



## Discussion

## Scientists' warning on population

Eileen Crist<sup>a,\*</sup>, William J. Ripple<sup>b</sup>, Paul R. Ehrlich<sup>c</sup>, William E. Rees<sup>d</sup>, Christopher Wolf<sup>b</sup><sup>a</sup> Department of Science and Technology in Society, Virginia Tech, Blacksburg, VA, United States<sup>b</sup> Department of Forest Ecosystems and Society, Oregon State University, Corvallis, OR, United States<sup>c</sup> Department of Biology, Stanford University, Stanford, CA, United States<sup>d</sup> School of Community and Regional Planning, University of British Columbia, Vancouver, BC, Canada

## ARTICLE INFO

Editor: Pavlos Kassomenos

## Keywords:

Population policy  
Climate mitigation  
Human rights  
Climate emergency

## ABSTRACT

Humanity must commit to transformative change on all levels in order to address the climate emergency and biodiversity collapse. In particular, stabilizing and ultimately reducing the human population size is necessary to ensure the long-term wellbeing of our species and other life on Earth. We show how this transition can be accomplished in an equitable framework that promotes human rights. Specifically, we issue a global appeal for women and men to have at most one child and call for policy-makers to implement population policies that improve education for girls and young women and ensure the availability of high-quality family-planning services.

A recently published world scientists' warning of a climate emergency, with >11,000 signatories, submitted, as one of six actions to mitigate climate change upheavals, that the human population “must be stabilized—and, ideally, gradually reduced—within a framework that ensures social integrity” (Ripple et al., 2020, p. 11). In this paper, which is part of the ongoing series of scientists' warning publications, we propose steps to accomplish this within a framework that ensures and furthers human rights.

While the speed at which climate disruption and biodiversity destruction are unfolding is alarming, the population factor continues to be ignored, sidestepped, or denied (Bongaarts and O'Neill, 2018; Ehrlich and Ehrlich, 2013; Kopnina and Washington, 2016; Ripple et al., 2017). This makes no sense—population is a primary variable underlying humanity's net consumption and waste output and thus a significant driver of global change. It took 200,000 years for human numbers to reach one billion in the early 19th century, then just 200 years (1/1000th as much time) to grow exponentially by over seven-fold to 7.9 billion today (Fig. 1). One result is that half the fossil fuels ever consumed by humans have been burned in just the past 35 years, accompanied by half of all climate-driving anthropogenic CO<sub>2</sub> emissions.

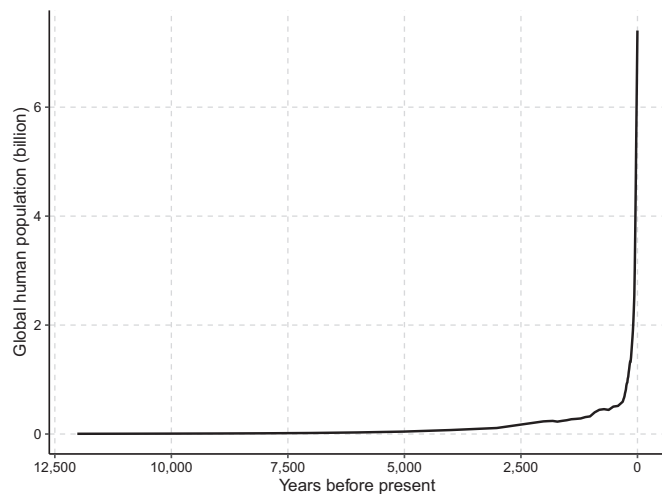
Despite the connection of population size to eco-catastrophe, the trajectory of global population growth toward 10 to 11 billion by the end of the century is usually treated as a given, even though socially desirable policies and actions exist that can alter our demographic destiny (Crist et al., 2017; Engelman, 2016). Indeed, alternative projections by the United Nations (UN) demonstrate the massive difference in the global population that

results from even slight differences in family size (Fig. 2), accentuating the urgent need for public engagement with the population question. We propose steps that will expedite a demographic trajectory below the UN median scenario, thereby facilitating humanity's capacity to protect biodiversity, alleviate climatic disruption, and preempt human and nonhuman suffering and displacements.

We tackle the population question as a global issue. On a nation-by-nation basis, demographic trends vary greatly around the world, and actions to reduce population size and growth in different places are both overlapping and divergent (Ezeh et al., 2012). Beyond societal variances, the international imperative in this time of converging calamities is to lower the total fertility rate (TFR) beneath the replacement figure of 2.1 (currently it is 2.4), in order to slowly reduce the global population beneath current levels. Environmental analysts regard a sustainable human population as one enjoying a modest, equitable middle-class standard of living on a planet retaining its biodiversity and with climate-related adversities minimized. Analysts' estimate of that population size vary between 2 and 4 billion people, a figure obviously well below the present 7.9 (Dasgupta, 2019; Pimentel et al., 2010; Rees, 2020). While the global fertility rate has been declining since the late 1960s, it continues to remain well above the replacement level, and the total population size is likely to reach 8 billion by early 2023. By pursuing the actions and policies we propose below, the human population can stop growing within this century and begin to gradually decline, more reliably and with far less suffering than the “invisible hand” of modernization and urbanization (or, as it is appearing likely, eco-catastrophe) would effect sometime in the 22nd century. In broad terms, we call for two types of actions for 1) individuals and 2) policy-makers.

\* Corresponding author.

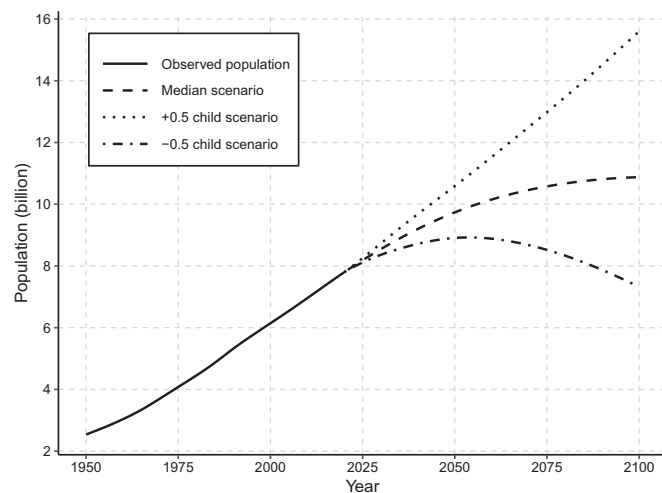
E-mail address: [ecrist@vt.edu](mailto:ecrist@vt.edu) (E. Crist).



**Fig. 1.** Historical trend of global human population. From 10,000 BCE to 2000 CE, the world population increased from 2 to 6145 million people. This resulted in a concurrent increase in the density of humans from  $<0.1$  person  $\text{km}^{-2}$  to nearly 46 persons  $\text{km}^{-2}$ .

Data source: Goldewijk et al. (2017).

Our first action call is a direct, global appeal to all women and men to choose none or at most one child. Individuals, especially if they aspire to large families, may pursue adoption, which is a desirable and compassionate choice for children who are here and need to be cared for. A trend of voluntarily choosing one or no children, or adoption, is already rising as a grassroots phenomenon among young people indisposed to bringing children into a world strained to the breaking point by species extinctions, extreme weather, soil degradation, freshwater shortages, global toxification, desertification, escalating mega wildfires, environmental refugees, and the potential of resource wars (possibly nuclear) (Schneider-Mayerson and Leong, 2020). Taking advantage of social media and other linkages outside the operations of governments, a civil society “No-to-Low Birth” movement can exercise enormous leverage vis-à-vis decelerating the population momentum. Opting for reproduction at the lowest end of “below replacement” represents an intentional individual/family choice that can contribute to consciousness



**Fig. 2.** Past and projected global population to the year 2100 under three different scenarios, including where total fertility is projected to reach levels that are 0.5 births above and below the total fertility in the median scenario. The world population sizes at year 2100 for the three scenarios are approximately 15.6 billion, 10.9 billion, and 7.3 billion for the high, median, and low scenarios respectively.

Data source: United Nations (2019).

raising and a global social shift. It is a choice that challenges received pronatalist norms and childbearing expectations that do not presently serve the greater good. Such a voluntary movement could occur globally, and thus reflect local cultures and values. Consequently, it is at low risk of being misapplied to justify coercive government mandates, in the way that some have argued U.S. scientists' recommendations were a driving force behind China's one-child policy that restricted many families to having at most one child (Greenhalgh, 2003).

Our second action call is for policy-makers to implement population policies with two key female empowerment components involving education and family-planning services. Nations with high gender inequality have high fertility rates. Thus where moderate to rapid population growth is still occurring, the most effective and human-rights enhancing antidote is achieving full gender equality, including economic opportunities and legal rights for women, beginning with ensuring education of all girls and young women (Dasgupta and Ehrlich, 2013). The average number of children a woman brings into the world drops proportionately with her years of schooling, with the most dramatic drop occurring with completion of secondary education (Cohen, 2008). Alongside ambitious investment in schooling girls (and more broadly, of course, all children), priority should be given to making high-quality family-planning services available to every woman on the planet, while economic, geographic, and cultural barriers to access should be removed (Bongaarts, 2016; Campbell and Bedford, 2009). The combination of institutional support to plan one's child-bearing choices and educational attainment, including enhanced opportunity for higher education for women, yields immediate fertility declines. The reason this occurs is that when women are empowered both socioculturally and pragmatically to decide how many children to have, they overwhelmingly choose few (or no) children, regardless of their religious, national, and ethnic background. What certain demographers describe as, on average, women's “latent desire” for fewer children surfaces when women's empowerment conditions line up (Campbell and Bedford, 2009).

Additionally, we advocate for the global dissemination of the UN curriculum of “Comprehensive Sexuality Education” (CSE). The need for this in-depth curriculum applies to all countries (wealthy, middle-income, and poor), regardless of their demographic profile, for it delivers profound benefits to young people's quality of life. Because CSE fosters critical thinking across the spectrum of sexuality issues, those who enroll in it are more prone to delay sexual initiation, use contraceptives when sexual relations begin, create fulfilling and egalitarian intimate relationships, and show respect for different sexual orientations (Kaidbey and Engelman, 2017). Regarding the demographically-relevant effects of CSE, it results in dramatic reduction of unintended pregnancy, which in turn contributes to decelerating population growth (Engelman, 2012). The latter aggregate effect supervenes because the averted pregnancies either occur later as intentional ones or do not occur at all.

In-depth sexuality education needs to be recognized internationally as a fundamental human right. Critical thinking about sexuality empowers individual decision-making and fosters greater equity and sensitivity, while also contributing to global population reduction almost as a side effect. Sexuality education initiatives may be most empowering when they are holistic and provide historical context about struggles by women to manage their fertility (e.g., Horga et al., 2013). Indeed, a comprehensive sexuality curriculum should be enthusiastically embraced across the political spectrum: by liberals and feminists for its effect of heightening awareness around gender roles, body image, and gay rights issues; and by conservatives for substantially reducing the need for abortion by preempting its main cause—unintended pregnancy (Sedgh et al., 2014).

In countries and regions where moderate to rapid population growth continues, the root causes are gender inequality and inequity (patriarchy), poverty, child marriage, and the synergies between them (Campbell et al., 2007; Dasgupta and Ehrlich, 2013). Redressing these factors calls for both targeted financial interventions and consciousness raising. With respect to poverty alleviation, we support instituting a global wealth tax to counter conditions of impoverishment that underlie the demographic trap of population growth feeding continued poverty in a vicious circle. Wealth

redistribution from such a global tax should be directed toward clean sanitation and water availability, food sovereignty, and electrification via renewables (McKibben, 2019; O'Neill et al., 2018). This redistribution is socially just in that the largest contributors would generally be the wealthy nations, industries, and people who have benefitted the most from humanity's massive-scale historical and contemporary use of fossil fuels. In contrast, per capita emissions in less wealthy regions are far lower, although this will change (barring economic collapse or other surprises) as globalization continues and the global middle class expands.

The global community, however, no longer measures poverty strictly in terms of lacking the basics. Alleviating poverty also includes provisioning public services, most especially healthcare and education. Global wealth redistribution should also be directed to family-planning services, including facilities, expert personnel, and robust networks to bring reproductive-health amenities and the full array of contraceptives to people in all rural and urban settings (Cleland et al., 2006). Family planning is not an issue for women alone; significant funding should be allocated to educate men about the option of vasectomy and to ensure this procedure is safe and readily available to men who choose it. Additionally, funds can be used for building schools, paying teachers, and provisioning educational supplies, so education and literacy become universal achievements. Regarding cultural interventions advancing human rights—especially children's and women's rights—financial, legal, media, and educational programs can be fast-tracked to raise awareness about gender inequality and injustice, to incentivize parents to school their children, and to institute zero tolerance toward child marriage and all forms of child exploitation (Wodon et al., 2017). Unsurprisingly, the cultural practice of “child brides” plagues societies where rapid population growth is occurring. The international community must mobilize to abolish this form of child abuse, and to affirm in action girls' (and boys') rights to be protected, educated, and cared for into adulthood.

In the developed and emerging-economy regions, where the TFR is at or below replacement, this is a demographic attainment to be celebrated. To allay fears about pension and social security shortfalls, precautionary policies can forestall problems arising from an inevitable period of age imbalance and senior-heavy societies (Smeeding, 2014). Such policies include encouraging savings and curbing debt, as well as reforming food subsidies, guidelines, and advocacy toward healthier, more plant-based diet choices in order to slash ballooning public healthcare budgets (Willett et al., 2019). Additionally, given the substantial movements of people expected in this century, falling populations in developed countries with aging populations can foster greater leniencies toward immigration flows from the developing world.

Countering the threat of funding shortfalls for seniors is a matter of political will—it is not an insurmountable problem. Consequences of aging population structures surface sooner or later: populations cannot go on growing indefinitely and on average (extrapolating from past trends) people are living longer. In a world facing existential threats from multiple directions, it is folly to bank old-age security on continued population growth. Instead, we can move toward decelerating population growth within human-rights frameworks, while rethinking retirement funding strategies by revising budget allocation priorities. On that note, we support calls for an international initiative to redirect an equal, sizeable fraction of all countries' military budgets toward social security, pension, and universal basic income (Klein, 2019). Our ecological predicament, which is imperiling human and nonhuman worlds alike, exposes the absurdity of investing vast sums of money, energy, and brainpower into military ventures.

The policy directions we advocate, along with our No-to-Low Birth appeal to civil society, if pursued, will direct human population size toward a destination where we can meet the Sustainable Development Goals (United Nations, 2022). Deliberately and humanely sloping the population trajectory downward will reduce pressures that additional people would place on the planet, while also substantially lessening anticipated hardships and suffering in this century. Although much more work is needed, there are some promising signs, including the development of the FP2030 global partnership, which is built on a vision for sexual and reproductive health

based on equity, rights, voluntarism, and accountability (Hardee and Jordan, 2021). Concurrently, affluent overconsumption must be curbed since wealthy people are responsible for substantial greenhouse gas emissions and other environmental impacts (Wiedmann et al., 2020). This can be accomplished using policies that support economic degrowth—down-scaling resource and energy throughput while securing wellbeing (Kallis et al., 2018; Wiedmann et al., 2020).

The twenty-first century is a bottleneck through which we must endeavor to save and restore Earth's biodiversity and the crucial ecological life-supports it supplies, to tame climate change, and to avert and minimize disease, starvations, conflict, and displacement (Bradshaw et al., 2021; Ceballos et al., 2017; Díaz et al., 2019). Moving through this bottleneck will have greater odds of success if child-bearing women globally voluntarily choose to have no children or no more than one, over the remaining course of the 21st century. Many currently proposed solutions are single-mindedly focused on the short term—especially what to do in the next few years to address the climate emergency and widening global inequality (Bokat-Lindell, 2019). While an orientation toward the short-term is critically important, redressing the population factor through voluntary individual choice and human-rights frameworks directs humanity toward the equally important horizons of the medium- and long-term. This is especially critical when one considers the multiple population interactions with overconsumption in a world where the global middle class is growing, and with the use of malign technologies in degrading Earth's ecological integrity (Ehrlich and Holdren, 1971; Kharas, 2017). It follows that attempting to address either population or overconsumption alone is inadequate (Bradshaw et al., 2021). This is encapsulated in the “IPAT” framework, which relates environmental Impacts (I) to Population (P), Affluence (A), and Technology (T), and can be used to model ecological overshoot (Ehrlich and Holdren, 1971; McBain et al., 2017).

Human beings are endowed with attributes of discerning intelligence, including capacities for logic, evidence-based reasoning, compassion, and deliberately shaping the future. We are also capable of extraordinary levels of intergroup cooperation in pursuit of shared goals. The future of all complex life depends on unprecedented international collaboration in the application of our best science and reasoning capabilities in a global redirection toward the common good. Through an intentional global course away from the 11-billion median projection, we can chart a far more hopeful trajectory than the one to which we are presently committed: toward inhabiting a planet of still-thriving biodiversity, in which climate change has been rendered less turbulent, and a solid foundation for inclusive justice, human and nonhuman, has been deliberately laid.

#### CRediT authorship contribution statement

**Eileen Crist:** Conceptualization, Writing - Original Draft, Writing - Review & Editing. **William J. Ripple:** Conceptualization, Writing - Review & Editing. **Paul R. Ehrlich:** Writing - Review & Editing. **William E. Rees:** Writing - Review & Editing. **Christopher Wolf:** Writing - Review & Editing.

#### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

#### Acknowledgments

We thank Axel Hochkirch for reviewing a draft of the paper and providing helpful comments.

#### References

- Bokat-Lindell, S., 2019. Do We Need the Green New Deal? [WWW Document]. The New York Times. <https://www.nytimes.com/2019/09/03/opinion/climate-change-green-new-deal.html>. (Accessed 21 August 2021).
- Bongaarts, J., 2016. Development: slow down population growth. *Nat. News* 530, 409.

- Bongaarts, J., O'Neill, B.C., 2018. Global warming policy: is population left out in the cold? *Science* 361, 650–652.
- Bradshaw, C.J., Ehrlich, P.R., Beattie, A., Ceballos, G., Crist, E., Diamond, J., Dirzo, R., Ehrlich, A.H., Harte, J., Harte, M.E., et al., 2021. Underestimating the challenges of avoiding a ghastly future. *Front. Conserv. Sci.* 1, 9.
- Campbell, M., Bedford, K., 2009. The theoretical and political framing of the population factor in development. *Philos. Trans. R. Soc. Lond., B, Biol. Sci.* 364, 3101–3113.
- Campbell, M., Cleland, J., Ezech, A., Prata, N., 2007. Return of the population growth factor. *Science* 315, 1501–1502. <https://doi.org/10.1126/science.1140057>.
- Ceballos, G., Ehrlich, P.R., Dirzo, R., 2017. Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. *Proc. Natl. Acad. Sci.* 114, E6089–E6096.
- Cleland, J., Bernstein, S., Ezech, A., Faundes, A., Glasier, A., Innis, J., 2006. Family planning: the unfinished agenda. *Lancet* 368, 1810–1827.
- Cohen, J.E., 2008. Make secondary education universal. *Nature* 456, 572–573.
- Crist, E., Mora, C., Engelman, R., 2017. The interaction of human population, food production, and biodiversity protection. *Science* 356, 260–264.
- Dasgupta, P., 2019. *Time and the Generations: Population Ethics for a Diminishing Planet*. Columbia University Press.
- Dasgupta, P.S., Ehrlich, P.R., 2013. Pervasive externalities at the population, consumption, and environment nexus. *Science* 340, 324–328.
- Díaz, S., Settele, J., Brondízio, E.S., Ngo, H.T., Agard, J., Arneth, A., Balvanera, P., Brauman, K.A., Butchart, S.H., Chan, K.M., et al., 2019. Pervasive human-driven decline of life on earth points to the need for transformative change. *Science* 366.
- Ehrlich, P.R., Ehrlich, A.H., 2013. Can a collapse of global civilization be avoided? *Proc. R. Soc. B Biol. Sci.* 280, 20122845.
- Ehrlich, P.R., Holdren, J.P., 1971. Impact of population growth. *Science* 171, 1212–1217.
- Engelman, R., 2012. Trusting women to end population growth. In: Cafaro, P., Crist, E. (Eds.), *Life on the Brink: Environmentalists Confront Overpopulation*. The University of Georgia Press, Athens and London, pp. 223–239.
- Engelman, R., 2016. Nine population strategies to stop short of 9 billion. In: Washington, H., Twomey, P. (Eds.), *A Future beyond Growth: Toward a Steady State Economy*. Routledge, London, pp. 32–42.
- Ezech, A.C., Bongaarts, J., Mberu, B., 2012. Global population trends and policy options. *Lancet* 380, 142–148.
- Goldewijk, K.K., Beusen, A., Doelman, J., Stehfest, E., 2017. Anthropogenic land use estimates for the Holocene–HYDE 3.2. *Earth Syst. Sci. Data* 9, 927–953.
- Greenhalgh, S., 2003. Science, modernity, and the making of China's one-child policy. *Popul. Dev. Rev.* 29, 163–196.
- Hardee, K., Jordan, S., 2021. Advancing rights-based family planning from 2020 to 2030. *Open Access J. Contracept.* 12, 157.
- Horga, M., Gerds, C., Potts, M., 2013. The remarkable story of romanian women's struggle to manage their fertility. *J. Fam. Plann. Reprod. Health Care* 39, 2–4.
- Kaidbey, M., Engelman, R., 2017. Our bodies, our future: Expanding comprehensive sexuality education. *EarthEd: Rethinking Education on a Changing Planet*, State of the World. Island Press, Washington D.C., pp. 179–189.
- Kallis, G., Kostakis, V., Lange, S., Muraca, B., Paulson, S., Schmelzer, M., 2018. Research on degrowth. *Annu. Rev. Environ. Resour.* 43, 291–316.
- Kharas, H., 2017. *The Unprecedented Expansion of the Global Middle Class: An Update*. Working Paper 100. Brookings Global Economy and Development.
- Klein, N., 2019. *On Fire: The (Burning) Case for a Green New Deal*. Simon & Schuster, New York.
- Kopnina, H., Washington, H., 2016. Discussing why population growth is still ignored or denied. *Chin. J. Popul. Resour. Environ.* 14, 133–143.
- McBain, B., Lenzen, M., Wackernagel, M., Albrecht, G., 2017. How long can global ecological overshoot last? *Glob. Planet. Chang.* 155, 13–19.
- McKibben, B., 2019. *Falter: Has the Human Game Begun to Play Itself Out?* Henry Holt and Company, New York.
- O'Neill, D.W., Fanning, A.L., Lamb, W.F., Steinberger, J.K., 2018. A good life for all within planetary boundaries. *Nat. Sustain.* 1, 88–95.
- Pimentel, D., Whitecraft, M., Scott, Z.R., Zhao, L., Satkiewicz, P., Scott, T.J., Phillips, J., Szimák, D., Singh, G., Gonzalez, D.O., et al., 2010. Will limited land, water, and energy control human population numbers in the future? *Hum. Ecol.* 38, 599–611.
- Rees, W.E., 2020. Ecological economics for humanity's plague phase. *Ecol. Econ.* 169, 106519.
- Ripple, W.J., Wolf, C., Newsome, T.M., Barnard, P., Moomaw, W.R., 2020. World scientists' warning of a climate emergency. *Bioscience* 70, 8–12.
- Ripple, W.J., Wolf, C., Newsome, T.M., Galetti, M., Alamgir, M., Crist, E., Mahmoud, M.I., Laurance, W.F., 15,364 scientist signatories from 184 countries, 2017. World scientists' warning to humanity: A second notice. *BioScience* 67, 1026–1028.
- Schneider-Mayerson, M., Leong, K.L., 2020. Eco-reproductive concerns in the age of climate change. *Clim. Chang.* 163, 1007–1023.
- Sedgh, G., Singh, S., Hussain, R., 2014. Intended and unintended pregnancies worldwide in 2012 and recent trends. *Stud. Fam. Plan.* 45, 301–314.
- Smeeding, T.M., 2014. Adjusting to the fertility bust. *Science* 346, 163–164. <https://doi.org/10.1126/science.1260504>.
- United Nations, 2022. Sustainable development goals [WWW Document]. <https://www.undp.org/sustainable-development-goals>. (Accessed 25 June 2022).
- [United Nations] United Nations Population Division, Department of Economic and Social Affairs, 2019. *World Population Prospects 2019*, Online Edition. Rev. 1.
- Wiedmann, T., Lenzen, M., Keyßer, L.T., Steinberger, J.K., 2020. Scientists' warning on affluence. *Nature communications* 11, 1–10.
- Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., et al., 2019. Food in the anthropocene: the EAT–Lancet commission on healthy diets from sustainable food systems. *Lancet* 393, 447–492.
- Wodon, Q.T., Tavares, P.M.T., Fiala, O., Nestour, A.L., Wise, L., 2017. *Ending Child Marriage: Child Marriage Laws and Their Limitations*. The World Bank.