Human Impacts on the Environment: A Focus on Climate Change

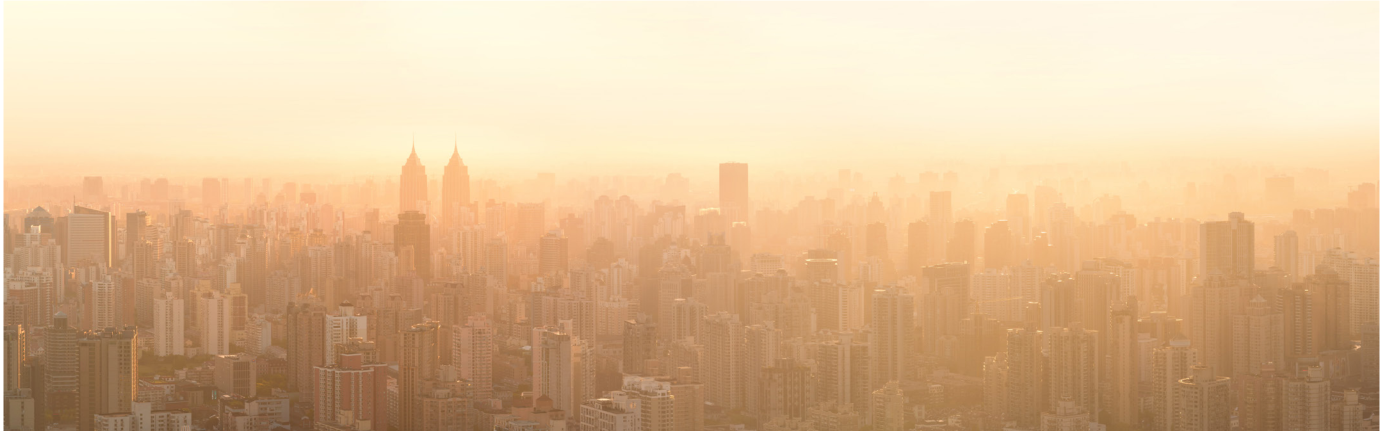
POPULATION CONNECTION

Earth's complex natural systems sustain all life. Biodiverse terrestrial, freshwater, and marine ecosystems also enhance human livelihoods and well-being.

When human numbers were small, our impact on the environment was local. However, as the global population has grown and technologies have evolved, pressure on nature has increased. Human activities are driving large scale changes through land and sea use; the hunting and harvesting of organisms; pollution; and invasive species introductions [1]. The sustained overuse of natural resources has caused unprecedented levels of environmental destruction, including the loss of ecosystems and biodiversity [2].

One overarching result of this overreach is climate change. Greenhouse gases emitted from land use and the escalating use of fossil fuels are elevating Earth's temperature faster than at any point since the dawn of civilization [3]. This warming is altering Earth's capacity to supply food and fresh water and to sustain human health and well-being [4]. Climate impacts such as weather extremes and wildfires are hitting harder and sooner than scientists anticipated even 10 years ago [4].

With the global population projected to grow substantially through the end of the century [5], humanity's footprint on the environment is likely to increase. If patterns of energy use, transportation, agriculture, and other land use do not change, ecosystem degradation and climate change threaten human prospects. Limiting the impacts of climate change requires a global shift toward renewable energy sources, sustainable land use practices, and responsible consumption patterns [6]. Underlying this shift is the need to stabilize human populations by ensuring that family planning information and services are available to all who desire them.



In Shanghai, a city of over 27 million people, pollution and haze cover the cityscape at sunset. Adobe Photos

HUMANITY'S ENVIRONMENTAL FOOTPRINT

While it is impossible to put a price tag on a healthy planet, economists calculate that the value of the services provided each year by well-functioning terrestrial ecosystems is at least equivalent to the annual global gross domestic product (GDP) [7]. Thriving ecosystems produce oxygen, purify water, protect from storms, provide food, and regulate the climate.

Yet, humanity has an extensive history of using Earth's life-sustaining natural resources unsustainably. The aggregate human demands on resources have exceeded the planet's regenerative capacity since the 1970s. The Global Footprint Network notes that "more than 80% of the world's population lives in countries that are running ecological deficits, using more resources than what their ecosystems can renew" [8]. The organization explains that at the global level "it now takes the Earth one year and eight months to regenerate what we use in a year. We use more ecological resources and services than nature can regenerate through overfishing, overharvesting forests, and emitting more carbon dioxide into the atmosphere than forests can sequester" [8].

A CHANGING CLIMATE

For most of human history, people had little effect on the global climate. The dawn of the industrial era signaled a turning point. Starting around 1750, growing and industrializing populations ramped up the burning of fossil fuels, emitting heat-trapping greenhouse gases—namely carbon dioxide (CO_2)—into the atmosphere. Over the years, the use of fossil fuels has increased, first with coal, then oil, and then natural gas. Meanwhile, the clearing of forests and other natural ecosystems for farming and development has released additional greenhouse gases while reducing capacity for carbon absorption [9].

In the past 270 years, humans have released enough greenhouse gases into the atmosphere to raise the average global temperature by about 1°C (close to 2°F) [10]. Most of this warming has come since the mid-1900s [11], during which time the global population has more than doubled. The effects of this warming vary by region and include longer wildfire seasons, more powerful and destructive tropical storms, rising sea levels, and extreme weather such as heatwaves and flooding [9, 12, 13]. Climate scientists warn that global temperature increases of 1.5°C and beyond will have far more devastating effects, from stronger storms and prolonged droughts to the loss of coastal areas from mounting sea-level rise [10]. The impacts are magnified with each additional degree of warming.

Governments around the world are working to avoid dangerous climate change. Nearly every country is party to the 2015 Paris Agreement Under the United Nations Framework Convention on Climate Change, which aims to hold the global temperature rise "to well below 2°C above pre-industrial levels and pursu[e] efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change" [14]. While some progress is being made to achieve national goals, global emissions have continued to rise. Holding climate change in check will involve making steep emissions cuts. Delaying action will only increase costs [15, 16].

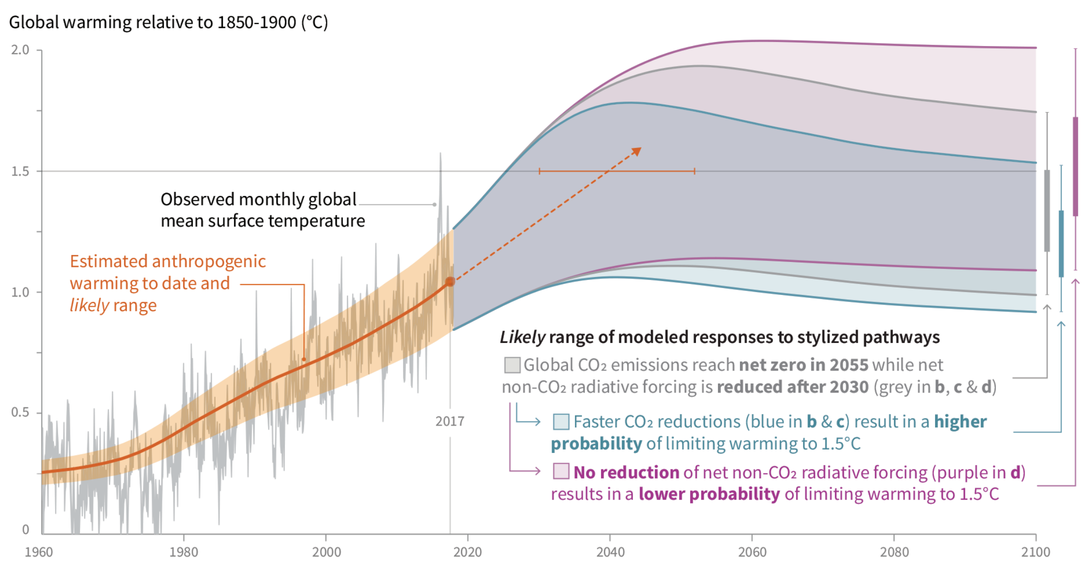
At current emissions rates, the Intergovernmental Panel on Climate Change (IPCC) estimates that warming could reach 1.5°C between 2030 and 2052 (Figure 1) [10]. Climate scientists maintain that keeping warming from exceeding that level would require global greenhouse gas emissions to decrease by 7.6% each year between 2020 and 2030 [17].

The risks from climate change are multiplying. Regardless of the trajectory of future emissions trends, the warming that has already resulted from the pre-industrial period to the present will continue for hundreds to thousands of years [10]. These changes will impact the world's population in many ways, but specifically in terms of the capacity to use and manage land, adapt to extreme weather events, produce food, and access vital resources such as fresh water [6]. Limiting the temperature rise is a civilizational imperative.

FIGURE 1.

Cumulative emissions of CO_2 and future non-CO_2 radiative forcing determine the probability of limiting warming to 1.5° C

a) Observed global temperature change and modeled responses to stylized anthropogenic emission and forcing pathways



Source: IPCC 2019: https://www.ipcc.ch/sr15/chapter/spm/

GROWING POPULATIONS AND INCREASING GREENHOUSE GAS EMISSIONS

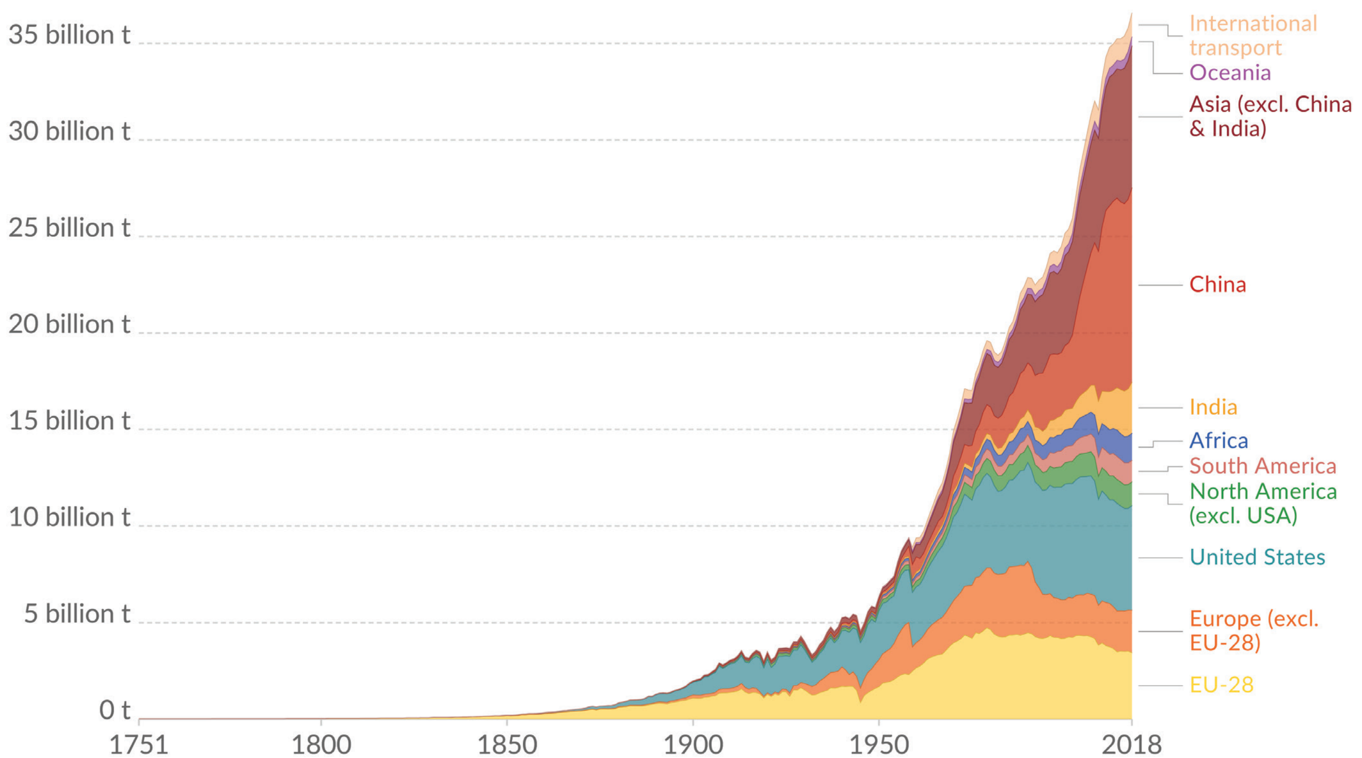
Economic growth and population growth drive climate change, according to the IPCC, with economic growth taking on outsized importance since the turn of the 21st century [11]. The largest growth in greenhouse gas emissions comes as economies industrialize. From a historical perspective, early industrializing countries, specifically the United States, Russia, Germany, United Kingdom, and Japan have added the most CO_2 into the atmosphere and thus are most responsible for climate change [18]. In recent decades the world's two most populous countries, China and India, have joined the top carbon emitters (see Figure 2). Overall, just ten countries account for over two-thirds of current annual energy-related greenhouse gas emissions [19, 20].

Carbon emissions per person are greatest in countries where energy use is high and consumption is relatively inexpensive, namely in the United States, Australia, and Canada, as well as in smaller oil and gas producing countries such as Qatar, Trinidad and Tobago, Kuwait, and the United Arab Emirates [18]. On average each American, Australian, and Canadian emits close to 16 tons of CO_2 each year, more than twice as much as the average Chinese and over 8 times more than the average Indian (see Figure 3) [18]. Per person emissions in the least developed countries are negligible, even though these countries are the least prepared and most vulnerable to the effects of climate change.

FIGURE 2.

Annual total CO_2 emissions, by world region

This measures CO_2 emissions from fossil fuels and cement production only – land use change is no included.

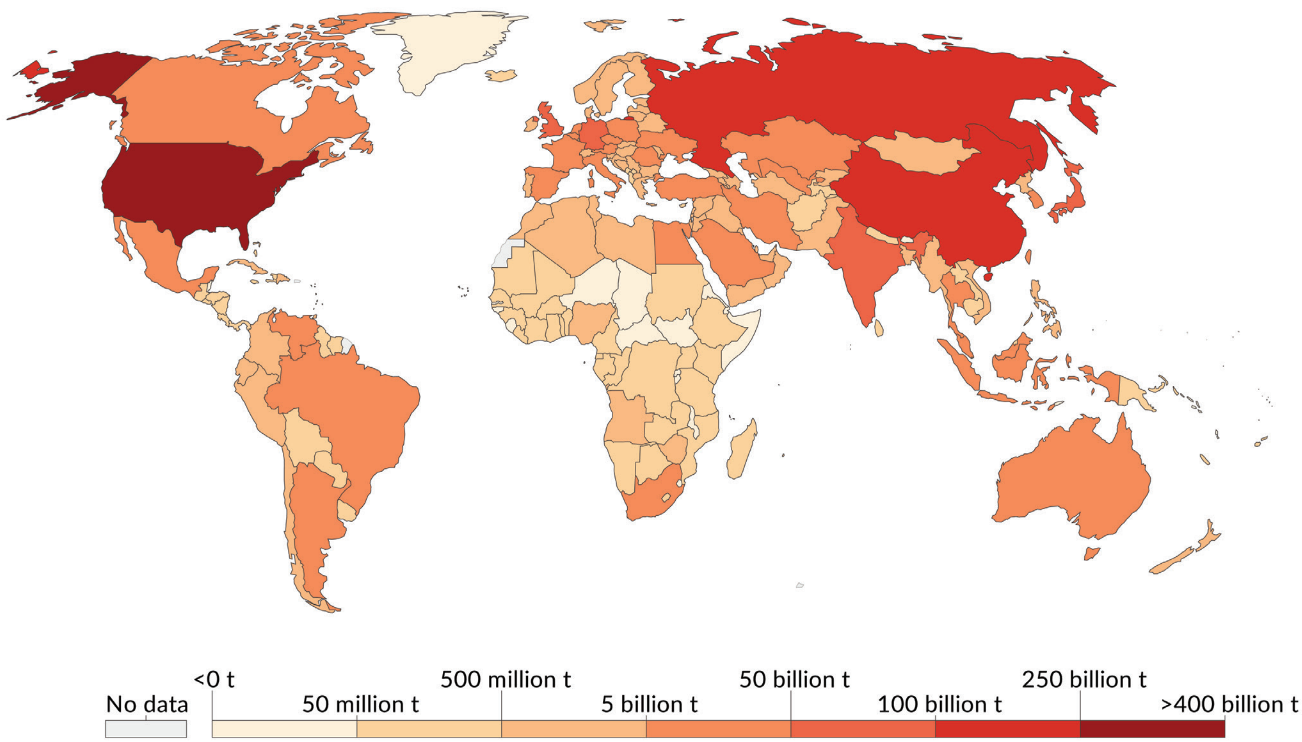


Source: Carbon Dioxide Information Analysis Center (CDIAC); Global Carbon Project (GCP)
Note: 'Statitistical differences' included in the GCP dataset is not included here.
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY

FIGURE 3.

Per capita CO_2 emissions, 2018

Average carbon dioxide (CO_2) emissions per capita measured in tonnes per year. This measures CO_2 emissions from fossil fuels and cement production only – land use change is not included.



Source: Global Carbon Project (GCP); Carbon Dioxide Information Analysis Centre (CDIAC)
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Industrialization facilitates economic growth and societal advances, which eventually result in improved living standards and corresponding consumption patterns. Over the last decade, CO_2 emissions have fallen in the United States and many European countries, even while economic growth has continued [21]. This is largely due to a reduction in reliance on coal, in part from switching to natural gas, as well as a ramp up in the use of renewable energy [19]. Many of the wealthiest countries also have, in effect, outsourced some of their emissions through trade in carbon-intense goods like steel and cement and other manufactured items [22, 23].

Meanwhile, emissions are surging in emerging economies such as Brazil, China, India, Indonesia, and Nigeria [19]. Large-scale increases in average incomes and reductions in overall levels of absolute poverty, particularly since the year 2000, have greatly increased the size of the global middle class [24]. Future emissions trends depend on a variety of factors, including economic growth, technological change, demographic trends, and consumption rates. Because industrialization and other developmental processes typically involve the exploitation of resources to facilitate economic growth, infrastructure development, and urbanization, carbon emissions in middle-income countries, home to 75% of the world's population, are likely to continue to rise [25].

As population growth contributes to emissions that cause global warming, it also works to compound the effects of climate change on the individual and state levels. High fertility rates and the availability family planning information and services (or lack thereof) all play a role in climate adaptation, or a country's capacity to readily respond to and recover from climate impacts in institutional and ecological contexts. Regions of high population growth, high fertility, and high unmet need for family planning are also disproportionately vulnerable to climate impacts [26]. Together, the world's 47 least developed countries are projected to double in population by 2050 [5]. These are the countries that have contributed the least to climate change but are poised to suffer the most.

RELIANCE ON FOSSIL FUELS

The burning of oil, coal, and natural gas has facilitated economic development across the world. Oil largely is used in transportation, whereas coal and natural gas are more often used for heating and in power plants to produce electricity that powers homes, businesses, and factories. Fossil fuels are also used directly in industry, such as in steel manufacturing and plastics production. Despite record growth in renewable energy across the globe, fossil fuels still dominate the world's energy systems [19].

Aerial views of an oil refinery on the Texas Gulf Coast. Adobe Photos

Close to three-quarters of global greenhouse gas emissions are from fossil fuels [20]. The majority of these come from electricity and heat production (30%); manufacturing, industry, and buildings (23%); and transportation (16%) [20]. Coal is the most carbon intense of the fossil fuels, followed by oil, and then natural gas. Between 1970 and 2019, world oil use doubled, and natural gas use quadrupled [19]. While oil and gas use both have climbed over the last decade, coal use may have peaked, falling 2.5% since 2013 [19].

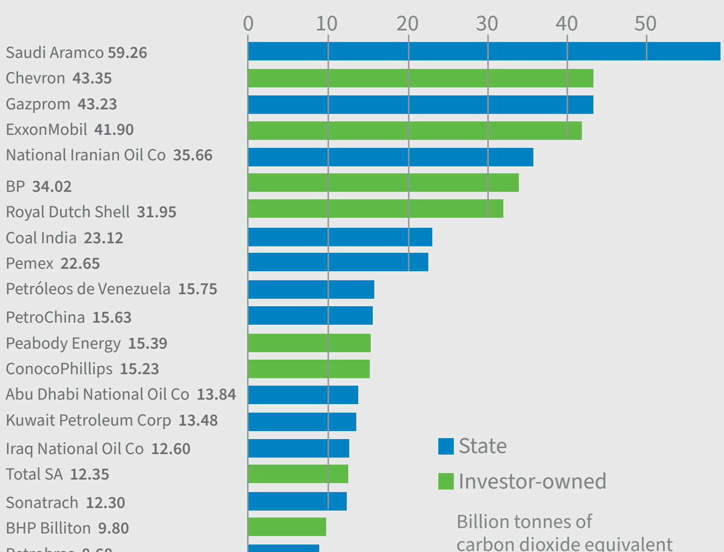
Transportation, including cars, buses, airplanes, and ships, is fueled largely by oil [20]. Because mobility—and the ability to travel more broadly—largely reflect socio-economic status, the per capita carbon emissions associated with transportation tend to be highest among the world's wealthiest people. In the United States, for example, where heavy reliance on cars has encouraged sprawling development, the transportation sector generates 28% of the country's greenhouse gas emissions [27].

CORPORATE CULPABILITY

A small fraction of the world's fossil fuel corporations are driving the climate crisis. Research from the Climate Accountability Institute reveals that just 20 companies are responsible for 35% of energy-related carbon dioxide and methane emissions since 1965 (Figure 4) [28]. Close to 70% of emissions can be linked back to just 103 fossil fuel and cement companies [29]. The fact that such a small number of corporations contribute the overwhelming majority of greenhouse gas emissions signals one unjust tragedy of the climate crisis: Nearly 8 billion people are enduring climate impacts for which a small number of polluting entities profited.

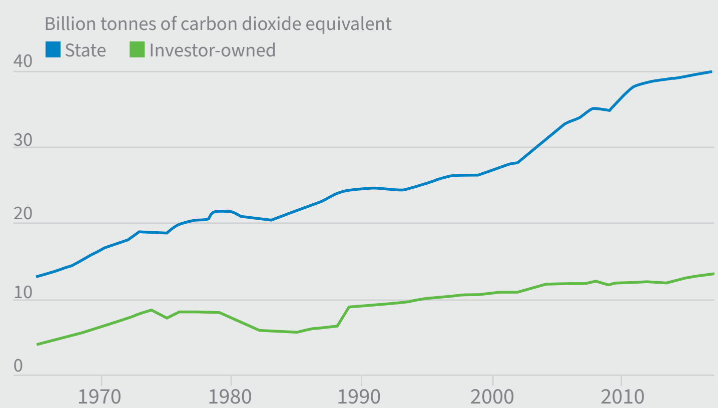
FIGURE 4.

The top 20 companies have contributed 480bn tonnes of carbon dioxide equivalent since 1965



Guardian graphic | Source: Richard Heede, Climate Accountability Institute. Note: table includes emissions for the period of 1965 to 2017 only.

The top 20 companies have contributed 35% of all carbon dioxide and methane since 1965



Guardian graphic | Source: Richard Heede, Climate Accountability Institute.

UNSUSTAINABLE LAND USE

The growing human population has dramatically altered Earth's ecosystems, transforming forests, grasslands, and other wilderness areas into farms, pasture, timberland, mines, and settlements. People are now using close to 75% of Earth's ice-free land area directly [6] and are indirectly affecting the rest of the globe through pollution and climate change. Tallied together, global agricultural systems, land use, and forestry contribute close to 20% of all human-caused greenhouse gas emissions [6, 20].

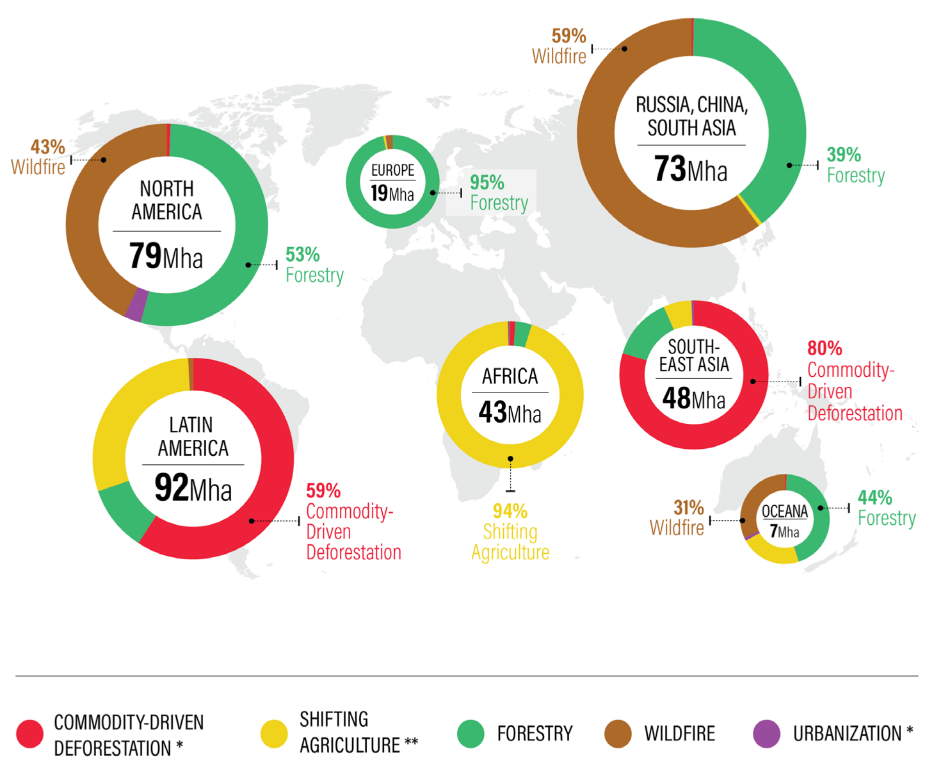
SHRINKING FORESTS

Trees and other plants take in CO_2 and release oxygen during photosynthesis, making them key actors for planetary health and climate regulation. Yet human changes to landscapes, especially deforestation, have released carbon back into the atmosphere for centuries. In fact, forest loss prior to 1850 continues to affect atmospheric carbon dioxide concentrations, and thus the global climate, today [9].

According to the Food and Agriculture Organization of the United Nations (FAO), the world lost around 10 million hectares (25 million acres) of forest each year between 2015 and 2020, an area equal to the size of South Korea [30]. Data from Global Forest Watch reveal that tropical deforestation, which is pervasive in many of the world's low- and middle-income regions, currently accounts for 8% of the world's annual CO_2 emissions [31]. This means that if tropical deforestation were a country, it would be the world's third largest greenhouse gas emitter, following China and the United States.

FIGURE 5.

Regional Tree Cover Loss by Driver for the Period 2001–2018



* Permanent deforestation
** May or may not lead to permanent deforestation

Note: Numbers reported as of March 3, 2020
Source: Global Forest Watch
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GLOBAL FOREST WATCH
WORLD RESOURCES INSTITUTE

FARMS EXPANDING, BUT MORE ARE HUNGRY

The leading contributor to global forest loss is agriculture. However, agricultural practices vary widely around the world and therefore affect regional environments differently (Figure 5). The main agricultural drivers include deforestation to clear land for cattle grazing or the production of commercial crops such as palm oil or soybeans, as well as forest loss from small scale farming—also known as shifting agriculture—in which farmers work on small plots of land for short periods and then move to other plots once the soil has been depleted. This technique is most common in landscapes where soil fertility is relatively low, such as in the tropics.

Expanding industrial agriculture—large-scale farms and livestock operations—disproportionately contributes to soil degradation, unsustainable water use, biodiversity loss, and waste production.

Climate-changing greenhouse gas emissions from the agricultural sector are roughly split between emissions from land clearing and emissions from food production practices [32]. About half of those production emissions come from ruminant livestock, namely cattle, sheep, and goats [32]. Producing beef, the most common of the ruminant meats, requires more than 20 times more land and creates more than 20 times more greenhouse gases per calorie of edible protein compared to plant proteins like beans or lentils [32]. These animals are major sources of methane pollution, a greenhouse gas roughly 30 times more potent than carbon dioxide [9]. Likewise, manure management, soils, and nitrogen fertilizer used in industrial agriculture account for roughly two-thirds of nitrous oxide emissions, which carry nearly 300 times the warming potential of carbon dioxide over a century [33].

Satellite image of deforestation pattern and cattle farms in Paraguay. Adobe Photos

Current farming methods can degrade soil more than 100 times faster than new soil is formed [34]. Over plowing and overgrazing turn fertile land into wasteland, which in turn increases both food insecurity and climate vulnerability, especially for the over 500 million people already living in areas that have recently experienced desertification [6]. Far more people live in populous arid regions where land degradation poses a risk to food production. As soils erode, the land loses its capacity to store climate-warming carbon.

Even as world food production has grown, so have the number of people hungry—nearly reaching 690 million in 2019 [12, 35]. Feeding the additional 2 billion people projected to be added to the planet by 2050 will require rebalancing food supply and demand [36]. As emerging economies continue to grow, so too will the demand for resource-intensive foods like animal products. The demand for ruminant meat (beef, lamb, and goat) is projected to increase 88% between 2010 and 2050 [32]. Such consumption patterns pose challenges to curbing agricultural greenhouse gas emissions and preventing the conversion of remaining forests to farmland. In fact, recent analysis from the United Nations, the World Bank, and the World Resources Institute concluded that without major increases in agricultural productivity, the land area required to feed the world's growing population could wipe out most of the world's forests and woodlands by mid-century—further accelerating the impacts of climate change [32].

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COMBATING CLIMATE CHANGE

Reducing the impacts of climate change and meeting the goals set forth by the Paris Agreement [37] will require immediate and ambitious action to decarbonize economies, halt deforestation, restore ecosystems, and remove CO_2 from the atmosphere [4]. Wealthier industrial countries bear the greatest responsibility to cut emissions and help less affluent countries move onto a sustainable development path through financial and capacity-building assistance [14].

THE FUTURE IS GREEN

The global conversion to renewable energy is essential to addressing the world's current climate crisis. That means shifting electricity production from fossil fuels to renewable sources, predominantly solar and wind. It also means electrifying transportation to reduce reliance on oil and ramping up energy efficiency across the board. Because fossil fuels represent the majority of global greenhouse gas emissions, the potential impact of shifting to renewable sources is substantial. This is especially important given projections for population growth and increased consumption levels in lower- and middle-income countries [5]. Scientists estimate that to avoid exceeding a 2°C rise in temperature, much of remaining fossil fuel reserves need to be left in the ground: over 80% of coal, half of natural gas, and one-third of oil [38].

Wind farm in the Indian province of Kerala. Adobe Photos

The good news is that though they are starting from a comparatively small base, solar and wind power are now the fastest growing sources of energy [19]. In a growing number of locations around the world, solar and wind are also the cheapest sources of electricity [39]. Between 2010 and 2019, the cost of generating electricity from wind farms fell by 39%, and from solar projects by a massive 82% [39]. In Australia, for example, government data revealed that solar power would undercut coal-generated electricity on cost, even if the coal itself were free [40]. In the United States, well over 300 of the country's 520 coal-fired power plants have recently closed or announced retirement [41].

Modelling reveals that robust connected electric grids with solar, wind, and hydropower can balance fluctuations in renewable energy supply [42]. With the costs of batteries also falling quickly, the potential carbon emissions cuts in the energy sector grow. For instance, half of new solar systems in Germany are installed with battery storage [43]. Combining rooftop solar systems with storage batteries and electric vehicles makes it possible to replace oil with sun-power for driving [40].

For the nearly 850 million people in the world without access to electricity, off-grid rooftop solar systems are a winning option that can be installed quickly and relatively inexpensively [44]. For instance, in India, solar panels plus efficient light bulbs have proved cheaper than repeated purchases of kerosene for lanterns, and also are far less polluting [40]. The growing energy needs of low-income and emerging economies can be supplied more cleanly with a broader range of sustainable options than what was available to their industrialized predecessors. By incentivizing renewables, countries can contribute to combating global warming while still increasing GDP [45].

THE FUTURE IS CLIMATE-SMART FOOD PRODUCTION

Over recent decades, farmers around the world have increased the amount of food they produce from a given parcel of land. Such efficiency gains can also reduce farming's climate impact. In the United States, for example, crop and livestock output increased by roughly 30% over the last 20 years, while farm-based greenhouse gas emissions rose by 6% [35, 46]. However, researchers maintain that the global agriculture sector must reduce emissions by two-thirds or more by 2050 against 2010 levels in order to avoid dangerous climate change [32]. This target includes ceasing the conversion of forests to agriculture and actively reforesting large areas of land around the world. Additional increases in crop yields will be necessary to achieve that goal while reducing hunger.

Climate Smart Agriculture in Zambia. World Bank 2018

Climate Smart Agriculture (CSA) is described by the World Bank as an "integrated approach to managing landscapes—cropland, livestock, forests, and fisheries—that addresses the interlinked challenges of food security and climate change" [47]. The goals of CSA are to simultaneously increase productivity and climate resilience while reducing emissions [48]. A number of CSA programs have already made impressive improvements around the world. For example, in China, since 2014, more than 29,000 farmer cooperatives have reported advances in income levels and climate resilience associated with a World Bank project expanding water use efficiency and soil quality across 44,000 hectares [47]. In Burkina Faso and Niger, in Africa's Sahel region, an FAO-supported agro-forestry program has helped to restore productivity to 12,000 hectares of degraded land [49].

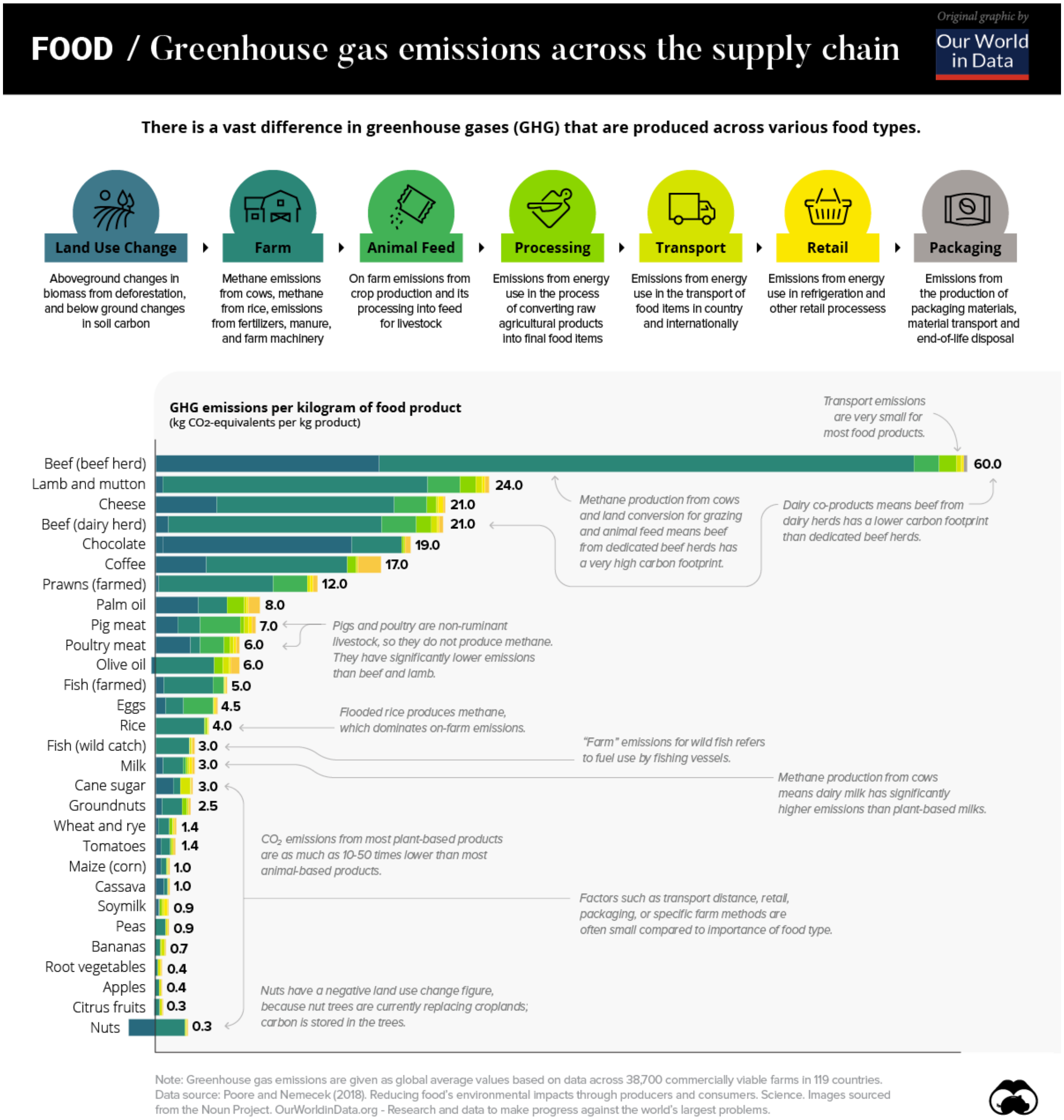
> **The goals of CSA are to simultaneously increase productivity and climate resilience while reducing emissions [48].**

THE FUTURE IS CONSCIOUS CONSUMPTION

Reducing agricultural emissions while feeding a growing population also entails ensuring that the food produced makes it to dinner tables rather than being wasted. Approximately one-third of the food raised or prepared does not get consumed [50]. Food waste is to blame for about 8% of global greenhouse gas emissions [51]. Food waste can be reduced through a variety of interventions from the farm to the consumer, ranging from improvements in infrastructure for storage, processing, and transportation in food supply chains to the establishment of national food-waste targets and policies that discourage wasteful consumption [52].

Additionally, the fact that raising livestock for meat, milk, and eggs generates substantial greenhouse gas emissions and is among the leading causes of deforestation, biodiversity loss, and water pollution signals the potential environmental benefits of limiting consumption of animal products (Figure 6) [53-55]. For example, if each person chose to limit their average daily beef consumption to 52 calories (adding up to about 6 hamburgers per month), we could greatly reduce the amount of land needed to raise cattle and grow feed crops, while making close to half the cuts in greenhouse gas emissions needed in agriculture by 2050, according to the World Resource Institute [56].

FIGURE 6.



Source: https://www.visualcapitalist.com/visualising-the-greenhouse-gas-impact-of-each-food/

Creating a sustainable food future will involve major economic and cultural shifts, including better land management and reduced demand—the latter requiring cuts in food loss and waste and heavy meat consumers transitioning their diets towards plant-based foods [32]. Innovations in agricultural production are paramount to addressing food security and climate change. The future of food security will depend on the development of new and sustainable food systems that facilitate equitable production and consumption, reduce degradation, prevent biodiversity loss, and build climate resilience.

Some of the most effective interventions to reduce future food demand and thus agriculture-related greenhouse gas emissions will be those that facilitate slower population growth. This is especially true for the regions in which population growth is expected to occur the fastest. Stabilizing population involves increasing educational opportunities for girls, expanding access to high quality reproductive health services, and reducing infant and child mortality rates through improved health services [32].

THE FUTURE IS FORESTS

Natural systems like forests pull carbon from the atmosphere. Tree planting and ecosystem restoration are therefore critical to limiting climate change. Recent estimates show that letting saplings regrow on land where forests have been cleared could increase global forested area by one-sixth and remove on the order of 200 billion metric tons of carbon from the atmosphere [57]. Pervasive ecological restoration sequesters a good share of the 300 billion metric tons of carbon that have accumulated in the atmosphere from a century of human emissions [57-59].

Forest restoration is integral for maintaining biodiversity and mitigating species extinction. It also provides a variety of social and economic benefits. Many conservation efforts are focused on the world's highly biodiverse tropical forests, only half of which remain standing [60]. A recent study identified more than 100 million hectares throughout Central and South America, Africa, and Southeast Asia where forest restoration would be most cost-effective and feasible, providing climate mitigation and adaptation benefits, improvements to water security, and other positive outcomes [60]. Six sub-Saharan African countries—Rwanda, Uganda, Burundi, Togo, South Sudan, and Madagascar—had the highest potential for low-cost and high-benefit forest restoration. Reforestation efforts in these countries, home to some of the fastest growing populations in the world [36], could cost-effectively provide a range of benefits to local people while mitigating climate change and improving climate adaptation capacity.

Overall, replanting degraded lands, reforesting ecological landscapes, and stopping tree clearing could reduce emissions and increase nature's carbon storage capacity. This would also benefit biodiversity and enhance ecological services, such as air and water purification, soil stabilization, and storm buffering, all of which will become more important in a warmer world.

CONCLUSIONS

Understanding the links between population and the environment is critical to combating climate change. Human impacts on the environment are compounded by population growth and growing affluence. Global population pressures can strain the availability and equitable allocation of natural resources. Increasing demand for food and energy generally results in higher total emissions, although as more efficient practices are adopted, increasing demand may have less of an impact on emissions going forward. The future trajectory of production practices and consumption patterns will determine the scope and severity of climate change, the effects of which will be most devastating for the world's most marginalized people. Ultimately, the countries and corporations most responsible for global emissions are most responsible for mitigating climate change.

As the world's population continues to grow, so too will the demand for finite resources. The environmental implications of slowing population growth through measures like voluntary family planning and education are compelling. Project Drawdown argues that meeting the global unmet need for contraceptives, together with increasing access to education for women and girls, could result in emissions reductions of up to 85 gigatons of CO_2 equivalent by 2050 [50, 52]. This is comparable to permanently closing over 22,000 coal-fired power plants [61].

Voluntary reductions in fertility are amplified across generations. For example, if the whole world today adopted the fertility rate of Germany, Japan, Spain, Portugal, or Italy, the population would shrink to just above 4 billion by 2100, as opposed to the 10.9 billion currently projected by the United Nations Population Division [5, 62]. Reducing fertility rates through rights-based development strategies such as voluntary family planning services and girls' education has the potential to yield a myriad of social and environmental benefits—among them increased climate resilience and adaptive capacity, especially for the world's most vulnerable populations, as well as a significant reduction in global greenhouse gas emissions over the long-term.

Ultimately, curbing human impacts on the environment and slowing climate change involves shifting the global economy in favor of renewable energy sources, reshaping food production and consumption patterns, ending deforestation, and ecosystem protection and rehabilitation. Slowing population growth is an important tool in tackling these challenges.

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