Hunger and Equity in an Era of Genetic Engineering

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"[T]he question is not whether we can end hunger. It's whether we will."[1]

Our food system is profoundly inequitable. There is a shockingly unequal distribution of food among the earth's 7.3 billion human inhabitants. The privileged throw away vast amounts of food while millions go hungry. Despite a theoretical

* Professor CUNY School of Law, Director CUNY Center for Urban Environmental Reform. This article benefited from discussions at the UC Irvine Food Equity Symposium. Thanks to Professor Sarah Lamdan for her help tracking down hard-to-locate sources.

1. Hillary Clinton, *Attacking Hunger at Its Roots*, HUFFINGTON POST (July 12, 2009), http://www.huffingtonpost.com/hillary-clinton/attacking-hunger-at-its-r_b_214351.html [https://perma.cc/G69K-SXVV].

"right to food,"[2] which ranks among the core human rights, nearly 800 million people were undernourished in 2015.[3] That is one in nine people on the planet. An even greater number were "food insecure," meaning they lack reliable access to sufficient amounts of safe and nutritious food.[4] On its face, this seems like a problem of supply and demand—too much demand and too little supply. Yet, the reality is more complex. The United Nation's Food and Agriculture Organization (FAO) estimates the average human needs to consume somewhere around 1844 calories[5] per day.[6] The good news is that in 2015, the world produced roughly 2900 kcal/person/day[7]—more than enough to meet demand.[8] Yet, in the face of plenty, hundreds of millions face persistent undernourishment. This imbalance underscores

2. *See, e.g.*, International Covenant on Economic, Social and Cultural Rights [ICESCR] art. 11(1), Dec. 16, 1966, 993 U.N.T.S. 3 (requiring states party to the ICESCR to respect, protect, and fulfill the international right to food); G.A. Res. 217 (III) A, art. 25(1), Universal Declaration of Human Rights (Dec. 10, 1948) (declaring that every person has a right to an adequate standard of living, including access to food).

3. U.N. FOOD AND AGRIC. ORG. [FAO], THE STATE OF FOOD INSECURITY IN THE WORLD—MEETING THE 2015 INTERNATIONAL HUNGER TARGETS: TAKING STOCK OF UNEVEN PROGRESS 4 (2015) [hereinafter FAO, THE STATE OF FOOD INSECURITY], http://www.fao.org/3/a-i4646e.pdf [https://perma.cc/6EEX-4EJK]. That means that they were unable to acquire sufficient food to meet their dietary energy requirements for at least an entire year. *Id.* at 53. The cutoff point for undernourishment is based on calculations about the minimum dietary energy requirement (MDER) associated with a representative individual of a population. *See id.* at 49. Because these figures vary based on age, gender, and levels of physical activity, they vary with the age structure and gender balance in a population. For that reason, the FAO regularly recalculates the MDER to update it with new population data. *Id.* at 51.

4. For example, in the United States alone, 14% of the population was food insecure in 2014. U.S. DEP'T OF AGRIC. [USDA], ECON. RESEARCH SERV., ERR-237, HOUSEHOLD FOOD SECURITY IN THE UNITED STATES IN 2016, at 7 tbl.1A, 9, 12 fig.3 (2017) [hereinafter USDA, HOUSEHOLD FOOD SECURITY], https://www.ers.usda.gov/webdocs/publications/84973/err-237.pdf?v=42979 [https://perma.cc/HMF8-ZHVN] (providing a clear explanation of the difference between food insecurity and undernourishment).

5. A calorie is the amount of energy needed to heat a gram of water 1 degree Centigrade. A kilocalorie is the amount of energy required to heat a kilogram of water. The energy quotient of food is measured in kilocalories, even though common parlance typically refers to calories instead. This Paper will use the terms kcal and calorie interchangeably.

6. FAO, MINIMUM DIETARY ENERGY REQUIREMENT (2008), https://www.google.com/url?q=http://www.fao.org/fileadmin/templates/ess/documents/food_security_statistics/MinimumDietaryEnergyRequirement_en.xls&sa=U&ved=0ahUKEwiwlafbxdbRAhWGrlQKHUaBB_cQFggGMAE&client=internal-uds-cse&usg=AFQjCNHOxisN0WV5GOMbxPCeuwcUyiRnIg. The World average MDER was 1844 kcal/person/day. The number varies based on age and size. The FAO also calculates minimum daily energy requirements for each country, based on population and demographics. The range is fairly narrow—from a low of 1690 kcal/person/day in Timor-Leste to a high of 1990 kcal/person/day in Oman. *Id.*

7. FAO, STATISTICAL POCKETBOOK: WORLD FOOD AND AGRICULTURE 24 fig.42 (2015) [hereinafter FAO, STATISTICAL POCKETBOOK], http://www.fao.org/3/a-i4691e.pdf [https://perma.cc/X7BT-N4X6].

8. For perspective, the FAO pegs the average minimum daily energy requirement at 1844 kcal/person/day, more than 1000 kcal/person/day below global production. *Id.* at 48.

Amartya Sen's profound insight that the problem of hunger is a problem of food distribution, rather than one of food scarcity.[9]

A tragic irony embedded in this imbalance is that a very high percentage of the world's food insecure are also food producers—with food insecurity particularly rampant among subsistence farmers in Southern Africa and South Asia.[10] Moreover, the very act of food production often destroys ecosystems while simultaneously jeopardizing the health of farmers and field workers, who are often exposed to pesticide levels far exceeding the test amounts considered in making safety assessments.[11] Sadly, climate change will surely exacerbate this situation.

Facing these seemingly intractable inequities, policymakers look for a way to rewrite the script. It is very difficult to convince people, policymakers included, that the answer is not simply producing more food. Solutions that claim to offer a way to produce more food, on less land, with less effort hold an obvious attraction. This Article focuses on one such solution—the oft-repeated assertion that one or all of these food production inequities can be resolved through widespread adoption of genetically engineered agricultural crops. Purveyors of genetically engineered crops routinely make extravagant claims about their product's ability to redress food insecurity. They claim to have harnessed the power of science to feed the world,[12] all while reducing environmental degradation. Anyone standing in their way is a Luddite. Some advocates of genetically engineered crops go further, accusing even thoughtful opponents of ignoring the plight of hungry children, and choosing anti-science over science.[13] There is certainly an anti-science strain in some opposition to genetically engineered crops,[14] but the technology's proponents often use the

9. AMARTYA SEN, POVERTY AND FAMINES: AN ESSAY IN ENTITLEMENT AND DEPRIVATION 1 (1981).

10. FAO, THE STATE OF FOOD AND AGRICULTURE 2015 IN BRIEF 2 (2015) [hereinafter FAO, FOOD AND AGRICULTURE IN BRIEF], http://www.fao.org/3/a-i4953e.pdf [https://perma.cc/8B4K-DK8R].

11. Christopher Gerry, *Feeding the World One Genetically Modified Tomato at a Time: A Scientific Perspective*, HARV. UNIV. GRAD. SCHOOL OF ARTS AND SCIENCES: SCIENCE IN THE NEWS (Aug. 9, 2015), http://sitn.hms.harvard.edu/flash/2015/feeding-the-world/ [https://perma.cc/7BPU-MPNK].

12. In 1998, for example, Monsanto spent $1.6 million on a European ad campaign under the banner: "Worrying about Starving Future Generations Won't Feed Them. Food Biotechnology Will." Claudia Parsons, *Aid Agencies Say Biotechnology Won't End Hunger*, REUTERS (Sept. 25, 1998). Hoechst ran a similar ad inviting readers to "imagine a world where harvests grew just as fast as the population." VANDANA SHIVA, STOLEN HARVEST: THE HIJACKING OF THE GLOBAL FOOD SUPPLY 96 (2016).

13. *See, e.g.*, ROBERT PAARLBURG, STARVED FOR SCIENCE: HOW BIOTECHNOLOGY IS BEING KEPT OUT OF AFRICA (2008); Joel Achenbach, *107 Nobel Laureates Sign Letter Blasting Greenpeace Over GMOs*, THE WASH. POST (June 30, 2016), https://www.washingtonpost.com/news/speaking-of-science/wp/2016/06/29/more-than-100-nobel-laureates-take-on-greenpeace-over-gmo-stance/ [https://perma.cc/9DA7-WP4C] (text of the signed letter can be found at http://supportprecisionagriculture.org/why-greenpeace-is-wrong-about-gmos-and-golden-rice_rjr.html [https://perma.cc/H7QA-753T]); William Saletan, *Unhealthy Fixation*, SLATE (July 15, 2015), http://www.slate.com/articles/health_and_science/science/2015/07/are_gmos_safe_yes_the_case_against_them_is_full_of_fraud_lies_and_errors.html [https://perma.cc/MB8W-7PN9].

14. *See, e.g.*, Caitlyn Sheeterly, *The Bad Seed: The Health Risks of Genetically Modified Corn*, ELLE (July 24, 2013), http://www.elle.com/beauty/health-fitness/advice/a12574/allergy-to-genetically-

anti-science fringes to gloss over a legitimate, and fundamental critique of the technology—one rejecting the proposition that, in a world already awash with food, food insecurity should be framed as a problem amenable to technical solution. This critique does not reject the technology *per se*, but instead rejects its relevance to food equity and food security.[15]

This Article tests the notion that genetically engineered crops are a tool in the fight against hunger. The question is posed in the context of a world in flux—with a rapidly increasing human population and a growing potential for agricultural disruption from climate change. To try to produce an answer, the Article uses two criteria: first, does the proposed solution address the actual problem of hunger; and second, does the solution contribute to food equity. In doing so, this Article highlights how narratives about science and equity are deployed both by the pro-agricultural biotechnology forces and by their opponents.

Part I offers a brief overview of the equity crisis in food production and distribution, and describes how the twin challenges of a growing population and climate change are expected to deepen this crisis. Part II situates genetically engineered crops in a broader dialogue about food security. The Part begins with a brief introduction to the development and use of these crops. It then critically examines some of the oft-repeated arguments that biotech crops are indispensable for solving the problems of undernourishment and food insecurity in a rapidly warming world. In Part III, the focus then turns to the power dynamics that underlie promotion and adoption of genetically engineered crops, notably the struggles for control over food production and farmer choice, over public and private research agendas, and over public access to information.

The key working assumptions for this analysis are that viable solutions must offer the possibility of access to adequate and culturally appropriate food; must promote food production that empowers rather than exploits producers; and must not degrade the environment or threaten human health. With those criteria in mind, this Article concludes that although the technical potential embodied by genetic engineering might contribute to a transformation in food production, the economic and political power structures in which that technical potential is being realized

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modified-corn/ [https://perma.cc/K5NX-HGV5] (attributing a host of health symptoms to a GMO allergy); Vani Hari, *The United States of GMOs—Keeping Us in the Dark*, FOOD BABE (Sept. 26, 2012), http://foodbabe.com/2012/09/26/the-united-state-of-gmos-keeping-us-in-the-dark [https://perma.cc/TTC3-DD3S] (asserting that "GMOs are foods biologically manufactured in laboratories—injected with new DNA, viruses, herbicides, insecticides and/or other chemicals").

15. Indeed, one major critique of these crops is the role they play in normalizing an economic and political system that has consolidated seed ownership and agricultural production in the hands of few, largely Western, multinational corporations, even as the rhetoric focuses on the desperate poor in developing countries. *See, e.g.*, Wangari Maathai, *Let Nature's Harvest Continue: African Counter-Statement to Monsanto*, 25 REV. OF AFRICAN POL. ECON., 529, 529 (1998). See generally Dominick Glover, *Made by Monsanto: The Corporate Shaping of GM Crops as a Technology for the Poor* 4 (STEPS Centre, Working Paper 11, 2008) (analyzing the "simultaneous production of a technology widely recognized as having limited relevance to poverty alleviation alongside a narrative that strongly implied it was intended and designed to achieve that goal . . . ."), for a full evaluation of this theme.

instead underscore existing imbalances, and thus work against promoting or achieving equity in this context. In doing so, this Article sheds light on some core questions of accountability for food insecurity in an era of climate change.

I. THE EQUITY CRISIS IN FOOD PRODUCTION AND DISTRIBUTION

Every man, woman and child has the inalienable right to be free from hunger and malnutrition in order to develop fully and maintain their physical and mental faculties.[16]

Roughly 2 billion people are employed in agriculture, many of them poor.[17] To address food insecurity and undernutrition, agriculture has what the World Bank calls "a special power,"[18] because it has the potential both to raise incomes and to make food more available. But, it will only do so if agriculture develops and grows in ways that provide economic opportunities to the poor. Women make up the majority of agricultural workers in many developing countries.[19] Raising women's income has disproportionate benefits for alleviating hunger,[20] so assisting women farmers is a particularly effective way to reduce poverty and enhance food security.

A. What Is Food Security?

The FAO defines food security as a "situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life."[21] In the United States, the U.S. Department of Agriculture (USDA) similarly defines food security as having "access at all times to enough food for an active, healthy life for all household members."[22] Food *in*security is the absence of this situation. The most severe form of food insecurity is undernourishment, which means a person is not able to acquire enough food to meet the daily minimum

16. G.A. Res. 3180 (XXVIII), Universal Declaration on the Eradication of Hunger and Malnutrition (Nov. 16, 1974).

17. *See* THE WORLD BANK, AGRICULTURE AND POVERTY REDUCTION (2008), http://siteresources.worldbank.org/INTWDR2008/Resources/2795087-1191440805557/4249101-1191957549239/Brief_AgPovRedctn_web.pdf [https://perma.cc/WE2N-4XNE]; *see also* WORLD RESOURCES INSTITUTE, CREATING A SUSTAINABLE FOOD FUTURE: A MENU OF SOLUTIONS TO SUSTAINABLY FEED MORE THAN 9 BILLION PEOPLE BY 2050, at 2 (2014), http://www.wri.org/sites/default/files/wri13_report_4c_wrr_online.pdf [https://perma.cc/J8JU-5SLJ].

18. WORLD BANK, *supra* note 17, at 1.

19. *See* SOFA Team & Cheryl Doss, *The Role of Women in Agriculture* (FAO, Agric. Dev. Econ. Div. [ESA], Working Paper No. 11-02, 2011), http://www.fao.org/docrep/013/am307e/am307e00.pdf [https://perma.cc/E2F2-LRSX].

20. *See* REKHA MEHRA & MARY HILL ROJAS, INT'L CTR. FOR RESEARCH ON WOMEN, WOMEN, FOOD SECURITY AND AGRICULTURE IN A GLOBAL MARKETPLACE (2008), http://www.icrw.org/wp-content/uploads/2016/10/A-Significant-Shift-Women-Food-Security-and-Agriculture-in-a-Global-Marketplace.pdf [https://perma.cc/ACN4-LEHB].

21. FAO, THE STATE OF FOOD INSECURITY, *supra* note 3, at 53.

22. USDA, HOUSEHOLD FOOD SECURITY, *supra* note 4, at i.

dietary energy requirements, over a period of one year.[23] The United States deploys slightly different terminology, using the term "very low food security" to mean that normal eating patterns of one or more household members were disrupted and food intake was reduced at times during the year because they had insufficient money or other resources for food.[24] In 2014, 14% of U.S. households were food insecure, with 5.6%, or roughly 6.9 million Americans, suffering from very low food security.[25] At the same time, more than 40% of all food in the United States is thrown away uneaten.[26] It would be difficult to even conceive of a more graphic example of food inequity in action.

The year 2015 was supposed to be a watershed for resolving food insecurity. That is because 2015 was the designated endpoint for two major hunger-related initiatives—the World Food Summit target[27] and the Millennium Development Goals.[28] Under these two major initiatives, the global community committed to halving both the absolute number of people who were undernourished[29] and the proportion of the human population suffering from undernourishment.[30] While many parts of the world came close to reaching the latter, less ambitious Millennium Development Goal, attempts to meet the World Food Summit target fell short by more than a quarter of a billion people (265 million to be precise).[31]

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23. FAO, THE STATE OF FOOD INSECURITY, *supra* note 3, at 53. FAO defines hunger as being synonymous with chronic undernourishment. I will use the two terms interchangeably in this Article.

24. USDA, *supra* note 4, at i.

25. *Id.* at 7.

26. Suzanne Goldenberg, *The US Throws Away as Much as Half Its Food Produce,* WIRED (July 14, 2016), https://www.wired.com/2016/07/us-throws-away-much-half-food-produce/ [https://perma.cc/L3EX-5BPB].

27. See *Monitoring Progress Since the World Food Summit*, FAO (2005), http://www.fao.org/monitoringprogress/index_en.html [https://perma.cc/M442-9P28], for details of the World Food Summit target.

28. See *Millennium Development Goals and Beyond 2015*, UNITED NATIONS [hereinafter *Millennium Goals,* UNITED NATIONS], http://www.un.org/millenniumgoals/poverty.shtml [https://perma.cc/5BTD-T286] (last visited Jan. 15, 2017), for information about the Millennium Development Goals.

29. As part of the 1996 Rome World Food Summit, representatives of 182 governments pledged "to eradicate hunger in all countries, with an immediate view to reducing the number of undernourished people to half their present level no later than 2015 . . . ." FAO, *Rome Declaration on World Food Security and World Food Summit Plan*, World Food Summit, U.N. Doc. W3613 (Nov. 13, 1996) [hereinafter FAO, *Rome Declaration*], http://www.fao.org/DOCREP/003/W3613E/W3613E00.HTM [https://perma.cc/FD27-ZNXH].

30. At the 2000 Millennium Summit, 189 nations called for recognizing that every individual has the right to dignity, freedom, equality, and a basic standard of living that includes freedom from hunger and violence. This pledge led to the formulation of eight Millennium Development Goals (MDGs) in 2001. In adopting Millennium Development Goal 1, the nations of the world committed to "eradicate extreme poverty and hunger." *Millennium Goals*, UNITED NATIONS, *supra* note 28. This Goal was then made operational through the establishment of three distinct targets: Target 1A: halving global poverty, Target 1B: achieving full and productive employment, and Target 1C: halving the proportion of people who suffer from hunger by 2015. *Id.*

31. FAO, THE STATE OF FOOD INSECURITY, *supra* note 3, at 9. However, since the global population increased by about 1.9 billion over that same period of time, the initiative achieved more than is suggested by simply comparing starting and ending levels of undernourishment. *Id.* at 8.

And, this World Food Summit target itself represented diminished global ambition in tackling food insecurity. The first global initiative responding to hunger and food insecurity was the 1974 World Food Conference.[32] At this Conference, the 135 country-attendees[33] adopted the Universal Declaration on the Eradication of Hunger and Malnutrition, which articulated a much more ambitious goal—the complete eradication of food insecurity and undernutrition within a decade.[34] The Declaration defined food security as a common responsibility of the international community,[35] and proclaimed that governments had the fundamental responsibility to both increase food production and more equitably distribute existing food supplies.[36] No less a personage than United States' Secretary of State Henry Kissinger proclaimed that "within a decade no child will go to bed hungry, that no family will fear for its next day's bread, and that no human being's future and capacities will be stunted by malnutrition."[37] The United Nations General Assembly endorsed this goal, and established the World Food Council to operationalize its proposals.[38] In conjunction with the Conference, the U.S. Congress adopted a resolution declaring "every person throughout the world has the right to a nutritionally adequate diet."[39] At the time, roughly 500 million people were suffering food insecurity,[40] but there was reason for optimism. The FAO reported that food supplies exceeded demand, and that both energy and protein requirements were

32. THE U.N. WORLD FOOD CONFERENCE, REPORT OF THE WORLD FOOD CONFERENCE, (1974).

33. *Id.*

34. Universal Declaration on the Eradication of Hunger and Malnutrition, *supra* note 16, at 2 (connecting, explicitly, food insecurity to colonialism and announcing that "[s]ociety today already possesses sufficient resources, organizational ability and technology and hence the competence to achieve this objective").

35. FAO Council Res. 1/64, *World Food and Agriculture Situation: International Undertaking on World Food Security* (Nov. 1974), http://www.fao.org/docrep/meeting/007/F5340E/F5340E00.htm [https://perma.cc/7FTM-LD32].

36. *Id.* ¶ 46.

37. Henry Kissinger, U.S. Sec'y of State, U.S. Dep't of State, Address at The World Food Conference (Nov. 5, 1974), *in* DEP'T ST. BULL., Dec. 1974, at 829.

38. G.A. Res. 3348 (XXIX), World Food Conference, at 7 (Dec. 17, 1974).

39. H.R. Con. Res. 737, 94th Cong. (1976).

40. Report of the Preparatory Committee for the World Food Conference on its Third Session, E/Conf. 65/6 Annex X, Draft Declaration prepared by the Secretariat in Compliance with the request made by the Preparatory Committee at its Third Session; *see also*, FAO, *The State of Food and Agriculture 1974*, at 108 (1974) [hereinafter FAO, *1974*], http://www.fao.org/docrep/017/f3350e/f3350e.pdf [https://perma.cc/W6WX-DTQK] (indicating that 460 million people were undernourished in 1971–1973, but acknowledging that this number was likely to be an underestimate). In 1992, the FAO retroactively revised its calculations to estimate that 941 million had in fact been food insecure in the early 1970s. FAO, *The State of Food and Agriculture 1992*, at 21–22 (1992) [hereinafter FAO, *1992*], http://www.fao.org/3/a-t0656e.pdf [https://perma.cc/7PYL-GATN]. Since that time, FAO has continued to retroactively revise its estimates of food insecurity, making comparisons across time difficult. *See, e.g.*, Mark Carapparós, *Counting the Hungry*, N.Y. TIMES (Sept. 27, 2014), https://www.nytimes.com/2014/09/28/opinion/sunday/counting-the-hungry.html?mcubz=3 (describing the shifting baselines for success in global efforts at hunger eradication). For purposes of this analysis, the key point is that in 1974, global leaders *believed* the scale of the crisis they faced was that 500 million people were food insecure.

"well in excess of requirement."[41] Rather than a production issue, the FAO defined the problem as one of "far from equitable" distribution of that food.[42]

Two decades later, when representatives of 182 governments reconvened for the 1996 World Food Summit, the number of food insecure had increased to 949.5 million.[43] More than 200 million children were going to bed hungry.[44] This dramatic rise in food insecurity happened even though food production *increased* significantly, in both absolute terms and on a per capita basis. More than a decade after the World Food Conference deadline for eradicating food insecurity, the world produced much more food, but food security remained a vexing problem. Hunger alleviation had foundered by failing to address inequitable distribution.

In response, the assembled representatives at the World Food Summit took a dramatic step away from the ambitious hunger eradication goals they had embraced at the World Food Conference. Instead, the Rome Declaration that emerged from this meeting adopted a much more modest goal of halving the number of people suffering food insecurity by 2015.[45] Given that roughly a billion people were suffering food insecurity in 1996, success on that point would have brought that number down to roughly 500 million—a far cry from the World Food Conference goal of eradicating hunger. In two short decades, ambition and optimism had dwindled. Success was redefined away from eradicating food insecurity to tolerating numbers of food insecure people on par with those that in 1974 sparked the international institutional efforts for food security in the first place. Of course, population had increased significantly over those two decades. But so had food production. Even with the increased population, global food production was well in excess of the level necessary to not just feed, but overfeed every single human being on the planet. Just take a moment to contemplate the imbalance and inequity inherent in electing such a modest goal in the wake of those numbers. In a world awash with food, the "ambitious" 2015 goal, the one that was not met, would still

41. FAO, *1974*, *supra* note 40, at 104.

42. *Id.*

43. *Food Security Indicators*, FAO (Dec. 16, 2016) [hereinafter *Food Security Indicators*], http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/ [https://perma.cc/VCE4-SABZ]. *See also* FAO, *World Food Summit Technical Background Document 5* (1996) http://www.fao.org/docrep/003/w2612e/w2612e5a.htm [https://perma.cc/DS2H-PHSG] (indicating that the lion's share [841 million] of those suffering food insecurity were in developing countries); FAO, *The State of Food and Agriculture 1996*, at 272 (1996), http://www.fao.org/docrep/003/w1358e/w1358e00.htm [https://perma.cc/TFY2-9FTK].

44. *See* Boutros Boutros-Ghali, Secretary-General of the U.N., Statement at the World Food Summit (Nov. 13, 1996), *in* REPORT OF THE WORLD FOOD SUMMIT, Nov. 1996, http://www.fao.org/WFS/begin/speech/boutro-e.htm [https://perma.cc/5VGH-P2FK]; UNICEF, *The State of the World's Children 1998*, at 6 (1998), https://www.unicef.org/sowc/archive/ENGLISH/The%20State%20of%20the%20World's%20Children%201998.pdf [https://perma.cc/Z487-AEGJ]. Indeed, 11,000 children were dying each day as a result of malnutrition, a rate of one every eight seconds. Celestine Bohlen, *Rome Talks to Examine Aid to Hungry*, N.Y. TIMES (Nov. 13, 1996).

45. FAO, *Rome Declaration*, *supra* note 29.

have left the combined populations of the United States, Germany, France, and Poland[46] suffering from food insecurity.

A few years later, the 2000 Millennium Summit lowered the bar even further. Rather than striving for eliminating hunger, or for halving the *number* of people living with food insecurity, the Millennium Development Goals instead proposed halving the *percentage* of people suffering from food insecurity by 2015.[47] Given that population was expected to rise to 7.2 billion in 2015, and that in 2000, 15% of the world's population (924 million people)[48] were food insecure, the Millennium Development Goal defined success as *only* 576 million people suffering food insecurity.[49] Thus, the new goal left more people suffering food insecurity than the number that in 1974 had been deemed a global crisis, and only marginally improved on the FAO's 1999 projections that, under a "business as usual," scenario 600 million people would suffer food insecurity in 2015.[50] What makes this goal particularly inequitable, is that when the global community adopted it in 2000, world food production (2721 kcal/person/day) was already enough to provide adequate nutrition to every person on the planet.[51]

Food production continued to increase more rapidly than population. In 2015, the endpoint for both the World Food Summit and the Millennium Development Goals, world food production amounted to 123% of global demand.[52] Nevertheless, the global community was only able to declare partial success in reaching the less ambitious Millennium Development Goals,[53] and fell far short of meeting the World Food Summit targets.[54] The FAO report summarizing progress toward these goals took stock of both successes and failures, but characterized the

46. *World's 50 Most Populous Countries: 2015*, INFOPLEASE (July 2016), http://www.infoplease.com/world/statistics/most-populous-countries.html [https://perma.cc/FGX2-33Q2].

47. *Millennium Goals*, UNITED NATIONS, *supra* note 28 (proposing, in Target 1.C, to reduce by half the proportion of people who suffer from hunger by 2015). This goal used the 1990–1992 years as a baseline for the number of hungry people.

48. These figures represent a three-year average from 1999–2001. *Suite of Food Security Indicators*, FAO (Feb. 9, 2016), http://www.fao.org/faostat/en/#data/FS [https://perma.cc/BH3R-33MF].

49. FAO, ECON. AND SOCIAL DEP'T, THE STATE OF FOOD INSECURITY IN THE WORLD: 2005, at 6 (2005) ftp://ftp.fao.org/docrep/fao/008/a0200e/a0200e.pdf.

50. FAO, *The State of Food Insecurity in the World 1999*, at 4 (1999), http://www.fao.org/NEWS/1999/img/SOFI99-E.pdf [https://perma.cc/P4SW-LSPN].

51. *Food Security Indicators*, *supra* note 43. FAO provides this food availability data in three year increments: the dietary energy supply for 1999–2001 was 2717 kcal/person/day, and for 2000–2002 was 2721 kcal/person/day. According to FAOSTATs, global production was 116% of demand. *Suite of Food Security Indicators*, *supra* note 48.

52. *Food Security Indicators*, *supra* note 43, at v1.1, http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/ [https://perma.cc/4N2Y-XDDF].

53. *Id.* (noting that 72 of the 129 countries monitored under the Millennium Development Goals had reached the target of halving the percentage of hungry people, a record the FAO characterized as "almost" meeting the Millennium Development Goal).

54. *Id.* (noting that 29 of 129 countries reached the "more ambitious" World Food Summit goals).

lingering food insecurity as "unacceptable."[55] It noted the importance of social protection policies for achieving food security.[56]

In designing a plan forward, the 2016 Sustainable Development Summit turned away from the 1996 World Food Summit's incremental approach to food security, an approach that had built in specified levels of persistent undernourishment. Instead, by adopting the Sustainable Development Goals, the United Nation's 193 member states committed themselves to "end hunger, achieve food security and improve nutrition" by 2030.[57] This more ambitious goal was actually a return to the commitment embraced by the 1974 Universal Declaration on the Eradication of Hunger and Malnutrition.[58] To achieve this Sustainable Development Goal, the United Nations adopted the *Zero Hunger Challenge*,[59] which calls for actualizing the right to food,[60] and for transforming the global food system. It identifies five integrated steps necessary for achieving this goal: (1) making all food systems sustainable; (2) ending rural poverty; (3) adapting food systems to eliminate waste and loss; (4) ensuring access to healthy and adequate diets for all people, all year round; and (5) ending malnutrition in all its forms.[61]

B. Will More Food Help?

As we look forward to 2050, global population is expected to reach 9.7 billion people[62]—a staggering 2 billion more mouths to feed. Despite the *Zero Hunger Challenge*'s emphasis on structural inequality, far too much of the public rhetoric still focuses on increasing food production to satisfy this burgeoning population. It makes intuitive sense that the solution to hunger rests in producing more food, but it simply is not the case.

We already produce enough food to feed every man, woman, and child on the planet,[63] as well as those expected over the next decades.[64] Food production has

55. FAO, THE STATE OF FOOD INSECURITY, *supra* note 3, at 8.

56. *Id.* at 10, 18.

57. U.N. Dep't of Econ. & Soc. Aff., *SDG 2: End Hunger, Achieve Food Security and Improve Nutrition and Promote Sustainable Agriculture* (Dec. 1, 2014), https://sustainabledevelopment.un.org/?page=view&nr=164&type=230&menu=2059 [https://perma.cc/5XNW-MYYT].

58. Universal Declaration on the Eradication of Hunger and Malnutrition, *supra* note 16.

59. U.N. DEP'T OF ECON. & SOC. AFF., ZERO HUNGER CHALLENGE (June 15, 2016), http://www.un.org/en/zerohunger/pdfs/ZHC%20-%20Pathways%20to%20Zero%20Hunger.pdf [https://perma.cc/8RD3-7QHN].

60. *Id.* at 3 ("The Zero Hunger Challenge is guided by a set of core principles that are grounded in . . . the right of everyone to have access to safe and nutritious food, consistent with the right to adequate food and the fundamental right of everyone to be free from hunger.").

61. *Id.* at 2.

62. *World Population Projected to Reach 9.7 Billion by 2050*, U.N. DEP'T OF ECON. & SOC. AFF. (July 29, 2015), http://www.un.org/en/development/desa/news/population/2015-report.html [https://perma.cc/R4WX-KDW5].

63. FAO, STATISTICAL POCKETBOOK, *supra* note 7, at 16 (providing, in chart 24, that there was an average of approximately 122% production of the necessary dietary energy supply for the world in 2015).

64. *Id.* at 24 fig.42. Therein, the FAO states that global food production was approximately 2900 kcal/person/day in 2015, more than the USDA daily recommendations for even those with

outpaced population growth for quite some time now. We just do not use that food to feed the people who are food insecure. Instead, an increasing percentage of grains that would otherwise be available for human consumption has been diverted into livestock production[65] and biofuels.[66] Biofuels currently claim 40% of the U.S. corn crop, and 23% of the soy crop. Animal feed takes a comparable share. That leaves only 20% of the corn and 50% of the soy available for human consumption. There is no reason to think that increased production alone will change this dynamic.

The United States alone raised nearly 90 million cattle for food in 2015,[67] resulting in production of 23.69 billion pounds of beef.[68] Across the globe there were roughly 1.5 billion cattle, 19.6 billion chicken, and 977 million pigs.[69] It takes 2 and 4 pounds of grain to produce one pound of chicken,[70] 3.5 pounds of grain to produce one pound of pork,[71] and 6 pounds of grain to produce one pound of

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the highest caloric demands. *Estimated Calorie Needs Per Day by Age, Gender, and Physical Activity Level*, USDA [hereinafter, *Estimated Calorie Needed Table*], https://www.cnpp.usda.gov/sites/default/files/usda_food_patterns/EstimatedCalorieNeedsPerDayTable.pdf [https://perma.cc/SFT4-GK8D] (last visited Feb. 9, 2017). With a global population of roughly 7.3 billion people, that means current production is 2.117 trillion kcal/day. *See* Robert Schlesinger, *The 2015 U.S. and World Populations,* U.S. NEWS (Dec. 31, 2014, 12:00 P.M.), http://www.usnews.com/opinion/blogs/robert-schlesinger/2014/12/31/us-population-2015-320-million-and-world-population-72-billion [https://perma.cc/JC8M-DG5A]. Divide that by 9.6 billion or 10 billion people, and the resulting production is 2205.76 or 2117 kcal/person/day—enough to meet the nutritional needs of a global population that range from 1000 kcal/person/day per day for young children up to 2800 kcal/person/day for the most active adult males. *See Estimated Calorie Needed Table*, *supra.*

65. *See* FAO, WORLD LIVESTOCK 2011: LIVESTOCK IN FOOD SECURITY 78, 83 (2011), http://www.fao.org/docrep/014/i2373e/i2373e.pdf [https://perma.cc/UDU5-ZYD2]. By 2050, demand for meat and dairy products is expected to rise by 58% and 63%, respectively. This growth is driven not only by population increase but also by changing consumption patterns linked to increasing wealth. *See id.* at 79 tbl.15.

66. *U.S. Bioenergy Statistics*, USDA, ECON. RES. SERV. tbls.5, 6, http://www.ers.usda.gov/data-products/us-bioenergy-statistics.aspx [https://perma.cc/2U9P-MKHA] (last updated Aug. 8, 2017). In 2015, approximately 40% of the corn and 23% of the soy produced in the United States were used to produce ethanol. *Id.* Another 45% of the corn crop went into animal feed. James Conca, *It's Final—Corn Ethanol Is of No Use*, FORBES (Apr. 20, 2014), http://www.forbes.com/sites/jamesconca/2014/04/20/its-final-corn-ethanol-is-of-no-use/#7a1b0bc22ca2 [https://perma.cc/FX3V-45NH].

67. USDA, NAT'L AGRIC. STAT. SERV., AGRICULTURAL STATISTICS 2015, at VII-1 (2015), https://www.nass.usda.gov/Publications/Ag_Statistics/2015/Chapter07.pdf [https://perma.cc/U62A-2EGW].

68. *Beef Industry Statistics*, NAT'L CATTLEMEN'S ASS'N, http://www.beefusa.org/beefindustrystatistics.aspx [https://perma.cc/5D2S-TCRY] (last visited Nov. 11, 2016).

69. Brad Plumer, *These Maps Show Where All the World's Cattle, Chickens, and Pigs Are*, VOX (Feb. 5, 2015), http://www.vox.com/2014/6/20/5825826/these-maps-show-where-all-the-worlds-cattle-chickens-and-pigs-live [https://perma.cc/E3MA-6LQQ] (providing that the earth had about 19.6 billion chickens, 1.4 billion cattle, and 980 million pigs in 2015). Populations of sheep and goats raised for food are much smaller, with farmers raising just over a million each in 2013 (the latest data available at FAO, STATISTICAL POCKETBOOK, *supra* note 7, at 30 tbl.5).

70. *Feed Conversion Ratio*, U.K. POULTRY SECTOR, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/448965/ghgindicator-7poultrysector-29jul15.pdf [https://perma.cc/E4P4-26JQ] (last visited Nov. 11, 2016).

71. Dan W. Shrike, *Beef Cattle Feed Efficiency*, UNIV. OF ILL. AT URBANA-CHAMPAIGN 3 (2013), http://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1027&context=driftlessconference.

beef.[72] And, that is not even to consider the loss of habitat, generation of wastes (including greenhouse gases), and water resources invested in meat production.[73] As a result, projections for the amount of food needed from agriculture in the future diverge widely depending on what kinds of assumptions about meat consumption are made.

In addition to food diverted into biofuels or animal feed, an astonishing amount of food is simply wasted. According to the FAO, roughly one-third of all food produced for consumption worldwide, 1.3 billion tons, gets lost[74] or wasted[75] rather than consumed.[76] When this figure is converted to calories, this means that about one in four calories intended for consumption is never actually eaten. Not only is the food itself wasted, but so are all of the resources invested in producing that food, and the greenhouse gas emissions generated by producing it. The causes of food loss and waste range from inadequate refrigeration and lack of processing facilities in developing countries to rigid appearance standards and consumer waste in wealthier countries.[77] This makes reducing food waste an obvious target for attempts to reduce both food insecurity and agricultural impact on the global environment.

The FAO reports that in 2014 (the most recent data available), global agriculture produced enough food to meet 123% of demand.[78] In other words, farmers in 2014 produced enough food to feed all 7.3 billion people currently on earth. Yet, that same year, nearly 11% of the human population was undernourished.[79] This disconnect between available food supplies and levels of food insecurity is a function of poverty and inequality. For example, the United States, which is consistently rated a food secure country[80] and is home to a population that routinely throws away roughly 40% of all available food,[81] pegs its

72. *Id.*

73. For example, it takes about 1500 liters of water to produce a kilogram of wheat and ten times that much (about 16,000 liters) to produce a kilogram of beef. Charles Ebikeme, *Water World*, SCITABLE: EYES ON ENVIRONMENT (July 25, 2013), http://www.nature.com/scitable/blog/eyes-on-environment/water_world [https://perma.cc/PWK4-CS3F].

74. "Food loss" refers to the decrease in edible food mass throughout the supply chain. It can refer to losses during production, postharvest or processing. FAO, GLOBAL FOOD LOSSES AND FOOD WASTE—EXTENT, CAUSES AND PREVENTION 2 (2011) [hereinafter FAO, GLOBAL FOOD LOSSES], http://www.fao.org/docrep/014/mb060e/mb060e00.pdf [https://perma.cc/4LGV-UXED].

75. "Food waste" refers to the behavior and choices of retailers and consumers. *Id.*

76. FAO, FOOD LOSS AND FOOD WASTE (2016), http://www.fao.org/food-loss-and-food-waste/en/ [https://perma.cc/623C-DKGK].

77. FAO, GLOBAL FOOD LOSSES, *supra* note 74, at 11–14.

78. FAO, STATISTICAL POCKETBOOK, *supra* note 7, at 48.

79. *Id.*

80. *See id.* at 15 fig.6.

81. *See* JEAN C. BUZBY, HODAN F. WELLS, & JEFFREY HYMAN, USDA, ECON. RESEARCH SERV., EIB-121, THE ESTIMATED AMOUNT, VALUE, AND CALORIES OF POSTHARVEST FOOD LOSSES AT THE RETAIL AND CONSUMER LEVELS IN THE UNITED STATES 18 (2014), https://www.ers.usda.gov/webdocs/publications/43833/43680_eib121.pdf [https://perma.cc/QH4G-C8GH]. For perspective, that amounts to 1,249 calories of food wasted per day for every man, woman, and child in the United States. *Id.*

domestic food insecurity rate as 14%.[82] That means one in seven Americans suffers food insecurity,[83] while the other six out of seven each throws away more than 1250 calories worth of food per day.[84] If even a small percentage of that wasted food were diverted to feeding the food insecure, the problem could easily be resolved. What is lacking is not the food but some kind of institutional or social mechanism for accomplishing this diversion.

The United States is not alone in tolerating hunger in the face of food abundance. Nor is this a new phenomenon. Indeed, even as it abandoned the goal of eradicating food insecurity, the 1996 World Food Summit Plan of Action specifically noted that "[t]he 5.8 billion people in the world today have, on average, 15 percent more food per person than the global population of 4 billion people had 20 years ago."[85] It is the phrase "on average" that causes all the problems because food is not distributed on average—there is no equal share allotted on a per capita basis. National-level food security does not mean that all individuals living within that state will be food secure.[86]

C. What the Past Teaches Us

More than three decades ago, Amartya Sen convincingly demonstrated that food insecurity is a problem of food distribution not a food production problem.[87] Even in the midst of famine, farmers have produced enough food. For example, during the nineteenth century Irish Potato Famine, Ireland was *exporting* food to various other English colonies.[88] There was a crisis with the potato crop, and the British landlords prevented reallocation of other crops to fill the gap. During the Great Indian Famine of 1876–78, grain merchants exported record quantities of grain *out* of India, rather than diverting the grain to relieve local starvation.[89] They did so under the strict instructions of the British Viceroy. There were definitely weather problems that affected the crops, but even at the time, it was clear that this famine, and the 1899–1902 famine that followed, were not caused by food

82. ALISHA COLEMAN-JENSEN, MATTHEW P. RABBITT, CHRISTIAN GREGORY & ANITA SINGH, U.S. DEP'T OF AGRIC., ERR-194, HOUSEHOLD FOOD SECURITY IN THE UNITED STATES IN 2014, at v (2015), https://www.ers.usda.gov/webdocs/publications/45425/53740_err194.pdf?v=42515 [https://perma.cc/KK2Y-4VG2].

83. *See id.*

84. *Cf.* BUZBY ET AL., *supra* note 81.

85. FAO, *Rome Declaration*, *supra* note 29, ¶ 5.

86. *See* Josef Schmidhuber & Francesco N. Tubiello, *Global Food Security Under Climate Change*, 104 PROC. NAT'L ACAD. SCI. 19703, 19703 (2007) (noting that "national self-sufficiency is neither necessary nor sufficient to guarantee food security at the individual level").

87. SEN, *supra* note 9, at 1–7.

88. CECIL WOODHAM-SMITH, THE GREAT HUNGER: IRELAND 1845–1849, at 75–77 (1962).

89. *See, e.g.*, B.M. BHATIA, FAMINES IN INDIA: A STUDY IN SOME ASPECTS OF THE ECONOMIC HISTORY OF INDIA (1860–1945), at 37–39, 137–38 (1963) (showing that grain exports more than doubled during the famine years, and tripled during the worst years). British colonial rulers' twin insistence on noninterference in grain export markets and a refusal to provide relief to those unable to purchase food combined to create crisis after crisis.

shortages.[90] There was enough food available to feed all the people.[91] It was just exported instead. These famines were a manifestation of the colonial political structure.[92]

The (British) Famine Commissions instituted to investigate these famines were clear in their understanding that the massive Indian death toll was not due to a lack of food availability.[93] Thus, the official Famine Commission investigation of the 1899–1902 famine emphasized that "supplies of food were at all times sufficient, and it cannot be too frequently repeated that severe privation was chiefly due to the dearth of employment in agriculture (arising from the drought)."[94] The Famine of 1873–74 was similarly deemed to be one of "high prices rather than of scarcity of food."[95]

These famines, which produced tens of millions of deaths,[96] were caused not by lack of food *per se*, but by the interactions between an agricultural crisis and a colonial political system that had other priorities. The real problem was that the hungry could not afford to eat, and their governments took no action to help. Indeed, famine has always been about distribution—about who has access to the food that is produced.[97] The Indian Famine Commission of 1878–80 underscored this point, when it approvingly noted the political calculation behind a decision not to provide food to famine victims:

> [T]he doctrine that in time of famine the poor are entitled to demand relief . . . would probably lead to the doctrine that they are entitled to such relief at all times, and thus the foundation would be laid of a system of

90. J. RAMSAY MACDONALD, THE AWAKENING OF INDIA 163 (1910).

91. BHATIA, supra note 89, at 8–10 (quoting report contemporaneous with the famine that acknowledged that food was "always purchaseable (sic) in the market though at high and in some remote places at excessively high prices."); MACDONALD, *supra* note 90, at 161–64; LALA LAJPAT RAI, ENGLAND'S DEBT TO INDIA 274–81 (Hindustan Books 2012) (1917).

92. MIKE DAVIS, LATE VICTORIAN HOLOCAUSTS: EL NIÑO FAMINES AND THE MAKING OF THE THIRD WORLD 156–64 (2001) (reporting contemporaneous accounts of the famine). *See generally* ROMESH C. DUTT, OPEN LETTERS TO LORD CURZON ON FAMINES AND LAND ASSESSMENTS IN INDIA vii-xvi (1900) (making the case that colonial over-taxation of Indian farmers caused mass starvation).

93. RAI, *supra* note 91, at 294–305.

94. GOV'T OF INDIA, REPORT ON THE FAMINE IN THE BOMBAY PRESIDENCY 1899-1902 para. 4 (1903), http://dspace.gipe.ac.in/xmlui/handle/10973/38215 [https://perma.cc/KC2U-3CYH].

95. *See, e.g.*, ARDASEER DINSHAWJI CHINOY, CENSUS OF INDIA, 1901 paras. 75–76 (1902), http://dspace.gipe.ac.in/xmlui/handle/10973/18819 [https://perma.cc/W2JS-GQAF].

96. DAVIS, *supra* note 92, at 7 tbl.P1 (citing an estimate by The Lancet of 19 million deaths in the 1896–1902 famine).

97. SEN, *supra* note 9. *But see* Amrita Rangasami, *Failure of Exchange Entitlement's Theory of Famine: A Response*, 20 ECON. & POL. WKLY., Oct. 12, 1985, at 179 (critiquing Sen's theory as insufficiently attuned to social forces).

> general poor relief, which we cannot contemplate without serious apprehension.[98]

Amartya Sen summed it up clearly, writing that "[s]tarvation is the characteristic of some people not *having* enough food to eat. It is not the characteristic of there *being* not enough food to eat."[99]

A century later, that fundamental dynamic has not changed. For example, in the mid-2000s food production exceeded the population's nutritional requirements across Latin America and the Caribbean by over 40%.[100] Nevertheless, some 45 million people still did not have access to sufficient food, and 4 million children under the age of five were underweight.[101] Yield alone was not enough. In 2008, at the height of a global economic meltdown, food insecurity rates shot up alarmingly, to roughly 1 billion.[102] Yet, even as more people than ever before in history were hungry, global agriculture produced enough food to provide every person on earth with 2811 calories of food per day,[103] a figure well in excess of the levels necessary to avoid undernourishment. Every major region of the globe, including the least-developed and low-income-food deficit countries, had food enough to supply more than the estimated average daily energy requirements to all inhabitants.[104] Summing up the situation, U.S. Secretary of State Hillary Clinton commented that it was not a question of whether we *could* solve hunger but whether we *would.*[105]

D. What Does Climate Change Do to Food Production?

Even granting that past (and current) food insecurity is not a function of production, there are real questions about how climate change will affect agriculture going forward. Over the next three decades, as human population is projected to

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98. GOV'T OF INDIA, REPORT OF THE INDIAN FAMINE COMMISSION: PART I. FAMINE RELIEF ¶ 181 (1880), https://archive.org/details/FamineCommission [https://perma.cc/2C3V-N6RU].

99. SEN, *supra* note 9, at 1.

100. *See* FAO, Minimum Dietary Energy Requirement, http://www.fao.org/ [https://perma.cc/DGT5-FQKD] (search "Minimum Dietary Energy Requirement" from the homepage) (showing average dietary energy supply in Latin American nations exceeded 1,900 kcal/person/day during the 2000s).

101. Rodrigo Martinez et al., *Food and Nutrition Insecurity in Latin America and the Caribbean*, at 7, U.N. Doc. LC/W.274 (Oct. 2009).

102. Oxfam, *A Billion Hungry People*, 127 Oxfam Briefing Paper (Jan. 2009), https://www.oxfamamerica.org/static/oa3/files/a-billion-hungry-people.pdf [https://perma.cc/C546-27AQ].

103. *Dietary Energy Supply Spreadsheet*, FAO, http://www.fao.org/ [https://perma.cc/DGT5-FQKD] (search "Dietary Energy Supply Spreadsheet" from the homepage).

104. *Average Dietary Energy Supply Adequacy Spreadsheet*, FAO, http://www.fao.org/ [https://perma.cc/DGT5-FQKD] (search "Average Dietary Energy Supply Adequacy Spreadsheet" from the homepage). However, fifteen states reported inadequate average daily energy supplies, with North Korea and Haiti at the bottom (with food supplies sufficient to meet only 88% of their average daily energy supply).

105. Clinton, *supra* note 1.

reach 9.6 billion, global mean temperature is expected to increase by nearly 2°C.[106] The attendant changes in the global climate will depress agricultural productivity, just as population hits a new peak. For this reason, the Asian Development Bank identified climate change as "the greatest threat to food security."[107]

More than twenty years ago, the 196 Parties to the United Nations Framework Convention on Climate Change (UNFCCC), committed themselves to stabilizing greenhouse gas concentrations in the atmosphere at a level that "would prevent anthropogenic interference with the climate system," while at the same time "ensur[ing] that food production is not threatened."[108] Yet in 2014, the Intergovernmental Panel on Climate Change (IPCC) stated with *high confidence* that climate change is already negatively affecting agriculture around the world.[109] The severity of these impacts is expected to increase during the course of this century. This is not merely a hypothetical, or a matter for future concern. The global plant-based agricultural system is already "being disrupted by climate change."[110]

In terms of how climate change will affect agriculture, we are in uncharted territory. There is growing evidence that increased temperatures and erratic weather are already depressing yield. How that will play out as temperatures continue to rise is unclear. Climate change affects atmospheric CO_2 levels, temperature and precipitation patterns, all of which impact agriculture. Because under laboratory conditions rising CO_2 levels have been shown to increase photosynthesis, there were some hopes that as atmospheric CO_2 levels climb, agricultural production might increase.[111] However, it is becoming increasingly clear that the yield drag from rising temperatures will overcome any boost from elevated CO_2 levels.[112]

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106. World Res. Inst. [WRI], *Creating a Sustainable Food Future: A Menu of Solutions to Sustainably Feed More Than 9 Billion People by 2050*, at 2, 12 (2013).

107. Asian Dev. Bank [ASD], *Food Security and Poverty in Asia and the Pacific*, at 21 (Apr. 2012).

108. United Nations Framework Convention on Climate Change art. 2, May 9, 1992, U.N. Doc. FCCC/INFORMAL/84.

109. John R. Porter et al., *Food Security and Food Production Systems*, *in* CLIMATE CHANGE 2014: IMPACTS, ADAPTATION, & VULNERABILITY. PART A: GLOBAL AND SECTORAL ASPECTS. CONTRIBUTION OF WORKING GROUP II TO THE FIFTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 485, 488 (C.B. Field et al. eds., 2014).

110. Elizabeth Grossman, *Climate Change Poses Serious Threats to Food Distribution,* EARTH ISLAND NETWORK (Mar. 4, 2015), http://www.earthisland.org/journal/index.php/elist/eListRead/climate_change_poses_serious_threats_to_food_distribution [https://perma.cc/4HGP-D8LM] (quoting New School Food Policy Professor Nevin Cohen); *see also* David Lobell, Wolfram Schlenker & Justin Costa-Roberts, *Climate Trends and Global Crop Production Since 1980*, 333 SCIENCE 616, 617–18 (2011); Shaobing Peng et al., *Rice Yields Decline with Higher Night Temperature from Global Warming*, 101 PROC. NAT'L ACAD. SCI. 9971, 9974 (2004).

111. Elizabeth A. Ainsworth & Stephen P. Long, *What Have We Learned from 15 Years of Free-air CO_2 Enrichment (FACE)? A Meta-Analytic Review of the Responses of Photosynthesis, Canopy Properties and Plant Production to Rising CO_2*, 165 NEW PHYTOLOGIST 351, 357–60 (2005) (showing that in the absence of climate change, crops respond positively to elevated CO_2 levels).

112. Caroline C. Ummenhoffer et al., *How Climate Change Affects Extremes in Maize and Wheat Yield in Two Cropping Regions*, 28 J. CLIMATE 4653, 4655 (2015); Lobell et al., *supra* note 110; Christopher J. Kucharik & Shawn P. Serbin, *Impacts of Recent Climate Change on Wisconsin Corn and Soybean Yield Trends*, 3 ENVTL. RES. LETTERS 1, 1–10 (2008).

As temperatures rise above 32°C (90°F), many widely grown crops experience heat stress, which negatively affects flowering, fruit set, and seed production.[113] Unfortunately, even under the most optimistic UNFCC projections, we can expect significantly more days above 32°C/90°F.[114] At higher emissions scenarios, most of July will exceed 32°C/90°F across the United States.[115] Because the U.S. heartland is one of the most agriculturally productive regions (producing 36% of the global corn crop,[116] and about 15% of global wheat exports),[117] repercussions from any climate-related decreases in the United States' production would be felt widely. And, the United States is not alone in feeling this negative effect of climate change. Experts warn that reduced global yields are likely under all UNFCC scenarios.[118]

At the same time that increased temperatures depress crop yield, climate change also adversely affects growing conditions by producing more extreme precipitation events. Extreme weather is already delaying spring plantings, flooding fields (and destroying standing crops),[119] and increasing run off. Somewhat paradoxically, in conjunction with more extreme precipitation, droughts will also become more common. Together, the twin challenges of drought and flood will negatively, albeit unpredictably, affect yield.

These climate-induced production decreases could not come at a worse time—not only will population increase by 2 billion, but because of changing consumption patterns, resource use is projected to triple.[120] The combined impact of climate, population, and consumption will threaten planetary boundaries[121] and

113. *See* David Lobell, *Nonlinear Heat Effects on African Maize as Evidenced by Historical Yield Trials*, 1 NATURE CLIMATE CHANGE 42 (2011); Wolfram Schlenker & Michael J. Roberts, *Nonlinear Temperature Effects Indicate Severe Damages to U.S. Crop Yields Under Climate Change*, 106 PNAS 15594, 15594 (2009); *see also* Zhongwen W. Rang et al., *Effects of High Temperature and Water Stress on Pollen Germination Spikelet Fertility in Rice*, 70 ENVTL. & EXPERIMENTAL BOTANY 58 (2011).

114. JERRY HATFIELD ET AL., CLIMATE CHANGE IMPACTS IN THE UNITED STATES: THE THIRD NATIONAL CLIMATE ASSESSMENT 155 (U.S. Gov't Printing Office 2014), https://data.globalchange.gov/file/86b13591-508e-4257-abf0-0e3ef7ca2454 [https://perma.cc/7HL6-49F9].

115. *Id.* at 337.

116. *See* U.S. DEP'T OF AGRIC., FOREIGN AGRICULTURAL SERVICE, GRAIN: WORLD MARKETS AND TRADE 3 (Oct. 2016), http://www.fas.usda.gov/data/grain-world-markets-and-trade [https://perma.cc/4RDV-W6XL].

117. *Id.* at 6.

118. *See generally* Martin L. Parry et al., *Effects of Climate Change on Global Food Production under SRES Emissions and Socio-Economic Scenarios*, 14 GLOBAL ENVTL. CHANGE 53, 66 (2004).

119. *See* Assaf Anyamba et al., *Recent Weather Extremes and Impacts on Agricultural Production and Vector-Borne Disease Outbreak Patterns*, 9 PLoS ONE 1, 7 (2014), http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0092538 [https://perma.cc/KBS8-G689].

120. United Nations Env't Programme, *Decoupling Natural Resource Use and Environmental Impacts from Economic Growth*, at xi (UNEP 2011), http://wedocs.unep.org/handle/20.500.11822/9816 [https://perma.cc/T7PD-6YAR].

121. The nine planetary boundaries are the stratospheric ozone layer; biodiversity; chemical dispersion; climate change; ocean acidification; freshwater consumption and the global hydrological cycle; land system change; nitrogen and phosphorous inputs to the biosphere and oceans; and atmospheric aerosol loading. For more detail, see Johan Rockström et al., *Planetary*

global food security.[122] Agriculture must meet the nutritional demands of a growing population increasingly interested in consuming resource-intensive foods like meats, while simultaneously providing economic opportunities for hundreds of millions of rural poor farmers currently mired in desperate poverty. And, all this must happen while agricultural practices simultaneously reduce their ecological footprint to decrease ecosystem degradation and greenhouse gas emissions.

The Intergovernmental Panel on Climate Change warns that climate change is already compromising global agriculture, and some experts view a potential breakdown of the food system as among climate change's biggest threats.[123] The problems climate change poses for agricultural production are clear, but the severity of their impact is less certain. It all hinges on the ability of agricultural producers to adapt to changing growing conditions. Facing a potentially catastrophic climate shift, agricultural policymakers often assume that technology will save the day. Official reports blithely assert (typically in the passive voice) that new crops *will be developed* to meet these climate change-induced drought and heat challenges.[124] The assumption is that new technologies can and will be materialize in response to identified needs. It is at this point that genetically engineered crops come in to the story.

II. ENTER GENETICALLY ENGINEERED CROPS

Genetically engineered crops are the latest iteration of an approach to agriculture that dates back to the Green Revolution of the mid-twentieth century.[125] During the Green Revolution, agronomists used selective breeding techniques to transform global agriculture into a resource-intensive, technology-driven industry.[126] Led by plant pathologist Norman Borlaug and funded by the Rockefeller Foundation, the Green Revolution emerged from efforts to develop

Boundaries: Exploring the Safe Operating Space for Humanity, 14 ECOLOGY & SOC. 32 (2009). Loss of biodiversity from habitat destruction associated with all three of these phenomena has already become so extreme that researchers are calling it the "sixth mass extinction." *See generally* Gerardo Ceballos et al., *Accelerated Modern Human-Induced Species Losses: Entering the Sixth Mass Extinction*, 1 SCI. ADV. 1, 4 (2015), http://advances.sciencemag.org/content/1/5/e1400253.full [https://perma.cc/ATN7-PFBA].

122. *See generally* David Tilman et al., *Global Food Demand and the Sustainable Intensification of Agriculture*, 108 PROC. NAT'L ACAD. SCI. U.S. 20260, 20264 (2011).

123. Tim Folger, *The Next Green Revolution,* NATIONAL GEOGRAPHIC 1, 2, http://www.nationalgeographic.com/foodfeatures/green-revolution [https://perma.cc/GT27-6NH4] (last visited Nov. 4, 2016) (quoting Michael Oppenheimer, a lead author of the IPCC report).

124. *See generally* C.L. Walthall et al., *Climate Change and Agriculture in the United States: Effects and Adaptation*, USDA-ARS Technical Bulletin No. 1935, at 13 (2013) ("[D]eveloping drought and heat resistant crops will improve the ability of farmers to cope with increasing frequency of temperature and precipitation variability . . . .").

125. Indeed, these crops are widely referred to, by both critics and supporters as the next green revolution. *See* Folger, *supra* note 123 (quoting Robert Fraley, Monsanto's CTO, for the proposition that "the next green revolution will supercharge the tools of the old one").

126. *Id.* at 2, 5.

new varieties of corn, wheat, and rice.[127] Scientific breeding techniques allowed researchers to select for plants that produced more grain on shorter stalks. With more of energy diverted into seed production and less into plant growth, per plant grain yields were dramatically higher. The Green Revolution was hailed as an unalloyed success, winning Norman Borlaug a Nobel Peace Prize[128] and the epithet "the man who saved a billion lives."[129] The Rockefeller Foundation and the Eisenhower Administration heavily backed these new crops as a foreign policy tool, on the theory that "[w]here hunger goes, Communism follows."[130]

The yield gains from the new Green Revolution crops were dramatic,[131] and as Borlaug often noted, had an important ecological benefit—less land was converted to agriculture, thereby preserving ecosystems that might otherwise have been destroyed.[132] The Nobel Committee, and Borlaug himself expected that this increased yield would create new social structures to more equitably spread income and support rural communities, thereby ending cycles of grinding poverty.[133] Sadly, these expectations of social transformation lagged behind increases in yield. Expensive input requirements, like fertilizer and pesticides, together with seeds that must be purchased annually, meant that poorer farmers were often unable to participate in the gains from the Green Revolution. Many were pushed off their land, joining the millions of their fellow citizens unable to afford enough to eat.[134] Because these crops relied heavily on fertilizers, pesticides, and irrigation,[135] some

127. Lowell S. Hardin, *Meetings That Changed the World: Bellagio 1969: The Green Revolution*, NATURE 470–71 (September 25, 2008); John H. Perkins, *The Rockefeller Foundation and the Green Revolution 1941–1956*, 7 AGRICULTURE AND HUMAN VALUES 6 (1990).

128. In presenting the Nobel Peace Prize to Borlaug, the Chair of the Nobel committee proclaimed that, "more than any other single person of this age, he has helped provide bread for a hungry world." Aase Lionaes, Chairman, Nobel Comm., The Nobel Peace Prize 1970—Presentation Speech (Dec. 10, 1970), http://www.nobelprize.org/nobel_prizes/peace/laureates/1970/press.html [https://perma.cc/E9MQ-Z9TU].

129. Gregg Easterbrook, *Forgotten Benefactor of Humanity,* THE ATLANTIC, Jan. 1997, at 1–2; Vishnu V.J., *Why is Norman Borlaug Known as the Man Who Saved a Billion Lives?* QUORA (Aug. 10, 2014), https://www.quora.com/Why-is-Norman-Borlaug-known-as-The-Man-Who-Saved-A-Billion-Lives.

130. David Rieff, *Where Hunger Goes: On the Green Revolution,* THE NATION, Feb. 17, 2011, http://www.thenation.com/article/158676/where-hunger-goes-green-revolution [https://perma.cc/763Q-UAJJ].

131. Raj Patel, *The Long Green Revolution*, 40 J. PEASANT STUD. 6 (2013) (citing statistics and sources).

132. *See generally* Lionaes, *supra* note 128, at 2.

133. *Id.*

134. *See generally* NICK CULLATHER, THE HUNGRY WORLD 70, 128, 160 (2010).

135. "Between 1970 and 1990, fertilizer applications in developing countries shot up by 360 percent while pesticide use increased by 7% to 8% per year. The amount of land under irrigation increased by one-third. The gains in production were dramatic," but so was the social and economic toll these production methods created. FOOD & AGRIC. ORG. OF THE U.N., *Towards a Green Revolution*, http://www.fao.org/docrep/x0262e/x0262e06.htm [https://perma.cc/2M4A-Z7XE] (last visited Nov. 11, 2016).

of their environmental and social impacts were devastating.[136] Pesticide use skyrocketed.[137] Demands for irrigation meant that water was pumped water at unsustainable rates, depleting aquifers, and salinizing fields. The Green Revolution's reliance on irrigation, chemical fertilizers, and pesticides laid the groundwork for widespread ecological and social damage.[138]

Yet, famines, even devastating Indian famines, were not only, or even predominantly about a failure of food production. They were about a lack of access to food. The Green Revolution's focus on technology produced impressive yield gains, but was not responsive to that core problem of access. Even as harvests increased, the Green Revolution laid no foundation for more equitable distribution of the resulting food. Inequitable land distribution and insecure land tenure, coupled with subsidies that discriminated against small holders, meant that the Green Revolution's benefits often bypassed the very poor they were intended to help.[139] Indeed, as early as 1974, the FAO was cautioning that the Green Revolution disproportionately benefitted large farmers, and that agrarian reform was a necessary precondition for successful eradicating food insecurity.[140]

136. These advances arguably created an "agricultural treadmill" in which the relationship between technological innovations and increased productivity create a social trap for farmers. WILLARD COCHRANE, FARM PRICES: MYTH AND REALITY 85–103 (1958).

137. *See generally* FOOD & AGRIC. ORG. OF THE U.N., *supra* note 135.

138. Borlaug resisted the social and environmental complexity of his legacy, instead asserting that these were the elite concerns of Western environmentalists who had "never experienced the physical sensation of hunger." He claimed: "If they lived just one month amid the misery of the developing world, as I have for 50 years, they'd be crying out for tractors and fertilizer and irrigation canals and be outraged that fashionable elitists in wealthy nations were trying to deny them these things." Gregg Easterbrook, *The Man Who Diffused the Population Bomb,* WALL STREET J., Sept. 16, 2009, at 1.

139. Prahbhu L. Pingali, *Green Revolution: Impacts, Limits and the Path Ahead,* 109 PROC. NAT'L ACAD. SCI. U.S. 12302, 12304 (2012).

140. FAO, *1974*, *supra* note 40, at 97.

Fifty years later, the epicenters of the Green Revolution—Pakistan,[141] India,[142] Sri Lanka,[143] Bangladesh,[144] the Philippines,[145] and Indonesia[146] remain among the most undernourished nations in the world. Collectively these countries account for 300 of the 795 million undernourished,[147] with sky-high levels of childhood stunting. In fact, the FAO ranks all these countries as high food insecurity countries that made slow or no progress toward achieving the World Food Summit goals.[148] Overall, the region's collective share of the world's food insecure grew from 28.8% in 1990 to 35.4% in 2016.[149] Technology did not solve this problem.[150]

The fact that high levels of food insecurity remain is not, in itself, an indictment of the Green Revolution. Yet it does call into question some of the sweeping claims made on behalf of the Green Revolution. Pointing to famines that were presumably averted, and to projections about the cost of food *but for* the increased yields associated with Green Revolution technology,[151] advocates often paint a picture in which continued embrace of technological solutions to hunger are imperative. However, this framing relies on the assumption that the only alternative to Green Revolution's actual track record is a dystopian world where agricultural practices stagnate. But, these are not the only possible scenarios.

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141. Sixty percent of the population faces food insecurity, and 44% of children are chronically malnourished. World Food Program, Pakistan Country Brief (Sept. 2016), http://documents.wfp.org/stellent/groups/public/documents/ep/wfp272142.pdf?_ga=1.131469199.1842053973.1468854187 [https://perma.cc/NYC2-WK4N].

142. One-fourth of all the undernourished people in the world, and one-third of the stunted children live in India. *See generally 10 Facts About Food and Nutrition in India*, WORLD FOOD PROGRAMME (Jul. 26, 2016), http://www.wfp.org/stories/10-fact-about-food-and-nutrition-india [https://perma.cc/7A5F-KYHP]. Overall economic growth has failed to benefit the poor.

143. In Sri Lanka, a third of the population cannot afford a nutritious diet, and 23% are undernourished. World Food Programme, Sri Lanka Country Brief (Sept. 2016), http://documents.wfp.org/stellent/groups/public/documents/ep/wfp273248.pdf?_ga=1.131943183.1842053973.1468854187 [https://perma.cc/5YJ9-MH6H].

144. One quarter of the population suffers food insecurity, with 36% of children stunted. World Food Programme, Country Report: People's Republic of Bangladesh (Sept. 2016), http://www.wfp.org/countries/bangladesh [https://perma.cc/JYY9-THPF].

145. In the Philippines, 33% of children suffer from chronic malnutrition. World Food Programme, Philippines Country Brief (June 2016), http://documents.wfp.org/stellent/groups/public/documents/ep/wfp269064.pdf?_ga=1.230139676.1842053973.146885418 [https://perma.cc/2F89-A3RN].

146. In Indonesia, 37% of children—more than one in three—are stunted, with nearly 10 million children undernourished. *10 Facts About Malnutrition in Indonesia*, WORLD FOOD PROGRAMME (Dec. 22, 2014), https://www.wfp.org/stories/10-facts-about-malnutrition-indonesia [https://perma.cc/T3RY-8KBL].

147. *See generally* FAO, THE STATE OF FOOD INSECURITY, *supra* note 3, at 4, 46.

148. *See id.* at 45.

149. *Id.* at 10.

150. For a lay description of some of these reasons, see Daniel Pepper, *In India Farmers Find that Benefits of Pesticides and Herbicides May Come at a Tragically High Cost*, U.S. NEWS (July 7, 2008, 4:15 P.M.), http://www.usnews.com/news/world/articles/2008/07/07/the-toxic-consequences-of-the-green-revolution [https://perma.cc/3FJZ-3C4N].

151. Pingali, *supra* note 139, at 12303–08.

Among its key messages in 1974, the FAO asserted that social protection programs would be critical to progress in reducing undernourishment.[152] Had the international community taken this key message to heart, it might have made social protection the focus of its efforts, perhaps by taking steps to actualize the human right to food. Had food insecurity been recognized as primarily a distribution problem, rather than a production problem, the international community might not have invested so heavily in the technology-intensive, resource-guzzling production of Green Revolution crops. That same level of investment and attention might instead have been poured into building more equitable food distribution networks, and more effective public institutions—resulting in societies with greater access to food, with real educational opportunities for the rural poor, and where women farmers receive the same services as their male counterparts.

The overlooked possibility that the world might have instead chosen an alternative path toward ending undernourishment matters because the Green Revolution continues to shape policy decisions going forward. At the 1996 World Food Summit, U.S. Agriculture Secretary Dan Glickman espoused what was standard rhetoric in the halls of the U.S. government, that technology, and especially agricultural *bio*technology was essential to solving food insecurity.[153] Indeed, the focus of much of the conference was on increasing production to match a growing population, even though the FAO identified "a more equitable sharing of opportunities and entitlements to widen the access to adequate food" alongside "faster growth in available food supplies" as necessary for progress.[154] It was left to Pope John Paul II to decry the "intolerable" gap and profound global inequality that has the wealthy enjoying a glut of food while the poor starve,[155] and to Lester Brown to call out the emphasis on production as "playing into the game plan of the agribusiness industry, which, like any industry, thrives on increased demand."[156]

Twenty years later, not much has changed. Even though the FAO made it clear in 1996 that the production increases necessary to meet demand were "really very small,"[157] food security policy remains focused on increasing food supply rather than on a more equitable sharing of existing supplies. And biotechnology is still being touted as the key to solving the problem. Increasingly, backers of genetically engineered crops not only claim that these crops play a critical role in hunger alleviation, but also that climate change makes their adoption even more

152. *Id.*

153. Rone Tempest, *Ending Hunger Takes on New Complexity*, L.A. TIMES (Nov. 18, 1996).

154. *Assessment of Feasible Progress in Food Security*, FAO (1996), http://www.fao.org/docrep/003/w2612e/w2612e14a.htm [https://perma.cc/6V3Z-3YX9].

155. His Holiness Pope John Paul II, Special Message at the World Food Summit (Nov. 13, 1996), http://www.fao.org/WFS/begin/speech/papa-e.htm [https://perma.cc/9VGQ-SSBW].

156. Rick Nichols, *At Summit, Food Wasn't the Only Issue on the Table*, PHILLY.COM (Nov. 17, 1996), http://articles.philly.com/1996-11-17/news/25647718_1_world-hunger-food-shortages-world-food-summit [https://perma.cc/6G3E-Z7L9].

157. *Assessment of Feasible Progress in Food Security*, *supra* note 154, ¶ 2.12.

critical.[158] Before delving into the strengths and weaknesses of this claim, this Part will first provide a general introduction to genetically modified organisms.

A. What Are Genetically Modified Organisms?

Proponents of genetically modified organisms like to claim that humans have been genetically modifying plants (and animals) for millennia.[159] This superficially true statement has intuitive appeal. One need only compare corn stalk with its wild ancestor teosinte,[160] to see the incredible differences that human interventions have wrought on the plant. Advocates regularly point to beer brewing and bread rising as ancient forms of biotechnology.[161] As a rhetorical flourish, this is very effective. Who could be against beer? How could bread, the staff of life, be new or threatening? Opponents of the technology are thus Luddites, or part of a "pernicious anti-science movement."[162] However, attempts to fold modern biotechnology into the warm embrace of comfort foods deceive more than they inform. The problem is that these statements, which might be technically accurate depending on how expansively one defines biotechnology, capture only part of reality.

There is no question that human beings spent much of the Holocene Epoch modifying plants to enhance agronomically desirable traits and suppress less desirable ones. After Gregor Mendel's work with pea plants, insight into the mechanisms of genetic inheritance[163] allowed a more systematized form of selective breeding. As farmers gained experience with controlling pollination, their selection processes improved. Many fruits and vegetables were bred for appearance,[164]

158. Thomas Lee, *Monsanto Official: Climate Change Makes Genetic Crops More Urgent*, S.F. CHRON. (Mar. 3, 2015) (quoting Monsanto's Chief Technology Officer Robert Fraley).

159. Henry I. Miller and Frank E. Young, *"Old" Biotechnology and "New" Biotechnology: A Perspective*, *in* INTERAMERICAN STUDY GROUP OF THE NEW BIOTECHNOLOGY IN AGRICULTURE AND HEALTH, 12 (1988).

160. For a simple explanation of selective breeding, using teosinte as a case study, see *The Other Green (R)evolution* (Feb. 2007), http://evolution.berkeley.edu/evolibrary/news/070201_corn [https://perma.cc/K7MF-3XLD].

161. *See, e.g.*, Miller & Young, *supra* note 159, at 3; KESHAV TREHAN, BIOTECHNOLOGY 19–20 (1990); REV. FR. DR. S. IGNACIMUTHU, BASIC BIOTECHNOLOGY xi (2007); The Maureen & Mike Mansfield Ctr. for Ethics & Pub. Affairs, Introduction to the Biotechnology Debate, http://www.umt.edu/ethics/debating%20science%20program/odc/Biotechnology/Introduction/default.php [https://perma.cc/XJ23-KES2].

162. Miller & Young, *supra* note 159, at 12.

163. Gregor Mendel, *Experiments in Plant Hybridization* (1865), http://www.mendelweb.org/MWpaptoc.html [https://perma.cc/89KW-P4ZX]. Working with pea plants, Gregor Mendel conclusively demonstrated some key principles of genetic inheritance. His insights about the heritability and independent assortment of traits have become known as the Mendelian Laws. *See* DNA from the Beginning, COLD SPRINGS HARBOR LABORATORY, (2002), http://www.dnaftb.org/dnaftb/ [https://perma.cc/5FCK-9EPK]. For a good explanation of these principles in lay terms, see ROBIN MARANTZ HENIG, THE MONK IN THE GARDEN: THE LOST AND FOUND GENIUS OF GREGOR MENDEL, THE FATHER OF GENETICS (1999).

164. Nick Stockton, *The Genetic Quest to Make Strawberries Taste Great Again*, WIRED (June 2015), https://www.wired.com/2015/06/genetic-quest-make-strawberries-taste-great/ [https://perma.cc/9ZZ7-HAH2].

delayed ripening,[165] increased yield,[166] prolonged shelf life, and disease resistance.[167] Among the most commercially desirable were traits that facilitated long-distance shipping and post-harvest ripening. These new techniques made possible all kinds of hybrid crops tailored to specific market or culinary demands. Hybrids had the additional characteristic of not breeding true, thus farmers growing crops from hybrid seeds had to buy new seeds for each growing season. A business model was born.

Modern genetic engineering[168] is both a continuation and a break with this tradition. Where selective breeding can only enhance or suppress traits already present in a species,[169] genetic engineering frees plant breeding from this constraint. Through a process called transformation, researchers can transfer genes across all barriers of species, class, phylum, and kingdom.[170] These techniques literally recombine the genes themselves. Thus we have corn with bacteria genes,[171] goats with spider genes,[172] and bacteria with human genes.[173] As such, modern genetic engineering creates organisms that would not—and could not—exist without such intervention.[174]

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165. Amolkumar U. Solanke & P. Anada Kumar, *Phenotyping of Tomatoes*, *in* PHENOTYPING FOR PLANT BREEDING 193 (Siva Kumar Panguluri & Ashok Kumar, eds. 2013).

166. *Case Study: History of Selective Corn Breeding* 313, http://www.polytechpanthers.com/ourpages/auto/2014/11/21/55598352/SGI%207a%20History%20of%20Selective%20Corn%20Breeding.pdf [https://perma.cc/57VV-NS2M] (last visited on Nov. 19, 2016).

167. Stockton, *supra* note 164.

168. By modern genetic engineering, I mean plants (or animals) whose cells have been modified through the use of molecular genetic techniques that insert, remove, or silence one or more genes from an unrelated species in order to express or suppress specific traits. For a more detailed explanation, see Scott Reid, *Transgenic Crops: An Introduction and Resource Guide*, http://cls.casa.colostate.edu/transgeniccrops/faqpopup.html [https://perma.cc/4NUS-ETJM].

169. This constraint is actually less restrictive than it might seem on first glance. Variety is ubiquitous in nature. Plus, breeders have developed an array of mutagenic techniques to create new traits within a species. Some of these techniques, like irradiation, would probably shock anti-GMO advocates clinging to a more romantic notion of selective breeding as somehow "natural" or "organic."

170. Watson and Crick's 1953 discovery of the structure of DNA ushered in the era of modern biotechnology. *See* James Watson & Fredrick Crick, *A Structure for Deoxyribose Nucleic Acid*, 171 NATURE 737 (1953); *see also* J. Schell, *Transgenic Plants as Tools to Study the Molecular Organization of Plant Genes,* 237 SCIENCE 1176–83 (1987); Stanley Cohen et al., *Construction of Biologically Functional Bacterial Plasmids In Vitro*, 70 PROC. NAT. ACAD. SCI. 3240–44 (1973).

171. One of the most common genetic modifications commercially available are *Bt* corn and cotton, which have been genetically modified by insertion of genes from the soil bacteria *Bacillus thuringiensis*.

172. Miles O'Brien & Marsha Walton, *Got Silk? Researchers are Spinning Spiders Silk from Goats Milk,* NAT'L SCI. FOUND. (May 3, 2010), http://www.nsf.gov/news/special_reports/science_nation/spidersilk.jsp [https://perma.cc/GE5C-8E63].

173. Suzanne White Junod, *Celebrating a Milestone: FDA's Approval of First Genetically-Engineered Product*, FDA (Apr. 9, 2010), http://www.fda.gov/AboutFDA/WhatWeDo/History/ProductRegulation/SelectionsFromFDLIUpdateSeriesonFDAHistory/ucm081964.htm [https://perma.cc/L6H7-Q2BR] (describing the approval process for recombinant insulin production in E. coli).

174. NORMAN CARL ELLSTRAND, DANGEROUS LIAISONS? WHEN CULTIVATED PLANTS MATE WITH THEIR WILD RELATIVES 171–73 (2003).

Since the 1990s, companies like Monsanto have invested heavily in using genetic engineering to develop new crop varietals.[175] Despite soaring rhetoric about improved nutrition, drought resistance and other benefits from this new technology, two kinds of modification make up the overwhelming majority of genetically engineered crops to date: insect resistance and herbicide tolerance. These modifications address traits of interest to farmers, rather than consumers.[176] Crops engineered for insect resistance have been modified with bacterial genes that enable these plants to produce proteins toxic to many common Lepidoptera pests. Engineering for herbicide tolerance enables farmers to spray broad-spectrum weed killers on their crops without killing the crop plant, thereby simplifying herbicide-based weed management systems.

Widespread planting of these genetically engineered crops began in 1996 with the introduction of Monsanto's Roundup Ready Soybeans and *Bt* corn.[177] Since then, there have been 400 different approvals for genetically engineered crops around the world,[178] with transgenic corn, cotton, soybean, and canola varietals making up the lion share of approvals and plantings.[179] In the United States, genetically engineered crops are ubiquitous, making up the overwhelming majority

175. The other major so-called "life science companies" are DuPont, Syngenta, Bayer CropScience, and Dow. For a distribution of the permits and authorizations for releasing genetically engineered crops in the United States, see USDA, ECON. RESEARCH SERV., GENETICALLY ENGINEERED CROPS IN THE UNITED STATES 7 (2014).

176. Recently, both Canada and the United States have "approved" a genetically engineered apple modified to resist browning. Because of the unique structure of the U.S. regulatory system, the only "approval" the developer actually needed to obtain was a decision that the trees themselves did not pose a plant pest risk. *See* USDA, ANIMAL AND PLANT HEALTH INSPECTION SERV., DETERMINATIONS OF NON-REGULATED STATUS FOR OKANGAN SPECIALTY FRUIT'S GD742 AND GS784 APPLES (May 29, 2014), https://www.aphis.usda.gov/brs/aphisdocs/10_16101p_det.pdf [https://perma.cc/76C8-U8HR]. The FDA has interpreted its authority to preclude any requirement for pre-market food safety review or approval. Thus, the FDA's participation in the regulatory process was limited to reviewing the purveyor's conclusion that FDA approval was not required, in light of whatever information the purveyor voluntarily supplied, and issuing a letter indicating that it had "no further questions." *See* FDA Letter to Okanagan Specialty Fruit Inc., (Mar. 20, 2015), http://www.fda.gov/Food/FoodScienceResearch/GEPlants/Submissions/ucm436163.htm [https://perma.cc/CVR4-59AU].

177. *See* Monsanto, Company History, http://www.monsanto.com/whoweare/pages/monsanto-history.aspx [https://perma.cc/E3UB-DSLV]. Although most of the public discourse about genetically engineered plants has focused on commodity crops like maize, soybeans and cotton that have been genetically engineered either to be resistant to glyphosate or to endogenously produce various *Bacillus thuringensis* (Bt) toxins, the first transgenic food was actually a tomato. Calgene's Flavr Savr tomato hit the markets in 1994. However, the transgenic tomato was a commercial failure and has been withdrawn from the market. *See* G. Bruening & J. M. Lyons, *The Case of the FLAVR SAVR Tomato*, CAL. AGRIC., July 1, 2000, at 6, http://calag.ucanr.edu/Archive/?article=ca.v054n04p6 [https://perma.cc/8QXA-LUL9].

178. GM Approval Database Advanced Search for GM Crop Events Approved in Any Country, Commercial Trait, Developer, Type of Approval, ISAAA (International Service for the Acquisition of Agri-Biotech Applications) http://www.isaaa.org/gmapprovaldatabase/advsearch/default.asp?CropID=Any&TraitTypeID=Any&DeveloperID=Any&CountryID=Any&ApprovalTypeID=Any [https://perma.cc/7SLQ-P79W] (last visited Jan. 22, 2017).

179. *Id.*

of the soybean, corn, canola, cotton, and sugar beet crops.[180] Over 180 different genetically engineered crop lines have been approved for planting.[181]

Introduction of these crops paralleled an important development in global trade—the founding of the World Trade Organization (WTO).[182] One of the WTO's component agreement, The Agreement on Trade-Related Aspects of Intellectual Property[183] (the TRIPS agreement), for the first time required that states recognize patent or patent-like protections for plants and living organisms.[184] Selling seeds suddenly became a global industry, sparking a wave of consolidations.[185] Within two decades, there were six massive "life science" companies[186]—Monsanto, Syngenta, DuPont, Dow, Bayer, and BASF—that owned virtually every seed company. That number is in the process of shrinking even further because of recently announced mergers.[187]

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180. USDA, Econ. Research Serv., Adoption of Genetically Engineered Crops in the United States, Recent Trends in GE Adoption (2016), http://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us/recent-trends-in-ge-adoption.aspx [https://perma.cc/ZS6Y-XKJM] (noting that for the 2016 planting season, genetically modified varietals made up 94% of soybean crop, 93% of cotton, and 92% of corn). The figures for canola and sugar beets are comparable. *See* Catherine Greene, Seth J. Wechsler, Aaron Adalja & James Hanson. *Economic Issues in the Coexistence of Organic, Genetically Engineered (GE), and Non-GE Crops*, 11–12, EIB-149, U.S. DEP'T OF AGRIC., ECON. RESEARCH SERV. (Feb. 2016).

181. GM Crop Events Approved in the United States, ISAAA (International Service for the Acquisition of Agri-Biotech Applications), http://www.isaaa.org/gmapprovaldatabase/approvedeventsin/default.asp?CountryID=US&Country=United%20States%20of%20America [https://perma.cc/9FKH-CPEK] (last visited Jan. 22, 2017).

182. *See* WORLD TRADE ORG., https://www.wto.org [https://perma.cc/HWC9-DDP9] (last visited Jan. 22, 2017).

183. Agreement on Trade Related Aspects of Intellectual Property Rights, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, Legal Instruments-Results of the Uruguay Round, 1869 U.N.T.S. 299, 33 I.L.M. 1197 (1994).

184. *Id.* at art. 27(3)(b).

185. S*ee* Philip H. Howard, *Visualizing Consolidation in the Global Seed Industry: 1996–2008,* 1 SUSTAINABILITY 1266, 1267 (2009) (providing background on consolidation in the seed industry).

186. Civil society groups have coined the term "the Big Six" to refer to Dow, DuPont, Bayer, Monsanto, Syngenta and BASF. *See e.g.*, *Big Six Pesticide and GMO Corporations,* SourceWatch http://www.sourcewatch.org/index.php/%22Big_6%22_Pesticide_and_GMO_Corporations [https://perma.cc/6RXH-3MTY]; Hope Shand, *The Big Six: A Profile of Corporate Power in Seeds, Agrochemicals, and Biotech*, SeedSavers (2012) http://www.seedsavers.org/site/pdf/HeritageFarmCompanion_BigSix.pdf [https://perma.cc/LS7S-YLEC]. The term has been picked up by the popular press.

187. In December 2015, Dow and DuPont announced plans to merge. The combined company will control 40% of the U.S. corn-seed and soybean markets. *See* Drew Harwell, *Dow and DuPont, Two of America's Oldest Giants, to Merge in Jaw-Dropping Megadeal*, THE WASH. POST, Dec. 11, 2015, https://www.washingtonpost.com/news/business/wp/2015/12/11/dow-and-dupont-two-of-americas-oldest-giants-to-merge-in-job-dropping-megadeal/?utm_term=.62abde2ecb04 [https://perma.cc/D4Z2-CTYU]. This news was rapidly followed with the announcement that Bayer and Monsanto would also merge, News Release, *Bayer and Monsanto to Create a Global Leader in Agriculture* (Sept. 14, 2016), http://news.monsanto.com/Bayer-Monsanto-acquisition [https://perma.cc/2MYF-4V85], and that Syngenta would combine with Chinese chemical giant ChemChina. Syngenta International AG, ChemChina Cash Offer to Acquire Syngenta at a Value of Over US $43 Billion, CISION PR NEWSWIRE (Feb. 3, 2016). For an analysis of these mergers and their impact on food

The industry is even more consolidated than this might suggest because companies cross license their technologies. For example, in 2013, Monsanto entered cross-licensing agreements with Dow AgroSciences[188] and Bayer,[189] dramatically extending its reach. Indeed, 90% of the seeds currently marketed in the United States include a Monsanto patented trait,[190] giving the company inordinate market reach and making it the face of agricultural biotechnology in the public's eye. And Monsanto, along with its fellow agbiotech giants, has spent the past two decades deploying its patent rights to obtain market dominance through adhesion licenses. Farmers can no longer purchase seeds outright, but can only license seeds for a single growing season.[191] Among the license conditions are clauses barring seed saving[192] and limiting any warranties to use of associated brand-named herbicides.[193] The fact that Monsanto is also the major supplier of glyphosate,[194] the primary herbicide for which resistance has been bred, gives the company unprecedented control over agricultural markets.

B. Can Genetically Engineered Crops Solve Food Insecurity?

The challenge of resolving food insecurity as populations continue to grow is often framed as a binary choice: either farmers will have to glean higher yield from existing farmland under new less favorable conditions, or more land will be converted to agriculture.[195] The latter option has obvious negative environmental

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security, see Rebecca Bratspies, *Owning All the Seeds: Consolidation and Control in Ag-Biotech,* 47 ENVT'L L. 583 (2017).

188. Press Release, Monsanto, Dow AgroSciences, Monsanto Cross-License Advanced Corn Trait Technology, Designed to Provide Exceptional New Tools for Weed and Insect Management (April 11, 2013) http://news.monsanto.com/press-release/corporate/dow-agrosciences-monsanto-cross-license-advanced-corn-trait-technology-desig [https://perma.cc/W38S-PMLH].

189. Press Release, Monsanto, Bayer CropScience and Monsanto Enter into Cross-Licensing Agreements for Next-Generation and Enabling Technologies (April 16, 2013) http://news.monsanto.com/press-release/corporate/bayer-cropscience-and-monsanto-enter-cross-licensing-agreements-next-generat [https://perma.cc/Y99A-NRPN].

190. Letter from Diana L. Moss, President, Am. Antitrust Inst. et al., to Renata Hesse, Principal Deputy Assistant Attorney Gen., U.S. Dep't of Just. Antitrust Div. (May 31, 2016), http://www.antitrustinstitute.org/sites/default/files/AAI%20F%26WW%20NFU_Dow-Dupont_5.31.16_0.pdf [https://perma.cc/NK9F-AAKW] (citing Keith Fuglie, et al., *Rising Concentration in Agricultural Input Industries Influences New Farm Technologies*, 10 AMBER WAVES 4, 4 (Dec. 2012)). *See also,* Dan Mitchell, *Why Monsanto Always Wins*, FORTUNE (June 26, 2014), http://fortune.com/2014/06/26/monsanto-gmo-crops/ [https://perma.cc/2Y4B-6DP9] (noting that about 80% of U.S. corn and more than 90% of U.S. soybeans are grown with seeds containing Monsanto's patented seed traits).

191. *See, e.g.*, 2015 Monsanto Technology/Stewardship Agreement, Section 4(f), www.rispensseeds.com/Images/Monsanto.pdf [https://perma.cc/8FEW-EUPZ] (last visited Jan. 22, 2017).

192. *Id.* at 4(g).

193. *Id.* at 4(r).

194. Howard, *supra* note 185, at 1271.

195. RICHARD DOBBS ET. AL., MCKINSEY & CO., RESOURCE REVOLUTION: MEETING THE WORLD'S ENERGY FOOD AND WATER NEEDS 39 (2011); *Toughest Rome Food Summit Challenge Is Not How to End Famine—but Preserving Wildlife*, 18 Glob. Food Quarterly 1, 1 (1996) (asserting that "[i]t's not a question of whether 9 billion people will feed themselves . . . [but] how we protect the

ramifications, so policymakers focus on techniques designed to increase production on existing croplands.[196] With this framing, genetically engineered crops are touted as the clear answer. These claims about genetic engineering are built on a series of contested propositions. First, that undernourishment is a production problem susceptible to resolution by increased production. Second, that genetically engineered crops are necessary to increase yield. Third, that only through genetic engineering can we rapidly produce crop varietals able to thrive in the face of climate change. If these propositions were true: *if* undernourishment were a production problem, *and* genetically engineered crops increased yields, *and* these crops were the best way to ensure continued or increased production as growing conditions deteriorate, this would be virtually unanswerable moral claim. However, there is, as yet, no reason to believe that any of these claims are accurate.

1. Do Genetically Engineered Crops Actually Increase Food Production?

Monsanto and other promoters of agricultural biotechnology claim that genetically engineered crops must have a major role in attempts to solve undernourishment in the face of an increasing population.[197] Over the past few decades, genetically engineered crops have been touted as the answer to world hunger,[198] to pesticide overuse,[199] and to negative environmental impacts of agriculture more generally.[200] The assumption is that these crops are necessary to meet the food security needs of a burgeoning human population.[201] As former

world's wildlands . . . while they do it"). This claim echoes Green Revolution assertions that high-yield crops were all that prevented rampant deforestation, and wholesale conversion of land to farming. *See* Easterbrook, *supra* note 129.

196. For example, in its 1998 "Let the Harvest Begin" ad campaign, Monsanto characterized biotechnology as "one of tomorrow's tools in our hands today" and cautioned that "[s]lowing its acceptance is a luxury our hungry world cannot afford." *See* "Monsanto Fact Sheet on the Green Revolution Food Needs and Global Benefits" attachment to Letter from Dr. Donald B. Easum, Vice President, Global Business Access Ltd., http://www.ukabc.org/gaiam2_1.htm [https://perma.cc/54VZ-43A8].

197. *See* Mark Leibman et al., Comparative Analysis of Maize (Zea Mays) Crop Performance: Natural Variation, Incremental Improvements and Economic Impacts, 12 PLANT BIOTECH. J. 941 (2014).

198. *See, e.g.*, Press Release, Monsanto, Do GM Crops Increase Yields (Nov. 26, 2012) http://www.monsanto.com/newsviews/Pages/do-gm-crops-increase-yield.aspx [https://perma.cc/A2BP-S2BN]; Maggie Urry, *Genetic Products Row Worsens,* FIN. TIMES, June 20, 1997, at 4 (quoting former USDA Secretary Dan Glickman for the proposition that "[g]rowing pest-resistant crops would alleviate world hunger, reduce pesticide damage to the environment, and save rain forests from being cleared for food production").

199. Graham Brookes & Peter Barfoot, *GM Crops: Global Socio-Economic and Environmental Impacts*, PG Economics Ltd, UK, May 2015, at 80-2; S*ee also Biotechnology,* MONSANTO, http://www.monsantoafrica.com/biotechnology/default.asp [https://perma.cc/DTF8-2GQA] (last visited Nov. 16, 2016) (asserting that "other innovations" can contribute to decreased use of pesticides).

200. Graham Brookes & Peter Barfoot, *GM Crops: Global Socio-Economic and Environmental Impacts 1996–2013*, PG Economics Ltd, UK, May 2015, at 83–88.

201. For example, Ismail Serageldin CGIAR Chief and World Bank Vice-President characterized biotechnology as "a crucial part of expanding agricultural productivity in the 21st century." He characterized biotechnology as "a tremendous help in meeting the challenge of feeding

Secretary of Agriculture Dan Glickman wryly described, the United States' unofficial position toward agricultural biotechnology "was good and that it was almost immoral to say it wasn't good because it was going to solve the problems of the human race and feed the hungry and clothe the naked."[202] Opponents of the technology were accused of fearmongering,[203] fraud,[204] and worse.[205]

Yet, as demonstrated above, food insecurity flows from inequitable distribution of food rather than from underproduction. Arguments about increased yield alone are therefore not responsive to the actual contours of the food insecurity problem. Indeed, this framing marginalizes the importance of more equitable distribution of existing food, and of minimizing food waste.

Moreover, it is not at all clear that genetically engineered crops increase yield. Reviewing the many dueling studies claiming that crop yields have either increased, held steady, or decreased,[206] the National Research Council concluded that genetically engineered crops "do not have greater potential yield than [non–genetically engineered] counterparts."[207] This conforms with USDA's Economic Research Service's assessment which found the yield record for herbicide tolerant crops to be at best a mixed bag, with some researchers finding increased yield, others finding a decrease, while still others finding no effect on yields.[208] Nor is

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an additional three billion human beings, 95 percent of them in the poor developing countries, on the same amount of land and water currently available," albeit with the caveat that for this to occur, the technology must first be "safely deployed." Monsanto capitalized on this notion in its ad campaign titled "9 Billion, Now What." *Economic Issues*, The GMO Question, https://sites.google.com/site/thegmoquestion/home/economic-issues (last visited Nov. 16, 2016). Interestingly, even though this ad was published on the back cover of *The New Yorker* magazine, it, like many others of the ads referred to in this Article, is next to impossible to find online.

202. Bill Lambrecht, *Outgoing Secretary Says Agency's Top Issue is Genetically Modified Food*, INST. FOR AGRIC. AND TRADE POLICY, Jan. 26, 2001, at 3.

203. In a recent open letter by Nobel Laureates, opposition to genetically engineered crops is characterized as a crime against humanity. Achenbach, *supra* note 13.

204. Saletan, *supra* note 13.

205. Some go so far as to allege that rejecting the technology is a crime against humanity. *See The Crime Against Humanity*, Allow Golden Rice Now, http://www.allowgoldenricenow.org/the-crime-against-humanity [https://perma.cc/Y579-ER8X] (last visited Nov. 16, 2016).

206. DOUG CURIAN-SHERMAN, FAILURE TO YIELD: EVALUATING THE PERFORMANCE OF GENETICALLY ENGINEERED CROPS, UNION OF CONCERNED SCIENTISTS 13 (Apr. 2009); B.L. Ma & K.D. Subedi, *Development, Yield, Grain Moisture and Nitrogen Uptake of Bt Corn Hybrids and their Conventional Near-Isolines*, 93 FIELD CROPS RESEARCH 199, 209 (2005). *Contra* Wilhelm Klümper & Matin Qaim, *A Meta-Analysis of the Impacts of Genetically Modified Crops*, 9 PLOS ONE 1, 4 (2014) (claiming that GMOs have increased yields). Similarly, conflicting research purports to show that pesticide use has either dropped precipitously or skyrocketed. *Compare* Charles M. Benbrook, *Impact of Genetically Engineered Crops on Pesticide use in the U.S.—the First Sixteen Years*, 24 ENVTL. SCIENCES EUROPE 2012 1, 1 (2012) (finding that pesticide use has increased by approximately 404 million pounds or 7%), *with* Klümper & Qaim, *supra* (reporting a 37% reduction in chemical pesticide use).

207. NAT'L ACAD. OF SCI. ET AL., GENETICALLY ENGINEERED CROPS: EXPERIENCES AND PROSPECTS 12 (2016) [hereinafter NAS, *Genetically Engineered Crops*].

208. JORGE FERNANDEZ-CORNEJO ET AL., USDA-ERS, GENETICALLY ENGINEERED CROPS IN THE UNITED STATES 16 (2014) (documenting the wide array of results in studies examining the yield differential from crops genetically engineered for herbicide tolerance).

there a clear case for a net economic benefit to farmers for adopting these crops.[209] The National Research Council specifically noted there is virtually no difference in gross margins between conventional and genetically engineered crops across most of the world.[210] In short, the technology's performance is much more tepid than the extravagant claims made on its behalf.

One thing is clear: two decades of genetically engineered crops has done little to solve the problem of food insecurity. The tantalizing prospect that genetic engineering could help feed the world's hungry[211] has so far "been a somewhat empty promise."[212] Indeed, the pattern has been one in which the benefits claimed for these crops repeatedly fail to materialize. The National Academy of Science cautions that, "given the uncertainty about how much emerging genetic-engineering technologies will increase crop production, viewing such technologies as major contributors to feeding the world must be accompanied by careful caveats."[213] Many experts continue to assert that conventional breeding, rather than genetic engineering, offers the best hope for increasing yield.[214]

Of course, the current array of genetically modified crops was not engineered with reducing food insecurity in mind, so measuring them against that yardstick is not entirely fair. But that is, in many ways, the problem. These crops were developed by a few large multinational corporations as a tool for enhancing the scope, scale, and profitability of industrial agriculture. They embody a vision agriculture built around private ownership of patented seeds that are licensed, not sold, to farmers. Because farmers can only purchase the right to use seeds for a single growing season, farmers can no longer save seed. Moreover, because this business model is built on trade secrets and patent rights, the free exchange of germplasm and agronomic information—the intellectual cornerstone of agricultural research for most of the past century—is inhibited.[215] That structure at best renders the poorest

209. NAS, *Genetically Engineered Crops*, *supra* note 207, at 176–79.

210. NAS, *Genetically Engineered Crops*, *supra* note 207, at 176 (citing a comprehensive, multi-national meta-analysis done by Robert Finger et. al., *A Meta-Analysis on Farm-Level Costs and Benefits of GM Crops*, 3 SUSTAINABILITY 743 (2011)). Dr. Fred Gould, chair of the committee drafting the report, further asserted: "The expectation from some of the [GMO] proponents was that we need genetic engineering to feed the world, and we're going to use genetic engineering to make that increase in yield go up faster. We saw no evidence of that." Dan Charles, *GMOs are Safe, But Don't Always Deliver on Promises, Top Scientists Say,* NPR (May 17, 2016).

211. For an example of the scope of these claims, *see Monsanto: Identity, Video and Ad Campaign*, Condon+Root, http://www.condonandroot.com/work/view/monsanto-print [https://perma.cc/WVP8-P8CL] (last visited Nov. 16, 2016).

212. David Rotman, *Why We Will Need Genetically Modified Foods*, MIT TECH. REV., Dec. 17, 2013.

213. NAS, *Genetically Engineered Crops*, *supra* note 207, at 275.

214. Nat'l Acad. of Sciences, *GE Crops: Meeting 1, Day 1, Major Goodman*, VIMEO (September 15, 2014), https://vimeo.com/album/3051031/video/106866601 [https://perma.cc/EW8A-L9QT]; World Resources Inst., *Creating a Sustainable Food Future* 6 (2014).

215. *See* 2015 Monsanto Technology/Stewardship Agreement, *supra* note 186; 2017 Bayer Grower Technology Agreement Terms & Conditions, https://www.cropscience.bayer.us/~/media/Bayer%20CropScience/Country-United-States-Internet/Documents/Products/Traits/LibertyLink/BGTA-Terms-and-Conditions.ashx [https://perma.cc/V9FC-7XUK]; Dow Agrosciences

of the poor invisible to seed developers' decision-making, and at worst, compounds the problems of poverty and food insecurity associated with treating food as global commodities.

2. Can Genetically Engineered Crops Save Us from Climate Change?

Climate change affects everyone. It jeopardizes all of conventional agriculture by changing the biogeophysical conditions that underpin current productivity levels. If the current level of food insecurity is grim, challenges that agriculture will face because of climate change will make it even worse.[216] The rapidity of the change seems to make a compelling case for embracing new technologies, including genetic engineering. Backers insist that genetic engineering offers our best hope of creating crops capable of maintaining yield in the face of climate change. Monsanto has consistently described climate change-related agricultural impacts as a potential "opportunity."[217] The core of their argument is that we do not have the luxury of time, and only genetic engineering can respond with the necessary rapidity.[218]

Most assessments of climate change's impact on agriculture are optimistic about the role of new technologies.[219] Policymakers generally assume that growers will adapt by switching to more heat-tolerant or drought-resistant varietals able to thrive under the new climatic conditions.[220] Indeed, official reports and studies are

Technology Use Agreement, http://msdssearch.dow.com/PublishedLiteratureDAS/dh_091e/0901b8038091ea46.pdf?filepath=mycogen/pdfs/noreg/010-12440.pdf&fromPage=GetDoc [https://perma.cc/A668-2HXM]; Syngenta Grower Stewardship Agreement, http://www.syngenta-us.com/seeds/vegetables/processor_sweet_corn/sweet_corn_attribute_agreement.pdf [https://perma.cc/FLD5-VQWQ] (specifically prohibiting the purchaser from transferring any of the purchased seeds).

216. ASIAN DEVELOPMENT BANK, FOOD SECURITY AND POVERTY IN ASIA AND THE PACIFIC: KEY CHALLENGES AND POLICY ISSUES 21 (2012) (identifying climate change as the greatest challenge to food security).

217. MONSANTO COMPANY, INVESTOR CDP 2013 INFORMATION REQUEST, https://www.cdp.net/sites/2013/30/12330/Investor%20CDP%202013/Pages/DisclosureView.aspx [https://perma.cc/LW7L-7A3R]**;** *See also* Kieron Monks, *Getting Rich from Climate Change? How Business can Thrive in Extreme Conditions*, CNN, Nov. 17, 2014, http://edition.cnn.com/2014/11/11/business/food-gets-rich [https://perma.cc/SR8W-JSFK].

218. Beth Kowitt, *Can Monsanto Save the Planet,* FORTUNE (June 6, 2016), http://fortune.com/monsanto-fortune-500-gmo-foods/ [https://perma.cc/J7VN-898T]. *But see* WORLD RESOURCES INST., CREATING A SUSTAINABLE FOOD FUTURE 6 (2014) (cautioning that "more fundamental crop improvements from genetic engineering, such as improved uptake of nutrients and reduced losses of water, are uncertain and will take decades to come to fruition . . . ." Thus the report argues that conventional breeding is more likely to offer near-term responses to climate change.).

219. *See* John R. Porter et al., *Intergovernmental Panel on Climate Change, Food Security and Food Production Systems*, in *Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* at 485–533 (2014); C.L. WALTHALL ET AL., USDA, CLIMATE CHANGE AND AGRICULTURE IN THE UNITED STATES: EFFECTS AND ADAPTATION 6 (2013); Heleen de Coninck et al., *International Technology-Oriented Agreements to Address Climate Change,* 36 ENERGY POLICY 335 (2008); W. Neil Adger et al., *Adaptation to Climate Change in the Developing World,* 3 PROGRESS IN DEV. STUDIES 179 (2003).

220. Porter et al., *supra* note 219, at 485–533.

replete with claims that (unspecified) new crops and technologies will emerge to meet challenges of climate change.[221]

This is where genetic engineering usually comes in. Monsanto explicitly makes the claim that food security in an era of climate change will require agricultural biotechnology.[222] One recent ad campaign, titled *Produce More, Conserve More,* makes the case that biotechnology is the core of sustainable production in an era of climate change.[223] Indeed, the company's 2014 sustainability report proudly claims that its business "revolves around delivering agricultural innovations . . . [to] address . . . climate change, resource conservation and, ultimately, how we will collectively feed a global population of more than 9.6 billion by the year 2050."[224] Others second the claim that genetic engineering is "critical" for meeting increasing demand in an era of climate change,[225] and that there is "a 'desperate need'" for the technology.[226] Some go so far as to suggest that rejecting the technology is akin to a crime against humanity.[227]

This "save the world" rhetoric is certainly lofty, but there is scant evidence that genetically engineered crops can actually deliver results. One major international report characterized many of the claims made for these crops as "unproven."[228] The FAO wryly noted that successful development of drought resistant crops through genetic engineering has "been anticipated several times . . . [but] has had very limited impact so far."[229] For example, the Bill and Melinda Gates Foundation[230] has been pouring billions of dollars into a project

221. *Id.*; *see also* WALTHALL ET AL., *supra* note 219; de Coninck et al., *supra* note 219; Adger et al., *supra* note 219.

222. Margaret Zeigler, *Climate Change Is Another Obstacle to Global Food Security*, MONSANTO, http://www.monsanto.com/improvingagriculture/pages/climate-change-an-obstacle.html.

223. Hugh Grant, *Our Commitment to Produce More, Conserve More: Remarks at The Future of Agriculture Seminar*, MONSANTO (June 9, 2008), http://www.monsanto.com/newsviews/pages/ourcommitmenttoproducemore.conservemore.aspx.

224. MONSANTO, FROM THE INSIDE OUT: MONSANTO 2014 SUSTAINABILITY REPORT 8 (2015), http://www.monsanto.com/sitecollectiondocuments/csr_reports/monsanto-2014-sustainability-report.pdf.

225. Nina V. Fedoroff, et. al., *Radically Rethinking Agriculture for the 21st Century,* 327 SCI. 833, 833 (2010).

226. Philip Clarke, *Lack of GMOs Costs Lives, Claims Leading Scientist,* FARMERS WEEKLY, Jan. 20, 2010 (on file with author) (quoting Sir David King, a former Cambridge University professor and the former Chief Scientific Advisor to the British Government).

227. The Crime Against Humanity, *supra* note 205.

228. E. Toby Kiers et al., *Agriculture at a Crossroads*, 320 SCI. 320 (2008) (explaining the Report conclusions).

229. HUGH TURRAL ET AL., FAO, CLIMATE CHANGE, WATER, AND FOOD SECURITY xxiii (2011), http://www.fao.org/3/a-i2096e.pdf [https://perma.cc/GM5T-VC5N].

230. Press Release, Bill & Melinda Gates Foundation, African Agricultural Technology Foundation to Develop Drought Tolerant Maize Varieties for Small-Scale Farmers in Africa (Mar. 2008), http://www.gatesfoundation.org/Media-Center/Press-Releases/2008/03/African-Agricultural-Technology-Foundation-to-Develop-DroughtTolerant-Maize-for-SmallScale-Farmers-in-Africa [https://perma.cc/47VB-APNT].

called Water Efficient Maize for Africa (WEMA).[231] The explicit intention of this project is to harness genetic engineering to alleviate poverty and to better equip poor farmers to respond to climate change.[232] In 2014, WEMA announced great preliminary success in developing new drought-resistant seeds. However, the seed was produced not through genetic engineering but through conventional breeding.[233] The WEMA experience is not an isolated incident. DuPont recently used conventional breeding to produce a drought resistant corn (*Optimum Aquamax*) that it markets as an alternative to genetically engineered drought resistant crops.[234] Similarly, researchers recently introduced a widely adopted flood-resistant rice developed not by genetic engineering, but through conventional breeding.[235] These crops drew on the techniques and insights of molecular genetics to facilitate more rapid conventional breeding—thereby harnessing modern science without creating genetically engineered seeds.

The recent International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD)[236] report *Agriculture at a Crossroads* neatly captured this nuanced view of the technology. Characterizing genetic engineering's potential to contribute to food security as "unfulfilled," the Report concluded that genetically engineered crops were "appropriate in some contexts, unpromising in

231. Monsanto, *Water Efficient Maize for Africa*, http://www.monsanto.com/improving agriculture/pages/water-efficient-maize-for-africa.aspx [https://perma.cc/T6KF-TKCN] (last visited Jan. 22, 2017). A public/private partnership, WEMA is led by the Kenyan-based African Agricultural Technology Foundation (AATF). Additional funding comes from the Howard G. Buffett Foundation and USAID.

232. *See* Raj Patel et al., *Ending Africa's Hunger*, THE NATION (Sept. 2, 2009), http://www.thenation.com/article/ending-africas-hunger [https://perma.cc/B725-QA6A].

233. *See* Press Release, African Agricultural Technology Foundation, First Harvest of New Drought-Tolerant Seed Shows Strong Promise of Improved Maize Crops for Smallholder Farmers of Africa (May 16, 2014), http://www.aatf-africa.org/media-center/First-Harvest-of-New-Drought-Tolerant-Seed-Shows-Strong-Promise [https://perma.cc/5KT8-P3LM].

234. *See DuPont's New Drought Tolerant Corn Can Help Improve Yields and Gain Market Share*, TREFIS (March 14, 2013), http://www.trefis.com/stock/dd/articles/173705/duponts-drought-tolerant-corn-can-help-improve-yields-and-gain-market-share/2013-03-14 [https://perma.cc/QFW3-UWLW].

235. Gina Kolata, *A Proposal to Modify Plants Gives GMO Debate New Life*, N.Y. TIMES (May 28, 2015), https://www.nytimes.com/2015/05/29/health/a-proposal-to-modify-plants-gives-gmo-debate-new-life.html?_r=0.

236. The IAASTD is a multithematic, multispatial, multitemporal global collaboration. It was initiated by the World Bank and the United Nations, with a multi-stakeholder Bureau cosponsored by the FAO, various United Nations organs, the World Bank and World Health Organization (WHO). Its governance structure is a unique hybrid of the Intergovernmental Panel on Climate Change (IPCC) and the nongovernmental Millennium Ecosystem Assessment (MA). International Assessment of Agricultural Knowledge, Science and Technology for Development [IIASTD], AGRICULTURE AT A CROSSROADS, SYNTHESIS REPORT: A SYNTHESIS OF THE GLOBAL AND SUB-GLOBAL IIASTD REPORTS, at vii (2009), https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwiFuOimq5zWAhWjxVQKHU9mD0oQFggyMAE&url=http%3A%2F%2Fapps.unep.org%2Fpublications%2Fpmtdocuments%2F-Agriculture%2520at%2520a%2520crossroads%2520-%2520Synthesis%2520report-2009Agriculture_at_Crossroads_Synthesis_Report.pdf&usg=AFQjCNFwCucKqOmj030lwqvwTU8H62VtbQ.

others, and unproven in many more."[237] The authors went on to note that these crops have, so far, not offered solutions to the broad, socioeconomic dilemmas posed by poverty and food insecurity.[238] Despite the urgent picture painted by the technology's backers, genetic engineering is just one option among a growing array of techniques intended to adapt agricultural production to climate change. Rejecting hyperbole is not the same as rejecting science.

C. What Are the Equity Ramifications of Genetically Engineered Crops?

If we recognize, as we must, that food insecurity and undernutrition are not just functions of food production, we are left with questions of equity and power—why do people starve or suffer food insecurity amidst plenty? How do we change the patterns of distribution and consumption that produce these dismal results? Those are not questions of science or of production. They hint at a problem that is not amenable to a technical solution. Yet, purported technical solutions abound.

The decade-long Golden Rice saga is a good illustration of what happens when decision-makers insist on pursuing purely technical solutions to problems created by poverty and inequity. Golden Rice is rice that has been genetically engineered to contain beta carotene in an attempt to ward of vitamin A deficiencies that leads to blindness and death. In 2000, *Time Magazine* profiled Golden Rice on its cover, proclaiming *This Rice Could Save a Million Kids a Year*.[239] Golden Rice instantly became the poster child for biotechnology, a life-saving negation of the assertion that agricultural biotechnology only generated benefits for multinational corporations.[240] Monsanto and other agricultural biotech companies mounted a slick ad campaign using Golden Rice to stake out moral high ground in debates over genetic engineering.[241] These ads sought to inextricably link "the dream of a tomorrow without hunger" to biotechnology as "the science that promises hope."[242] Critics found themselves accused of perpetuating a "nutritional

237. Kiers et al., *supra* note 228.

238. *Id.*

239. *See* J. Madeline Nash, *This Rice Could Save a Million Kids a Year*, TIME (July 31. 2000), http://content.time.com/time/magazine/article/0,9171,997586,00.html.

240. *See* Dan Charles, *In a Grain of Golden Rice, A World of Controversy Over GMO Food*, NPR, March 7, 2013, http://www.npr.org/sections/thesalt/2013/03/07/173611461/in-a-grain-of-golden-rice-a-world-of-controversy-over-gmo-foods.

241. Under the auspices of the Council for Biotechnology Information, Monsanto and other biotechnology companies built a $50 million marketing campaign around a series of ads claiming that biotechnology could help end world hunger. *See, e.g.*, Marion Nestle, *Safe Food: The Politics of Food Safety* 181, fig. 17 (2010) (reproducing ad claiming that biotechnology is "helping provide ways for developing countries to better feed a growing population"); *See e.g.,* Glenn D. Stone and Dominic Glover, *Disembedding Grain: Golden Rice, The Green Revolution, and Heirloom Seeds in the Philippines*, J. AGRICULTURE, FOOD, AND HUMAN VALUES (2016) (reprinting Council for Biotechnology Information Golden Rice Advertisement, proclaiming "Biotechnology researchers call it 'golden rice.' For the color. For the opportunity.").

242. *See* Monsanto Fact Sheet, *supra* note 196.

holocaust,"[243] and of condemning poor children to suffer and die.[244] Recently, an open letter from 104 Nobel Laureates demanded, "How many poor people in the world must die before we consider [opposition to Golden Rice] a 'crime against humanity?'"[245]

To say that Golden Rice has failed to live up to this "world changing" hype would be a significant understatement. When it was featured on *Time*'s cover, an at-risk child would have had to eat fifteen pounds of Golden Rice per day to obtain the benefits described in the article.[246] Responding to that disconnect, Michael Pollen called it "the world's first purely rhetorical technology" designed "to win an argument rather than solve a public-health problem."[247] Greenpeace, a staunch opponent of genetic engineering, called Golden Rice an "overpriced public relations exercise."[248] Even the Rockefeller Foundation, which bankrolled the Golden Rice project, acknowledged that the industry advertisements and public relations campaigns built around Golden Rice had "gone too far," and were promising benefits that the technology could not, and might never be able to deliver.[249]

There is no question that Vitamin A deficiency is a major public health crisis. Affecting 250 million children a year, vitamin A deficiency causes up to half a million cases of childhood blindness annually.[250] Not only is vitamin A deficiency the leading cause of preventable blindness,[251] but a disturbingly high percentage of children who lose their sight to vitamin A blindness die within a year.[252] Pregnant

243. See Biofortified rice as a contribution to the alleviation of life-threatening micronutrient deficiencies in developing countries, GOLDEN RICE PROJECT (last visited Jan. 22, 2017), http://www.goldenrice.org/index.php (suggesting that technophobes are perpetrating a "Nutritional Holocaust" by opposing GMOs).

244. Ingo Potrykus, *The Golden Rice Tale*, 10 (2001), http://www.goldenrice.org/PDFs/The_GR_Tale.pdf [https://perma.cc/J962-LLXH] (asserting that "GMO opposition has to be held responsible for the foreseeable unnecessary death and blindness of millions of poor every year").

245. *Laureate Letter Supporting Precision Agriculture (GMOs)*, SUPPORT PRECISION AGRIC. (June 29, 2016), http://supportprecisionagriculture.org/nobel-laureate-gmo-letter_rjr.html [https://perma.cc/AS9K-YSZR]. *See* ALLOW GOLDEN RICE NOW SOCIETY, http://www.allowgoldenricenow.org/ [https://perma.cc/BB3L-ZNAD] (last visited Jan. 22, 2017). The British Minister of the Environment characterized opponents of golden rice as "wicked." Matt McGrath, *GM Golden Rice Opponents Wicked, Says Minister Owen Paterson,* BBC (Oct. 14, 2013), http://www.bbc.com/news/uk-politics-24515938 [https://perma.cc/8M2R-YZAF].

246. Michael Pollan, *The Way We Live Now: The Great Yellow Hype*, N.Y. TIMES, March 4, 2001, http://www.nytimes.com/2001/03/04/magazine/the-way-we-live-now-3-04-01-the-great-yellow-hype.html.

247. *Id.*

248. Lorraine Chow, *Greenpeace to Nobel Laureates: It's Not Our Fault Golden Rice Has "Failed as a Solution*," ECOWATCH (July 7, 2016), http://www.ecowatch.com/greenpeace-to-nobel-laureates-its-not-our-fault-golden-rice-has-failed-1896697050.html [https://perma.cc/S8X7-WPZJ].

249. Letter from Gordon Conway, President, Rockefeller Foundation, to Dr. Doug Parr, Greenpeace (Jan. 22, 2001), http://www.agbioworld.org/newsletter_wm/index.php?caseid=archive&newsid=965 [https://perma.cc/HM4E-UJTX].

250. *Micronutrient Deficiencies: Vitamin A Deficiency*, WHO, http://www.who.int/nutrition/topics/vad/en/ [https://perma.cc/962Q-AEUQ] (last visited Jan. 22, 2017).

251. *Id.*

252. *Id.*

women are also vulnerable, with vitamin A deficiency causing night blindness and maternal health complications.[253] Vitamin A deficiency is concentrated in South Asia, where nearly half of all pre-school children are affected.[254] Incidentally, the rates are highest in India, Bangladesh, and Pakistan[255]—the very countries that were the focus of Green Revolution interventions.

When researchers genetically engineered rice to produce beta carotene,[256] a key vitamin A precursor, it seemed like an elegant technical solution to a vexing public health problem.

Sixteen years later, Philippine researchers are still working on Golden Rice. Their first order of business was to improve the beta carotene levels.[257] Once that was accomplished, their attention turned to trying to embed the traits in strains of rice appropriate for growing in Philippine fields.[258] To date they have had little success. The modified rice still lags behind conventional rice in yield,[259] and its developers have not given an estimate of when they expect to have a version ready to distribute.[260] Despite the millions of dollars invested in this high-tech solution, and despite the save-the-world rhetoric, Golden Rice has simply failed to achieve its promise. This failure is not due to opposition from opponents of genetically engineered crops, nor is it due to burdensome regulatory requirements, but is because of much more prosaic agronomic concerns.[261] Yet, even as Golden Rice languishes, the Philippines nevertheless made significant progress in reducing

253. *See* Parul Christian et al., *Night Blindness During Pregnancy and Subsequent Mortality Among Women in Nepal: Effects of Vitamin A and Beta-Carotene Supplementation*, 152 AM. J. EPIDEMIOL. 542 (1999).

254. Saeed Akhtar et al., *Prevalence of Vitamin A Deficiency in South Asia: Causes, Outcomes, and Possible Remedies*, 31 J. HEALTH POP. NUTR. 413, 415 (2013).

255. *Id.*

256. For a first-hand account of this research, see *Potrykus*, supra note 244.

257. *What Is the Status of the Golden Rice Project Coordinated by IRRI?*, INT'L RICE RESEARCH INST., http://irri.org/golden-rice/faqs/what-is-the-status-of-the-golden-rice-project-coordinated-by-irri [https://perma.cc/TP4N-M7N8] (last visited Nov. 11, 2016).

258. *Id.*

259. *Id.* (reporting that "[r]esults of the first round of multi-location trials of Golden Rice showed that beta carotene was produced at consistently high levels in the grain, and that grain quality was comparable to the conventional variety. However, *yields of candidate lines were not consistent across locations and seasons*.") (emphasis added). This language had originally read: "average yield was unfortunately lower than that from comparable local varieties already preferred by farmers." Stone, Photograph of IRRI Post, *Golden Rice: Bringing a Superfood Down to Earth*, FOOD, FARMING, AND BIOTECH., Aug. 28, 2015, https://fieldquestions.com/2015/08/28/golden-rice-bringing-a-superfood-down-to-earth/ [https://perma.cc/AV5L-AXCE]. For a full discussion, *see* Glenn D. Stone and Dominic Glover, *Disembedding Grain: Golden Rice, The Green Revolution, and Heirloom Seeds in the Philippines,* 33 J. AGRIC. & HUMAN VALUES 1 (2016).

260. Tom Philpott, *WTF Happened to Golden Rice*, MOTHER JONES (Feb. 3, 2016), http://www.motherjones.com/tom-philpott/2016/02/golden-rice-still-showing-promise-still-not-field-ready [https://perma.cc/3X8D-2F2N].

261. Wash. Univ. in St. Louis, *GMO Golden Rice Falls Short on Lifesaving Promises, Researcher Says*, LAB. EQUIP. (June 3, 2016), http://www.laboratoryequipment.com/news/2016/06/gmo-golden-rice-falls-short-lifesaving-promises-researcher-says [https://perma.cc/Y8SM-WL7X].

vitamin A blindness.[262] Due to a significant public health campaign, 86% of children in the Philippines now receive vitamin A supplementation.[263] The result has been a dramatic reduction in vitamin A deficiency,[264] achieved wholly through conventional nutrition programs.

In short, even as the Rockefeller Foundation poured millions of dollars into developing Golden Rice, there were readily available solutions to the problem Golden Rice was supposed to address. Many countries were requiring that staples like flour, cooking oil[265] and sugar[266] be fortified with vitamin A—techniques which proved to be effective, and extremely inexpensive ways to maintain vitamin A levels. UNICEF spearheaded a wide-ranging fortification program built around periodic high-dose vitamin A supplementation. This low-tech, low-cost approach has long been known to prevent childhood blindness and reduce associated illnesses such as measles and diarrhea.[267] Indeed, it is credited with reducing childhood mortality by 24%.[268] Moreover, because this supplement is typically delivered during biannual Child Health events, periodic supplementation had an additional benefit—it creates an opportunity to shore up fragile public health systems and to provide a package of locally tailored interventions like immunizations and deworming.[269] The success rates for this very simple intervention are proven, and extremely inexpensive.

Golden Rice, by contrast has been inordinately expensive, and as yet remains unproven. It was an elegant idea, but it does not yet work. If and when it actually manages to live up to the hype, it will merely add an additional arrow in a quiver

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262. Food and Nutrition Research Inst., *7th National Nutrition Survey: 2008*, DEPT. OF SCI. AND TECH. (2008), http://www.fnri.dost.gov.ph/images/sources/biochemical_vad.pdf [https://perma.cc/97VB-STZ8].

263. *Vitamin A Supplementation Interactive Dashboard*, UNICEF (Apr. 20, 2016), http://data.unicef.org/nutrition/vitamin-a.html [https://perma.cc/ZZD7-8762].

264. The percentage of children newborn to age five with vitamin A deficiencies plummeted from a high of 40% in 2003 to 15% in 2008. The rates for pregnant and lactating women showed comparable declines. (Note: the 2008 results are the most recent results available. The 2014 results should be available soon). Food and Nutrition Research Inst., *supra* note 262. In response, IRRI notes that Golden Rice, "if it is found to be safe, shown to improve vitamin A status, and used in combination with existing programs" might be a way to help those still affected by vitamin A deficiency. IRRI, *Why Is Golden Rice Needed in the Philippines Since Vitamin A Deficiency is Already Decreasing?*, http://irri.org/golden-rice/faqs/why-is-golden-rice-needed-in-the-philippines-since-vitamin-a-deficiency-is-already-decreasing (last visited Nov. 11, 2016). This heavily caveated claim by those actually developing the crop is notably more modest than the sweeping claims made for Golden Rice by its most vocal advocates.

265. BASF, *Oil Fortification*, http://www.food-fortification.com/About_Food_Fortification/Application/Oil_Fortification.aspx (last updated 2011).

266. Omar Dary & Jose O. Mora, *Food Fortification to Reduce Vitamin A Deficiency: International Vitamin A Consultative Group Recommendations*, 132 J. NUTRITION 2927S, 2929S (2002).

267. *Vitamin A Supplementation Interactive Dashboard*, *supra* note 262.

268. UNICEF, VITAMIN A SUPPLEMENTATION: A STATISTICAL SNAPSHOT [Brochure] 1, 4 (2016), http://data.unicef.org/resources/vitamin-supplementation-statistical-snapshot/ [https://perma.cc/38TS-VACK]; Damian K Francis, *Vitamin A Supplementation for Preventing Morbidity and Mortality in Children from 6 Months to 5 Years of Age*, COCHRAN LIB. 1 (Jan. 14, 2011), http://www.cochranelibrary.com/editorial/10.1002/14651858.ED000016 [https://perma.cc/D36D-6JH8].

269. *Vitamin A Supplementation: A Statistical Snapshot*, *supra* note 267, at 10.

already filled with effective, less-expensive solutions. The disconnect between the abundance of available ways to address the problem, and the vocal insistence that Golden Rice was necessary seemed to justify accusations like Golden Rice was about winning an argument than about helping those at risk.[270] It truly did seem like the best reason to pursue Golden Rice was to justify the use of genetic engineering.

Subsequent developments in the Golden Rice saga only underscore this concern. In 2012, after conducting experiments in China, a Tufts University researcher announced that Golden Rice had finally achieved the same effectiveness as the direct supplementation approach pursued by the WHO and UNICEF.[271] So, after twenty years of effort, and millions of dollars, the technology was now capable of doing exactly what low-tech solutions had been doing all along.[272] However, in their eagerness to prove their case, these researchers overstepped major legal and ethical boundaries. They failed to inform parents that their children were being fed genetically modified rice because they were concerned that mentioning Golden Rice was "too sensitive."[273] Moreover, the researchers illegally imported the rice into China, and fabricated required approvals.[274] In the process, the researchers violated federal guidelines and IRB protocols with regard to the proper treatment of human subjects. The breaches were so serious that the *American Journal of Clinical Nutrition* ultimately retracted its publication of the results[275] and Tufts University sanctioned

270. Pollan, *supra* note 246, at 1; Dr. Vandana Shiva, *The Golden Rice Hoax: When Public Relations Replaces Science*, S.F. ST. U. (Jan. 12, 2009), http://online.sfsu.edu/repstein/GEessays/goldenricehoax.html [https://perma.cc/LY4F-AFS4].

271. Guangwen Tang et al., *ß-Carotene in Golden Rice is as Good as ß-Carotene in Oil at Providing Vitamin A to Children*, 96 AM. J. CLINICAL NUTRITION 658, 658 (2012). Unfortunately, this test on healthy school children does not necessarily indicate how malnourished children will handle Golden Rice.

272. Some researchers have questioned whether these results in healthy children can be extrapolated to malnourished children whose diets (and bodies) lack adequate fat to absorb and process vitamin A. Washington University in St. Louis, *supra* note 261.

273. Jane Qiu, *China Sacks Officials Over Golden Rice Controversy*, NATURE (Dec. 10, 2012), http://www.nature.com/news/china-sacks-officials-over-golden-rice-controversy-1.11998 [https://perma.cc/Z38Q-4LRB]. The parental consent form instead merely indicated that the rice contained ß-carotene.

274. Tufts Univ., Statement on Golden Rice Research, ACADEMICS REVIEW (Sept. 17, 2013), http://academicsreview.org/2013/09/tufts-university-statement-on-golden-rice-research/ [https://perma.cc/L4F9-NUK3].

275. Retraction of Guangwen Tang et al., *ß-Carotene in Golden Rice is as Good as ß-Carotene in Oil at Providing Vitamin A to Children*, AM. J. CLINICAL NUTRITION (July 29, 2015), http://ajcn.nutrition.org/content/early/2015/07/29/ajcn.114.093229.full.pdf+html.

the researcher,[276] describing the conduct as "constituting 'serious and continuing non-compliance with federal regulations' and with Tufts IRB policy."[277]

Unfazed by these major ethical breaches, advocates of Golden Rice continued to tout the results.[278] Their unwillingness to acknowledge the significance of failing to get proper government approvals or parental consent before feeding children an experimental genetically modified product speaks volumes. Research rules governing prior informed consent are not a technicality—they are all that stand between vulnerable populations and serious exploitation.

The importance of these questions should be self-evident. The choice to pursue a technology-based solution to a problem rooted in poverty had consequences. There are alternative, equally valid perspective about whether vitamin A deficiency, and by implication issues of hunger and diet-related disease more broadly, are problems in need of technical or social solutions. Had the hundreds of millions of dollars spent developing Golden Rice been instead used to support the pre-existing, albeit less glamorous poverty alleviation efforts, or straightforward initiatives to provide vitamin A supplements directly to vulnerable populations, perhaps today's statistics would look very different. As Peter Rosset, director of Food First, emphasized, "People do not have vitamin A deficiency because rice contains too little vitamin A but because their diet has been reduced to rice and almost nothing else."[279] Poverty is the core issue in vitamin A deficiency and in food insecurity more generally. Technology, by itself, cannot solve the problem.[280]

III. SOME ADDITIONAL COSTS OF GENETICALLY ENGINEERED CROPS

Even assuming that the promised new innovations from genetic engineering actually materialize,[281] their use and deployment raises some real questions about accountability and transparency. The companies that own genetically engineered

276. Tufts Univ., *supra* note 274 (announcing that the researcher had been barred from doing human subject research for two years during which time the researcher would undergo retraining on human subjects research regulations and policies). After the two-year suspension, the University imposed what is essentially an additional two-year parole during which time the researcher would be able to do human studies only as a supervised co-investigator.

277. Martin Enserink, *Golden Rice Not So Golden for Tufts,* SCIENCE MAG. (Sept. 18, 2013), http://www.sciencemag.org/news/2013/09/golden-rice-not-so-golden-tufts [https://perma.cc/J5ET-RSHY].

278. *See, e.g.*, *The Crime Against Humanity*, ALLOW GOLDEN RICE NOW, http://www.allowgoldenricenow.org/the-crime-against-humanity [https://perma.cc/XGK2-LR8R] (last visited Nov. 12, 2016); Enserink, *supra* note 277 (quoting Golden Rice developer Ingo Potrykus as saying "[t]he study has shown that golden rice is a very effective source of vitamin A . . . . That's what's most important."); Saletan, *supra* note 13 (strongly suggesting that the outcry over the breach of law and ethics was irrelevant in light of the results, and arguing that the controversy was trumped up).

279. Letter to the Editor by Peter M. Rosset, *in GMO? Hell No!*, THE NATION (2001), https://www.thenation.com/article/gmo-hell-no/ [https://perma.cc/S2RL-G6WW].

280. *See, e.g.*, Kiers et al., *supra* note 227, at 320–21.

281. The fiercely fought battles over the safety of these crops for human consumption are outside the scope of this analysis, as are the potential environmental ramifications of these crops.

seeds, through a network of intellectual property rights, exercise an unprecedented level of control over agricultural production, and over information about the crops that are produced. Even if genetically engineered crops were capable of delivering higher yield under climate change conditions, those yields would come at a high price in terms of public discourse. Given that food security is not primarily a question of production, it is an open question as to whether that hypothetical yield would be worth the price.

A. Costs Due to Control over Production

There is really no such thing as a "seed company" anymore. In the last twenty-five years, the seed industry has undergone tremendous consolidation.[282] In fairly short order, a sector composed primarily of small, family-owned firms was transformed into an industry dominated by a small number of transnational pharmaceutical/chemical corporations.[283] A wave of mergers and consolidations produced a handful of "agricultural life science" conglomerates that hold intellectual property rights in pesticides, fertilizers, and seeds, most notably genetically engineered seeds. Over that same time period, the cost of a bag of seed corn has more than quadrupled, and soybean has more than quintupled.[284] This cost increase tracks the growing prevalence of the genetically engineered crops that dominate agriculture in the United States.[285]

Just a handful of companies control 75% the global agrochemical market, 63% of the global seed market, and conduct more than 75% of private sector agricultural research on seeds and pesticides.[286] Yet, small as that group is, it understates the level of consolidation that actually exists. One company, Monsanto, single-handedly dominates the market for genetically engineered crops. Monsanto directly control

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282. Seventy-five, erstwhile independent, seed companies were purchased by Monsanto, Dow AgroSciences, DuPont, Syngenta, and AgReliant. Dean V. Cavey, *Reflections on Consolidation in the Seed Industry*, VERDANT PARTNERS (June 13, 2016), http://www.verdantpartners.com/reflections-on-consolidation-in-the-seed-industry/ [https://perma.cc/NDD2-5JTB].

283. Howard, *supra* note 185, at 1266.

284. Over the last twenty-five years, a bag of seed corn went from $65 to $300 and soybean from $12 to over $70. Cavey, *supra* note 282.

285. *GMOs in Food*, INSTITUTE FOR RESPONSIBLE TECHNOLOGY, http://responsible technology.org/gmo-education/gmos-in-food/ [https://perma.cc/SAE9-42AN] (last visited Aug. 3, 2017). More than 90% of the corn, soybean, cotton, sugar beets, and canola planted in the United States are genetically engineered.

286. The so-called Big Six are BASF, Bayer, Dow, DuPont, Monsanto, and Syngenta. *See Breaking Bad: Big Ag Mega-Mergers in Play*, ETC GROUP 4 (Dec. 2015), http://www.etcgroup.org/sites/www.etcgroup.org/files/files/etc_breakbad_23dec15.pdf [https://perma.cc/SVV2-5M4J]. In December 2015, two of those companies, Dow and DuPont, announced a merger, *see* Sam Thielman, *Chemical Giants Dow Chemical and DuPont Announce $130bn Merger*, THE GUARDIAN (Dec. 11, 2015), https://www.theguardian.com/business/2015/dec/11/dow-chemical-dupont-merger-dowdupont [https://perma.cc/DH93-RXBP], that will give the combined company 40% of the U.S. corn and soybean markets, John Cassidy, *A Dow DuPont Merger Would Raise Big Questions*, NEW YORKER (Dec. 9, 2015), http://www.newyorker.com/news/john-cassidy/a-dow-dupont-merger-would-raise-big-questions [https://perma.cc/VZ7H-YCLY]. During that same time period, Monsanto unsuccessfully attempted to merge with another of the Syngenta. *See* ETC GROUP, *supra*, at 4.

over a quarter of the global seed market.[287] Within the United States, Monsanto's footprint is even larger—roughly 80% of U.S. corn and more than 90% of U.S. soybeans are grown with seeds containing Monsanto's patented seed traits (whether sold by Monsanto itself or by licensees).[288] This unprecedented level of control over the seed market has made Monsanto into the popular face of genetically engineered crops.

This control has had real-world consequences. Consolidation in the seed industry and the parallel rise of genetically engineered crops has meant a reduction in the nonengineered seeds available to farmers.[289] One European study showed that consolidation decreased in the number of available cultivars, a shift in focus to crops and hybrids more profitable to companies, and termination of breeding programs for regionally relevant crops.[290] By contrast, local seed companies and breeding organizations increase farmers' choices. Studies from the United States,[291] India,[292] and South Africa[293] have shown that introduction of genetically engineered crops eventually leads to reductions in available crop cultivars,[294] and in extreme situations, choice only between genetically engineered cultivars.[295] This causes a ripple effect across food markets more generally with processors and manufacturers struggling to find non–genetically engineered ingredients.[296] This information prompted the National Research Council to call for study on the effect of increasing

287. ETC GROUP, *supra* note 286, at 5.

288. Dan Mitchell, *Why Monsanto Always Wins*, FORTUNE (June 26, 2014), http://fortune.com/2014/06/26/monsanto-gmo-crops/ [https://perma.cc/6P3K-QX9J].

289. Angelika Hilbeck et al., *Farmer's Choice of Seeds in Four EU Countries Under Different Levels of GM Crop Adoption*, 25 ENV. SCI. EUR. 1, 1 (2013), http://www.enveurope.com/content/25/1/12 [https://perma.cc/P57B-LETG] (documenting that European countries permitting the sale of genetically engineered seeds have experienced a decline in available seed crop diversity, while that same measure of diversity has either remained the same or increased in countries that prohibit genetically engineered seeds); *see also* David Schimmelphennig et al., *The Impact of Seed Industry Concentration on Innovation: A Study of U.S. Biotech Market Leaders*, 30 AGRIC. ECON. 157, 158–59 (2004) (showing an inverse relationship between consolidation and innovation in the seed industry).

290. Svein Øivind Solberg & Line Breian, *Commercial Cultivars and Farmers' Access to Crop Diversity: A Case Study From the Nordic Region,* 24 AGRIC. & FOOD SCI. 150, 150 (2015).

291. *Finding Non-GMO Soybean Seed Becoming More Difficult*, THE ORGANIC & NON-GMO REPORT (July/Aug. 2008), http://www.non-gmoreport.com/articles/jul08/non-gmo_soybean_seed.php [https://perma.cc/AJ5X-8BT8].

292. Glenn Davis Stone, *Field Versus Farm in Warangal: Bt Cotton, Higher Yields, and Larger Questions,* 39 WORLD DEV. 387, 392–94 (2011).

293. Harald Witt et al., *Can the Poor Help GM Crops? Technology, Representation & Cotton in the Makhathini Flats, South Africa*, 33 REV. AFR. POL. ECON. 497, 507–08 (2006).

294. Hilbeck, *supra* note 289, at 1.

295. *Sugar Beet Industry Converts to 100% GMO, Disallows Non-GMO Option*, THE ORGANIC & NON-GMO REPORT (June 2008), http://www.non-gmoreport.com/articles/jun08/sugar_beet_industry_converts_to_gmo.php [https://perma.cc/3LW5-8P2K].

296. Carey Gillam, *U.S. Food Companies Find Going "Non-GMO" No Easy Feat*, REUTERS (Feb. 18, 2014), http://www.reuters.com/article/us-usa-food-gmo-analysis-idUSBREA1H1G42014 0218 [https://perma.cc/D7LM-QS36].

market concentration of seed suppliers on seed and cultivar diversity and farmer planting options.[297]

Sugar beets offer a cautionary tale of how loss of diversity can affect farmers.[298] USDA initially deregulated genetically engineered sugar beets in 2005.[299] This decision was mired in lengthy litigation challenging the adequacy of the agency's consideration of the environmental impacts associated with these crops.[300] Yet, within by 2010, 95% of the sugar beet crop was genetically engineered,[301] and non–genetically engineered seeds were next to impossible to find.[302]

However, many major food companies have begun announcing that they will eliminate genetically engineered ingredients, including sugar, from their consumer products.[303] That creates a problem for domestic farmers because roughly half of the United States' sugar production comes from sugar beets, virtually all of which is genetically engineered.[304] Manufacturers began switching from sugar beet sugar to cane sugar to avoid genetically engineered sugar beets. Hershey reformulated

297. NAT'L RESEARCH COUNCIL, THE IMPACT OF GENETICALLY ENGINEERED CROPS ON FARM SUSTAINABILITY IN THE UNITED STATES, at vii-viii, 2–4 (Norman Grossblatt ed., 2010).

298. Another issue flowing from lack of diversity is the emergence of weed and insect resistance. Overuse of glyphosate, in conjunction with Monsanto's Roundup-Ready line of genetically engineered crops (corn, cotton, canola, alfalfa, and sugar beets), has been the emergence of "superweed." *See Are Superweeds an Outgrowth of USDA Biotech Policy: Hearing Before the Subcomm. on Domestic Policy of the H. Comm. on Oversight and Government Reform*, 111th Cong. 23 (2010) (statement of Micheal D.K. Owen, Ph.D., Professor of Agronomy, Iowa State University), https://www.gpo.gov/fdsys/pkg/CHRG-111hhrg65559/html/CHRG-111hhrg65559.htm [https://perma.cc/6KAL-86U2]. Millions of acres are now infested with glyphosate-resistant weeds, like horseweed, pigweed, ragweed, and waterhemp. *Id.* at 3–4.

299. APHIS No. 51, Determination of Non-Regulated Status for Sugar Beets Genetically Engineered for Tolerance to the Herbicide Glyphosate, 70 Fed. Reg. 13007 (U.S.D.A. 2005). For background information, see APHIS Response to Petition 03-323-01p, USDA/APHIS Environmental Assessment (U.S.D.A. 2004), http://www.aphis.usda.gov/brs/aphisdocs/03_32301p_pea.pdf.

300. *See, e.g.*, Ctr. for Food Safety v. Vilsack, 753 F. Supp. 2d 1051, 1053 (N.D. Cal 2010), *vacated and remanded*, 636 F.3d 1166 (9th Cir. 2011), *appealed*, Nos. 11–16468, 11–16564, 502 F. App'x 647 (9th Cir. 2012). For a detailed discussion of this litigation, see Rebecca M. Bratspies, *Is Anyone Regulating? The Curious State of GMO Governance in the United States*, 37 Vermont L. Rev. 923, 948–51 (2013).

301. *U.S. Sugar Production*, USDA, ECON. RESEARCH SERV., http://www.ers.usda.gov/topics/crops/sugar-sweeteners/background.aspx [https://perma.cc/L5U9-K97V] (last updated Apr. 28, 2017).

302. Barry Estabrook, *Sugar-Beet Flip-Floppers, and Other Sustainability News*, ATLANTIC (Nov. 2, 2010), http://www.theatlantic.com/health/archive/2010/11/sugar-beet-flip-floppers-and-other-sustainability-news/65530/ [https://perma.cc/FET3-7VLA].

303. The list of major companies making this choice includes General Mills, Post, Hershey, and Unilever. *See* The Tipping Point is Here on GMOs, with 10 Major Companies Shifting to Non-GMO Products, GMO INSIDE BLOG (June 7, 2016), http://gmoinside.org/the-tipping-point-is-here-on-gmos-with-10-major-companies-shifting-to-non-gmo-products/ [https://perma.cc/H593-PTKM]. Del Monte is also eliminating genetically engineered ingredients. Lucinda Shen, *Del Monte is Making This Huge Change to its Products,* FORTUNE (Mar. 29, 2016), http://fortune.com/2016/03/29/del-monte-natural-products/ [https://perma.cc/D7ZR-KNDP].

304. About Roundup Ready Sugar Beets, USDA APHIS, https://www.aphis.usda.gov/aphis/ourfocus/biotechnology/brs-news-and-information/CT_Sugarbeet_about (last modified Jan. 26, 2016).

many of its products, including the iconic Hershey's kisses to replace beet sugar with cane sugar.[305]

Sugar beet farmers wanting to sell into the new and growing non–genetically engineered foods market must plant conventional sugar beet seeds. However, non–genetically engineered sugar beet seeds are no longer widely available and it will take years to develop a new supply of adequate seeds.[306] In the meantime, cane sugar sells for a premium over beet sugar, even though the two are virtually indistinguishable.[307] In May 2016, a bipartisan delegation of forty-five Senators and Congressional Representatives found themselves in the unenviable position of requesting that the Secretary of Agriculture lift an import quota on cane sugar.[308] USDA raised sugar imports quotas by 200,000 tons in order to meet demand.[309]

B. Costs Due to Control over Knowledge

The five major "agricultural life science" conglomerates hold intellectual property rights in many kinds of seeds, most notably genetically engineered seeds. These companies do not sell seeds, *per se*. Instead, working through dealers, the companies sell technology-licensing agreements that allow the use of those seeds for a single growing season. The only way to legally purchase these seeds is through a licensed dealer. And, every purchaser has to sign a technology/stewardship agreement—a lengthy contract that defines the rights of the seller and purchaser.

The influence the giant agbiotech companies wield over knowledge production about genetically engineered crops parallels their market dominance. Until recently, these technology/stewardship agreements explicitly prohibited the purchaser from conducting research on the seeds.[310] The agreements also

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305. Dan Charles, *As Big Candy Ditches GMOs, Sugar Beet Farmers Hit a Sour Patch,* MPR NEWS (May 12, 2016), http://www.mprnews.org/story/2016/05/13/npr-big-candy-ditches-gmos; Oliver Nieburg, *Hershey's Milk Chocolate and Kisses to Go Non-GM*, CONFECTIONERY NEWS (Feb. 23, 2015), http://www.confectionerynews.com/Ingredients/Hershey-in-non-GMO-and-no-high-fructose-corn-syruppledge?utm_source=AddThis_twitter&utm_medium=twitter&utm_campaign=SocialMedia#.VPYk_vvu—s.twitter.

306. Tom Meersman, *Hershey Dumps Sugar Beets Because of GM Concerns*, SPOKESMAN-REVIEW (Jan. 10, 2016), http://www.spokesman.com/stories/2016/jan/10/hershey-dumps-sugar-beets-because-of-gm-concerns/; Colleen Scherer, *GM Concerns Lead Hershey to Reject Sugar Beets,* FARM J'S AG PROF (Jan. 4, 2016), http://www.agprofessional.com/news/gm-concerns-lead-hershey-reject-sugar-beets.

307. Ron Sterk, *Where's the Sugar?*, FOOD BUS. NEWS (May 17, 2016), http://www.foodbusinessnews.net/Opinion/Ron-Sterk/Wheres-the-sugar.aspx?cck=1.

308. Letter from Senators and Congressional Representatives, to Tom Vilsack, Sec'y, U.S. Dep't of Agric. (May 5, 2016), https://s3.amazonaws.com/emma-assets/gesab/bed16a533f49848b78930ef6d0a1276d/Letter_to_Sec._Vilsack_Sugar_TRQ.pdf.

309. *USDA Increases FY 2016 U.S. Sugar Overall Allotment Quantity and Raw Cane Sugar Import Access*, USDA (May 17, 2016), http://www.fas.usda.gov/newsroom/usda-increases-fy-2016-us-sugar-overall-allotment-quantity-and-raw-cane-sugar-import-access ("USDA recognizes that America's beet sugar producers have made significant investments in a strong 2016 crop, but they continue to face uncertainty.").

310. Emily Waltz, *Under Wraps*, 27 NATURE BIOTECHNOLOGY 880, 880 (Oct. 2009), http://www.emilywaltz.com/Biotech_crop_research_restrictions_Oct_2009.pdf.

prohibited a purchaser from supplying seeds to someone else for research purposes.[311] As a result, there was no way for researchers to legally acquire seeds or conduct research without the explicit permission of the company involved. Researchers complained about needing to have "written permission from the companies for any science involving their seed, even if it was commercially available."[312] To obtain this permission, researchers had to get the company to sign off on the research design. The companies could pick and choose who could study the crops, and how the research would be conducted, giving them unfettered power to shape the information available on genetically engineered crops.[313]

1. Direct Control over Research

In an unprecedented 2009 letter to EPA,[314] twenty-six entomologists complained that the agricultural biotechnology companies were thwarting independent research on the effects of their genetically engineered crops.[315] They alleged that "[n]o truly independent research can be legally conducted on many critical questions."[316] These scientists asserted that this lack of research "unduly limited" the data that regulators had before them in making decisions about genetically engineered crops.[317] They pointed to technology/stewardship agreements as the culprit because of the astonishing level of control these agreements exert over farmers' use of licensed seeds. At the time, these agreements prohibited all research, including even an individual grower's personal experiments intended to compare yields in his/her own fields.[318] The scientists signing this letter all worked at public universities in corn growing regions—institutions with extension programs tasked with bringing "vital, practical information to agricultural producers" and "educating farmers . . . on modern agricultural science and technologies."[319] Because they could not freely conduct independent research, these scientists argued they were unable to fulfill their duty to "address critical public issues through teaching, research and outreach"[320] with regard to genetically

311. *Id.*

312. Nathanael Johnson, *Genetically Modified Seed Research: What's Locked and What Isn't*, GRIST (Aug. 5, 2013), http://grist.org/food/genetically-modified-seed-research-whats-locked-and-what-isnt/.

313. Waltz*, supra* note 310, at 881.

314. *See* Twenty-Six Leading Corn Scientists, Comment for the FIFRA Scientific Advisory Panel on Technology/Stewardship Agreement Required for the Purchase of Genetically Modified Seed (Feb. 22, 2009), https://www.regulations.gov/document?D=EPA-HQ-OPP-2008-0836-0044 [hereinafter Comment from Leading Corn Scientists].

315. Andrew Pollack, *Crop Scientists Say Biotechnology Seed Companies Are Thwarting Research*, N.Y. TIMES (Feb. 19, 2009), http://www.nytimes.com/2009/02/20/business/20crop.html?_r=0.

316. Comment from Leading Corn Scientists, *supra* note 314.

317. *Id.*

318. Waltz, *supra* note 310, at 880 (reporting that Syngenta prohibited any research intended to compare its commercial crops to other companies' crops).

319. *Extension*, USDA NIFA, https://nifa.usda.gov/extension (last visited Nov. 8, 2016).

320. *See, e.g.*, *About Extension: Creating a Stronger Minnesota Through Education and Research*, U. OF MINNESOTA EXTENSION, http://www.extension.umn.edu/about/ (last visited Nov. 8, 2016).

engineered crops. Fearing retaliation, the scientists submitted the letter anonymously.

This letter, and the press coverage it generated,[321] sent shock waves through industry and government circles. In response, the industry trade group, the American Seed Trade Association (ASTA) convened a meeting between the major agricultural biotechnology companies and research scientists. At this meeting, the industry agreed to a set of reforms,[322] including negotiation of institution-wide academic licenses, and some modifications to the prohibitions contained in the technology/stewardship agreements. Under a set of academic research principles, adopted by the companies, ASTA, and the Biotechnology Information Organization, researchers would have greater freedom to study questions deemed agronomic (things like the effects that genetically engineered crops have on soil, on pest populations, on pesticide use, and on the environment more generally).[323] However, research on the genetics of these crops, or anything akin to breeding was still prohibited under the technology/stewardship license. And, perhaps most troublingly, there were no provisions to allow research on crops in development, even though that is the moment when independent research might have the greatest impact.[324]

These research principles were then incorporated into the technology/ stewardship agreements. For example, as of 2011 Monsanto's Technology/ Stewardship Agreement prohibited purchasers from conducting research "*other than for making agronomic comparisons and conduct[ing] yield testing for Grower's own use*."[325] Purchasers are still prohibited from any kind of research that might involve breeding activities.[326]

Public reports suggest that academic researchers now have a much wider scope to research how crops interact with the environment, and which varieties perform best.[327] Monsanto has entered into about 100 Academic Research Licenses designed to allow university researchers to work with Monsanto's seeds without prior consultation with the company.[328] These agreements are between the University and

321. *See, e.g.*, Pollack, *supra* note 315.

322. *Research with Commercially Available Seed Products*, AM. SEED TRADE ASS'N (Sept. 17, 2009), http://www.amseed.org/pdfs/issues/biotech/research-commercially-available-seed-products.pdf.

323. *Id.*

324. Bruce Stutz, *Companies Put Restrictions on Research into GM Crops*, YALE ENVIRONMENT 360 (May 13, 2010), http://e360.yale.edu/feature/companies_put_restrictions_on_research_into_gm_crops/2273/.

325. 2011 Monsanto Technology/Stewardship Agreement, https://thefarmerslife.files.wordpress.com/2012/02/scan_doc0004.pdf (emphasis added). Pioneer's Agreement similarly provides that "You may not conduct research on Seed, grain or crop(s) produced from Seed other than to make agronomic comparisons and conduct yield testing for Your own use." Pioneer Hi-Bred Limited and Technology Use Agreement, https://www.pioneer.com/CMRoot/Pioneer/Canada_en/products/seed_trait_technology/2016_CA_TUA_English.pdf.

326. *See* 2011 Monsanto Technology/Stewardship Agreement, *supra* note 325.

327. Johnson, *supra*, at 312.

328. *The Myth About Controlling Research*, MONSANTO BLOG (Sept. 6, 2012), http://monsantoblog.com/2012/09/06/the-myth-about-controlling-research/.

the company, and cover all researchers at the University. This kind of blanket licensing agreement is undoubtedly an improvement, but it is shocking that this was a question in need of clarification in the first place. And, areas of research that are deemed "outside of agronomic research," most notably breeding, remain off limits. Moreover, the terms of these academic research agreements are confidential, leaving lingering questions about possible restrictions on the freedom to publish or to provide negative results to regulators. There were certainly past incidents in which the attempt to negotiate such agreements broke down over these questions.[329]

Even more astonishing than the prior restrictions on academic research is the fact that these same research limitations extended to regulators. Indeed, it was only in 2010 that Monsanto and the USDA Agricultural Research Service negotiated a license that allowed the government, the regulators overseeing Monsanto, the freedom to conduct research without first asking Monsanto's express permission for each individual experiment.[330] This license came sixteen years after genetically engineered crops were commercially planted. What makes this situation even more astonishing is that for those sixteen years, the fact that USDA had oversight and approval authority was regularly deployed by the companies involved as vouching for the safety and efficacy of these crops.

2. Indirect Control over Research

There is an ideological cast to any discussion about genetically engineered seeds. Both opponents and advocates are passionate in ways that go far beyond the actual data. Advocates see themselves as defending science,[331] and are quick to draw connections between opposition to these crops and the anti-vaccine movement.[332] They analogize rejecting genetically engineered crops to rejecting evidence of climate change.[333] Opponents, by contrast, talk about poisoned food[334] and corporate hegemony.[335] The heated, emotional rhetoric often swamps legitimate

329. Waltz, *supra* note 310, at 881.

330. Emily Waltz, *Monsanto Relaxes Restrictions on Sharing Seeds for Research*, 28 NATURE BIOTECHNOLOGY 996 (2010).

331. Keith Kloor, *Why Vaccine and GMO Denial Should Be Treated Equally,* Discover (Aug. 7, 2014, 11:46 AM), http://blogs.discovermagazine.com/collideascape/2014/08/07/vaccine-gmo-denial-treated-equally/#.V7b5_vkrKM8.

332. *See, e.g.*, *id.*; Joel Silberman, *A Reality Check for the Anti-GMO, Anti-Vaccine Folks,* L.A. TIMES (Nov. 13, 2014, 6:02 PM), http://www.latimes.com/nation/la-ol-vaccine-gmo-natural-20141113-story.html.

333. *GMO Opponents—Left's Version of Global Warming Deniers,* SKEPTICAL RAPTOR (Aug. 19, 2015), http://www.skepticalraptor.com/skepticalraptorblog.php/gmo-opponents-lefts-version-global-warming-deniers/.

334. For a striking example of the kind of hyperbolic, all-caps advocacy that gives rise to the "anti-science" allegations, see Mike Adams, *The GMO Debate Is Over; GM Crops Must Be Immediately Outlawed; Monsanto Halted from Threatening Humanity*, NATURAL NEWS (Sept. 21, 2012), http://www.naturalnews.com/037262_GMO_Monsanto_debate.html.

335. *See, e.g.*, *GMO Intro: GMOs Are Genetically Modified Organisms*, GMO FREE USA, http://gmofreeusa.org/education/gmo-intro/ (last visited Nov. 11, 2016).

concerns both about anti-science and about equity in the food system. With little room for nuance, dialogue becomes a shouting match.

Wading into these polarized waters can be treacherous, particularly for scientists. Given the way battle lines have been drawn, researchers whose work questions the benefits or safety of genetic engineering frequently pay a heavy price for their work. To advocates of the technology these scientists must appear as traitors, with publishing their work in respected scientific journals akin to giving aid and comfort to the enemy. At least that is what it seems like from the ferocity of their response.

The story of Ignacio Chapela and David Quist is case in point. In 2001, the two Berkeley researchers published a *Nature* article claiming that transgenic maize was growing in Oaxaca, the center of origin for maize.[336] Their findings were almost immediately confirmed by two independent teams of Mexican scientists.[337] And subsequently, Mexican officials found even more contamination than Quist and Chapela had initially reported.[338] However, that did not prevent the biotech industry from attacking the researchers in editorials. The Bivings Group, a PR firm affiliated with Monsanto, conducted a viral attack campaign online, posting on AgBioWorld under various names that were later traced back to the firm.[339] These comments were extremely negative, calling Chapela's objectivity and competence into question.[340] The Bivings Group deliberately used individual names on its postings in order to create the impression that these comments were coming from independent third parties. Indeed, at the time, the company's website touted the

336. David Quist & Ignacio H. Chapela, *Transgenic DNA Introgressed Into Traditional Maize Landraces in Oaxaca, Mexico*, 414 NATURE 541, 541 (2001).

337. On September 17, 2001, Mexico's Secretary for Environmental and Natural Resources confirmed that transgenic maize had been found in Oaxaca and nearby Puebla. Rex Dalton, *Transgenic Corn Found Growing in Mexico*, 413 NATURE 337 (2001). Subsequent studies further confirmed that Quist and Chapela's results were correct. *Id.* This is not to say there were no methodological issues in the research. There were plenty of *legitimate* methodological questions. But, the tenor of the critique, and its coordinated nature suggests that something more was going on.

338. By April 2002, the Mexican Ministry of the Environment confirmed that significant percentages of tested Mexican corn farms had traces of transgenic material. Paul Brown, *Mexico's Vital Gene Reservoir Polluted by Modified Maize*, THE GUARDIAN (Apr. 19, 2002), https://www.theguardian.com/environment/2002/apr/19/food.internationaleducationnews.

339. George Monbiot, *The Fake Persuaders*, THE GUARDIAN (May 14, 2002), https://www.theguardian.com/politics/2002/may/14/greenpolitics.digitalmedia; George Monbiot, *These Astroturf Libertarians Are the Real Threat to Internet Democracy*, THE GUARDIAN (Dec. 13, 2010), https://www.theguardian.com/commentisfree/libertycentral/2010/dec/13/astroturf-libertarians-internet-democracy (describing the activities of the Bivings Group).

340. Some of these postings have been reprinted in *A Lady in London and Ignacio Chapela,* GMWATCH (Dec. 10, 2003), http://www.gmwatch.org/news/archive/2003/8102-a-lady-in-london-and-ignacio-chapela; *see also Immoral Maize—Definitive Account of Chapela Affair*, GMWATCH (May 7, 2009), http://gmwatch.org/latest-listing/1-test/10959-immoral-maize-definitive-account-of-chapela-affair (quoting ANDREW ROWELL, DON'T WORRY (IT'S SAFE TO EAT) 149 (2003)).

effectiveness of strategically posting as an uninvolved third party to more effectively influence public opinion.[341]

As always, there were legitimate methodological questions about the research, but the tenor of the response went far beyond the kind of give and take one expects in a scientific discussion. The intensity of the vitriol prompted 144 civil society groups to issue a joint statement decrying the use of "intimidatory" techniques to "silence" dissident scientists.[342] Indeed, even public critics of the Quist/Chapela paper's methodology and conclusions admitted they had "never seen anything like it"[343] and that the attacks on the scientists went well beyond the scope of usual professional interactions.[344] One went so far as to characterize the attacks as "sending a message to any young scientists" in an attempt to stave off publication of other research on genetically engineered crops that "would break ranks."[345]

If this were merely an isolated incident, it might not raise concerns about the control advocates of genetic engineering and biotech companies wield over research. However, the Quist/Chapela story is one in a string of incidents in which reputable scientists publish something critical of genetically engineered crops and find themselves suddenly in a maelstrom. In 2007, Dr. Emma J. Rosi-Marshall, a stream ecologist, found herself at the center of a backlash when she published a paper finding that certain genetically engineered crops "may have negative effects on the biota of streams in agricultural areas."[346] Studying streams in Northern Indiana, Dr. Rosi-Marshall speculated that widespread planting of genetically engineered crops might be creating an unanticipated, ecosystem-wide effect.[347] Within weeks, advocates of genetic engineering were attacking her research design, her data, and her ethics, even going so far as to contact her funders with allegations of scientific misconduct.[348] This type of massive, concerted attack creates a real disincentive to pursue legitimate lines of inquiry.

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341. Monbiot, *These Astroturf Libertarians Are the Real Threat to Internet Democracy*, *supra* note 339 (quoting a Bivings Group article titled *Viral Marketing: How to Infect the World* as advising "there are some campaigns where it would be undesirable or even disastrous to let the audience know that your organization is directly involved . . . .").

342. JOINT STATEMENT ON THE MEXICAN GM MAIZE SCANDAL (Feb. 18, 2002) https://www.organicconsumers.org/old_articles/gefood/maizescandal022002.php (last visited Aug. 16, 2017).

343. Charles C. Mann, *Has GM Corn "Invaded" Mexico?*, 295 SCI. 1617, 1617 (2002) (quoting Peggy Lemaux, a UC Berkeley scientist engaged in genetic engineering research, and, at the time, one of the most public critics of the Quist-Chapela paper); *see also* Justin Gerdes, *Killing the Messenger*, MOTHER JONES (July 9, 2002, 7:00 AM), http://www.motherjones.com/politics/2002/07/killing-messenger (also quoting Peggy Lemaux).

344. Mann, *supra* note 343 ("There's been a lot of fighting about transgenics, but this is something else.").

345. Gerdes, *supra* note 343 (quoting Berkeley Professor Miguel Altieri).

346. Emma J. Rosi-Marshall et al., *Toxins in Transgenic Crop Byproducts May Affect Headwater Stream Ecosystems*, 104 PNAS 16204, 16206 (2007).

347. *Id.* at 16204.

348. Henry I. Miller et al., *Is Biotechnology a Victim of Anti-Science Bias in Scientific Journals?*, 26 TRENDS IN BIOTECHNOLOGY 122, 124 (2008).

Science depends on give and take. One researcher proposes a novel conclusion. Other researchers then conduct their own research, and publish results that either support the novel conclusion, or reject it in favor of other, more robust conclusions. Yet, none of the criticism poured onto Dr. Rosi-Marshall's paper called for further research on the question. Instead, the response was openly driven by the goal of "neutraliz[ing] any effects that Rosi-Marshall's paper might have on policy."[349] When questioned about the tenor of their response, the critics described their commitment to "specific ideas about how the risks of these crops should be scientifically assessed" and their belief that agricultural biotechnology has been "horrendously [and] unscientifically . . . over-regulated and . . . inhibited."[350] Golden Rice came up as an example.[351]

While critiquing and criticizing research design and results are the bread and butter of scientific interactions, the backlash directed at scientists like Rosi-Marshall and Quist/Chapella is different. There is a knee-jerk, *ad hominem*, and even emotional quality to the response that seems, well, unscientific. It is driven by a core of researchers committed to the proposition that genetically engineered crops are misunderstood and overregulated.[352] As such, it seems directed at shutting down rather than opening up discussion.

CONCLUSION

There is no question that the human population is growing or that the climate is changing. We do not yet know whether or how global agriculture will meet these twin challenges. But, it is increasingly clear that public rhetoric about "feeding the hungry" through increased technology, which has been so effectively captured by proponents of genetic engineering, is on the wrong track. In a world awash with both food and hunger, a relentless focus on measures designed to increase yields is at best a distraction and at worst counterproductive. Increasing food production might well be necessary to create the conditions for food security, but alone it will never be sufficient.[353] Indeed, even the National Academy of Science cautions that, "feeding the world involves much more than simply increasing crop production."[354] And yet, the oft-given response to persistent undernutrition is repeated and urgent calls to adopt technologies purporting to increase production.

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349. Emily Waltz, *Battlefield*, 461 NATURE 27, 28 (2009).

350. *Id.* at 30.

351. *Id.*

352. One manifestation of this coordination is the ASK-FORCE, organized under the auspices of the Public Research and Regulation Initiative with the mission of discussing "publications about biosafety and biotechnology that have gained much public attention but which are not supported by a clear majority of peer reviewed scientific publications." *Ask-Force*, THE PUBLIC RESEARCH AND REGULATION INITIATIVE, http://www.prri.net/working-groups/ask-force/ (last visited Nov. 17, 2016).

353. Int'l Assessment of Agric. Knowledge, Sci. and Tech. for Dev., *supra* note 236, at 5.

354. NATIONAL ACADEMY OF SCIENCES, GENETICALLY ENGINEERED CROPS: EXPERIENCES AND PROSPECTS 295 (Norman Grossblatt ed. 2016).

In taking stock of the successes and failures associated with past hunger alleviation initiatives, and in planning to implement the Sustainable Development Goals, it is important to be clear about what the problem actually is. Having the capacity to produce sufficient food is not enough. Unfortunately, even increasing levels of production are no guarantee that anything will change for the undernourished. The key question is a commitment to equity—to using the food that we have to feed people who need it.

Achieving the Sustainable Development Goal of eradicating undernutrition by 2030 will require an emphasis on improved distribution—both through improving the social safety net, and through improving opportunity and livelihoods for the poorest among us. Like other technological tools, genetically engineered crops do not address the complexity and wide variety of challenges that farmers face, especially smallholders. The possibility that genetically engineered crops will contribute to poverty alleviation, and thus to food security, depends heavily on social and economic context. At least some experts have concluded that genetically engineered crops were developed in too narrow a commercial context to offer much to this discussion.[355] Indeed, there is little in the development of these crops to date that positions them either as a tool for redistribution or as a response to the poverty of small and subsistence farmers. It is certainly possible that this situation will change. The key questions will be who invests in new genetically engineered crops, and which crops they prioritize.[356] If genetically engineered crops are going to contribute to achieving the Sustainable Development Goals, it will first require rethinking how research priorities are identified, and how costs and benefits associated with agricultural biotechnology are distributed.[357] The recent consolidation in the agbiotech industry sends a signal that no such rethinking is in the offing.

Complexity is easily lost in the heated public discourse surrounding these crops. Too often what should be a dialogue slips into thoughtless sloganeering. With advocates of genetic engineering intellectually and economically committed to their technology, and opponents equally resistant, the lines between evidence and dogma blur. Public discourse is impoverished when entire lines of inquiry are marked out as off limits, particularly when those boundaries line up with entrenched commercial interests.

This dynamic is increasingly clear to policymakers trying to steer a course forward. For this reason, the FAO cautions against a one-size-fits-all solution,[358] instead emphasizing that hunger alleviation initiatives must be tailored to local

355. Int'l Assessment of Agric. Knowledge, Sci. and Tech. for Dev., *supra* note 236, at 42.

356. NATIONAL ACADEMY OF SCIENCES, *supra* note 354.

357. Int'l Assessment of Agric. Knowledge, Sci. and Tech. for Dev., *supra* note 236, at 42.

358. Food and Agriculture Organization of the United Nations [FAO], International Fund for Agricultural Development [IFAD] and World Food Programme [WFP], *The State of Food Insecurity in the World. Meeting the 2015 International Hunger Targets: Taking Stock of Uneven Progress*, at 4, FAO Doc. I4646E/1/05.15 (2015), http://www.fao.org/3/a-i4646e/index.html.

conditions and political commitment.[359] Fierce rhetoric offers an appealing but false clarity about genetically engineered crops and their role in food security. Instead, we must learn to embrace a complicated and messy ambiguity.

359. *Id.*