Economic policy, "alternative data" and global agriculture: from the trans-Atlantic slave trade to agroecology

M. Chang (marina.chang@coventry.ac.uk)[1], C.-H. Huang[2], and I.S. Mian[3]

[1]Centre for Agroecology, Water and Resilience, Coventry University
[2]Department of Applied Mathematics, National Sun Yat-sen University
[3]Department of Computer Science, University College London

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Abstract

Fiscal policy refers to government actions regarding taxation and spending whilst monetary policy refers to central banking actions regarding the money supply and interest rates. These two main strands of economic policy determine and influence agricultural policy: laws and activities relating to domestic agriculture and imports of foreign agricultural products. Here, we address the challenge of using heterogeneous public data sets and information (re)sources to aid the task of identifying technical, legal, financial, policy and other mechanisms capable of serving the diverse needs of practitioners of agroecology (primarily small holder farmers) and advocates of food sovereignty. We show how disparate material in the public domain and open source software tools can be integrated to tell a story of interest to audiences ranging from the general public to policy makers. Specifically, we employ a variety of financial and non-financial ("alternative") data sets to explore the past, present and future of agriculture. In particular, we utilise some of the historical data released by the Bank of England in conjunction with other freely available data to paint a broad brush strokes picture of the impacts of Britain on the lands, agricultures, and economies of peoples and regions across the globe over five centuries. Our narrative considers three overarching and interconnected topics, (i) the trans-Atlantic slave trade and European Empires, (ii) 21st century large-scale land acquisitions, and (ii) traditional farming systems, agricultural biodiversity, and climate change. The three sets of background notes and data-driven visualisations – cartograms and timelines overlaid with event data – are autonomous yet interlinked and complemenary. By weaving together various historical, geographical, political, economic, and social threads, this triptych illustrates how the Bank of England is integral to the weft and warp national and global agriculture. We conclude by discussing how data science could contribute to two poorly investigated but critical important aspects of agricultural policy: the Community-led London Plan, a grassroots effort to transform the whole food system in a large and complex city and the public infrastructure pertinent to the science, development, financing, and practice of agroecology.

Keywords: Economic policy; agricultural policy; alternative data; Bank of England; trans-Atlantic slave trade; British Empire; Large-scale land acquisitions; Traditional farming systems; agricultural biodiversity; agroecology; Community-led London Plan; Visualisation

1 Introduction

An increasingly important objective of policymakers and central bankers is preventing or mitigating the triggers of financial crises. That is, greater monetary and financial stablity[†] (embodied in issues such as income inequality[†]) are emerging as much more prominent aspects of the work of the Bank of England[†] and the central banks of other countries[†]. Since its establishment in 1694[†] in the age of mercantilism through the industrial revolution and beyond, the history of the Bank of England is intertwined with that of the trans-Atlantic slave trade[†] and the British Empire[†], times when societies were treated as parts of economies rather than economies being considered parts of societies.

In February 2015, the Bank launched its "One Bank Research Agenda"[†], a wide-ranging and ambitious framework aimed at transforming and guiding

its future research, and as part of a committment to forging closer ties between policymakers and researchers, started to open up more of its millenium of data† to the public. The Agenda theme "Central bank response to fundamental technological, institutional, societal and environmental change"† posed the question "What is the role of central banks in addressing risks from climate change?"†. Seven months later during a speech delivered at Lloyd's†, Governor Mark Carney† warned that "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". Given the Bank's mission of promoting the good of the people of Britain†, the economic health of whole food systems† plus the (re)building agricultural economies at home† and abroad† – including across the Atlantic† – are of more than passing interest.

Here we seek to illuminate the evolving relationship between fiscal policy and agricultural policy by painting a general picture of the impacts of Britain on the lands, agricultures and economies of peoples and regions across the globe over five centuries. Although not our focus, domestically during this period, trade, labour, accumulated wealth, and land (notably the Scottish clearances and Parliamentary Enclosures†) were of concern. Even today, land and its ownership is 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"†. Our aim is to highlight the concept of "agroecology" as described in the 2015 Report of the International Forum for Agroecology†: not just agriculture but the full diversity of food production, gathering and consumption – knowledge that is the outcome of diverse historical experiences and practices. That is, an applied science embedded in a social context†.

We propose that agroecology† – undergirded by food sovereignty†, land sovereignty†, the right to water†, agricultural biodiversity†, and environmental health† – provides a shared, direct and cost-effective response to issues of concern not only to society writ large but also to the Bank of England: fundamental technological, institutional, societal and environmental change† in general and risks from climate change† in particular. This is because agroecology's multiple benefits† include ensuring food sovereignty†, improving human health†, providing meaningful livelihoods†, sustaining resilient communities†, mitigating the effects of climate change†, and promoting local and stable economies†. In Britain, increasing access to land is a policy that would support new entrants to farming†. Furthermore, a signficant increase in the number of small agroecological market gardens (including those less than 5 hectares) could deliver environmental and social benefits such as reducing the trade gap for fruit and vegetables, providing year-round employment and rejuvenating communities – all key issues in the post-Brexit era†.

2 The trans-Atlantic slave trade and European Empires

2.1 Background notes

The 1494 Treaty of Tordesillas† and the 1529 Treaty of Zaragoza† defined a pattern for exploration and conquest of non-Christian worlds outside Europe by Iberian colonial interests. Whereas the former 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† in the "New World", irrespective of whether the traders were British, French, Spanish, Portuguese, Dutch, Norwegian, Swedish or Danish in origin†, humans† remained the most attractive commodity in trans-Atlantic trade crossings.

Europe, Africa and the Americas were the geographic pillars of the trans-Atlantic slave trade† that took place from the 16^{th} through to the 19^{th} 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, mahogony and indigo: raw goods whose import by Britain fuelled the country's Industrial Revolution† and satisfied its lifestyle†. During 35,000 slave voyages, over 12 million Africans were transported forcibly to the Americas†. More slaves were imported from Africa into Haiti (Saint-Domingue) than into North America†.

During the 16^{th} and 17^{th} centuries, financial, commercial, legal, and insurance institutions emerged to buttress Britain's overseas trade and imperial ambitions† with, for example, Lloyd's, founded in

1688, obtaining a monopoly on slave trade-related maritime insurance†. Banks and banking were essential in making capital available to and securing profits from the transnational business of enslavement† and empire†. When set up in 1694, the Bank of England braced the entire system of commercial credit† needed for the trans-Atlantic slave trade. Acknowledging the centrality of slave-grown cotton to the economy of north west England† and recogising the importance of Manchester as a commercial centre, the Bank established a branch† 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^{th}-century London†. In the early 19^{th} century, cotton was a commodity that determined the wealth of nations†.

Governors of the Bank of England† were well-placed to facilitate creation of the political and regulatory milieu necessary to (re)orient the performance, structure, behaviour and decision-making of the national, regional, and global economies. For instance, Sir John Houblon† (1694 –1697), Sir William Scawen† (1697 – 1699), and Sir Francis Eyles† (1707 – 1709) were directors also of the East India Company†, 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†. After this corporation's† hundred year military and administrative rule of large swathes of the Indian subcontinent, the British Crown assumed direct control of India in the mid-19^{th} century. Governors turned their gaze not only East but also West: Sir Humphrey Morice† (1727 – 1729) was a trans-Atlantic slave trader and Member of Parliament.

British slave-ownership† was instrumental in transmitting the fruits of colonial slavery† to metropolitan Britain, shaping the country and bequething a social, economic and political legacy† that reaches into the present†. Consider the Neave Baronetcy† created in 1795 for Richard Neave†, a London Jamaica merchant whose wife, seven children (such as son Sir Thomas Neave† and daugher Harriet Trevelyn†) and their descendants were claimants and/or beneficaries 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), and grandson Sheffield Neave† (1857 – 1859), 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"†. Founded in 1735, the Society exists today as the West India Committee†, a registered charity promoting agriculture, trade and manufacturing in the Caribbean and providing services to corporations, institutions, government and other organisations.

From the Bank through Lloyd's to the National Gallery, many of the financial, arts, cultural, religious, educational and other institutions in London†, Greater Manchester†, Oxford†, 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"†, 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†.

The late 16^{th} and early 17^{th} century settlement of islands and regions in the Carribean and North American mainland formed the basis of the British Empire†. By 1922, this "empire on which the sun never sets"† held sway over one-fifth of the world's population and covered almost a quarter of the Earth's total land area. Overall, the Bank of England, the trans-Atlantic slave trade, and the British Empire played pivotal roles in the making of modern Britain.

2.2 Visualisations: what data can tell us about ...

Our aim is not that each timelines and events chart be interpreted in great detail. Rather, collectively, the visualisations are designed to show broad trends in British economic growth (1270 – 1870) from the perspective of two labour forces. First, the internal workforce consisting of the population of England (1086 – 1870) and Great Britain (1700 – 1870). Second, the external workforce consisting of slaves and individuals from the dominions, colonies, protectorates, mandates and other territories ruled or administered by Britain.

. . . British economic growth (1270 – 1870) and the population of England (1086 – 1870) and Great Britain (1700 – 1870)†

English and British population plus English and British agricultural production (crops) This interactive timelines chart shows (a) English and British population (million). (b) English and British agricultural production (1270 – 1870): total arable output – wheat, rye, barley, oats, and pulses (million bushels). Data sources: [(a) A2; (b) A3-Table 3.06]

English and British population plus English and British agricultural production (livestock) This interactive timelines chart shows (a) English and British population (million). (b) English and British agricultural production (1270 – 1870): total output of livestock products – milk (million gals), beef (million lb), veal (million lb), mutton (million lb), port (million lb), wool (million lb), hides (million lb) and hay (milllion tons). Data sources: [(a) A2; (b) A3-Table 3.04]

English and British population plus English and British industrial production This interactive timelines chart shows (a) English and British population (million). (b) English and British industrial production (1270 – 1870): output of key industries – tin, iron, coal, wool/textiles, leather, foodstuffs, construction and printed books. Data sources: [(a) A2; (b) A4-Table 4.02]

English and British population plus English and British GDP(O) This interactive timelines chart shows (a) English and British population (million). (b) English and British GDP(O) (1271 – 1700): Real GDP – agriculture, industry, services, and GDP. Data sources: [(a) A2; (b) A6, A7]

English and British population plus regional trade This interactive timelines chart shows (a) English and British population (million). (b) Regional trade shares (1665 – 2015): export of goods to Europe, Africa, Asia, North Americal including West Indies to 1972, South and Central America and Australia; import of goods from these same regions. Data sources: [(a) A2; (a) A42]

. . . British economic growth (1270 – 1870)†, the number of captives transported, and the year a former British colony or dominion gained its independence

Number of captives transported plus English and British agricultural production (crops) This interactive timelines and events chart shows (a) Estimates of the number of captives embarked and disembarked at major sites in the Atlantic rim (1501 – 1866). (b) English and British agricultural production (1270 – 1870): total arable output – wheat, rye, barley, oats, and pulses (million bushels). (c) The year a colony or dominion gained its independence from Britain. Data sources: [(a)] [(b) A3-Table 3.06] [(c)]

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Number of captives transported plus English and British GDP(O) This interactive timelines and events chart shows (a) Estimates of the number of captives embarked and disembarked at major sites in the Atlantic rim (1501 – 1866). (b) English and British GDP(O) (1271 – 1700): Real GDP – agriculture, industry, services, and GDP. (c) The year a colony or dominion gained its independence from Britain. Data sources: [(a)] [(b) A6, A7] [(c)]

Number of captives transported plus regional trade This interactive timelines and events chart shows (a) Estimates of the number of captives embarked and disembarked at major sites in the Atlantic rim (1501 – 1866). (b) Regional trade shares (1665 – 2015): export of goods to Europe, Africa, Asia, North Americal including West Indies to 1972, South and Central America and Australia; import of goods from these same regions. (c) The year a colony or dominion gained its independence from Britain. Data sources: [(a)] [(b) A42] [(c)]

. . . The maximum extent of European Empires and major coastal regions involved in the trans-Atlantic slave trade

European Empires and the trans-Atlantic slave trade This interactive cartogram shows (a) The countries

and territories ruled or administered formerly by Belgium, France, Italy, Portugal, Spain, the Netherlands, Britain, 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. This visualisation is for illustrative purposes only and is by no means a definitive history of European colonialism and imperialism. (b) Major sites in the Atlantic Rim from which captives embarked and disembarked†. The size of the circle indicates the number of slaves involved. Data sources: [BE] [FR] [IT] [PT] [ES] [NL] [GB] [Other] [Captives transported]

3 21^{st} century large-scale land acquisitions and their consequences

3.1 Background notes

Since the turn of the century, estimates of the land acquired globally by international entities range from $\sim$ 48 million† to $\sim$ 67 million† hectares – concentrated mostly in middle and low income countries. Concommitant to the land, this massive and growing phenomenon appropriates the freshwater† available therein plus any associated soil, mineral, and hydrocarbon† resources. 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†. 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")† and passage of the U.S.A. Energy Policy Act that contained provisions promoting biofuels and setting targets†.

"21^{st} century colonialism† and "land grabbing"† 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†. Although enabled by investment de-regulation and trade liberalisation of the present, particularly international free trade agreements and laws†, the corporate land rush is bolstered by history†, notably the seizures of lands by colonial rulers. In essence, today's economic dispossessions are co-mingled with the forced dispossessions of slavery and empire.

The concentration of lands under increasingly larger holdings controlled by fewer people is affecting adversely the lives and livelihoods of small farmers and communities in Africa, Asia and Latin America† as well as in Europe†. 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. 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 12.1 million people in rural communities.

Green grabbing† is land appropriation for environmental purposes such as carbon trading initiatives. 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† and is hurting Africa's rural poor†. Small farmers everywhere face the serious challenges of land ownership, access to land, and water rights: from Africa† (particularly the sub-Saharan region†) through Haiti† to India† and beyond.

Particularly since the financial crisis of 2007 – 2009, farmland has come to be viewed as a safe investment, a precious global commodity: "like gold with yield"†. It is an attractive alternative economic asset† for investors† 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 "hard" assets overseas such as farmland†. The "financialisation of 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†.

Central banks use the interest rate to shape monetary policy, control the country's economy. Perhaps the most influential lever the Bank of England† and the Federal Reserve† have under their control, shifting this crucial rate has a drastic effect on the building blocks of macroeconomics, including the behaviour of investors in the U.K. and U.S.A. with respect to land internationally and domestically. As Britain's farmland becomes a tax haven†, prices outstripping even prime central London real estate†, land purchases are being undertaken by lifestyle buyers rather than farmers†. Increases in the Bank of England base rate place pressure on farmers reliant on

loans†, especially those used to support cash flow.

Marrying transnational commodity chains and global circuits of capital with agriculture and medicine is vital for understanding the financial and physical well-being of humans and communities as well as disease emergence in plants and animals. The field of Structural One Health† integrates the global political economy and multispecies biology (notably wildlife, livestock, crop, and human ecology) leading to, for example, propositions such as the recent Ebola outbreak may be agroeconomic† in origin.

3.2 Visualisations: what data can tell us about ...

... The interest rates of the central banks of Britain and the U.S.A., the economic contribution of agriculture to the GDP of countries that are the targets of global land acquisition and international trade agreements

Central bank interest rates and agricultural production in targets of land acquisition This interactive timelines and events chart shows (a) Interest rates† from the Bank of England (1694 – present)† and the Federal Reserve System (1919 – present)†. (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, Argentia, 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) International trade agreements: multilateral free trade agreements in operation† and Asian-African Conference of Bandung†. Data sources: [(a) UK A31] [(a) U.S.A. Federal Funds rate] [(b) Figure 1 from publication] [(c)]

... The targets of global large-scale land acquisitions and major investor countries

Global large-scale land acquisition: target countries and investor countries This interactive cartogram shows 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. As of August 2017, the U.S.A. is the top investor country involved in transnational land acquisitions in terms of the largest number of deals† and the largest area acquired†. Flags mark countries where investors from the U.S.A.† and the U.K.† have acquired land. [Data source]

4 Traditional farming systems, agricultural biodiversity and climate change

4.1 Background notes

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†. This joint vision of peasants†, fish harvesters and fish workers†, the world alliance of mobile indigenous peoples†, and many others 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 the small scale farmers, a group who produce most of the world's food with less than a quarter of all farmland, a paltry share that is shrinking†. Despite the legacies of slavery and colonialism, threats to their livelihoods from emerging technologies†, attempts to replace natural products by synthetic products†, disruptions caused by erratic weather patterns, and other many challenges, small scale food producers in Africa†, Honduras†, Haiti†, the Southern U.S.A.†, and elsewhere are feeding, healing, clothing, and fueling the world. Numerous success stories demonstrate the capacity of agroecological agriculture to mitigate the effects of climate change and address hunger and poverty whilst respecting farmers and the environment†.

Building on ancestral production systems developed over many millenia, the Declaration emphasized food sovereignty† 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† – are said to represent the "only viable and robust path to increase the productivity, sustainability and resilience of peasant-based agricultural production under predicted climate scenarios".

Agrocological practices such as building soil, recycling nutrients, dynamically managing (agricultural) biodiversity, and conserving energy at all scales both lessen the adverse impacts of food systems on the climate (adaptation) and reduce the emission of green house gas emissions (mitigation). Il-

lustrative techniques employed by small farmers include ones that provide effective control of pests and diseases†, produce carbon-rich soil through sustainable grazing by ruminant animals†, improve air quality through reduced nitrogen pollution†, enhance livelihoods through sustainable food and fibre production†, increase knowledge through farmer training†, and develop cultivars/breeds from traditional varieties and stock through farmer-scientist collaborative research†.

In addition to food and medicines, tangible products of agroecosystems include fibres† and dyes†. 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 "farm to fashion"† and "soil to skin to soil"†. Regenerative and sustainable agricultures and community-driven textile systems consider issues ranging from classical plant breeding methods with hierloom naturally coloured cotton varieties† through indigo cultivation and processing† to garment design and construction† – local fibres, local dyes, and local labour. These 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†.

At the turn of 1800, 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 dismal factories†. Between 1811 and 1813, a group of 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", that is, whilst sceptics about the dogma of technology as progress, they did not deny the real benefits of some technologies†. The "expansion of cotton manufacturing in Great Britain depended on violence across the Atlantic"†. Plantation owners in the Southern states of the U.S.A. melded agricultural science and labour management to alter, simplify and (re)organise humans and nature to meet the needs of capital†. 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."†. Many of the four million black slaves tilling fields in 1860 were human capital as well as workers: the commodities produced for sale by the American slave-breeding industry included not just tobacco, rice, sugar, and cotton but also people†. Today, some prison industries have "ancestral roots in the black chattel slavery of the South"† – 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"†.

The Bank of England's new research agenda† 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 build and strengthen 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†. In part, this is because food sovereignty helps to weather economic crises and the established link between public health and the economy† – the long term financial benefits of reduced mortality and morbidity flow to the state. Agrocology-based strategies for addressing serious economic and financial risks include increasing the capacity of local communities to experiment, evaluate and scale-up innovations† through farmer-to-farmer and field-based research and education, nationally† and internationally†, and where "innovation" and "technology" are not necessarily synonyms. Crucial factors in the success of such endeavours are land sovereignty† (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† (including in Europe†), and agricultural biodiversity†.

4.2 Visualisations: what data can tell us about ...

... The global atmospheric O_2 and CO_2 levels and El Niño and La Niña episodes

Average global oxygen and carbon dioxide levels and El Niño/Niña episodes This interactive timelines and

events chart shows (a) Global atmospheric O_2 and CO_2 levels based on measurements from different stations around the world (1989 – 2016)† (parts per million, ppm). The values are the averages of O_2 and CO_2 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. (b) El Niño (warm; red) and La Niña (cold; blue) episodes (1950 – present). These complex weather patterns† result from variations in ocean temperatures in the Equatorial Pacific and last between 9 months to 2 years. El Niño produces below-average rains and high temperatures resulting in, for instance, reduced Asian monsoons and triggering potentially prolonged droughts. Data sources: [(a) O_2] [(a) CO_2] [(b)]

. . . 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

Small scale food producers and agricultural biodiversity This interactive cartogram shows (a) Members of La Via Campesina (LVC), an international movement which brings together over 200 million small scale producers† – peasant small and medium-size farmers, landless people, women farmers, indigenous people, migrants and agricultural workers from around the world (including Europe†). (b) Members of the World Forum of Fish Harvesters and Fish Workers (WFF), an international body encompassing small scale fishers' organisations. (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. Rich in agricultural biodiversity and associated wildlife, they are also repositories of indigenous knowledge and culture – especially *materia dietetica* and *materia medica* (d) Centres of diversity of agricultural crops and livestock – geographical areas where groups of organisms, either domesticated or wild, first developed their distinctive properties†. Data sources: [(a)] [(b)] [(c)] [(d)]

5 Concluding remarks

The well-being of current and future generations requires (re)invigorating and (re)engaging agroecology by linking ecologists and traditional farmers†. Whilst necessary, this is likely insufficient meaning additional inter-, multi- and transdisciplinary partnerships will need to be forged. For instance, the notion that growing plants contribute to making rainfall via the ice nucleation-active microorganisms† they harbour ("bioprecipitation") is rooted deeply in agriculture – from grains to rains†. A study of large areas of southern Australia† observed a correlation between the dynamics of ice nuclei concentrations and patterns of positive rainfall feedback and suggested that wheat-growing areas, irrigated regions, and metropolitan areas provide more suitable habitats for ice nucleating microorganisms than natural vegetation.

As landscapes and systems where the biosphere, lithosphere, atmosphere and hydrosphere have coevolved over millenia, agricultural heritage sites and indigenous cultivation practices are propitious fora for investigating questions at the intersection of agroecology, geography, aerobiology, climatology, machine learning, and communication theory. For example, do these diverse areas have a high propensity for bioprecipitation and can the locally-adapted networks of intercommunicating plants, animals and microbes both induce and tailor weather patterns to satisfy their growth and development needs? Spatiotemporal analysis of (historical) rainfall data, direct field measurements of ice nucleation active particles and other biogeographic variables such as land use and biodiversity could illuminate whether the microbiomes of these sites are particularly adept at, for instance, influencing rainfall – seeding clouds to enhance rain on a regional scale. Thus, small farmer-scientist collaborations have the potential to generate fundamental new knowledge about biogeochemical processes and simultaneously, identify novel research directions for achieving food, feed, medicine, fibre and dye sovereignty.

6 Data science and agricultural policy

6.1 Whole food systems policy: Community-led London Plan through the lens of food

Over the centuries, London-based financial, commercial, legal, insurance and other institutions buttressed Britain's overseas trade and imperial ambitions. One legacy of these entities and their actions is today's global agriculture. That is, whole food systems are strategic sites for understanding everyday finance, law, economics, ethics, equity, ecosystems, environ-

ment, society, politics and history. Food integrates place, people and time across multiple scales and levels of organisation. Since it play critical roles in diverse areas, food falls under the remit of disparate local, regional, national and international bodies and departments – transport, housing, public health, education, environent, employment, local economy and so on. As the top-tier administrative body, the Greater London Authority (GLA) is responsible for co-ordinating land use planning in the 1579 km^2 (610 square miles) that make up Greater London, England. The individual London Borough Councils are legally bound to comply with the strategic plan, the "London Plan," produced by the Mayor of London.

The main work of Just Space and its member organisations[†] is "developing ideas about what a London Plan would be like if it were to prioritise – or at least protect – the interests of its citizens, its environment and the real economies in which we meet each others needs." That is, to shape research and policy development by the GLA planning teams working on the London Plan and the Mayor's other strategies.

In August 2016, Just Space released the document *Towards a community-led London Plan: policy directions and proposals*[†] and a year later additional material[†]. Inspired by the increasing interest in developing urban food policy around the world[†], the newly proposed project, *Community-led London Plan through the lens of food*, aims to increase human and environmental health and wellbeing[†], support fundamental and applied studies which result in innovations that are not "hurtful to commonality"[†], and reflect a genuine "people's control of the research agenda, objectives and methodology"[†]. It provides a vehicle for grass-roots and underrepresented groups such as the working class, universities and policy makers to transform the whole food system of a large and complex city whenever and wherever possible: to chart a roadmap for London to agroecology and food sovereignty.

An important challenge for Just Space's working groups and collaborators – individuals or organisations at different levels in the planning hierarchy (neighbourhood, borough, city, government) – is identifying (possibly generating) and analysing heterogenous public data to support the decision making process, enable the development of guidelines and facilitate the formulation of policies for the roadmap.

6.2 Research and development policy: public funds allocated to basic and applied studies in agroecology

In the future, we hope to examine a poorly investigated but critical aspect of agricultural policy: the public infrastructure pertinent to the science, development, financing, and practice of agroecology. Our initial focus will be a type investment made by governments that has particularly long term consequences: research projects supported by awards from national and/or transnational agencies in the U.K., E.U. and U.S.A. Specifically, we plan to use public data on successful research proposals to study the allocation of public funds for research in agroecology within and between countries. The first goal is to revisit a 2016 study of competitive funding from the U.S. Department of Agriculture[†] plus a 2017 assessment of spending by other agencies[†], to undertake an analysis of awards from Research Councils UK[†], and to compare our findings from these two countries. Analogous studies of awards made by public agencies elsewhere would provide material of interest to parties associated with the preparation of a report on The State of the World's Biodiversity for Food and Agriculture[†] for the Sixteenth Regular Session (2017) of the Food and Agriculture Organisation. The second goal is to develop approaches and strategies that are sufficiently general that they could be adapted easily by those wishing to study publicly funded research in other fields of science, techology, engineering, mathematics and medicine. Overall, our proposed framework may be of potential utility to researchers, policymakers and others interested in microeconomics and macroeconomics at the regional, national, transnational and international levels.

7 Supplementary Material

The resources required to reproduce[†] this article are as follows.

7.1 Files: details and availability

Files need to recreate the visualisations can be downloaded as follows

- R code
- Data set

7.2 Software: details and availability

All visualisations were produced using the R Project for Statistical Computing, a free software environ-

ment for statistical computing and graphics.

The R libraries and packages used for the timelines and events charts are as follows

- xts: eXtensible Time Series "Provide for uniform handling of R's different time-based data classes by extending zoo, maximizing native format information preservation and allowing for user level customization and extension, while simplifying cross-class interoperability".
- dygraphs "The dygraphs package is an R interface to the dygraphs JavaScript charting library. It provides rich facilities for charting time-series data in R".

The R libraries and packages used for the cartograms are as follows

- Leaflet "Leaflet is one of the most popular open-source JavaScript libraries for interactive maps".
- rworldmap: Mapping global data, vector and raster "Enables mapping of country level and gridded user datasets".
- RColorBrewer: ColorBrewer Palette "Provides color schemes for maps (and other graphics) designed by Cynthia Brewer".
- Classes and Methods for Spatial Data "Classes and methods for spatial data; the classes document where the spatial location information resides, for 2D or 3D data. Utility functions are provided, e.g. for plotting data as maps, spatial selection, as well as methods for retrieving coordinates, for subsetting, print, summary, etc."
- maptools: Tools for Reading and Handling Spatial Objects "Set of tools for manipulating and reading geographic data, in particular ESRI shapefiles; C code used from shapelib. It includes binary access to GSHHG shoreline files. The package also provides interface wrappers for exchanging spatial objects with packages such as PBSmapping, spatstat, maps, RArcInfo, Stata tmap, WinBUGS, Mondrian, and others."

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