Bank and the Federal Reserve

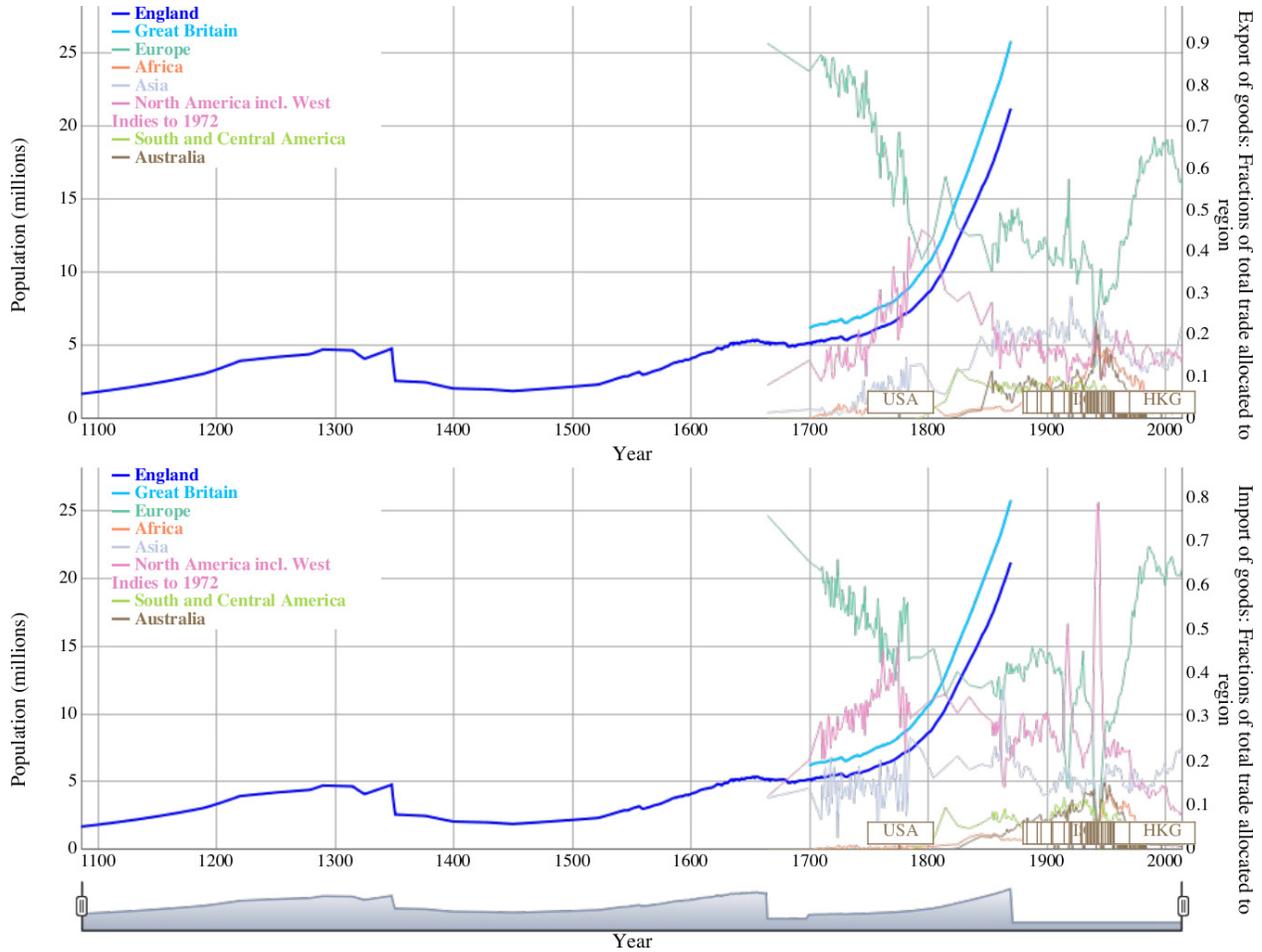


Figure 5: **British economic growth (1270 – 1870) and the “internal” workforce.** Timelines and events chart showing (a) English and British population (millions). (b) Regional trade: the export of goods (top) and the import of goods (bottom) from Europe, Africa, Asia, North America including West Indies to 1972, South and Central America, and Australia. (c) The year a colony or dominion gained its independence from Britain. For the interactive version of this still image, download and open this [HTML file](#) in a web browser.

System [151] have under their control, shifting the interest rate has a drastic effect on the building blocks of macroeconomies, including the behaviour of investors in the UK and USA with respect to land internationally, regionally, and domestically. As Britain’s farmland becomes a tax haven [152], prices outstripping even prime central London real estate [153], an increasing proportion of land purchases are being undertaken by lifestyle buyers rather than farmers [154]. Private investors view (English) farms both as safe assets in which to store wealth and highly-prized places to live [155]. Increases in the Bank’s base rate place pressure on farmers reliant on loans [156], especially those used to support cash flow.

Particularly since the financial crisis of 2007 – 2009, farmland is seen as a safe investment, a precious global commodity “like gold with yield” [157]. It is an attractive alternative economic asset class [158–160] for (global) investors [161] casting around for greater returns with low risk in a time of volatile markets for publicly traded securities and in a near zero interest rate environment for money-market and cash investments. Many investors have diversified their portfolios by reducing their exposure to equities whilst reallocating funds to “real” or “hard” assets overseas such as farmland [162]. The “financialisation of

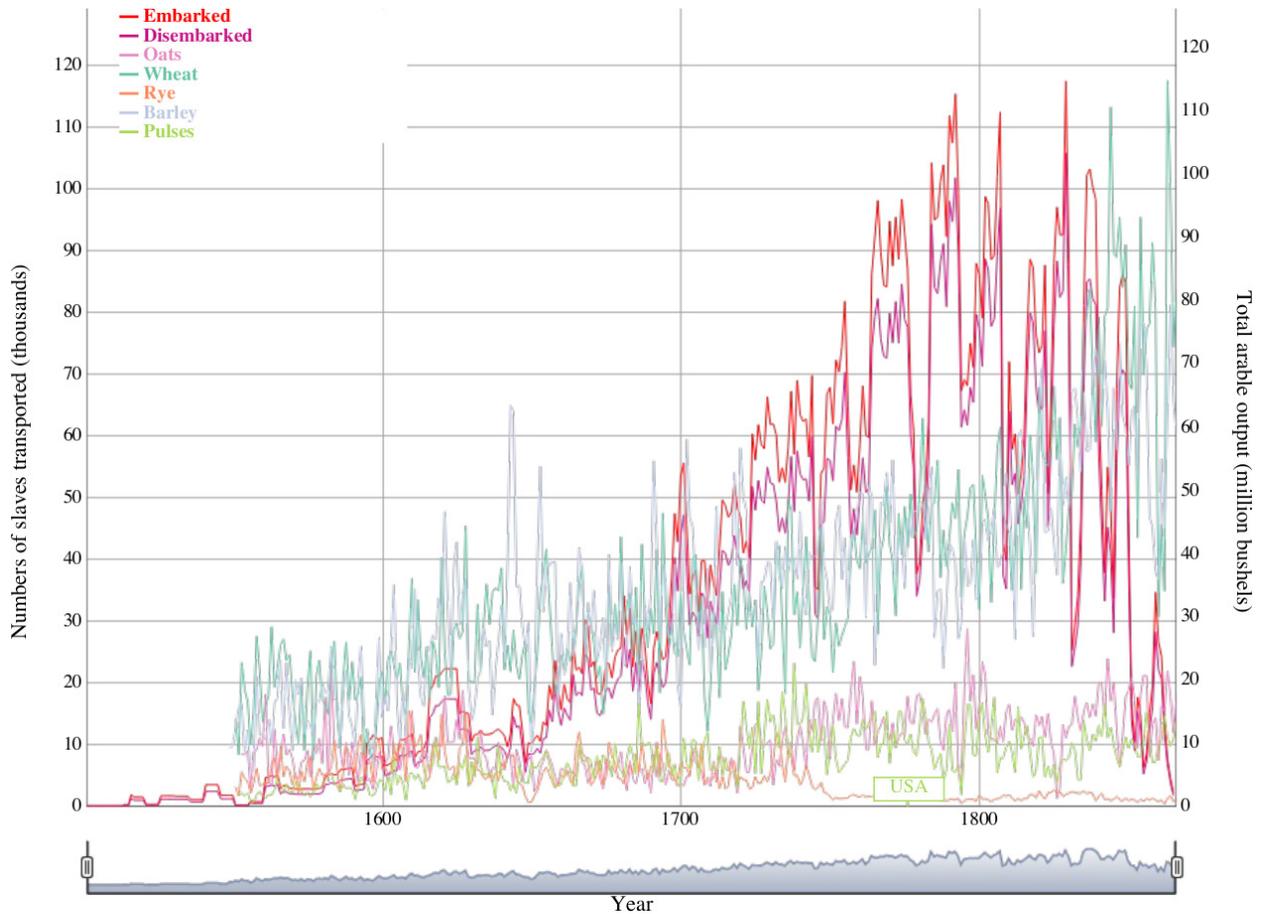


Figure 6: **British economic growth (1270 – 1870) and an “external” workforce.** Timelines and events chart showing (a) Estimates of the number of captives embarked and disembarked at major sites in the Atlantic rim. (b) English and British agricultural production (arable crops): total output of wheat, rye, barley, oats, and pulses (million bushels). (c) The year a colony or dominion gained its independence from Britain. For the interactive version of this still image, download and open this [HTML file](#) in a web browser.

farmland” means that decisions to buy or sell this “fictitious capital” is governed as much by the wider financial environment as by the agricultural use value of land: the appeal of land as a financial asset is highly dependent on interest rates [157].

Since the turn of this century, estimates of the land acquired globally by international entities range from ~48 million [163] to ~67 million [158] hectares, concentrated mostly in middle and low income countries. Concomitant to the land, this massive and growing phenomenon appropriates the freshwater [164, 165] available therein plus any associated soil, mineral, and hydrocarbon resources [166]. The appropriation of green water (precipitation stored in soils and consumed by plants through evapotranspiration) and blue water (water extracted from rivers, lakes, aquifers, and dams) poses socioenvironmental and political challenges [167]. Analysis of the geospatial and socio-ecological contexts of 139 transnational land acquisitions (>200 hectare per deal) in the Global South found that 35% of the deals targetted densely populated and easily accessible croplands, 34% remote forests with lower populations, and 26% moderately populated and accessible shrub- or grasslands [168]. In the 28 countries most affected by the global land rush from 2000 to 2014, one potential impact of transactions involving agricultural areas is loss of income and employment opportunities for over 12 million people in rural communities [169].

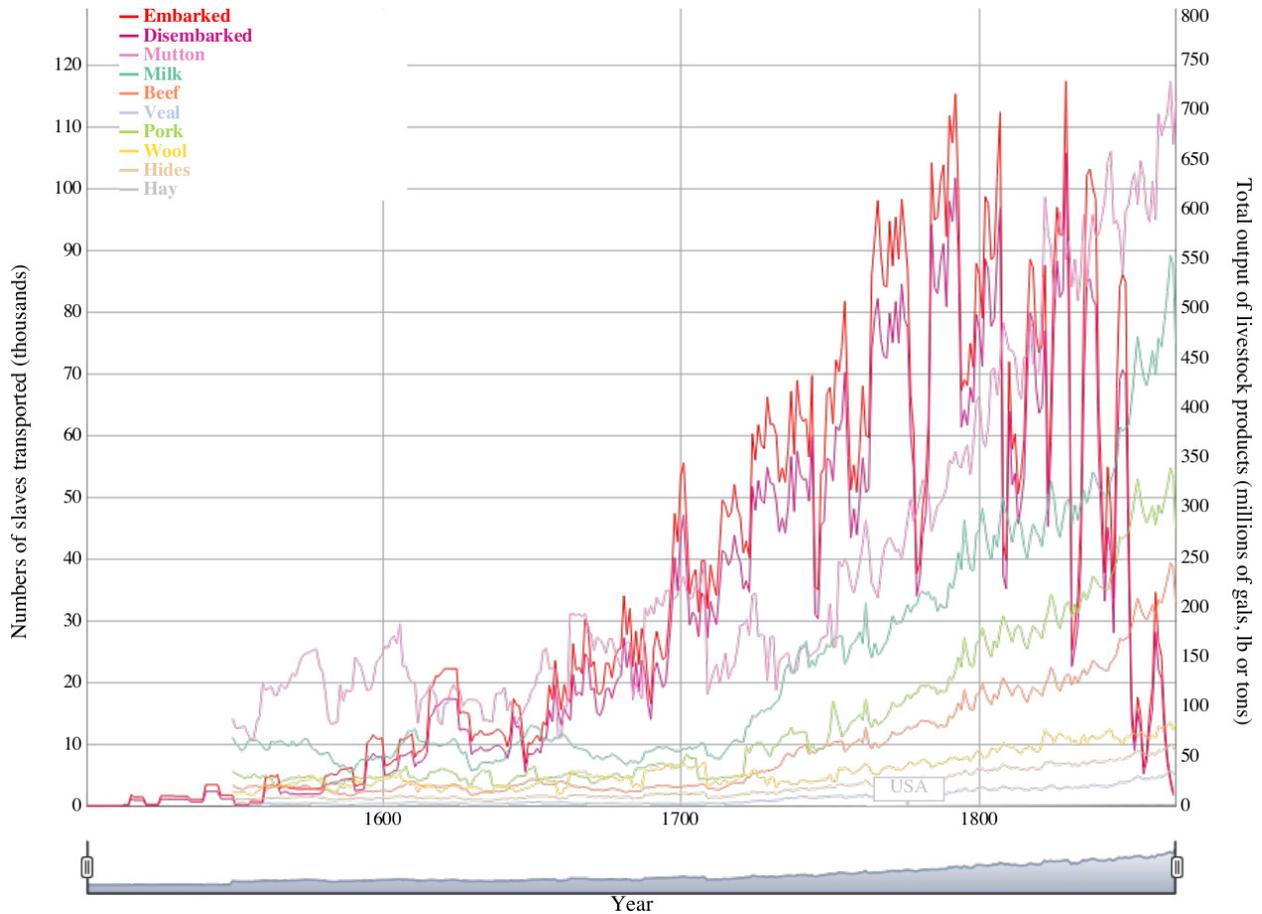


Figure 7: **British economic growth (1270 – 1870) and an “external” workforce.** Timelines and events chart showing (a) Estimates of the number of captives embarked and disembarked at major sites in the Atlantic rim. (b) English and British agricultural production (livestock products): total output of milk (million gals), beef (million lb), veal (million lb), mutton (million lb), pork (million lb), wool (million lb), hides (million lb) and hay (million tons). (c) The year a colony or dominion gained its independence from Britain. For the interactive version of this still image, download and open this HTML file in a web browser.

“21<sup>st</sup> century colonialism” [170] and “land grabbing” [171] are terms that have been applied to the transfer of the right to own or use the land from local communities to foreign investors through large-scale land acquisitions intended primarily, though not exclusively, for agriculture, forestry, conservation, biofuels and tourism [172–174]. Green grabbing [175] is land appropriation for environmental purposes such as carbon trading initiatives. Two major events in 2005 contributed to this global land rush: launch of the European Union Emissions Trading System (carbon trading or “cap and trade”) [176] and passage of the Energy Policy Act in the USA that contained provisions promoting biofuels and setting targets [163]. However, acquisition of forests and lands to establish forestry plantations intended to offset carbon emissions elsewhere in the world can take away local communities’ access to land [177] and hurt Africa’s rural poor [178]. Although enabled by investment de-regulation and trade liberalisation of the present, particularly international free trade agreements and laws [179], the corporate land rush is bolstered by history [165], notably the seizures of lands by colonial rulers. In essence, today’s economic dispossessions are co-mingled with the forced dispossessions of the trans-Atlantic slave trade and European empires.

The concentration of lands under increasingly larger holdings controlled by fewer people is affecting

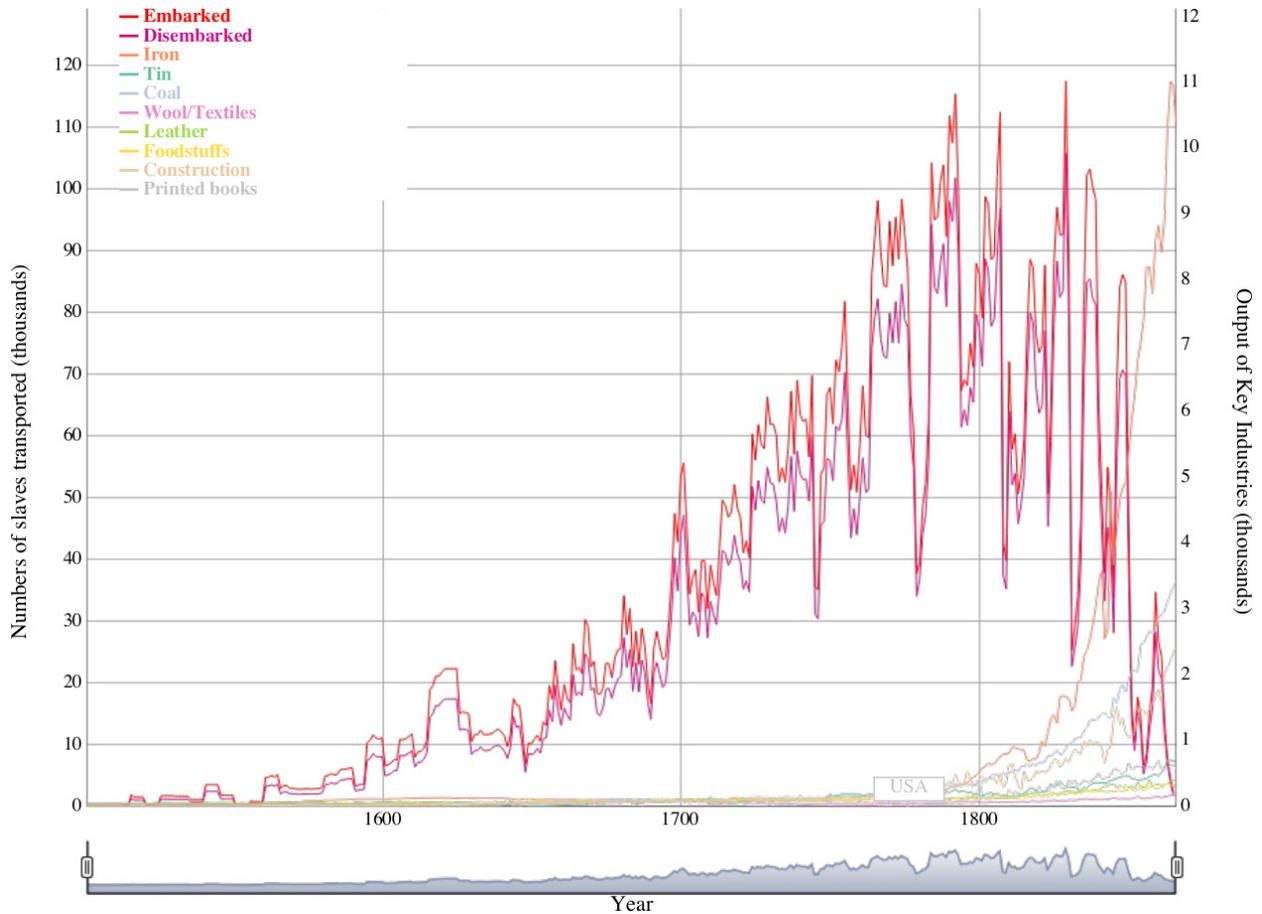


Figure 8: **British economic growth (1270 – 1870) and an “external” workforce.** Timelines and events chart showing (a) Estimates of the number of captives embarked and disembarked at major sites in the Atlantic rim. (b) English and British industrial production (key industries): output of tin, iron, coal, wool/textiles, leather, foodstuffs, construction and printed books. (c) The year a colony or dominion gained its independence from Britain. For the interactive version of this still image, download and open this HTML file in a web browser.

adversely the lives and livelihoods of small scale farmers and communities in Africa, Asia and Latin America [180, 181] as well as in Europe [182]. These farmers face the serious challenges of land ownership, land access, and water rights: from Africa [183] (particularly the sub-Saharan region [184]) through Haiti [185] to India [186] and Europe [187][188]. Beyond this, farmers need to grasp the international political ecology of new and emerging issues relevant to agriculture such as synthetic biology, gene editing and other biotechnologies [189–192].

Although the focus has been on the impacts of Britain on trade, labour, accumulated wealth, and land overseas, these same issues were and are relevant domestically. For example, land and its ownership were of concern during the period we consider – notably the Scottish clearances and Parliamentary Enclosures [193]. As elsewhere in the world, they remain a pressing issue: farms in England under 50 hectares are in danger of vanishing by 2050 even though they “create greater diversity in food production and conservation, both of which shape rural heritage and rural economies” [194]. In Britain, a policy of increasing access to land would support new entrants to farming [195]. Indeed, a significant increase in the number of small agroecological market gardens (including those less than 5 hectares) could deliver environmental and social

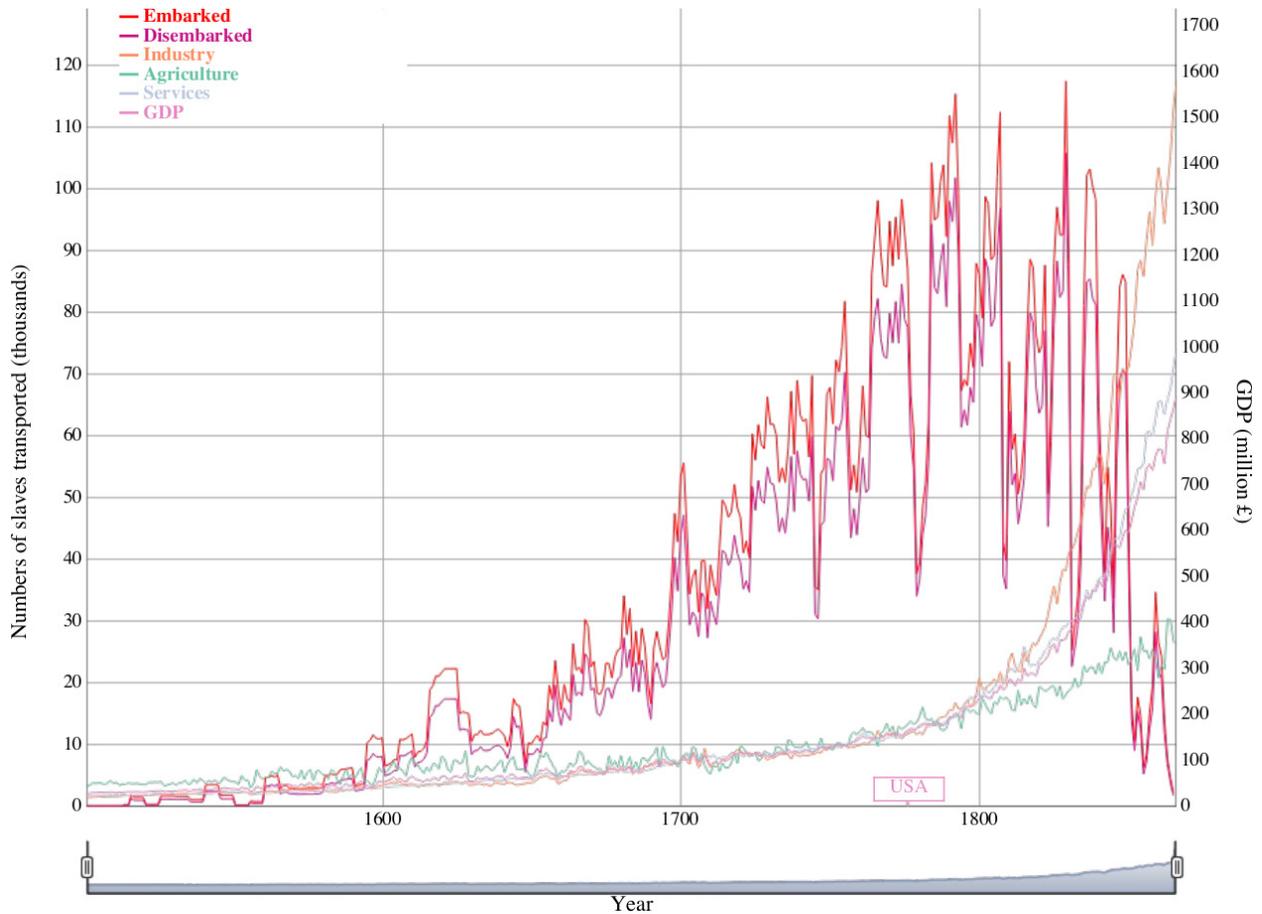


Figure 9: **British economic growth (1270 – 1870) and an “external” workforce.** Timelines and events chart showing (a) Estimates of the number of captives embarked and disembarked at major sites in the Atlantic rim. (b) English and British GDP(O) (real GDP): agriculture, industry, services, and GDP. (c) The year a colony or dominion gained its independence from Britain. For the interactive version of this still image, download and open this HTML file in a web browser.

benefits such as reducing the trade gap for fruit and vegetables, providing year-round employment and rejuvenating communities [196]. Agroecology- and whole food systems-related policies and issues are critical not just today but also tomorrow in the post-Brexit era [197, 198].

## Visualisations

“Private equity players and asset managers that acquire land or corporate farms, do not see food production as a complex ecological process, do not consider starvation, obesity and malnutrition as challenges that they have to address and, more importantly, do not recognize the role and existence of small scale farmers. On the contrary, they see food production as any other industrial operation, based on efficiency and satisfaction of the global demand, a matter of competition on the global market rather than a matter of socially and culturally embedded practices that can satisfy the needs and rights of the communities. Massive amounts of resources have thus been invested, and will be invested, in production and distribution of food not on the basis of what is ecological, socially acceptable, healthy or capable of guaranteeing the long-term resilience of

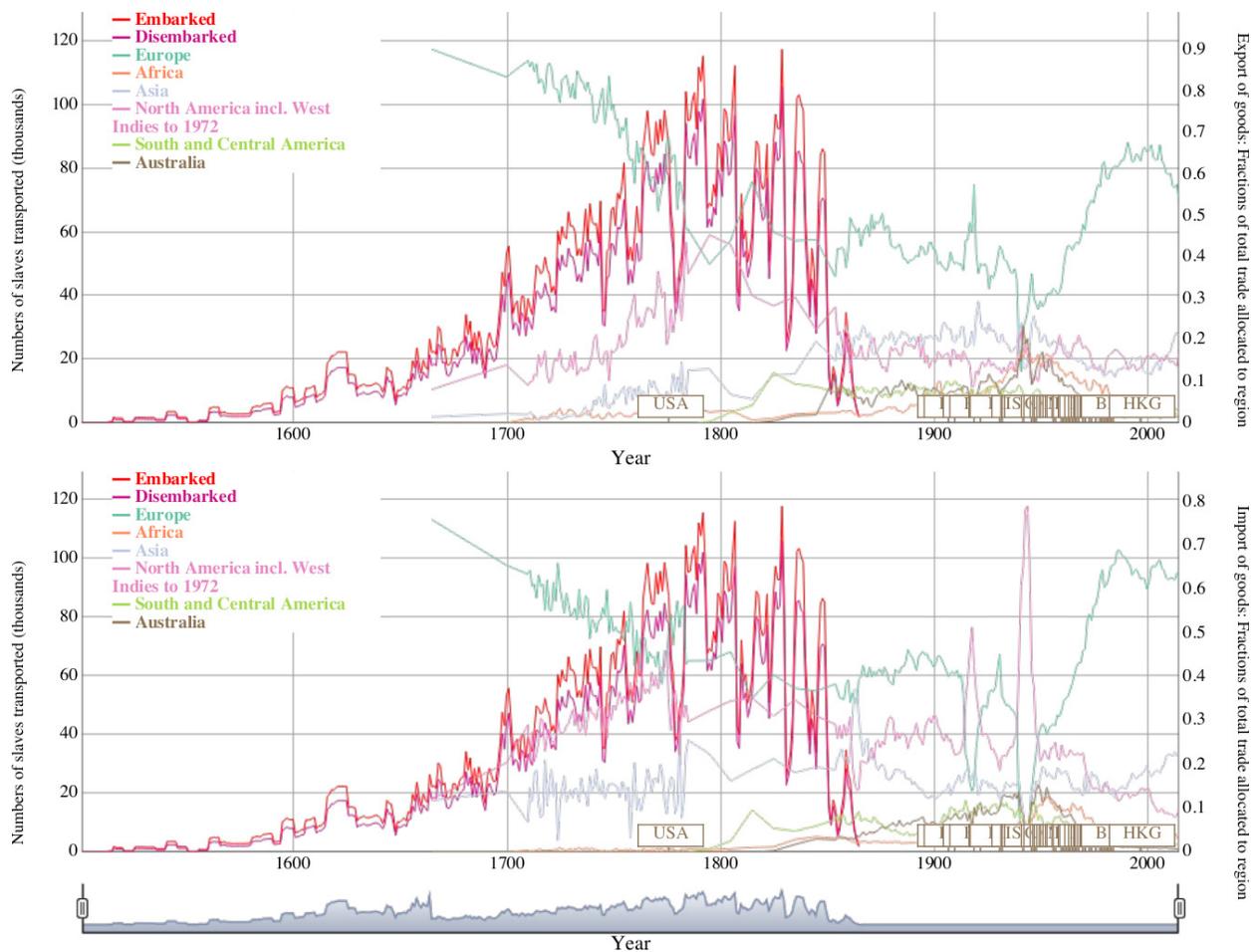


Figure 10: **British economic growth (1270 – 1870) and an “external” workforce.** Timelines and events chart showing (a) Estimates of the number of captives embarked and disembarked at major sites in the Atlantic rim. (b) Regional trade: the export of goods (top) and the import of goods (bottom) from Europe, Africa, Asia, North America including West Indies to 1972, South and Central America, and Australia. (c) The year a colony or dominion gained its independence from Britain. For the interactive version of this still image, download and open this [HTML file](#) in a web browser.

land and the ecosystem.” [199]

Our first goal is to illuminate the increasing role played by financial actors, institutions, markets, and motives in the operation of international and domestic economies by highlighting the connection between monetary policy (banks’ lending practices) and the financialisation of land and agriculture – for example, the interest rates of central banks [200] and the tendency of rich investors to target (poorer) economies with abundant land and water resources [172]. Our second goal is to highlight how growing connections between the financial and agrifood sectors are shaping the latter in areas ranging from food retail to land ownership [201, 202]. We utilised these public (re)sources.

- *Interest rates set by the central banks of the UK and USA.* (1) The Bank [145] (1694 – 2017). (2) The Federal Reserve System [203] (1954 – 2017).
- *Economic contribution of the agricultural sector to the GDP of countries that are major targets of large-scale land acquisition (1980 – 2010).* (1) Data underlying Figure 1 of [169].

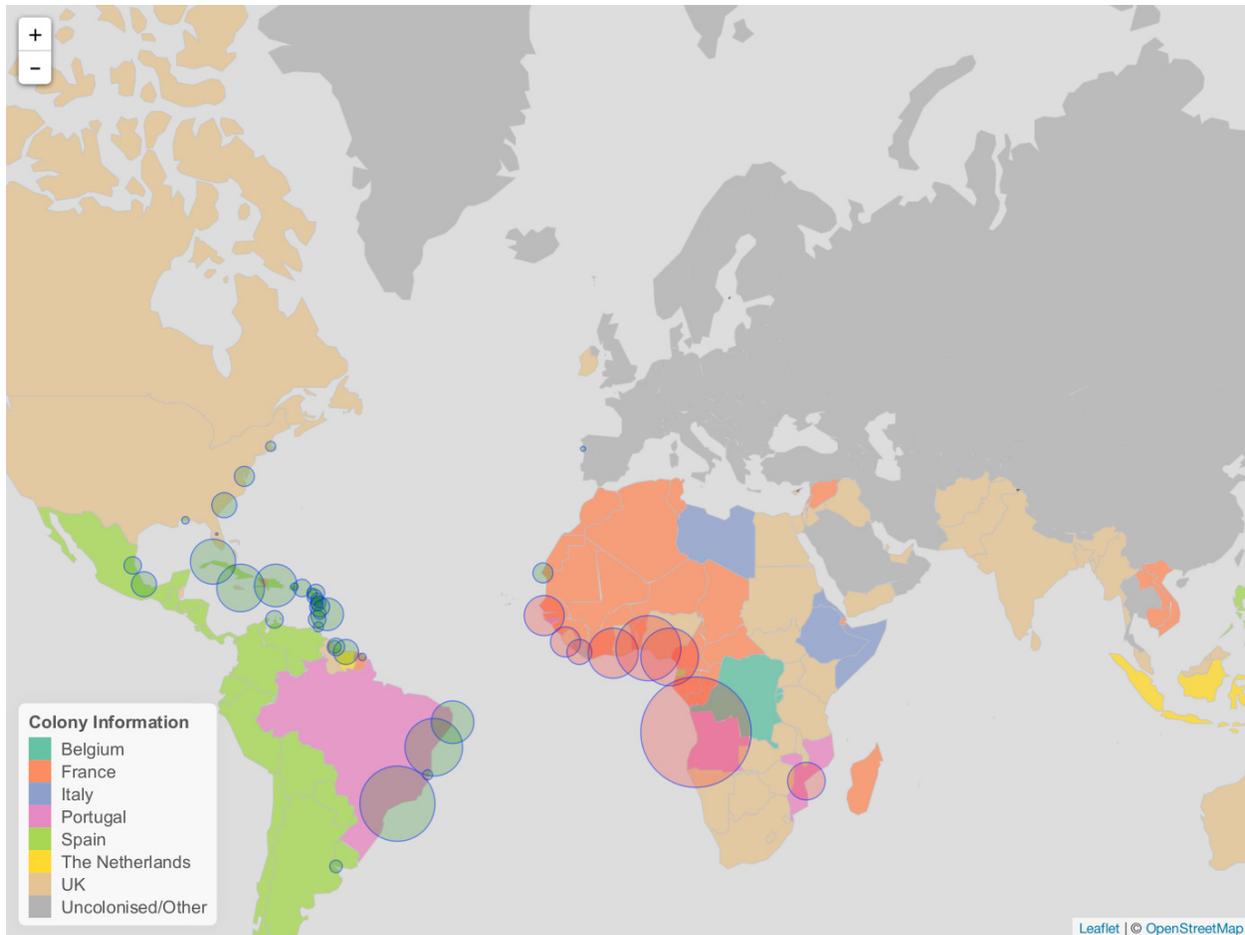


Figure 11: **The trans-Atlantic slave trade and European empires.** Cartogram showing (a) Major sites in the Atlantic Rim from which captives embarked (primarily the west coast of Africa) and disembarked (east coast of the Americas); a circle lists – and its size is an indicator of – the number of slaves transported from the embarkation region or to the specific disembarkation region. (b) The countries and territories ruled or administered formerly by Belgium, France, Italy, Portugal, Spain, the Netherlands, UK, or another country. The colour of a region indicates the last colonial ruler, for example, Guyana is shown as a former British Colony even though it was colonised first by the Netherlands. Like other visualisations, this cartogram is for illustrative purposes only and is by no means a definitive history of European colonialism and imperialism. For the interactive version of this still image, download and open this [HTML](#) in a web browser.

- *International trade agreements since the middle of the 20<sup>th</sup>.* (1) Historical international trade agreement arising from the Asian-African Conference of Bandung [204]. (2) Multilateral free trade agreements in operation [205].
- *Land acquired in a country and countries targetted by investors from the UK and USA as of October 2017* [206–210]. Whilst there are concerns with the definition, accuracy and dynamics of land deals [211–214], the Land Matrix dataset remains the only open source and comprehensive dataset of global large-scale land acquisitions.
- *Natural products being created using synthetic biology and their impacts on farmers* [215]. (1) Countries where traditional (agricultural) livelihoods and biodiversity may be adversely affected as these synthetic

biology substitutes of food, flavour, cosmetic and fragrance ingredients enter the market.

## **Timelines and events chart: central bank interest rates and agricultural production in targets of global land acquisitions**

Fig 12 shows interest rates set by the Bank and the Federal Reserve System (left vertical axis) and the agricultural sector's contribution to the GDP of 28 significantly grabbed countries (right vertical axis) in the context of trade agreements (horizontal axis). Although inflation and interest rates are often linked, and frequently referenced in macroeconomics, we do not show the rate at which prices for goods and services rose because our focus is more the relationship between UK and USA monetary policies and the agriculture in countries of the Global South. The oil shocks of the 1970s helped to take interest rates to their highest historical levels in both the UK and the USA. From 1980 – 2010, the fall in interest rates is mirrored by a decline in the economic contribution of the agricultural sector. The low interest rates in the 21<sup>th</sup> century reflect the dominant financial positions of the UK and the USA because the biggest investors consider these countries as safe havens where they can put money. Farmers have to contend with not only the (global) financial system but also a changing climate (see for example, Fig 14).

## **Cartogram: global large-scale land acquisitions and countries threatened by the replacement of natural products by compounds manufactured using synthetic biology**

Fig 13 highlights two challenges faced by small scale farmers: the appropriation of land and water by international entities and an emerging biotechnologies. The land being grabbed is mainly in the Global South and the UK and the USA are the main players (see also Fig 15).

## **Traditional farming systems, agricultural biodiversity and climate change**

In 2015, representatives of diverse constituencies from all continents that produce ~70% of the food consumed by humanity issued the Declaration of the International Forum for Agroecology [216, 217]. This joint vision of peasants, fish harvesters, fish workers, mobile indigenous peoples, and many others across the world [218–225] identified land and territories as well as collective rights and access to the commons as a fundamental pillar of agroecology. Agrarian reform is a common struggle for small scale farmers [226], a group who produce most of the world's food with less than a quarter of all farmland, a paltry share that is shrinking [227]. Despite the legacies of slavery and colonialism [159, 228], threats to indigenous peoples' livelihoods from emerging technologies [229–233], attempts to replace natural products with products containing synthetic biology ingredients [215, 234, 235], disruptions caused by erratic weather patterns, and other many challenges, small scale farmers in the Southern USA [236, 237], Haiti [238–240], Honduras [236, 241, 242], Zimbabwe [243, 244], the Andean region [38], Brazil [245], Mexico [246, 247], Peru [248], Pakistan [249], India [250–252], the Philippines [253], Tanzania [254, 255], California [256, 257], and elsewhere [258] are producing food, feed, fibre, medicines and other products. Numerous success stories and multiple case studies [259] demonstrate the capacity of agroecological agriculture to mitigate the effects of climate change and address hunger and poverty whilst respecting farmers and the environment [27, 52, 260, 261].

Building on ancestral production systems developed over many millenia, the Declaration emphasized food sovereignty [37] as the framework offering a collective path forward from today's food, public health, climate, environmental, and other crises. Given the intimate connection between the ability to cope with (even prepare for) extreme climatic events and high levels of on-farm biodiversity, traditional farming systems and agroecological strategies – particularly biodiversification, soil management and water harvesting – represent the “only viable and robust path to increase the productivity, sustainability and resilience of peasant-based agricultural production under predicted climate scenarios” [262].

Agroecology has two interacting and complementary pillars [28]: soil quality (enhancing organic matter and biological activity) and plant health (enhancing the habitat for beneficial biota) – that is, improving below-ground as well as above-ground community biodiversity and function. Agroecological practices such as building soil, recycling nutrients, dynamically managing biodiversity, and conserving energy at all scales both lessen the adverse impacts of food systems on the climate (adaptation) and reduce green house gas emissions (mitigation). Innovations created and/or employed by small scale farmers include ones that provide effective control of pests and diseases [263–266], produce carbon-rich soil through sustainable grazing by ruminant animals [267], improve air quality through reduced nitrogen pollution [268], enhance livelihoods through sustainable food and fibre production [249], increase knowledge through farmer training [255], develop cultivars/breeds from traditional varieties and stock through farmer-scientist collaborative research [253], promote demand-driven, application-oriented participatory research [269], and explore the design and implementation of closed-loop plant-based indigo production systems [270].

The key attributes of the ideal food system are “offers adequate nutrition and health,” “creates biodiversity and avoids negative ecological and environmental impacts,” and “ensures livelihood for farmers, diverse landscapes, equitable access to land, water, seeds, and other inputs” [271]. Whilst the relationship between soil fertility and the health of humans and animals has been known for decades if not millenia [272–275], recent efforts in pursuit of yield may have compromised biodiversity and nutritional quality, one culprit being soil depletion. For example, analysis of historical data on the nutrient content of food in the UK (1940 – 2002) [276, 277] and in the USA (1950 – 1999) [278] revealed declines during the periods studied [279]. Possible reasons for this downward trend include changes in varieties/cultivars, farming practices, the environment, soil minerals and microbes, (whole) food systems, and the acquisition and/or evaluation of food composition data. Across a wide range of plant species – including food crops, elevated concentrations of atmospheric carbon dioxide appear to reduce the concentrations of vital minerals and elements such as nitrogen, phosphorus, potassium, calcium, sulphur, iron, zinc, copper, and manganese in the plant [280]. Over the next 3 decades, higher  $CO_2$  and climate change are predicted to reduce the availability of three critical nutrients (protein, iron and zinc) in agricultural commodities [281, 282].

One protective response of a range of food crops to extreme weather such as drought conditions and increases in temperature is the synthesis of specific chemical compounds that could be harmful to human and animal health if consumed for a prolonged period of time [283]. Finally, external farming inputs such as fertilisers and pesticides affect the microbial communities in and around plants [284], an important issue given that the dynamic and reciprocal interactions at the soil-root interface influence root function and ultimately plant growth, production, and quality.

Agroecology is a way to design climate change-resilient farming systems [285] whose social, cultural, economic and environmental benefits include the provision of plant crops for human and/or animal consumption that meet consumer demand for nutritional quality and density. One explanation is that agroecological practices embody an understanding that each plant growing in field conditions is not a single individual but a community: the myriad connections between a plant and its (a)biotic environments are critical for meeting the challenges of food, fuel and fibre production. That is, the cornucopia of aerial- and soil-based associations and interactions amongst and between plants and microbes exert a strong influence on crop yield and economic viability [286] as well as nutrient value.

A keystone of agroecological practices is improving the well-being of the cornucopia of beneficial micro- and macro-organisms that reside in, on, and in the vicinity of plants and animals in general and crops and livestock in particular. The phyllosphere is the above-ground portions of plants inhabited by commensal and other microorganisms [287]. The rhizosphere is the narrow regions around a root where microorganisms and processes important for plant growth and health are located [288] and whose functions include helping plants to acquire nutrients from the environment (notably nitrogen, minerals and elements), improving water use efficiency, and protecting against pathogens [289]. A common mycorrhizal network is the system of fungal hyphae that link together the roots of most land plants [290]. Plants use this underground network to warn neighbouring plants of imminent attack from diseases and pests and to communicate unfavourable conditions such as drought whilst the services performed by the fungi include uptake of phosphate and mineral nutrients [291, 292]. Collectively, the phyllosphere, rhizosphere and common mycorrhizal network are key mediators

and determinants of the dynamic, reciprocal, multifaceted and intimate relationship between agroecosystem health (crops as well as livestock) and human health.

In addition to food, feed, and medicines, tangible products of agroecosystems include fibre and dye plants and animals [293–298]. For materials such as cotton (“white gold”), new global and local perspectives on the entire value supply chain and the complete cycle of production, processing, consumption, and recycling include “From Farm to Fashion” [299], “soil to soil” [300] and “field-to-fabric” [250]. Regenerative and sustainable agricultures and community-driven textile systems consider issues ranging from classical plant breeding methods with hierloom naturally coloured cotton varieties [301] through indigo cultivation and processing [302] and community supported cloth [303] to garment design and construction [304] – local fibres, local dyes, and local labour.

These and other agroecological approaches to and economic frameworks for perhaps the most important natural fibre crop worldwide stand in stark contrast to those that existed during the trans-Atlantic slave trade and British colonialism [305, 306]. At the turn of the 19<sup>th</sup> century, the lives and communities of skilled middle-class weavers and textile artisans in the English counties of Nottinghamshire, Yorkshire and Lancashire were being upended by low-skilled low-wage labourers toiling in factories [307]. Between 1811 and 1813, a group of cotton and wool workers rebelled by smashing machines which were destroying their trades, undercutting wages and forcing them into unemployment and destitution. These “Luddites” resisting destruction of livelihoods by industrialisation were opposed only to technology “hurtful to commonality”: whilst sceptics about the dogma of technology as progress, they did not deny the real benefits of some technologies [308, 309]. However, the “expansion of cotton manufacturing in Great Britain depended on violence across the Atlantic” [135], the expansion of cotton production overseas.

“What distinguishes the United States from virtually every other cotton-growing area in the world was planters’ command of nearly unlimited supplies of land, labor and capital, and their unparalleled political power ... The coercion and violence required to mobilize slave labor was matched only by the demands of an expansionist war against indigenous peoples” [310, 311]. Plantation owners in the Southern states melded agricultural science and labour management to alter, simplify and (re)organise humans and nature to meet the needs of capital [312]. Indeed, “most of the cotton picked by Valley slaves was Petit Gulf (*Gossypium barbadense*), a hybrid strain developed in Rodney, Mississippi, patented in 1820, and prized for its ‘pickability.’ The hegemony of this single plant over the landscape of the Cotton Kingdom produced both a radical simplification of nature and a radical simplification of human being: the reduction of landscape to cotton plantation and of human being to ‘hand.’ Cotton mono-cropping stripped the land of vegetation, leached out its fertility, and rendered one of the richest agricultural regions of the earth dependent on upriver trade for food” [313]. Many of the four million black slaves tilling fields in 1860 were both workers and human capital: the commodities produced for sale by the American slave-breeding industry included not only agricultural items such as tobacco, rice, sugar, and cotton but also people [314]. Today, some prison industries have “ancestral roots in the black chattel slavery of the South” [315] where, for instance, “much of the work on the 18,000-acre former slave plantation consists of backbreaking labor in the cotton, corn, and soybean fields, presided over by armed guards on horseback” [316]. Between 1910 and 1997, African Americans lost about 90% of their farmland with some land speculators legally forcing black southerners off family land [317]. Black agricultural landowners in America have lost 12 million acres over the past century – 6 million from 1950 to 1969 [159].

Can “ghost work” [318], the hidden labour supporting today’s algorithms and powering the platform economy, be seen as a contemporary simplification of nature and the reduction of human being to hand? For example, the *iCassava 2019 Fine-Grained Visual Categorization Challenge* [319] provides 9,436 labelled and 12,595 unlabelled images of cassava plant leaves for development of semi-supervised computer vision algorithms running on smart phones able to identify healthy plants and diagnose four common diseases. The authors “developed and deployed a crowdsourcing system where small-holder farmers in disparate places in Uganda were given smart phones with an application used to collect images of the crops in the farmers’ fields. ... Approximately 200 farmers sent images of plants from their gardens over the course of 1 year.” Every step in data preparation – acquisition, cropping, annotation, and verification – required manual input from experts with individuals asked to conform to the needs of the technology: “the images are not always

in focus even after farmers have been given instructions to center images on the leaf of interest.” Plantations “sought innermost control over the bodies of their enslaved work force,” a core impulse that pervades modern technology [320]. Moreover, “If today America promotes a particular kind of low-road capitalism – a union-busting capitalism of poverty wages, gig jobs and normalized insecurity; a winner-take-all capitalism of stunning disparities not only permitting but awarding financial rule-bending; a racist capitalism that ignores the fact that slavery didn’t just deny black freedom but built white fortunes, originating the black-white wealth gap that annually grows wider – one reason is that American capitalism was founded on the lowest road there is.” [320]

The Bank’s OBRA states “fundamental changes in the environment could affect economic and financial stability and the safety and soundness of financial firms, with clear potential implications for central banks”. Thus, the formulation and implementation of Bank policies that directly and/or indirectly strengthen small scale farmers and build rural and urban agroecology provide a simple, shared, and cost-effective way to tackle one of the major challenges faced by today’s national, regional, and global economies: systemic environmental risks such as climate change [48]. In part, this is because food sovereignty helps to weather economic crises plus the established link between public health and the economy [321] – the long term financial benefits of reduced mortality and morbidity flow to the state.

Agroecology-based strategies for addressing economic and financial risks include increasing the capacity of local communities to experiment, evaluate and scale-up innovations [322] through farmer-to-farmer and field-based research and education, nationally, regionally and internationally [323–325] – “innovation” and “technology” are not necessarily synonyms. Crucial factors in the success of such endeavours are land sovereignty [326] (the “right of working peoples to have effective access to, use of, and control over, land and the benefits of its use and occupation, where land is understood as resource, territory, and landscape”), the right to water [327] (including in Europe [328]) and the world’s biodiversity for food and agriculture [329]. Ultimately, “we need to address the agricultural research agenda if it is to serve the interests of farmers, consumers and society as a whole, rather than narrow but powerful economic interests” [330].

## Visualisations

Our first goal is to illuminate some of the weather- and climate-related conditions faced by national, regional and global food systems in general and small scale food producers in particular. Our second goal is to highlight the global distribution of heritage and current farming systems that are not only rich in agricultural biodiversity and associated wildlife but are also repositories of indigenous knowledge and culture – especially *materia dietetica* and *materia medica*. Critical engagement with local and indigenous knowledge systems [331] provides a better understanding of the challenges posed by climate change and how to respond to it, agroecology being one example [332, 333]. We utilised these public (re)sources.

- *Atmospheric oxygen ( $O_2$ ) and carbon dioxide ( $CO_2$ ) levels measured at nine locations around the world* [334].
- *The El Niño and La Niña phases of a naturally occurring global climate cycle known as the El Niño-Southern Oscillation that disrupt normal weather patterns in different ways across the globe* [335]. (1) Episodes from 1950 to 2018.
- *Organisations of small scale farmers and fisher folks around the world that helped to formulate the 2015 “Declaration of the International Forum for Agroecology”* [216].
- *Diverse, complex, locally adapted agricultural systems developed over centuries and generations. Globally Important Agricultural Heritage Systems (GIAHS)* [336].
- *Centres of agricultural biodiversity, crops and livestock.*

## Timelines and events chart: Average global oxygen and carbon dioxide levels and El Niño/Niña episodes

Fig 14 shows the irregular nature of the duration and pattern of El Niño and La Niña episodes since the mid-20<sup>th</sup> century. Since 1990, average global levels of O<sub>2</sub> have been decreasing whereas CO<sub>2</sub> levels have been increasing. These events and trends pose diverse physical and liability risks to the macroeconomies, for example, their impacts on agriculture, fisheries and forestry include disruption of whole food systems from production through to consumption. The contribution of the agricultural sector to the GDP is affected also by the global economic structure (see Fig 12).

## Cartogram: Small scale food producers and agricultural biodiversity

Fig 15 show groups representing peasants and fisher folk producing the majority of food consumed by humanity, globally important agricultural heritage systems and landscapes, and centres of agricultural biodiversity. Comparing with Fig 13, the areas where land grabbing is happening the most frequently are also the areas holding local, family and community initiatives. The Global South seems to represent an arena for two kinds of practices: global investors treating land as a commodity to be purchased, invested in, and dealt with as an asset and local groups seeing land as a vital resource to used to organise a way of living.

## Conclusion

We propose that agroecology [27, 28, 217, 339, 340] – undergirded by food sovereignty [37, 341–345], land sovereignty [326], the right to water [346], (agricultural) biodiversity [41, 42], and environmental health [40] – provides a shared, direct, cost-effective and underexplored strategic response to preventing, mitigating and reducing climate-related physical, liability and transition risks to the macroeconomy. Thus, policy tools and instruments supporting outcomes such as scaling up agroecology [347], improving the economic health of whole food systems [348], (re)building rural and urban agricultural economies [349–351], and ensuring agricultural research agendas serve the interests of farmers and consumers [330] are issues of concern not only to societies in the Global North and Global South but also to central banks in general and the Bank in particular. An open question is what impact a transition to an agroecology-centred agricultural sector would have on the banking and insurance sectors.

Since we consider human and natural systems across wide geographical and historical time scales, the study is pertinent also to the emerging field of planetary health [352–354], a field that “aims not only to investigate the effects of environmental change on human health, but also to study the political, economic, and social systems that govern those effects” [355]. Our approach illustrates recently proposed cross-cutting principles of planetary health education [356] such as “the crucial linkages, cause – effect relationships, and feedback loops between environmental change and human health” and “the complexity of interactions between the geographical scale, temporal scale, socioeconomic factors, and political and cultural context that shape specific challenges to and potential solutions for sustainable human health outcomes.” Similarly, the field of Structural One Health [357] integrates the global political economy and multispecies biology (notably wildlife, livestock, crop, and human ecology) leading to, for example, propositions such as neoliberal economics and land use providing the broader context in which Ebola emerged in West Africa [358]. A distinctive aspect of this study is its *historical* international political ecology perspective on the financial system, agriculture and climate. More broadly, marrying the past and present of transnational commodity chains and global circuits of capital with agriculture (the trans-Atlantic slave trade and European empires in this study) *and* medicine can enhance understanding of the financial and physical well-being of humans and communities as well as disease emergence in plants and animals.

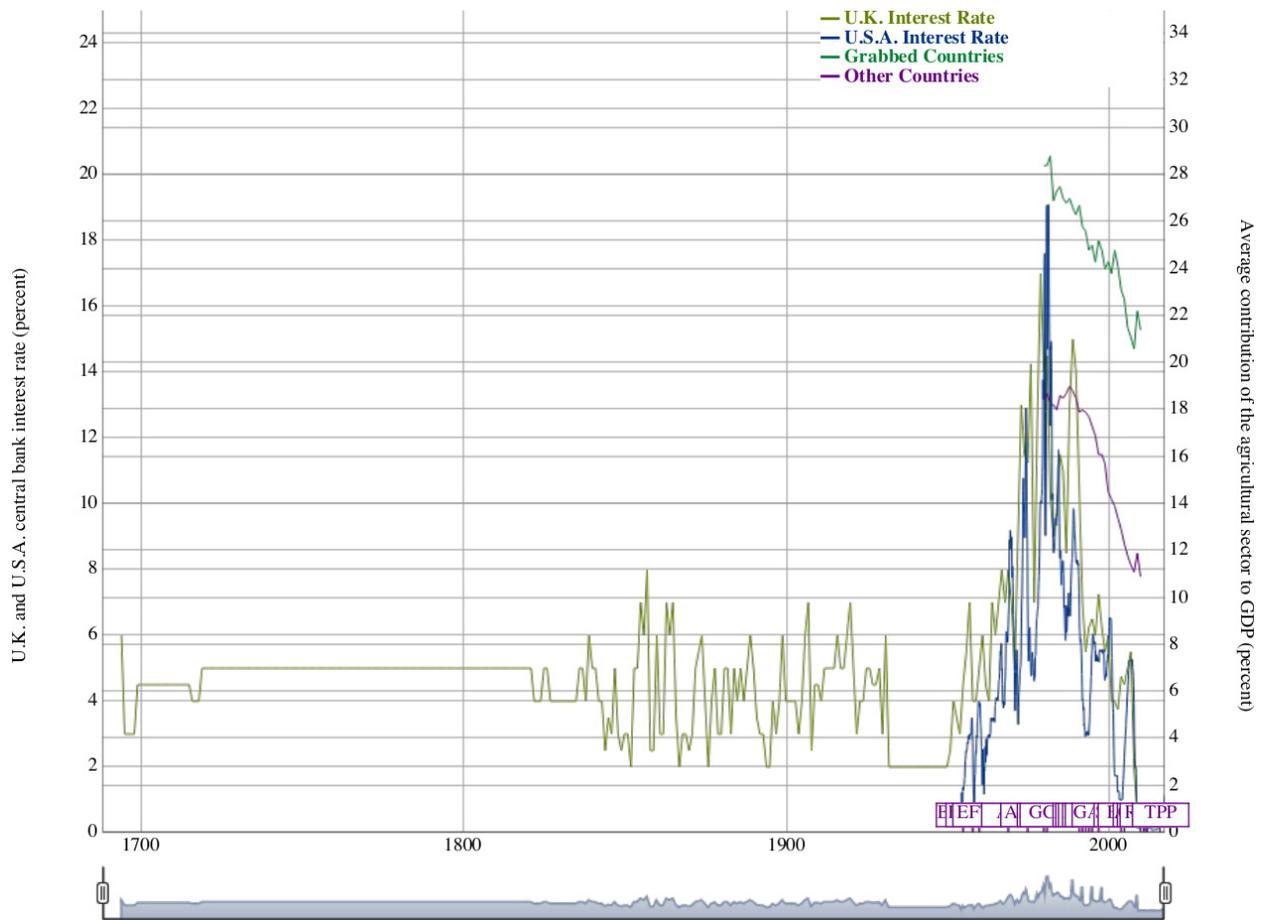


Figure 12: **Interest rates set by two central banks and agricultural production in targets of global land acquisitions.** Chart showing (a) Interest rates from the Bank of England (1694 – 2017) and Federal Reserve System (1954 – 2017). (b) The economic contribution of the agricultural sector to the GDP (average percent) for 28 countries that have been the targets of significant large-scale land acquisitions and all other countries (1980 – 2010). The significantly grabbed countries are Angola, Argentina, Benin, Brazil, Cameroon, Colombia, Congo, DRC, Ethiopia, Gabon, Ghana, Guatemala, Indonesia, Liberia, Madagascar, Malaysia, Morocco, Mozambique, Nigeria, Papua New Guinea, Peru, Philippines, Russia, Sierra Leone, South Sudan and Sudan, Tanzania, Uganda, and Uruguay. (c) Multilateral free trade agreements in operation and an historical international trade agreement arising from the Asian-African Conference of Bandung. The agreements shown are Bandung (Asian-African Conference of Bandung), EUCU (European Union Customs Union), EFTA (European Free Trade Association), AC (Andean Community), APTA (Asia-Pacific Trade Agreement), SADCFTA (Southern African Development Community Free Trade Area), GCC (Gulf Cooperation Council), MERCOSUR (Southern Common Market), CEFTA (Central European Free Trade Agreement), AFTA (ASEAN Free Trade Area), SICA (Central American Integration System), COMESA (Common Market for Eastern and Southern Africa), EEA (European Economic Area), NAFTA (North American Free Trade Agreement), G-3 (G-3 Free Trade Agreement), IGA (International Grains Agreement), GAFTA (Greater Arab Free Trade Area), DR-CAFTA (Dominican Republic-Central America Free Trade Agreement), SAFTA (South Asian Free Trade Area), EAC (East African Community), AANZFTA (ASEAN-Australia-New Zealand Free Trade Area), CISFTA (Commonwealth of Independent States Free Trade Area), PAFTA (Pacific Alliance Free Trade Area), RCEP (Regional Comprehensive Economic Partnership), and TPP (Trans-Pacific Partnership). For the interactive version of this still image, download and open this HTML file in web browser.

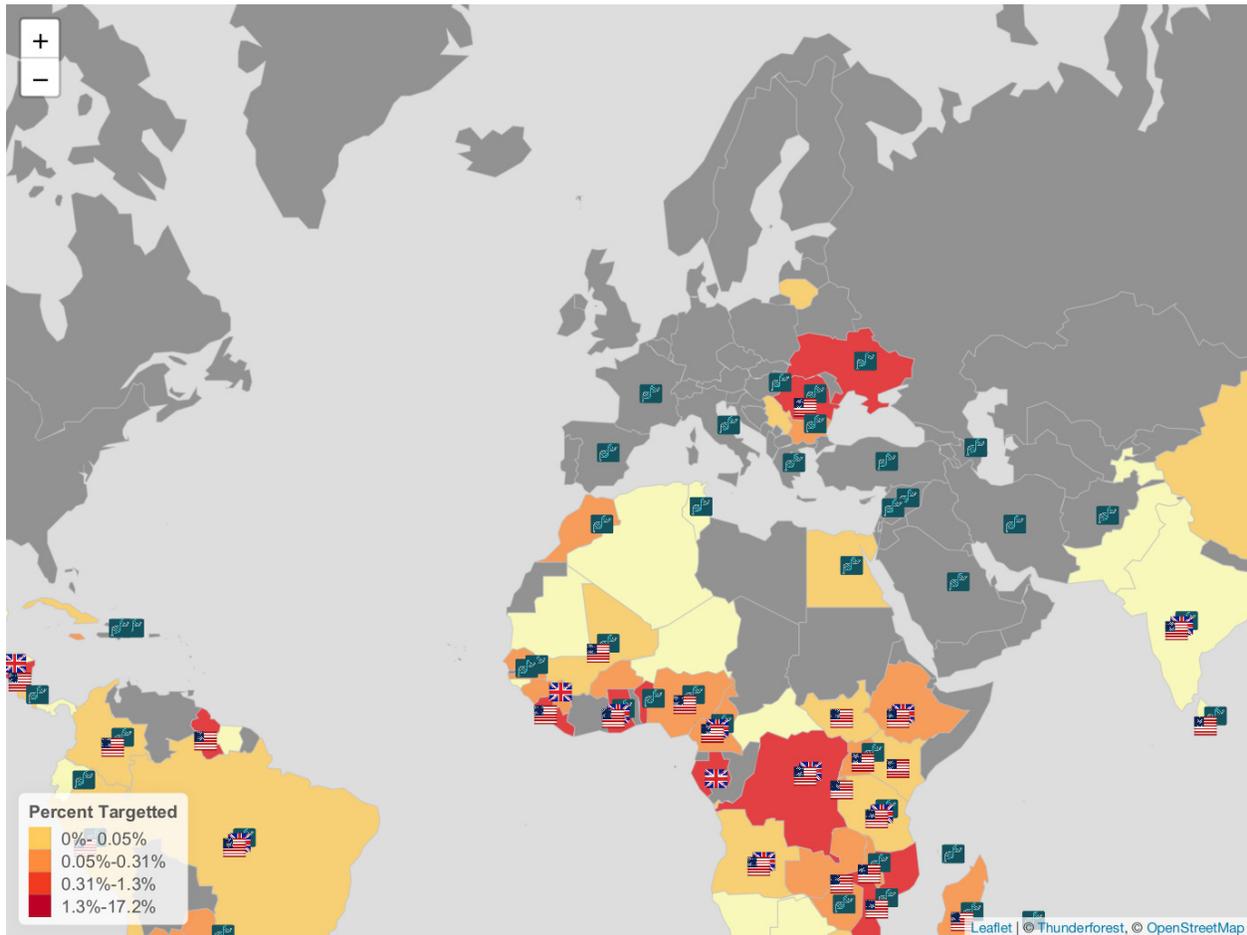


Figure 13: **Global large-scale land acquisitions and countries threatened by the replacement of natural products by compounds manufactured using synthetic biology.** Cartogram showing (a) Countries that are targets of the land grabbing phenomenon. The shading is proportional to the percent of the land area of a country that has been acquired in transnational deals. (b) Countries where investors from the USA and the UK have acquired land. These countries are marked using a flag icon (Union Jack, Stars and Stripe). As of October 2017, the top two investor countries involved in transnational land acquisitions in terms of the number of deals are the USA (143 deals) and the UK (129 deals); the top investor country in terms of the area of land acquired is the USA (9,979,713). (c) Countries where the traditional livelihoods of farmers, growers, pickers, harvesters and others as well as biodiversity are under threat because of the replacement of 13 natural products by compounds produced using synthetic biology. A country where one or more of these natural food, flavour, cosmetic and fragrance ingredients is grown is marked using a double helix icon; the 13 products are agarwood, ambergris/Clary Sage, artemisinin, ginseng, patchouli, rose oil, saffron, sandalwood, shea, cocoa butter and other cocoa butter equivalents (CBEs), squalenes (olives), stevia, vanilla and vetiver. For the interactive version of this still image, download and open this HTML file in a web browser.

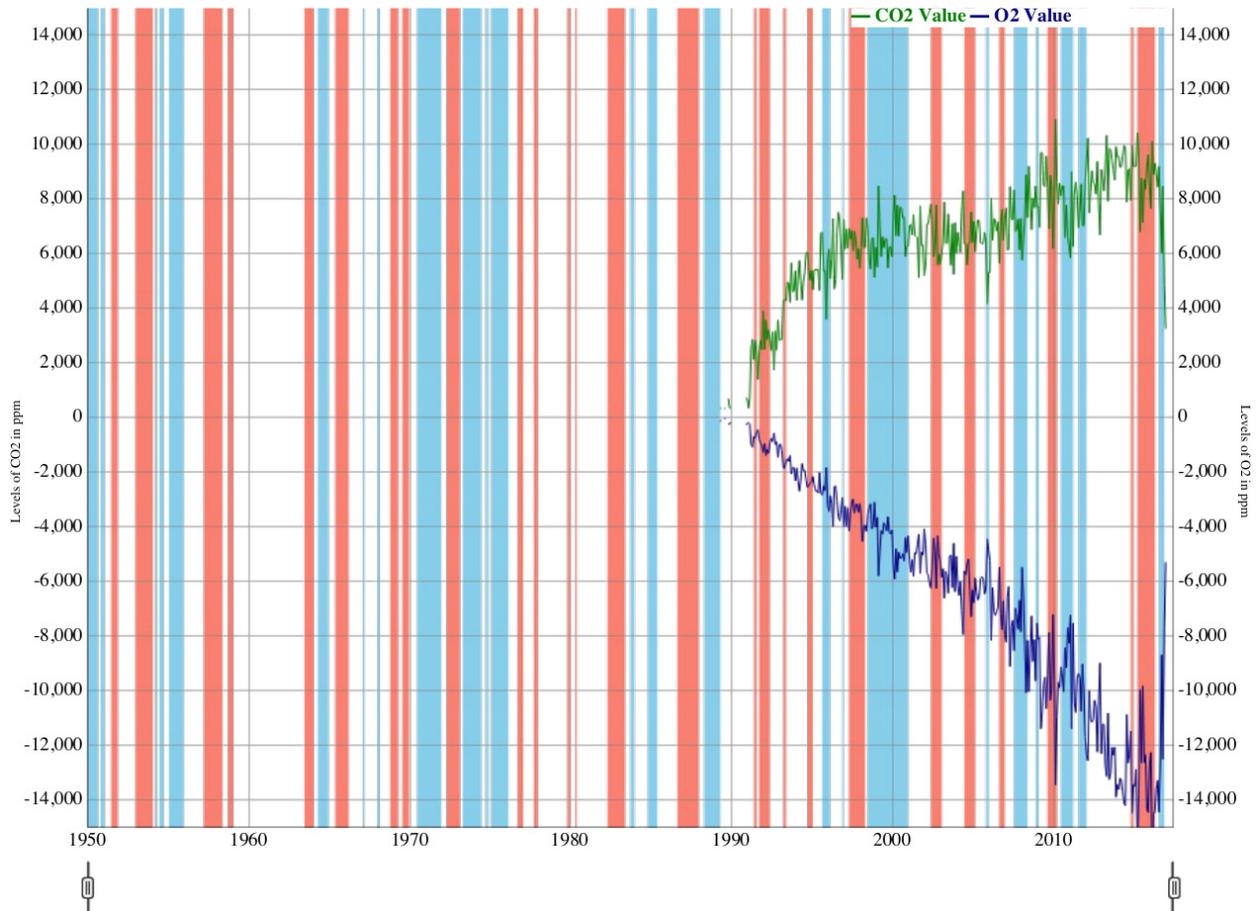


Figure 14: **Average global oxygen and carbon dioxide levels and El Niño/Niña episodes.** Chart showing (a) Global atmospheric O<sub>2</sub> and CO<sub>2</sub> levels based on measurements from nine different stations around the world (1989 – 2016; parts per million, ppm). The values are the averages of O<sub>2</sub> and CO<sub>2</sub> levels monitored at Alert, Canada; Cold Bay, Alaska; Cape Kumukahi, Hawaii; La Jolla Pier, California; Mauna Loa Observatory, Hawaii; American Samoa; Cape Grim, Australia; Palmer Station, Antarctica; and the South Pole [334]. (b) El Niño (warm; region highlighted in red) and La Niña (cold; blue) episodes of the El Niño-Southern Oscillation cycle (1950 – present). For the interactive version of this still image, download and open this HTML file in a web browser.

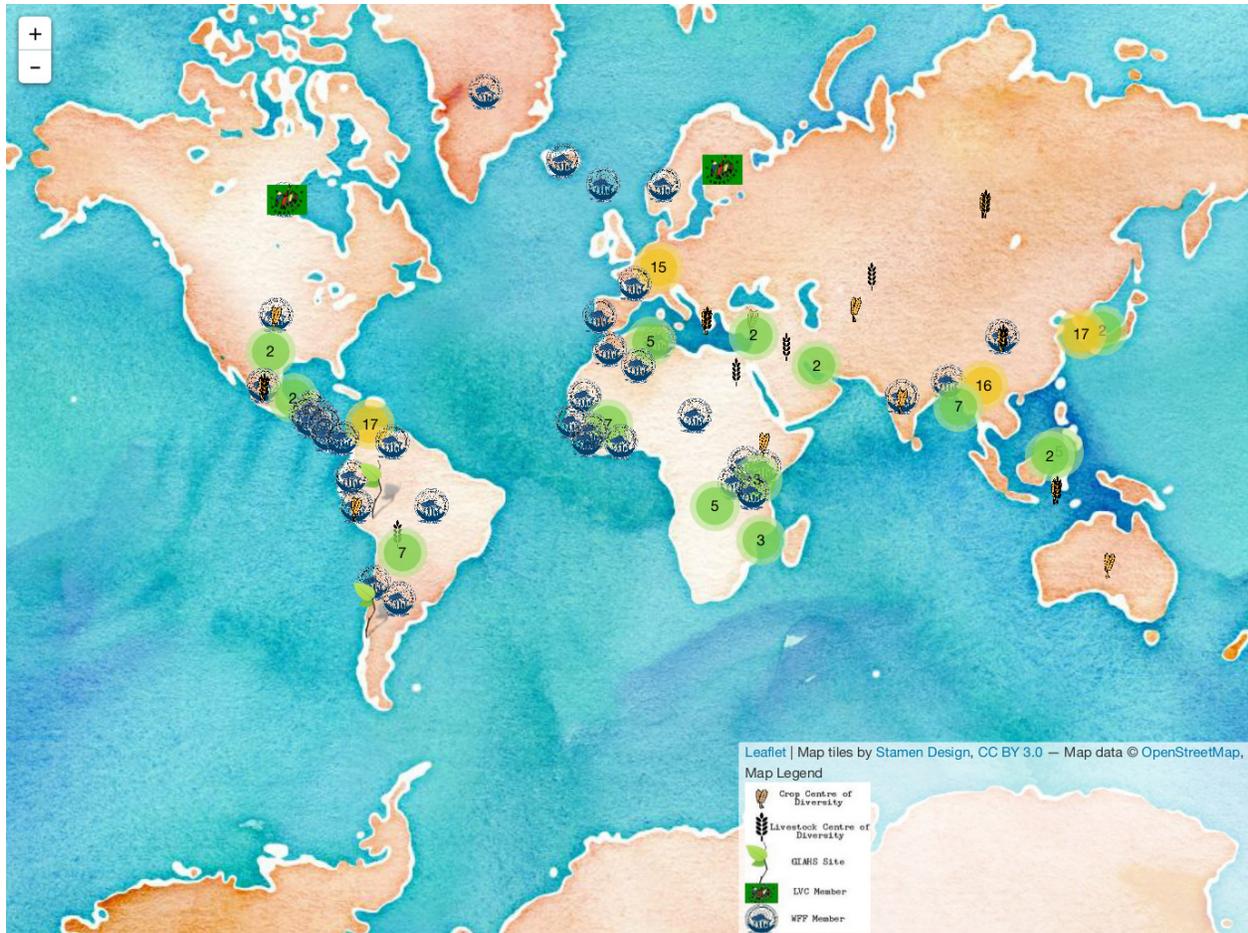


Figure 15: **Small scale food producers and agricultural biodiversity.** Cartogram showing (a) Members of La Via Campesina (LVC), an international movement which brings together over 200 million small scale producers [218] – peasant small and medium-size farmers, landless people, women farmers, indigenous people, migrants and agricultural workers from around the world (including Europe [337]). (b) Members of the World Forum of Fish Harvesters and Fish Workers (WFF), an international body encompassing small scale fishers’ organisations [222]. (c) Globally Important Agricultural Heritage Systems (GIAHS), sites that have been created, shaped and maintained by generations of farmers and herders, are based on diverse natural resources, and use locally adapted management practices [336]. (d) Centres of diversity of agricultural crops and livestock – geographical areas where groups of organisms, either domesticated or wild, first developed their distinctive properties [338]. For the interactive version of this still image, download and open this HTML file in a web browser.

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