Deforestation & Agriculture

Practitioner Report

Danielle Diaz

Introduction

Deforestation is the conversion of forested lands into non-forested, often resulting in long-term loss of land value to both humans and the biodiverse species that inhabit them (Olson et. al., 2019).

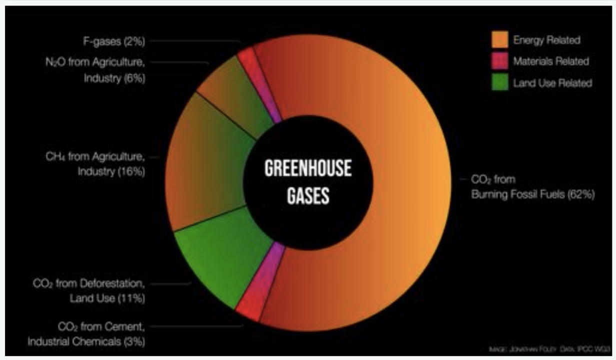
Deforestation directly plays a major role in climate change as it is responsible for approximately 11% of $CO2$ emissions (Figure 1).

The vast majority of deforestation occurs in tropical regions (Ritchie & Roser, 2021a), and is inextricably linked to agriculture, with agriculture responsible for approximately 90% of deforestation globally (Tandon, 2021).

Due to the agricultural processes occurring on the land cleared, deforestation indirectly contributes to two other important greenhouse gases, methane and nitrous oxide, as agriculture contributes approximately 50% and 75% of

Figure 1

Global greenhouse gases



Sourced from Project Drawdown (2021)

these global emissions, respectively (Lynch et al., 2021).

Deforestation has many global and regional effects — local populations experience direct climate impacts despite international forces playing a large role in driving deforestation (Ometto et al., 2022).

This report will focus on the substantial role agriculture has on deforestation; how that affects the environment and equity; implications for future trends; and some recommendations.

As food systems are responsible for approximately 21 - 37% of total GHG emissions, via deforestation, changes in land use, and agriculture processes (Mbow et al., 2019), it must be mentioned that the scope of this report is unable to comprehensively discuss the full gamete of impacts agriculture has on climate change, including methane and nitrous oxide emissions.

Deforestation and Climate Change

Deforestation has many detrimental impacts ranging from substantial loss of biodiversity; direct physical and economic harms to humans, most notably Indigenous peoples, women, children; and both the release of already stored carbon *and* loss of future carbon sequestration (Project Drawdown, 2022a).

The impacts of deforestation are interconnected and difficult to separate, yet any of these impacts on their own highlights the vast potential for future harms and need for solutions.

Carbon

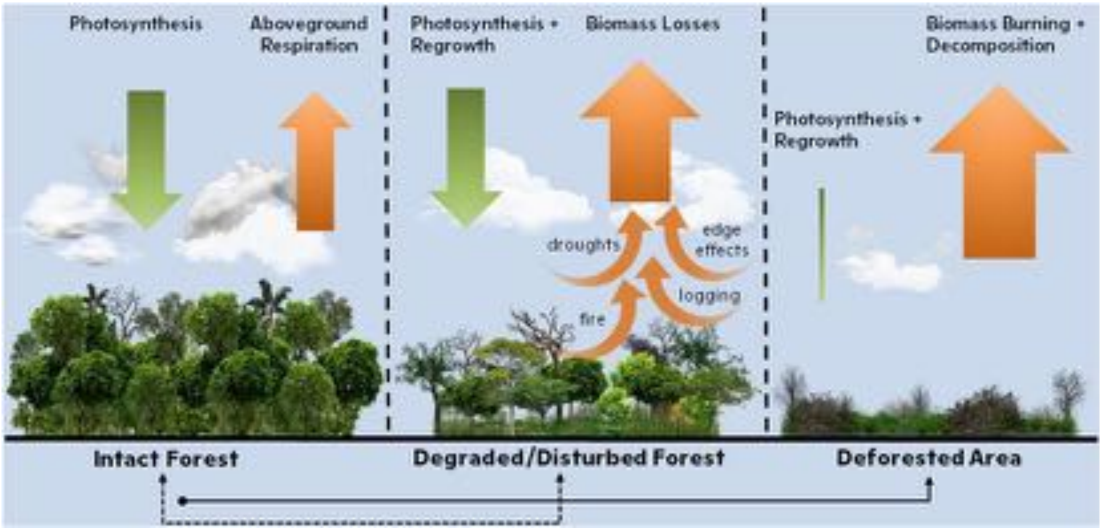
Deforestation presents a double hit with the combination of emissions release coupled with loss of future sequestration due to lost forests (see Figure 2).

Mature forests often represent centuries of stored carbon in their biomass and soil via photosynthesis, making them valuable carbon sinks (Project Drawdown, 2022a).

During the period from 2001 to 2019, forests were found to sequester double the amount of carbon they emitted, approximately 7.6 billion tonnes of CO2 annually (Harris & Gibbs, 2021). For context, global carbon emissions in 2021 were just over

Figure 2

Conceptual diagram of above ground carbon fluxes



Sourced from Kruid et al. (2021).

37 billion tonnes (Ritchie & Roser, 2020).

As forests are valuable carbon sinks, the vast amounts of sequestered carbon released through deforestation is a primary source of GHG emissions (Tandon, 2021).

The combination of carbon release plus loss of sunk carbon highlights the importance of reducing deforestation, with the potential to mitigate up to one third of global emissions by reduction in deforestation (Seymour & Gibbs, 2019).

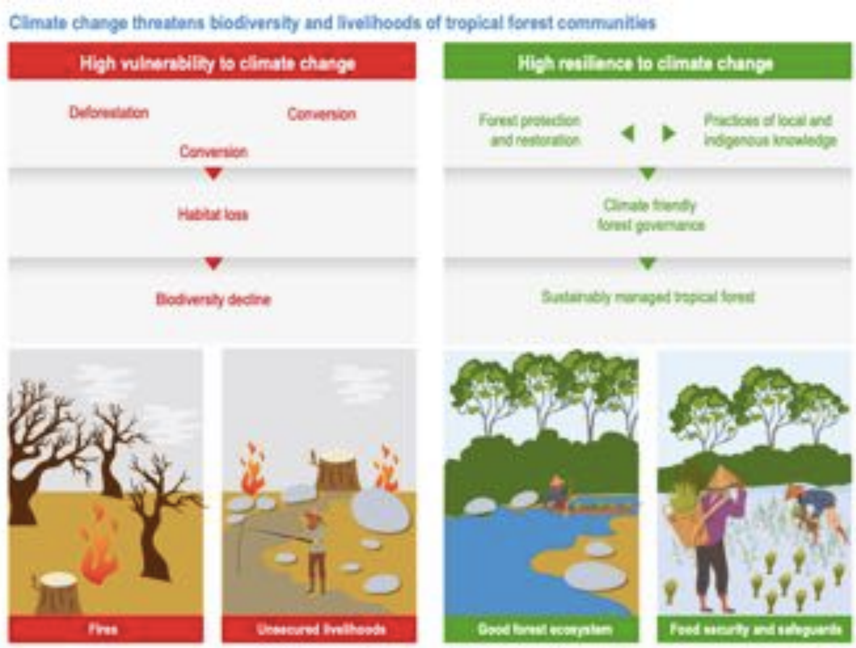
As stated by Smith et al. (2019) in an IPCC special report on climate change and land, "reducing deforestation and forest degradation rates represents one of the most effective and robust options for climate change mitigation, with large mitigation benefits globally" (p. 585).

The successful climate scenarios that achieve our target of 1.5C or less than 2C of warming beyond a preindustrial baseline all include land-use changes, particularly combinations of reduced deforestation and increased reforestation and afforestation (IPCC, 2019).

In other words, failure to address land-use changes, forest loss and degradation is failure to meet our climate targets of the Paris Agreement.

Figure 3

Impacts of climate change on tropical forest biodiversity



Sourced from Ometto et al. (2022)

Biodiversity

Biodiversity encompasses all that is the living world, ranging from genes, to organisms, species, ecosystems, and habitats — it is essential for human survival, health, and equity, (see Figure 3) (Dunne, 2022; United Nations, 2022).

We depend on biodiversity for many things, including carbon sequestration in forests, soil, and oceans; food systems via pollination and soil health; and water quality (Dunne, 2022; United Nations, 2022).

Tropical rainforest ecosystems are the richest in the world in biological biodiversity, in both density and overall amount (Ometto et al., 2022).

Forest loss and degradation are the biggest contributor to loss of biodiversity only recently challenged by the effects of climate change on species, communities and entire regions (Ometto et al., 2022).

Loss of biodiversity negatively impacts 80% of sustainable development goal targets including poverty, health, food and water security (Ometto, et al., 2022). Preserving biodiversity is an important consideration in the discussion of climate change.

Main Drivers of Deforestation

Agriculture is responsible for almost 90% of tropical deforestation (FAO, 2020), as shown in Figure 4.

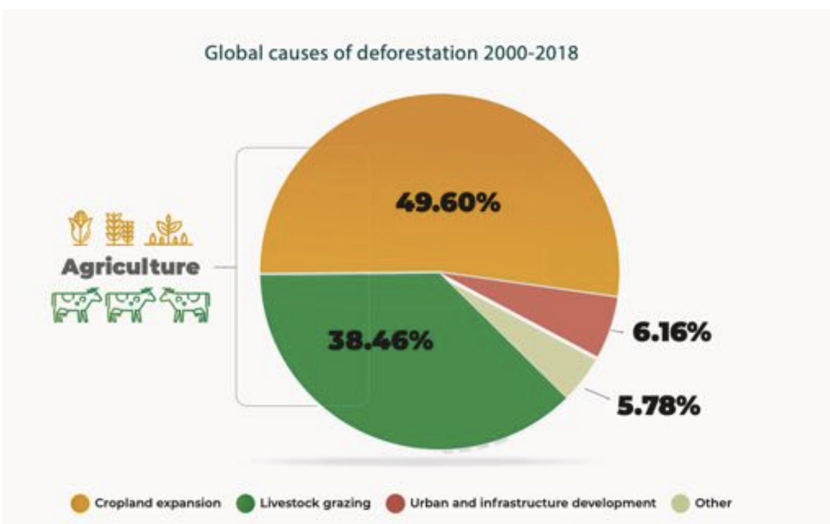
Within the realm of agriculture, the primary drivers are beef and soy and palm oilseeds (Ritchie & Roser, 2021a). To a lesser extent, coffee, cocoa, and other crops play a role in deforestation (DeValue et al., 2022), however the former three will be the focus due to their majority role.

Food waste also plays a prominent role by increasing food demand as approximately one third of food produced never gets consumed (Project Drawdown, 2022b).

In addition to agriculture, timber and infrastructure are additional drivers of deforestation that will not be covered in depth in this report (DeValue et al., 2022).

Figure 4

Global causes of deforestation 2000-2018



Sourced from FAO (2020)

Agriculture

Cattle and Soy

Deforestation is causally interconnected with beef production, Figure 5 provides a visualization of the drivers of deforestation and the role of beef (Ritchie & Roser, 2021a).

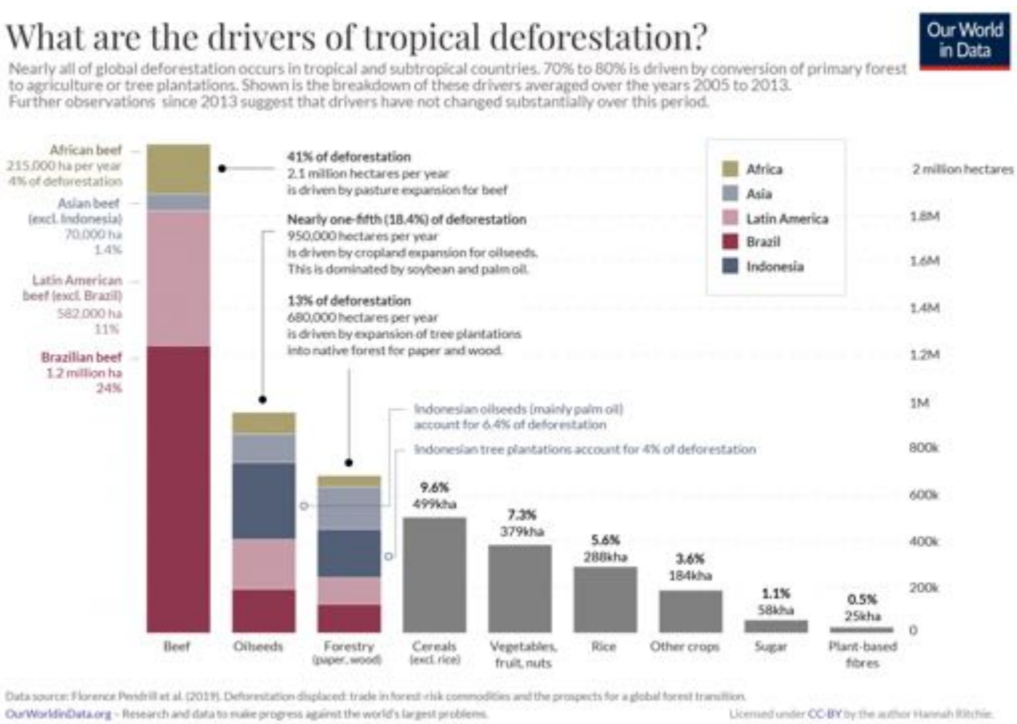
To break it down into numbers, 60% of deforestation is caused by three entities: beef, soy, and palm (Ritchie & Roser, 2021a).

The conversion of forested land into pasture for cattle is responsible for approximately 40% of deforestation (Ritchie & Roser, 2021a).

It is important to note that soy is closely linked to beef and dairy, as 77% of global soy production becomes livestock feed with a mere 7% being used to directly feed humans (Ritchie & Roser, 2021b).

Figure 5

Drivers of tropical deforestation



Sourced from Ritchie & Roser (2021a)

There is a connection between dietary choices and environmental impact with beef standing out as the single food with the greatest environmental impact in terms of GHG emissions and land-use (Mbow et al., 2019).

The imbalance of energy needed for energy-intensive animal-sourced food, particularly beef, is apparent when considering that beef accounts for 36% of food related emissions yet only provides 4% of food sold in the United States (Mbow et al., 2019).

Higher income countries consume the most animal-sourced food, with these products responsible for 70% of food based emissions versus 22% in lower income countries (Tandon, 2022). If the entire world adapted the standard U.S. diet, 178% of global land would be required to satisfy the demand (Mbow et al., 2019).

Currently, global population is projected to rise to 9.8 billion people by 2050 (Searchinger et al., 2018). If we keep on our current trajectory of food demand, there would be an increased demand of more than 70% for animal-sourced foods and an almost 90% increase in demand for ruminant meat (eg. beef and lamb) by 2050 as compared to 2010 (Searchinger et al., 2018).

In optimal situations, this level of demand would require and additional 593 million hectares of land, at minimum (Searchinger et al., 2018). This demand is already unsustainable at present and becomes further unsustainable with growing populations, incomes and demands for animal-based foods (Mbow et al., 2019).

Palm - The Other Oilseed

Palm oil is used worldwide in a variety of products from cosmetics to pastries to biofuels (Ritchie & Roser, 2021c). As increased demand of oils has increased, need to meet that demand has resulted in deforestation (Ritchie & Roser, 2021c).

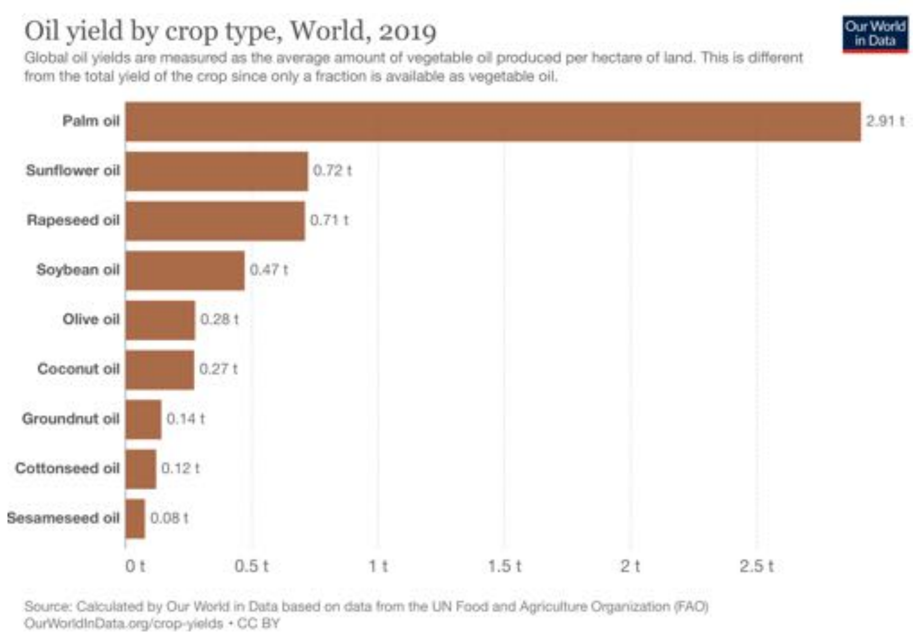
However, it must be noted that palm oil has significantly higher land efficiency versus other crops, with a yield up to 20 times that of other oilseeds, as shown in Figure 6 (Ritchie & Roser, 2021c). Palm oil provides 36% of oil globally yet requires only 6% of total land use (Ritchie & Roser, 2021c).

Palm oil has led to increased deforestation by meeting the needs of increased oil demand, however, its high yields make it a land-sparing option versus other oilseed crops (Ritchie & Roser, 2021c).

An alternative oil seed could potentially have a greater environmental impact through land-use. Much of the palm oil exported to European countries is used as biofuel which, when land used is factored in, actually emits higher levels of GHGs compared to gasoline (Ritchie & Roser, 2021c).

Figure 6

Oil yield by crop type



Sourced from Ritchie & Roser (2021c)
Note: Global yields measured by average amount produced per hectare of land

Despite palm oil being a driver for deforestation, alternative oils could potentially cause more environmental destruction. Attention should be paid to the use of palm oil as biofuel as it is an inefficient fuel source. Additionally, emphasis should be placed upon supporting certified, sustainably sourced palm oil (Pharo et al., 2019).

Food Waste

Food waste has a significant contribution to food insecurity and increased demand on agriculture (Mbow et al., 2019). For example, from 2010 - 2016, food waste totalled 8 -10% of total global emissions (Mbow et al., 2019).

This waste happens at every stage of production, from harvesting, packaging, refrigeration, transport and at the consumer level (Mbow et al., 2019). Developed nations tend to waste more food during retail and consumption versus developing nations where it is most likely to be lost in production and storage (Project Drawdown, 2022b).

In addition to increasing demand for food production and generating emissions through all stages of production and decomposition (Project Drawdown, 2022b), food waste also decreases food security (Mbow et al., 2019).

Potential solutions pertaining to deforestation, food production, and food security must address the significant portion of food that is already produced but wasted.

Key Issues

As discussed above, the impacts of deforestation are impacting climate change via emissions and land-use changes. However, these are not the only issues caused by this complex problem. This section will explore some of the climate and equity issues associated with deforestation, particularly preserving the land while feeding the growing population; and the balancing of food security, equity for most vulnerable populations, and climate change.

Preservation of Forests And Production of Food

Agriculture is the main driving force behind deforestation and a sustained, increasing, production of food is necessary to support human survival. Therefore, balancing food security with decreasing deforestation is essential.

The risk associated with climate change is dependent not only on level of warming, but also human behaviours, including how we consume, produce, and technologically evolve (IPCC, 2019).

Globally, the increase demand and production of energy-intensive food with failure to improve agricultural yields will result in increased water and food insecurity and land degradation (IPCC, 2019).

"There is no scenario in the IPCC that gets us to the Paris Agreement targets without halting the destruction of nature and deforestation particularly... yesterday"

- Per Pharo (2020, 26:45)

Food security is projected to be negatively impacted by climate change (Mbow et al., 2019), and continued destruction of forests for pasture will further exacerbate climate change, thereby worsening food security.

Failure to address land degradation is likely synonymous with failure to limit warming to our target (Olsson et al., 2019).

Socio-economic pathways (SSPs) are a set of five complex scenarios that represent a variety of potential pathways that make assumptions about human societies, such as land-use, population growth and technological advancements (ClimateData.ca, 2022).

These scenarios are combined with Representative Concentration Pathways (RCPs) which make assumptions about the concentration of emission that end up in the atmosphere, based on their radiative forcing in Watts per metre squared (ClimateData.ca, 2022).

There are low emission (RCP 1.9 and 2.6), intermediate (RCP 4.5 and 6.0) and high emission (RCP 8.5) scenarios (Government of Canada, 2018). The combination of SSPs with RCPs (e.g. SSP1-1.9, SSP5-8.5) are used within climate models to produce climate projections representing a range of potential futures (ClimateData.ca, 2022).

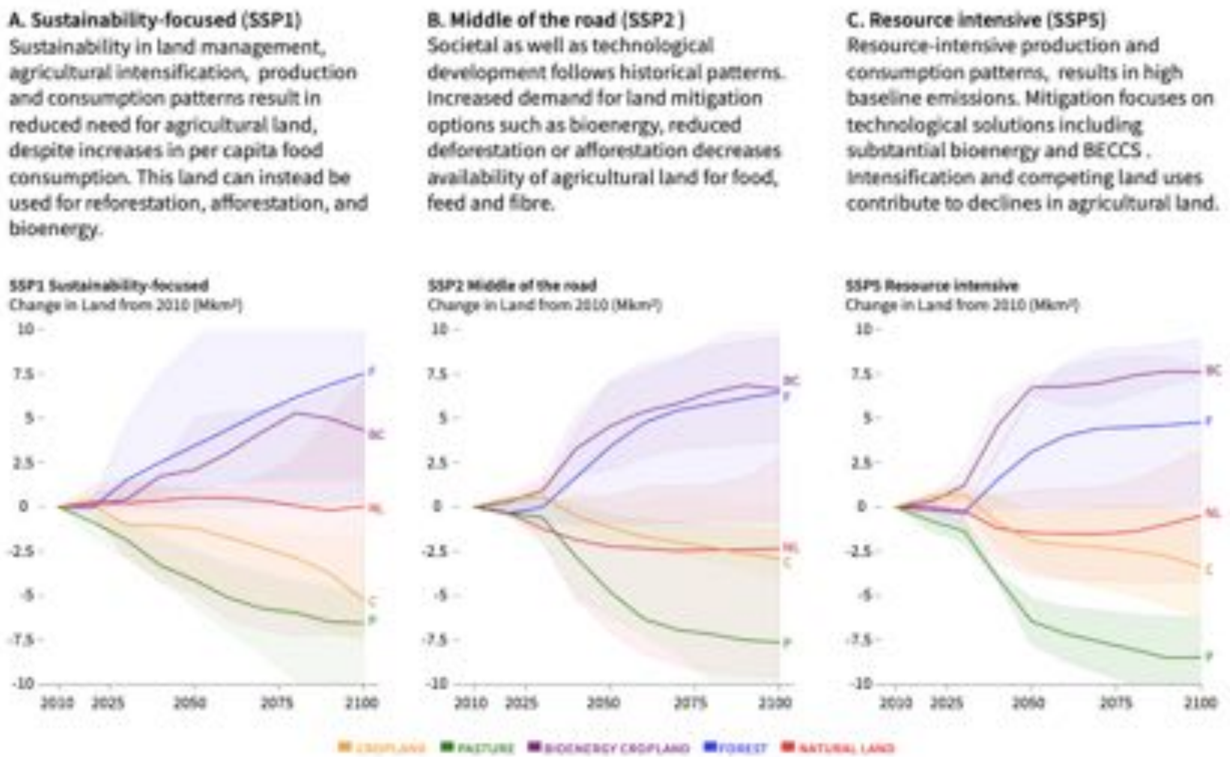
All SSPs project increases in: population, income, food and

water demand in 2050 (IPCC, 2019). The scenarios that employ a reduction in land conversion can actually result is less food insecurity (IPCC, 2019).

This concept is illustrated in Figure 7. Three SSPs (SSP1, 2, and 5) at RCP1.9 are shown with their corresponding projections of allocation of land use. In all three of these scenarios at this high level of mitigation and low level of emissions (RCP 1.9), forested land is increased, while pasture and cropland are decreased.

Figure 7

Pathways linking socioeconomic development, mitigation response and land



Sourced from IPCC (2019)

SSPs are important as they illustrate the impact of socio-economic choices on the effects and rate of temperature increases (IPCC, 2019).

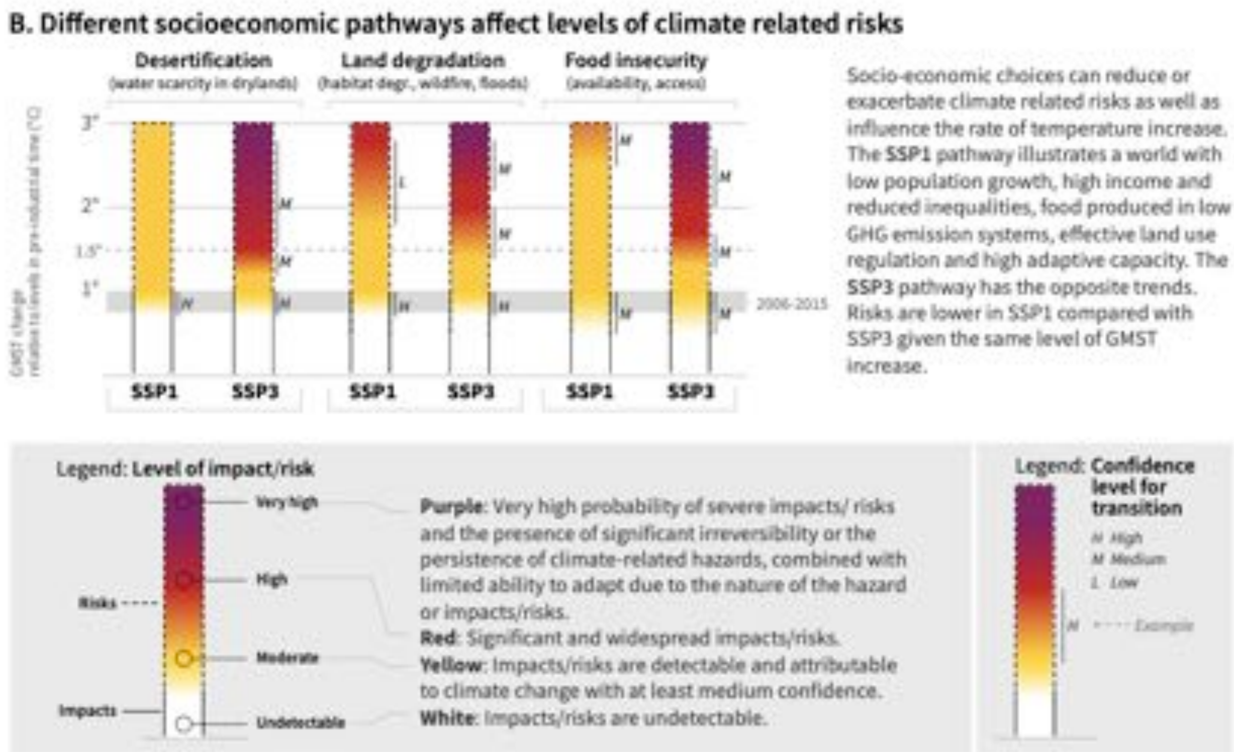
Figure 8 contrasts SSP1 and SSP3 at the same temperature. In SSP1, a decrease in agricultural land is needed despite increased food consumption due to land sustainability and intensification (Smith et al., 2019).

Conversely, SSP3 couples decreasing crop yields and increasing population growth with increased land use (Smith et al., 2019).

At comparable temperatures, SSP3 has projected far greater negative impacts in water scarcity, land degradation, and food insecurity (IPCC, 2019).

Figure 8

Different SSPs affect levels of climate related risks



Sourced from IPCC (2019).
Note: “Risks associated with desertification, land degradation, and food insecurity due to climate change and patterns of socio-economic development” (IPCC, 2019, p. 17).

To further complicate matters, future yield of agricultural crops is uncertain and likely decreasing (Mbow et al., 2019) and, in the case of livestock, will likely decrease due to animal stress from rising temperatures (Bezner Kerr et al., 2022).

If no increase in yields or change in food demands were achieved by 2050, production of food would essentially wipe out all remaining forests and savannahs (Searchinger et al., 2018).

Crop productivity is inversely related to rising temperatures, further highlighting the need to curtail emissions by adapting agricultural systems to sustainably intensify production while creating more sustainable food demands (Mbow et al., 2019).

Equity

Food security and climate change disproportionately impact low-income and vulnerable populations (Mbow et al., 2019). Certain populations are more vulnerable to the regional impacts of deforestation, particularly women and Indigenous peoples (Boyd, 2019).

Globally, 1.3 to 3.2 billion people are negatively impacted by degraded land, with the majority already living in poverty in low-income nations. (Olsson et al., 2019). Deforestation and land degradation directly impact their ability to secure food, shelter, and livelihoods. In consideration of adaptation and mitigation to climate change, equity must be incorporated (Moser, 2017).

Gender Inequality

Gender inequality persists in land use and management (Boyd, 2019). Despite carrying out most of the land-based responsibilities, women often have less influence and control over decisions (Olsson et al., 2019). In many regions, women have less access to resources and less ability to adapt to climate change and land degradation (Olsson et al., 2019). Further degradation of land and increasing impacts of climate change will lead to further harm, poverty, and food insecurity (Olsson et al., 2019).

Indigenous Knowledge

Deforestation destroys the land that Indigenous peoples directly depend upon for survival, with many living in or adjacent to tropical forests (Ometto et al., 2022).

The forests managed by Indigenous peoples, compromise some of the most well-preserved and ecologically diverse in the world (FAO & UNEP, 2020).

Despite contributing very little to climate change and generally maintaining the land and forests they inhabit, Indigenous peoples are especially vulnerable to climate impacts due to their close relationship to nature (Boyd, 2019). It is this close connection and understanding of eco-systems that makes Indigenous knowledge an effective strategy for climate change adaptation (Ometto et al., 2022).

It is becoming more widely recognized that Indigenous knowledge is closely aligned with scientific consensus and provides insights for successful policies in, amongst other areas, sustainable forest management (Smith et al., 2019).

Wealth Distribution

As with most areas of climate change, the poorest nations and people are positioned to be directly impacted and less able to adapt (Boyd, 2019). Deforestation is no exception.

Deforestation largely occurs in developing nations while 26% (and increasing) of demands come from developed nations (Pendrill et al., 2019). Additionally, the majority of the developed nations importing the products of deforestation, are experiencing decreased deforestation themselves - essentially displacing the burden to lower income nations (Pendrill et al., 2019).

Integrating equity into climate change solutions is not only morally just, it can often be beneficial. As stated in IPCC (2019), “ecosystem-based adaptation can, in some contexts, promote nature conservation while alleviating poverty and can even provide co-benefits by removing GHGs and protecting livelihoods” (p. 21).

Recommendations

Deforestation and land-use can represent potential harms leading us away from our climate goals or can represent a potential well of solutions, with reduced deforestation and reforestation restoring land, allowing meaningful adaptation, reducing emissions, and improving equity (Olsson, 2019).

This section is meant to provide a brief summary of some recommendations related directly to the material covered within this report. This is not a comprehensive list, some valuable, more detailed resources include Creating a Sustainable Food Future and Growing Better.

The following recommendations are categorized into four sections: demand, land-use, incentives, and investments.

"Consumption of healthy and sustainable diets present major opportunities for reducing GHG emissions from food systems and improving health outcomes"

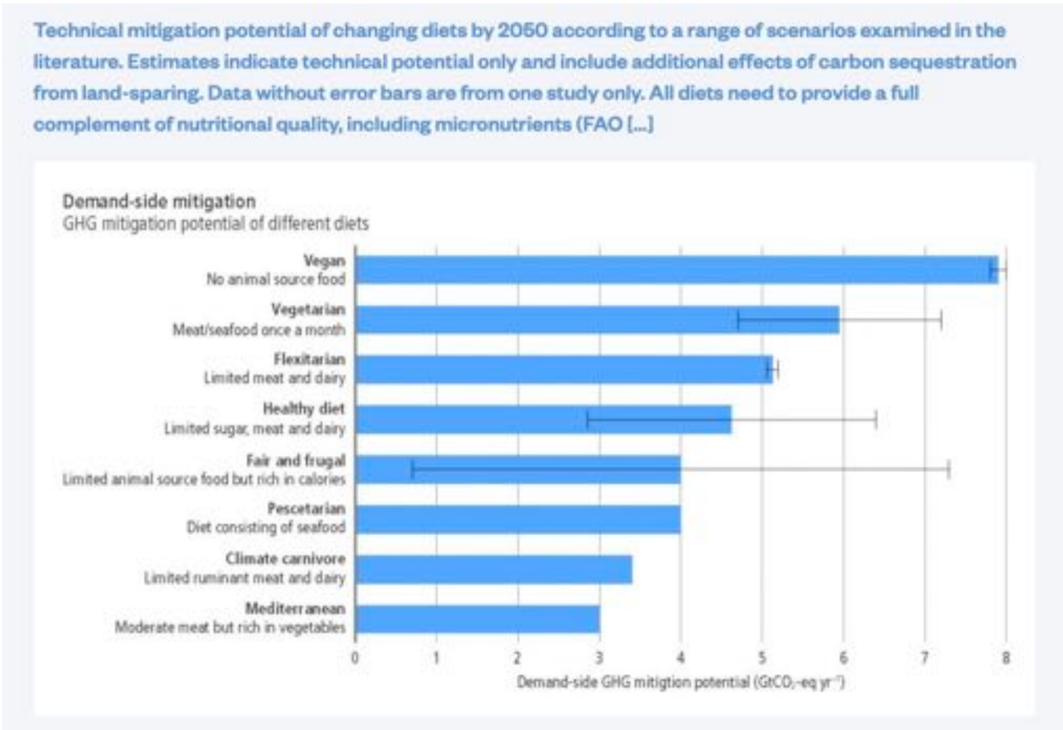
- Mbow et al. (2019, p.440)

Decrease Demand

Improved dietary changes are not associated with any negative impacts and include diets high in plant-based foods and low in animal-based foods, Figure 9 provides a direct comparison of the mitigation potential of dietary changes (Mbow et al., 2019).

Figure 9

Demand-side mitigation: GHG mitigation potential of different diets



Sourced from Mbow et al. (2019)

Recommend dietary changes
The dietary recommendation with the most positive impact would be the reduction in ruminant meat, beef, sheep and goat (Searchinger et al., 2018).

If the world's richest 20% decreased ruminant meat consumption by 40% (compared to 2010), this could virtually eliminate the need to expand agricultural land in 2050 and

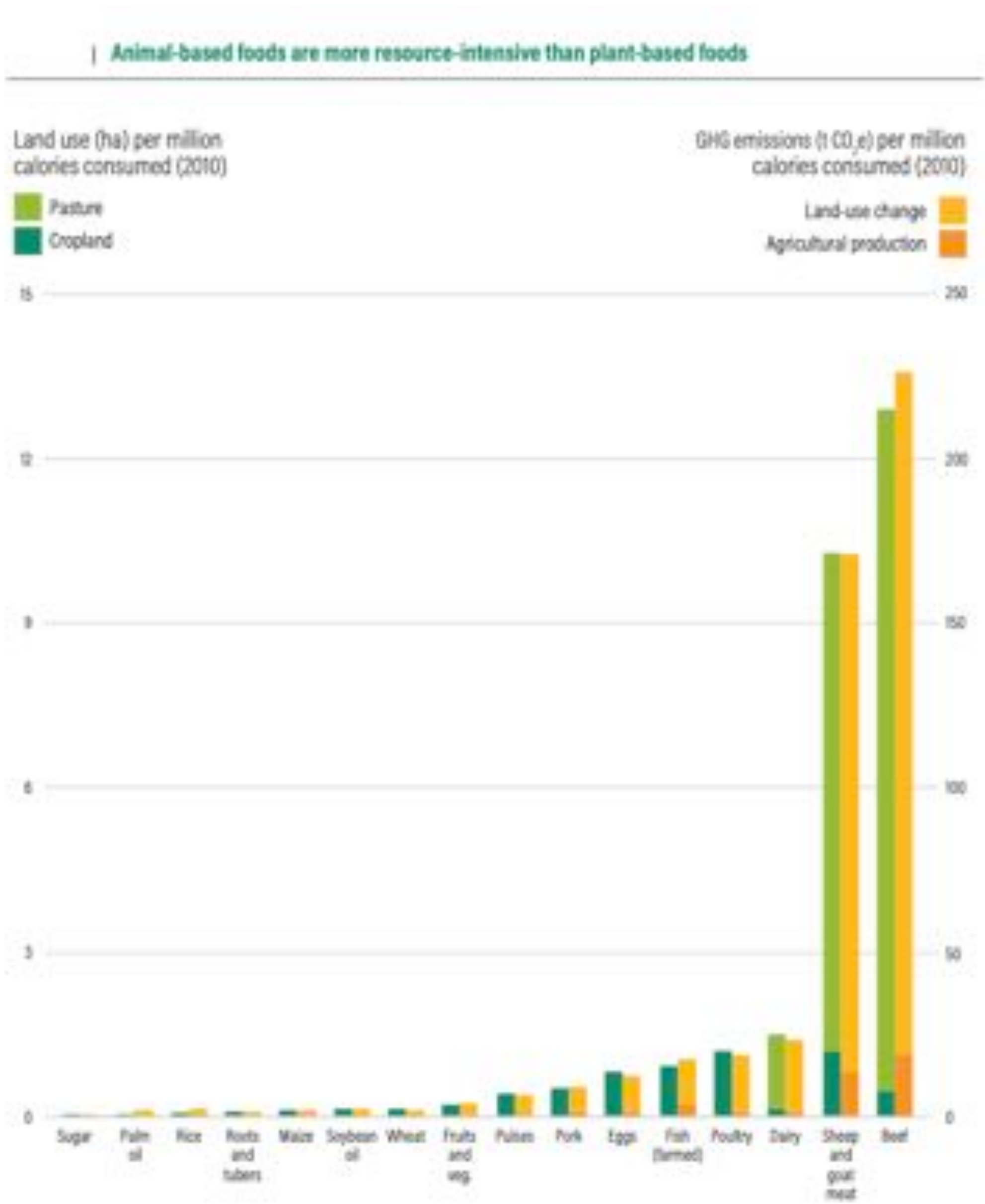
substantially decrease GHG emission (Searchinger et al., 2018). Figure 10 illustrates land use of specific foods versus amount of food produced.

Encourage replacement of land based animal-sourced protein with alternative proteins (eg. Plant-based meat substitutes, insects, lab created) and/or sustainably-sourced fish consumption to take pressure off of land (Pharo et al., 2019).

Decrease food waste in retail, consumption and reduce over-consumption (Mbow et al., 2019).

Figure 10

Resource intensity of animal-based versus plant-based foods



Sourced from Searchinger et al. (2018)

Stop Land Conversion

Raising productivity by increased efficiency of cropland is crucial to protect further land from being converted (Searchinger et al., 2018).

Use legislation to protect forests and eco-systems (Searchinger et al., 2018).

Use purchasing power to buy sustainable products, such as certified sustainable palm oil, cocoa, and coffee (Pharo et al., 2019).

Draw upon Indigenous knowledge for land and eco-system preservation (Boyd, 2019).

Provide Incentives

Repurpose agricultural subsidies to encourage sustainability and diversity in crops (Pharo et al., 2019).

Provide individual and organizational incentives for sustainable food choices (Pharo et al., 2019) and reducing food waste (Searchinger et al., 2018).

Incentivize sustainable fishing and farming of more sustainable ocean protein, such as mussels and oysters (Pharo et al., 2019). De-incentivize illegal and overfishing (Pharo et al., 2019).

Invest

Fund research geared toward technological innovations aimed at increasing crop productivity sustainably (Searchinger et al., 2019).

Invest in women including women's education, health, and reproductive services (Pharo et al., 2019). Global empowerment and equality of women plays a central role in sustainable, healthy agriculture and controlled population growth (Pharo et al., 2019).

References

Bezner Kerr, R., Hasegawa, T., Lasco, R., Bhatt, I., Deryng, D., Farrell, A., Gurney-Smith, H., Ju, H., Lluch-Cota, S., Meza, F., Nelson, G., Neufeldt, H., & Thornton, P. (2022). Food, fibre, and other ecosystem products. In In H.-O. Pörtner, D.C.Roberts, M.Tignor, E.S.Poloczanska, K.Mintenbeck, A.Alegría, M.Craig, S.Langsdorf, S.Löschke, V.Möller, A. Okem, B. Rama (Eds.), Climate change 2022: Impacts, adaptation and vulnerability. Contribution of working group II to the sixth assessment report of the intergovernmental panel on climate change. (pp. 713 – 906). Cambridge University Press. https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_Chapter05.pdf

Boyd, D. (2019). Safe climate: a report of the special rapporteur on human rights and the environment. United Nations [UN] Human Rights, Office of the High Commissioner. Report to UN General Assembly. https://documents-dds-ny.un.org/doc/UNDOC/GEN/N19/216/42/PDF/N1921642.pdf?OpenElement

ClimateData.ca. (2022). Understanding shared socio-economic pathways (SSPs). https://climatedata.ca/resource/understanding-shared-socio-economic-pathways-ssps/

DeValue, K., Takahashi, N., Woolnough, T., Merle, C., Fortuna, S., & Agostini, A. (2022). Halting deforestation from agricultural value chains: The role of governments. FAO (Food and Agriculture Organization of the United Nations). https://www.fao.org/3/cc2262en/cc2262en.pdf

Dunne, D. (2022). Explainer: Can climate change and biodiversity loss be tackled together? Carbon Brief. https://www.carbonbrief.org/explainer-can-climate-change-and-biodiversity-loss-be-tackled-together/

FAO (Food and Agriculture Organization of the United Nations). (2020). Tropical rainforest under pressure as agricultural expansion drives global deforestation. https://www.fao.org/3/cb7449en/cb7449en.pdf

FAO (Food and Agriculture Organization of the United Nations), & UNEP (United Nations Environment Programme. (2020). The state of the world's forests (SOFO). https://www.fao.org/state-of-forests/en/#:~:text=Between%202015%20and%202020%2C%20the,80%20million%20hectares%20since%201990

Government of Canada. (2018). Representative concentration pathways. https://climate-scenarios.canada.ca/?page=scen-rcp

Harris, N., & Gibbs, D. (2021). Forests absorb twice as much carbon as they emit each year. World Resources Institute. https://www.wri.org/insights/forests-absorb-twice-much-carbon-they-emit-each-year#:~:text=In%20other%20words%2C

%20forests%20provide,the%20United%20States%20emits%20annually

IPCC. (2019). Summary for policymakers. In P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley (Eds.), Climate change and land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food Security, and greenhouse gas fluxes in terrestrial ecosystems.(pp. 1 - 36). Cambridge University Press.https://www.ipcc.ch/srccl/chapter/summary-for-policymakers/

Kruid, S., Macedo, M.N., Gorelik, S.R., Walker, W., Moutinho, P., Brando, P.M., Castanho, A., Alencar, A., Baccini, A., & Coe, M.T. (2021). Beyond deforestation: Carbon emissions from land grabbing and forest degradation in the Brazilian amazon [Image]. Frontiers for Global Change, 4(645282), 3. https://doi.org/10.3389/ffgc.2021.645282

Lynch, J., Cain, M., Frame, D., & Pierrehumbert, R. (2021). Agriculture's contribution to climate change and role in mitigation is distinct from predominantly fossil CO2-emitting sectors. Frontiers Sustainable Food Systems, 4(518039), 1-9. https://doi.org/10.3389/fsufs.2020.518039

Mbow, C., Rosenzweig, C., Barioni, L.G., Benton, T.G., Herrero, M., Krishnapillai, M., Liwenga, E., Pradhan, P., Rivera-Ferre, M.G., Sapkota, T., Tubiello, F.N., Xu, Y. (2019). Food security. In P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley (Eds.), Climate change and land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food Security, and greenhouse gas fluxes in terrestrial ecosystems. (pp. 437 - 550). Cambridge University Press.https://doi.org/10.1017/9781009157988.007

Moser, S., Coffee, J., & Seville, A. (2017). Rising to the challenge, together: A review and critical assessment of the state of the US climate adaptation field. Kresge Foundation. https://kresge.org/wp-content/uploads/2020/06/rising_to_the_challenge_together_linked_0.pdf

Olsson, L., Barbosa, H., Bhadwal, S., Cowie, A., Delusca, K., Flores-Renteria, D., Hermans, K., Jobbagy, E., Kurz, W., Li, D., Sonwa, D.J., Stringer, L. (2019). Land degradation. In P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley (Eds.), Climate change and land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food Security, and greenhouse gas fluxes in terrestrial ecosystems. (pp. 345 - 436). Cambridge University Press. https://doi.org/10.1017/9781009157988.006

Ometto, J.P., Kalaba, K., Anshari, G.Z., Chacón, N., Farrell, A., Halim, S.A., Neufeldt, H, & Sukumar, R. (2022).

Cross chapter paper 7: Tropical forests. In H.-O. Pörtner, D.C.Roberts, M.Tignor, E.S.Poloczanska, K.Mintenbeck, A.Alegría, M.Craig, S.Langsdorf, S.Löschke, V.Möller, A. Okem, B. Rama (Eds.), Climate change 2022: Impacts, adaptation and vulnerability. Contribution of working group II to the sixth assessment report of the intergovernmental panel on climate change. (pp. 2369 - 2410). Cambridge University Press. https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_CCP7.pdf

Pendrill, F., Persson, U.M., Godar, J., & Kastner, T. (2019). Deforestation displaced: Trade in forest-risk commodities and the prospects for a global forest transition. Environmental Research Letters,14(5). https://doi.org/10.1088/1748-9326/ab0d41

Pharo, P., Oppenheim, J., Laderchi, C.R, & Benson, S. (2019). Growing better: Ten critical transitions to transform food and land use. The global consultation report of the food and land use coalition. The Food and Land Use Coalition. https://www.foodandlandusecoalition.org/wp-content/uploads/2019/09/FOLU-GrowingBetter-GlobalReport.pdf

Pharo, P. (2020). Growing better: Ten critical transitions to transform food and land use. [Video Presentation]. Food Systems, Land Use and Deforestation: FAO 7th World Forest Week. https://www.youtube.com/watch?app=desktop&v=TlANgsbsR0k

Project Drawdown. (2021). Global greenhouse gases [image]. https://drawdown.org/climate-solutions-101/unit-2-how-to-stop-climate-change

Project Drawdown. (2022a). Forest protection. https://drawdown.org/solutions/forest-protection

Project Drawdown. (2022b). Reduced food waste. https://drawdown.org/solutions/reduced-food-waste

Ritchie, H., & Roser, M. (2020). CO2 emissions. Our World in Data. https://ourworldindata.org/co2-emissions

Ritchie, H., & Roser ,M. (2021a). Drivers of deforestation. Our World in Data. https://ourworldindata.org/drivers-of-deforestation

Ritchie, H., & Roser, M. (2021c). Palm oil. Our World in Data. https://ourworldindata.org/palm-oil

Ritchie, H., & Roser ,M. (2021b). Soy. Our World in Data. https://ourworldindata.org/soy

Searchinger, T., Waite, R., Hanson, C., & Ranganathan, J. (2018). World resources report: Creating a sustainable food future: A menu of solutions to feed nearly 10 billion people by 2050. Synthesis Report. World Resources Institute. https://research.wri.org/sites/default/files/2019-07/creating-sustainable-food-future_2_5.pdf

Seymour, F., & Gibbs, D. (2019). Forests in the IPCC special report on land use: 7 things to know. World Resources Institute. https://www.wri.org/insights/forests-ipcc-special-report-land-use-7-things-know

Smith, P., Nkem, J., Calvin, K., Campbell, D., Cherubini, F., Grassi, G., Korotkov, V., Hoang, A.L., Lwasa, S., McElwee, P., Nkonya, E., Saigusa, N., Soussana, J.-F., Taboada, M.A., (2019). Interlinkages between desertification, land degradation, food security and greenhouse gas fluxes: Synergies, trade-offs and integrated response options. In P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley (Eds.), Climate change and land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food Security, and greenhouse gas fluxes in terrestrial ecosystems. (pp. 551 - 672). Cambridge University Press.https://doi.org/10.1017/9781009157988.008

Tandon, A. (2021, March 29). Scientists calculate trade-related 'deforestation footprint' of rich countries. Carbon Brief. https://www.carbonbrief.org/scientists-calculate-trade-related-deforestation-footprint-of-rich-countries/

Tandon, A. (2022, January 10). Rich nations could see 'double climate dividend' by switching to plant-based foods. Carbon Brief. https://www.carbonbrief.org/rich-nations-could-see-double-climate-dividend-by-switching-to-plant-based-foods/

United Nations. (2022). Biodiversity - our strongest natural defense against climate change. https://www.un.org/en/climatechange/science/climate-issues/biodiversity