FROM "FOOD MILES" TO "MONEYBALL": HOW WE *SHOULD* BE THINKING ABOUT FOOD AND CLIMATE

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Since Michael Pollan popularized the push to eat local food in his bestseller, *The Omnivore's Dilemma*,[1] the concept of "food miles" has been something of a rallying cry and an organizing principle in the marketing of the local food movement. Among locavores and their sympathizers, the term seems to encapsulate all that is wrong with the food system. Fresh grapes from Chile make their way to supermarkets from Maine to Minnesota, and even California. Major food conglomerates process commodity ingredients like corn, soy, and wheat into packaged food that travels across the country and across oceans before landing on a dinner plate. In a time when climate change is emerging as a widely accepted threat—perhaps *the* biggest threat—to the world as we know it, the concept of "food miles" alluringly invites us to take satisfying personal action where national and international governance have failed to forge an effective response to the warming planet. The term suggests that by acting locally, by eating locally, we can each do our own small, individual part to confront the enormity of this global problem—that shopping at the farmer's market is a virtuous act of global citizenship.

This Essay seeks to demonstrate the limits of that notion and to suggest a different way of thinking about food and climate. Whether or not it is true that food travels an average of 1,500 miles before it reaches the American table, the concept of "food miles" is not one which we should construct policy around to address the food system's contribution to global warming. This Essay seeks to bring to the discussion among American legal scholars[2] and local food activists what is becoming increasingly clear to ecologists and other scientists who study the impact of the food system on climate: The distance between American fork and farm, while it may be a part of the climate change puzzle, is not a keystone. Fossil-fueled transportation accounts for a relatively small portion of the food system's contribution to climate change. Far more important than transportation are the ways that farming is done, particularly the efficient uses of nitrogen fertilizer, the

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1. MICHAEL POLLAN, THE OMNIVORE'S DILEMMA: A NATURAL HISTORY OF FOUR MEALS (2006).

2. A number of legal scholars have examined "food miles" in a variety of contexts, and some have noted its limitations. *See, e.g.*, Jason J. Czarnezki, *Food, Law & the Environment: Informational and Structural Changes for a Sustainable Food System*, 31 UTAH ENVTL. L. REV. 263 (2011); Marne Coit, *Jumping on the Next Bandwagon: An Overview of the Policy and Legal Aspects of the Local Food Movement*, 4 J. FOOD L. & POL'Y 45 (2008); Nicholas R. Johnson & A. Bryan Endres, *Small Producers, Big Hurdles: Barriers Facing Producers of "Local Foods,"* 33 HAMLINE J. PUB. L. & POL'Y 49 (2011); Lauren Kaplin, *Energy (In)efficiency of the Local Food Movement: Food for Thought*, 23 FORDHAM ENVTL. L. REV. 139 (2012); Sarah B. Schindler, *Of Backyard Chickens and Front Yard Gardens: The Conflict Between Local Governments and Locavores*, 87 TUL. L. REV. 231 (2012).

management of manure and livestock, and the clearing of forests for cultivation to provide food and energy (biofuel) to a growing world population.

This Essay will proceed in two main parts. In order to choose the most effective policies it is essential to understand what is known about the impact of the food sector on climate change. Part I places "food miles" in context by describing the ways in which agriculture (the cultivation of food) contributes to global warming. It does so not just by looking at today's emissions from agriculture, but also by considering the climate impact of food production in future decades. Part II suggests a pragmatic policy approach to addressing climate change through the food and agriculture sector. It outlines a series of proposals, primarily to be undertaken on the international scale, that focuses on "low hanging fruit" by focusing on the sector's most significant greenhouse gas emissions. It identifies five "Moneyball"[3] strategies for smartly addressing the climate impacts of food production in the coming decades.

I. THE FOOD SECTOR'S CONTRIBUTION TO CLIMATE CHANGE: "FOOD MILES" IN A LARGER CONTEXT

A. Food's Slice of the Global Greenhouse Gas Pie

Food production, mainly agriculture, contributes a major share of greenhouse emissions. The Intergovernmental Panel on Climate Change (IPCC) estimated that global greenhouse gas emissions totaled about forty-nine gigatonnes of carbon dioxide equivalent per year in 2004.[4] The World Resources Institute (WRI) offers a slightly smaller estimate of forty-four gigatonnes.[5] Estimates of the agricultural share of this total vary somewhat, but they are generally accepted to be between 10% and 12% globally from non-CO_2 sources alone.[6] The U.S. Environmental Protection Agency estimated that the agricultural sector contributed more than 6,000 $MtCO_2$ equivalent in 2005 from emissions of nitrous oxide (N_2O) and methane (CH_4).[7] This constitutes nearly 60% of total non-CO_2 greenhouse gas

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3. MICHAEL LEWIS, MONEYBALL: THE ART OF WINNING AN UNFAIR GAME (2003) (chronicling the rise of sabermetrics, in which baseball managers use data analysis to identify low cost strategies for success).

4. Intergovernmental Panel on Climate Change, *Summary for Policymakers*, in CLIMATE CHANGE 2007: MITIGATION OF CLIMATE CHANGE 3 (2007), *available at* http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm [hereinafter CLIMATE CHANGE 2007]. As described further below, the warming potential of greenhouse gases are typically described in terms of the equivalent amount of carbon dioxide, the most prevalent greenhouse gas.

5. *World Greenhouse Gas Emissions in 2005*, WORLD RESOURCES INSTITUTE (2005), http://pdf.wri.org/world_greenhouse_gas_emissions_2005_chart.pdf [hereinafter *WRI Global GHG Chart*]; *see also* KEVIN A. BAUMERT ET AL., NAVIGATING THE NUMBERS: GREENHOUSE GAS DATA AND INTERNATIONAL CLIMATE POLICY 5 (2005) (estimating 41,775 $MtCO_2$ equivalent emissions in 2000).

6. PETE SMITH ET AL., *Agriculture*, *in* CLIMATE CHANGE 2007, *supra* note 4, at 503.

7. U.S. ENVTL. PROTECTION AGENCY, GLOBAL ANTHROPOGENIC NON-CO_2 GREENHOUSE GAS EMISSIONS: 1990-2020, at 5-1 to 5-2 (2006 revised), *available at* http://www.epa.gov/climatechange/Downloads/EPAactivities/GlobalAnthroEmissionsReport.pdf [hereinafter EPA].

emissions[8] and about 13.5% of total global greenhouse gas emissions.[9]

But not all agricultural emissions are non-CO_2 emissions. When the direct and indirect emissions of CO_2 from the agriculture sector are added to these non-CO_2 emissions, the agricultural sector's share rises to more than 25% of global greenhouse gas emissions. Energy use, primarily through the combustion of fossil fuels, still comprises by far the largest category of greenhouse emissions—a total of about two-thirds.[10] Thus, the energy, transportation, and industrial sectors appropriately remain a core focus of climate policy. But food production, primarily through agriculture, remains an underappreciated and relatively poorly understood slice of the climate problem.

B. The Components of the Agricultural Sector's GHG Contribution

An assessment of how best to address the climate impacts of food production is aided by an examination of agriculture's contribution to climate change. What follows is an overview of the ways that agriculture emits greenhouse gases.

1. Carbon Dioxide from Electricity, Heat and Fuel Combustion

Like other sectors of the economy, the food sector obtains energy from fossil fuels, but fossil fuels combustion represents a very small slice of the food sector's total greenhouse gas contribution. Tractors and other farm machinery are powered by diesel or other petroleum fuels, as are the trucks that carry both agricultural and processed foods to markets. In addition, agricultural operations use electricity, which is often generated by burning fossil fuels. These direct CO_2 producing activities produce about 9% of the agricultural sector's total climate change contribution in terms of CO_2 equivalent emissions.[11] But as a proportion of all global greenhouse gas emissions, direct CO_2 emissions from the agricultural sector amount to only 1.4%.[12] This assessment is roughly corroborated by other researchers developing life-cycle greenhouse gas analyses of the food sector.[13]

2. Agricultural Soils and Fertilizer (N_2O)

About 46%of the direct greenhouse gas emissions from agriculture are from agricultural soils and fertilizers in the form of N_2O. [14] Although N_2O is emitted in relatively small volumes, it has a great impact because it has 310 times the warming potential of CO_2.[15] Agricultural soils release N_2O through microbial processes known as nitrification and denitrification, which can occur directly primarily through the application of synthetic, nitrogen based fertilizers to the soil,

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8. *Id.* at 5-1 (estimating 59% in 1990 and 57% in 2020).
9. *See WRI Global GHG Chart*, *supra* note 5.
10. *Id*.
11. BAUMERT ET AL., *supra* note 5, at 86.
12. *Id*.
13. *See, e.g.*, WAYNE WAKELAND ET AL., *Food Transportation Issues and Reducing Carbon Footprint*, *in* GREEN TECHNOLOGIES IN FOOD PRODUCTION AND PROCESSING 211-14 (Joyce I. Boye and Yves Arcand eds., 2012).
14. BAUMERT ET AL., *supra* note 5, at 86; *WRI Global GHG Chart*, *supra* note 5.
15. EPA, *supra* note 7, at 1-3.

and the cultivation of nitrogen-fixing crops such as beans and legumes.[16] Additionally, N_2O is emitted from the management of livestock manure, including its use as fertilizer, though these practices constitute a small portion of N_2O emissions from agriculture.[17]

Aside from the potency of N_2O as a greenhouse gas, the uneven use of synthetic, nitrogen based fertilizers in agricultural production around the world is worth noting. The Green Revolution, which vastly increased agricultural yields between 1960 and the end of the twentieth century, developed and disseminated new technologies such as pesticides and nitrogen-based fertilizers.[18] The widespread application of these technologies in some countries, particularly the developed and developing countries (and their relative absence in the least developed countries), has important implications for where to target any increased use of nitrogen fertilizer in the future.

3. Livestock and Manure (Methane (CH_4))

The use and management of livestock and livestock manure also contributes a substantial portion of the food sector's greenhouse gas emissions, approximately 45% of agriculture's total contribution.[19] Both livestock and manure produce methane (CH_4), a greenhouse gas with a warming potential twenty-one times that of carbon dioxide.[20] Domesticated ruminants, especially beef and dairy cattle, buffalo, goats and sheep, produce methane through enteric fermentation, a microbial fermentation process during digestion.[21] Methane is also produced by the anaerobic decomposition of manure, mostly where it is managed in liquid form in lagoons or holding tanks, as is common in many large pig and dairy operations.[22] Methane emissions from gastric enteric fermentation are sensitive to the content of the feed, which determines the energy content of the manure as well as its digestibility by the livestock.[23]

4. Methane Emissions from Rice Cultivation

As it does with manure, the anaerobic decomposition of other organic material in liquid environments also emits methane. In the agricultural sector, this occurs significantly in rice production when rice fields are flooded, creating the conditions for methanogenic microbial decomposition of organic matter in the soil.[24]

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16. *Id.* at 5-2.

17. *See WRI Global GHG Chart*, *supra* note 5.

18. Jennifer A. Burney et al., *Greenhouse Gas Mitigation by Agricultural Intensification*, 107 PROC. NAT'L ACAD. SCI. 12052, 12054 (2010).

19. BAUMERT ET AL., *supra* note 5, at 86.

20. EPA, *supra* note 7, at 1-3.

21. *Id.* at 5-4. *See also* FOOD & AGRIC. ORG. OF THE UNITED NATIONS, LIVESTOCK'S LONG SHADOW—ENVIRONMENTAL ISSUES AND OPTIONS 95-96 (2006) [hereinafter LIVESTOCK'S LONG SHADOW]. Other animals, including non-ruminants like pigs and horses, as well as humans, produce methane too, but in smaller quantities. *Id.*; *see also* EPA, *supra* note 7, at 5-4.

22. LIVESTOCK'S LONG SHADOW, *supra* note 21, at 97. The application of manure in dry form to fields as fertilizer produces little methane. *Id.*

23. *Id.* at 97-98.

24. EPA, *supra* note 7, at 5-6.

Presently, methane emissions from rice cultivation constitute about 10% of the total greenhouse gas emissions from agriculture, excepting land use change,[25] and about 1.5% of total global greenhouse gas emissions.[26] Potential to reduce methane emissions from rice cultivation exists primarily through the development and cultivation of higher yielding varieties of rice, which would result in the same amount of acreage producing more rice.[27] In the context of overall greenhouse gas emissions from food production, it should be highlighted that the total warming potential of methane emissions from rice cultivation approximately equals total carbon emissions from energy use and combustion of fossil fuels, including in the transport of agricultural goods.[28]

5. Carbon Emissions from Land Use Change

One of the most important, though debated, categories of emissions that can be attributed to agriculture is the release of carbon from land use change. In the carbon cycle, carbon exists in the atmosphere, the terrestrial biosphere (including soil), and in the oceans. In what is known as carbon flux, by various processes, carbon moves between the media, including between terrestrial systems and the atmosphere. The removal of native vegetation to convert land for agricultural use alters the carbon flux in several ways. It removes or replaces photosynthesizing plants that take carbon dioxide from the atmosphere, typically resulting in a decreased flow of carbon dioxide out of the atmosphere into the ground. Forests sequester large amounts of carbon, which constitutes a great portion of their biomass (about 40% of the dry weight of trees is carbon). When forest land is cleared for crop production, the sequestered carbon is released into the atmosphere through combustion (when forests are cleared by burning) or by decomposition of the biomass. In addition to these initial, and relatively rapid, releases of carbon from burning and decomposition of the surface vegetation, converted lands continue to emit carbon for decades due to the slow decay of roots.[29]

There is considerable uncertainty over the full extent of greenhouse gas emissions attributable to agriculture induced land use changes. Estimates by the IPCC and others have indicated that emissions from deforestation and forest degradation contributed about 20% of anthropogenic greenhouse gas emissions.[30] More recent estimates, incorporating new information showing a lower rate of forest loss and degradation as well as ever increasing global fossil fuel emissions, suggest that the proportion may be closer to 12%.[31] Even with the considerable

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25. BAUMERT ET AL., *supra* note 5, at 86.
26. *WRI Global GHG Chart*, *supra* note 5.
27. EPA, *supra* note 7, at 5-7.
28. *See WRI Global GHG Chart*, *supra* note 5 (indicating that agricultural energy use contributes 1.4% of the total warming potential of world greenhouse gas emissions, compared with 1.5% from rice cultivation).
29. Joseph Fargione et al., *Land Clearing and the Biofuel Carbon Debt*, 319 SCIENCE 1235, 1236 (2008).
30. *See* G.R. van der Werf et al., *CO2 Emissions from Forest Loss*, 2 NATURE GEOSCIENCE 737, 737 (2009) (evaluating estimates of the IPCC Working Groups I and III).
31. *Id*. at 738.

uncertainty endemic in these estimates,[32] the overall greenhouse gas emissions caused by clearing land for agriculture are very large (about 5,000 $MtCO_2$ equivalent in 2005).[33] That means that land use change accounts for nearly half of agriculture's contribution to climate change. When considered cumulatively with the agricultural sector's other greenhouse gas contributions, emissions from land use change bring the sector's total contribution to more than 25% of total global emissions.

In the larger picture, it is more than just the magnitude of greenhouse gas emissions from land use that matters. Greenhouse gas emissions from land use change vary greatly across the globe due to several factors. First, of course, land varies in its capacity to hold carbon stocks. Tropical lands are particularly rich in biomass. Accordingly, the conversion of the same amount of land for agriculture has different impacts depending on where it is located. Second, carbon emissions from land use change tend to reflect the stage of economic development of a particular place. Land use change in developed countries today, including the United States, likely results in a net absorption of carbon, though the same countries released large amounts of carbon into the atmosphere in earlier decades and centuries when land was being cleared for agriculture.[34] The unsurprising result is that land use change in tropical countries account for a large proportion of all global emissions from land use change, with Brazil and Indonesia contributing about half.[35]

C. The Greenhouse Future—Global Food Demand in 2050 and Its Implications

Not only does the production of food produce upwards of a quarter of all greenhouse gases, but we should expect its contribution to grow considerably in absolute terms over the coming decades. Two inexorable trends—world population growth and the increasing wealth of that population—promise to result in dramatically increasing demands for food. In short, these trends suggest that not only will there be many more mouths to feed, but those mouths will be demanding food to meet a more carbon-intensive diet. These trends, therefore, have important implications for how we respond to the challenge of climate change in our food policies, both globally and nationally.

1. World Population Growth

Sometime in the last year or so, the world's population surpassed seven billion people. By 2050, the United Nations projects it will increase by nearly two billion people to 8.9 billion.[36] It will peak at 9.22 billion in 2075 before dropping back

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32. Van der Werf et al. estimate the range of deforestation's contribution to anthropogenic greenhouse gas emissions to be from six to 17%. *Id*.

33. *See WRI Global GHG Chart*, *supra* note 5.

34. *See* BAUMERT ET AL., *supra* note 5, at 91.

35. *Id*.

36. UNITED NATIONS, DEP'T OF ECON. & SOC. AFFAIRS/POPULATION DIV., WORLD POPULATION TO 2300, at 4 (2004).

slightly and stabilizing at about nine billion.[37] More people, of course, translates into more demand for food. If those nine billion people in the future eat about the same diet as the world population today, then demand for food might be expected to grow by two-sevenths, or about 28.5%. Meeting that demand will require greater agricultural production, which will emit more greenhouse gases.

2. Wealth and the Changing World Diet

But those nine billion people will not eat the same diet as the world does today. Compounding the problem of feeding an increasing number of mouths will be those mouths' taste for a more carbon intensive diet. Almost all of the population growth in the coming decades will be in the developing world, which will experience about 58% growth between 2000 and 2050 compared to 2% for the developed world.[38] Between now and 2050, these nations will become richer, and they will do so at a faster rate than wealthier nations. The share of all economic production contributed by developing nations will rise from about 20% today to 55% of the world's economic output in 2050.[39]

There is a range of estimates about what increasing wealth in developing nations means for food demand. The Food and Agriculture Organization of the UN estimated that total global demand for food in 2050 would be 70% higher than in 2005.[40] But some expect an even bigger increase. A team of researchers led by David Tilman of the University of Minnesota revealed a simple relationship between wealth and food demand: the richer a country, the richer its diet in terms of both calories and protein.[41] They measured national per capita demand for crops, including crops used for consumption by humans, livestock, and aquaculture, as well as waste and spoilage, over the period 1961 to 2007. They found that per capita crop use was dependent upon per capita GDP;[42] the wealthier the nation, the more calories and protein it demands for each person. Specifically, Tilman's team found that per capita demand for calories and protein in the richest countries is 256% and 430% higher, respectively, than it is in the world's poorest countries.[43] Even among countries with similar wealth, the relationship exists—the richer countries among each group, whether a group of poor nations, middle wealth nations, or wealthy nations, consume more per capita in calories and protein than its poorer cohort.[44] Tilman's team estimates that, in light of this increasing wealth, global demand for calories and protein will increase by 100% and 110% respectively from 2005 to 2050.[45]

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37. *Id*. at 1.
38. *Id*. at 4.
39. FOOD & AGRIC. ORG. OF THE UNITED NATIONS, HOW TO FEED THE WORLD IN 2050, at 7 (2009), *available at* http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf.
40. *Id*. at 8.
41. David Tilman et al., *Global Food Demand and the Sustainable Intensification of Agriculture*, 108 PROC. NAT'L ACAD. SCI. 20260, 20260 (2011).
42. *Id*.
43. *Id*.
44. *Id*.
45. *Id*. at 20261.

An important aspect of this analysis is the projected increased demand not just for calories but disproportionately for protein. As people in developing nations get wealthier, they will not just eat more,[46] but they will eat more protein, including more meat protein. For example, meat consumption has grown three-fold in Brazil and nine-fold in China since 1963.[47] Global meat consumption is projected to rise moderately in coming decades,[48] but the change will exacerbate climate impacts because producing meat protein is carbon-intensive compared to plant protein.[49]

In sum, in the coming decades the world will be more populous and richer. It will demand far more food overall and relatively more carbon-intensive food than it does today. This has profound implications for how the United States and its world partners should seek to best mitigate the climate impacts of food production.

II. STRATEGIES FOR RESPONDING: TOWARD A MONEYBALL APPROACH

How the United States responds to the daunting climate impacts of the agricultural and food sector is bounded by dual imperatives. One imperative is actually addressing climate change. It is becoming increasingly clear that "business as usual" is an inadequate response and that global greenhouse gas emissions must shrink. But just as surely, it is imperative that we find a way to feed the 9 billion people who will inhabit the planet in the future. Although these imperatives are seemingly at odds, various paths may exist to serve both. This part will examine a number of policies that research on agricultural yields and climate impacts indicate should guide global agricultural policy. In order to place these proposals in context, however, first consider two archetypical responses: meeting demand by placing more land into production (extensification), and meeting future demand by producing more food on land already in production (intensification).

A. Alternative Paths Toward Producing More Food

1. Extensification

One way to increase agricultural production is to cultivate more land. This is known as "extensification," because it employs existing agricultural practices on more extensive land. Theoretically, the increased demand for food in 2050 could be met solely by this method. For the purposes of bounding the climate impacts of doing so, we may assume that the cultivation of additional croplands would produce at the same yields and have the same climate and other environmental impacts as lands under cultivation today. The extent of agricultural production today is about 38% of Earth's ice-free land, or about 4.9 billion hectares.[50] About one-third of that is used as cropland, while two-thirds is used as pasture. Together,

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46. *See* John Kearney, *Food Consumption Trends and Drivers*, 365 PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOC'Y, BIOLOGICAL SCI. 2793, 2794 (2010) (indicating that daily per capita calorie consumption in developing countries will increase from 2,654 kcal to 3,070 kcal between the years 2000 and 2050).

47. *Id*. at 2796.

48. *Id*.

49. *See, e.g.*, Mark Bittman, *Rethinking the Meat-Guzzler*, N.Y. TIMES, Jan. 27, 2008.

50. Jonathan A. Foley et al., *Solutions for a Cultivated Planet*, 478 NATURE 337, 337 (2011).

pasturing and cropping constitute the largest use of the world's land.[51] Given constant yields, meeting world food demand in 2050 would require roughly doubling the land in agricultural production, to nearly 80% of the Earth's ice-free land.

Actually meeting the entire incremental food demand through extensification is almost certainly impossible, as the lands presently under cultivation are the ones best suited to agriculture.[52] But it is clear that that degree of extensification would entail huge releases of CO_2 into the atmosphere. Just how much may be unknowable, but one innovative study estimated the hypothetical carbon cost of meeting increased food demand (reflecting both population growth and improved living standards) between 1961 and 2000 solely through extensification.[53] Meeting that increased demand without intensification would have released some 161 gigatonnes of carbon in total, an astonishing 34% of all greenhouse gas emission by humans between 1850 and 2005.[54] Thus, pure extensification seems highly incompatible with the goal of reducing greenhouse gas emissions, or even carefully managing their growth in an essential sector.

2. *Intensification*

An alternative to extensification is "intensification." Intensification is the production of more food from the same amount of land through more intensive use of fertilizers and other technology. Under this archetypical approach, we could meet increased future demand solely by improving the productivity of existing cultivated land, and would not require placing new land into production. Like extensification, intensification imposes costs on the environment, including climate costs, by releasing more N_2O and CH_4. Still, some of these emissions might be avoided by several widely accepted strategies, including conservation tillage, efficient nutrient management, and water management.[55]

Although it may be possible to meet 2050 food demand solely by agricultural intensification, there are some well-recognized limits. Most significantly, agricultural technologies tend to demonstrate diminished returns in yield when they are most intensively adopted. For example, applying the same amount of nitrogen fertilizer in a field with already high use will produce a smaller increase in yield than it would in a field that uses little nitrogen fertilizer.[56] As a result, based on the existing level of fertilizer use, it is possible to identify the most strategic manner of intensification designed to maximize improvements in yield while minimizing greenhouse gas emissions.

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51. *Id*.
52. *Id*.
53. Burney et al., *supra* note 18, at 12053.
54. *Id*.
55. *Id*. at 12055; *see also* SMITH ET AL., *supra* note 6, at 506-22.
56. *See* Tilman et al., *supra* note 41, at 20262.

B. Five Strategies for Meeting Global Food Demand While Limiting Greenhouse Gas Emissions

1. Strategic Intensification

Research clearly indicates that intensification is the better alternative to extensification. Therefore, the greater part of increased global demand for food should be met by intensifying the use of fertilizers and other technologies on agricultural lands already in production.

Tilman's research team has demonstrated that intensification can effectively meet the demand for food in 2050 at a lower environmental cost than even the same level of extensification that has occurred in recent decades.[57] In addition to modeling national demand for agricultural output in relation to national GDP, Tilman used regression analysis to demonstrate the relationships among global use of nitrogen fertilizers, crop yields, land clearing, and greenhouse gas emissions. He then explores how well various strategies would meet global food demand and at what environmental cost. If the strategy mimicks past trends, poorer countries would respond to greater food demand through extensification while richer countries with already-higher yields would respond through intensification and further yield improvement. This "business as usual" pathway would result in the clearing of an additional one billion hectares of land by 2050, release three gigatonnes per year of carbon-equivalent greenhouse gases, and increase annual global nitrogen use from 94 million to 250 million tonnes.[58] In short, business as usual would produce disastrous climate and other environmental impacts, including loss of habitat and biodiversity.

But Tilman's research fortunately shows a smarter path. There exists today a great disparity between the agricultural yields of rich and poor countries. The agricultural yield of poorer, lower-yielding countries can be expected to increase dramatically with improving technology and the implementation of agricultural technology already in place in richer countries. Tilman shows that if poorer countries benefit from technological improvement and technology transfer (i.e., farmer education and infrastructure development) as well as from intensification of nitrogen fertilizer use (so that they may enjoy the same technologies and improvements as richer countries), the global demand for food in 2050 can be met with much lower greenhouse gas emissions and other environmental costs.[59] If emphasis were placed on minimizing land clearing in favor of intensifying production on existing lands, only about 0.2 million hectares of new land would need to be cleared, limiting the greenhouse gas emissions to about 1 gigatonne per year.[60] Under such a scenario, however, the use of nitrogen fertilizers would more than double in intensity, exacerbating other environmental impacts. Maintaining current nitrogen intensity would require about .5 million hectares of newly cleared land and would keep greenhouse gas emissions to about half of the "business as

57. *Id.*
58. *Id.*
59. *Id.* at 20262-63.
60. *Id.*

usual" scenario.[61]

This smart path to meeting future food demand at a lower cost in greenhouse gas emissions will require a fundamental shift in the application of agricultural technology and knowledge. Particularly, it will require focusing on policies to improve crop yields in areas where it greatly lags production potential. This will involve enhancing the productivity of soils through greater use of nitrogen fertilizers and/or agricultural practices that otherwise fix nitrogen in soil (e.g. rotational planting of legumes). It will also require more efficient use of nitrogen to avoid the application of nitrogen in excess of plant uptake.[62] This may involve a reduction of nitrogen fertilizer use in areas of low nutrient use efficiency and high excess nutrients, including the U.S., China, Northern India, and Western Europe.[63]

To be sure, there are substantial barriers to strategic intensification, especially to the degree that Tilman's research indicates is optimal for meeting future food demand with minimal increases to greenhouse gas emissions. Policies will need to be developed to make possible the transfer of agricultural technology, and to also inform the poorer, low-yield countries where we wish to forestall land clearing. In addition, substantial investments in infrastructure will be required, most likely financed by the wealthier nations, but the wisdom of the path is evident.

2. Limited and Strategic Extensification

Tilman et al. have shown that meeting future demand solely by intensification would increase the use of nitrogen by about 150%. It appears, therefore, that extensification is an unpalatable but necessary part of the solution. Like intenstification, however, extensification should be strategic. Much land clearing in recent years has been in the tropics. Nevertheless, converting land in the tropics has generally resulted in a poor return, particularly considering the high environmental cost, including the release of carbon into the atmosphere and the loss of biodiversity. Many tropical lands have low yields compared with temperate areas, and even the higher yield areas do not contribute greatly to the production of calories or protein.[64]

Interrupting the strong economic forces driving agricultural land use change will not be easy, but there are some things that can and should be done. Most importantly, the United Nations framework on reducing emissions from deforestation and degradation, known as REDD, must be completed and implemented. The basic idea behind REDD is to create incentives, financed by developed countries, to help developing countries address deforestation and forest degradation.[65] This would be most easily and widely implemented by creating verifiable emissions reduction credits for prevention of deforestation that could be traded in carbon markets. This might be done at the international, national, or even

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61. *Id*.
62. *Id*.; *see also* Foley et al., *supra* note 50, at 340.
63. Foley et al., *supra* note 50, at 340.
64. *Id*. at 339.
65. Randall S. Abate and Todd A. Wright, *A Green Solution to Climate Change: The Hybrid Approach to Crediting Reductions in Tropical Deforestation*, 20 DUKE ENVTL. L. & POL'Y F. 87, 99-102 (2010).

subnational levels, such as by incorporating REDD credits into California's cap and trade system.[66] In addition to REDD, economic incentives to preserve forests and prevent land clearing might include investments in ecotourism and other measures to enhance the value of forest preservation to communities in the developing world.

3. Shaping the World Diet

As discussed above, a significant proportion of future greenhouse gas emissions will be attributable to shifting global dietary patterns. A smart approach to greenhouse gas emissions in the agricultural sector will seek to minimize the trend. While this is surely no easy task, several strategies might be employed.

One potential strategy is suasion. Governments can attempt to influence the diet of their populations by convincing them that a carbon intensive diet is unwise, perhaps for health, cultural, or environmental reasons. In the United States, aggressive public information campaigns have helped reduce smoking and other behaviors deemed undesirable from a public health perspective. Little is presently known, however, about how to effectively influence dietary behaviors, particularly on a national or cultural scale.[67] Suasion might be enhanced if it were coupled with price signals. If a carbon intensive diet were more costly, then fewer people could afford it or would choose to afford it. Of course, many such price-influencing policies, such as taxing carbon intensive foods, would have to be implemented by individual countries through their own domestic laws.

One intriguing possibility that might indirectly affect price signals is to impose land use controls that limit what land can be used to produce carbon intensive foods like meat. Overall, up to 75% of land used for agriculture is used for raising animals and feed. To the extent such land is not otherwise suitable for food crops, this may be beneficial, because it increases overall calorie and protein production and improves both economic conditions and food security.[68] It is foolish, however, to use highly productive croplands to produce animal feed when the same land can produce grains for human consumption with less climate impact. Accordingly, governments should consider and be encouraged to directly limit the use of prime agricultural land for raising animals or for raising feed for animals meant for human consumption. Of course, effective land use limits might also drive the price of meat higher, resulting in less demand.

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66. California is implementing the first comprehensive, state-administered cap and trade system. Administered by the California Air Resources Board, the program covers about 20% of all regulated greenhouse gas emissions and aims to reduce emissions to 1990 levels "through efficiency measures, innovation, market credit purchase, and carbon offsets." Adam Regele, Note, *Forest Offsets and AB32: Ensuring Flexible Mechanisms are Firm*, 19 HASTINGS W.-NW. J. ENVTL L. & POL'Y 163, 164 (2013).

67. Tara Garnett, *Where Are the Best Opportunities for Reducing Greenhouse Gas Emissions in the Food System (Including the Food Chain)?* 36 FOOD POL'Y S23, S30 (2011); *see also* Fargione et al., *supra* note 29, at 1235. Some research has been conducted on influences on individual food choices, such as through labeling or education, though the results are mixed. Posting calories on restaurant menus, for example, does not appear to affect the overall number of calories purchased by low income people in New York City, even though customers reported knowing more about the caloric content of the food they were ordering. Brian Elbel et al., *Calorie Labeling and Food Choices: A First Look at the Effects on Low-Income People in New York City*, 28 HEALTH AFFS. 1110, w1116-17 (2009).

68. Foley et al., *supra* note 50, at 338.

4. Doing Biofuels the Right Way

The rapid rise of biofuels as part of the world's energy mix is exacerbating the climate impact of agriculture by creating more demand for scarce agricultural land. In some instances, as with corn ethanol, the very crops that once supplied food are diverted from the food system to produce fuel. In other instances, land that is producing food is shifted to grow crops for biofuels feedstock. In both cases, it becomes harder to meet the growing demand for food. Unfortunately, one response is that more land is cleared to grow food in order to compensate for production moved to biofuels. In path breaking research, Timothy Searchinger has demonstrated through lifecycle analysis that the climate benefits of using biofuels is eliminated for decades when the carbon debt of land clearing is considered as part of the overall carbon footprint.[69] Although burning biofuels emits less carbon than fossil fuels, the release of carbon from land being cleared is so great that the carbon debt is not repaid for many years. The "payback" period for corn ethanol is 167 years.[70]

There are several steps that may be taken to rationalize biofuels policy.[71] At a minimum, the direct use of food crops, such as corn, for biofuels should be ended. Furthermore, biofuels should only be produced in ways that eliminate or minimize the competition with food crops for land.[72] This might include biofuels made from feedstocks such as crop residues, perennials grown on degraded or abandoned agricultural land, forest residues from sustainable harvesting, and municipal waste.[73] Finally, policy benefits for biofuels, including subsidies, should be withheld unless lifecycle analysis indicates a substantial improvement over the use of fossil fuels.[74]

5. Reducing Food Waste

A final area of potentially "low hanging fruit" relates to food that is produced but never used. Between one third and half of all food is never consumed because it is lost between farm and fork.[75] In developing countries, much of the loss occurs because of poor storage and transport conditions. In developed countries, higher losses occur at the retail and consumer level.[76] The implications of such rampant waste are clear. In short, one third to half of all resources used by the food sector, whether expressed in terms of water use or greenhouse gas emissions, are attributable to food that feeds no mouths. Even so, waste seems to be a generally overlooked aspect of the food system.

Confronting food waste will likely require action by consumers and

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69. Timothy Searchinger et al., *Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change*, 319 SCIENCE 1238, 1238 (2008).

70. *Id.* at 1239.

71. *See* David Tilman, et al., *Beneficial Biofuels—The Food, Energy, Environment Trilemma*, 325 SCIENCE 270, 270-71 (2009).

72. *Id*. at 270.

73. *Id*.

74. *See id*. at 271.

75. Foley et al., *supra* note 50, at 340.

76. *Id*.

businesses, but governments can play an important role too.[77] Government might set goals for reducing waste and study the problem to identify the best opportunities to achieve greater efficiency.[78] Governments might also adopt policies to incentivize greater utilization of food, such as by providing tax relief for food donations or evaluating procurement policies.[79] In the United States, waste might be reduced by governmental clarification that voluntary "sell by" and "use by" dates do not relate to food safety.[80]

CONCLUSION

Climate change is serious business. And so is feeding nine billion people. Meeting the imperatives of saving the planet and also feeding it will require making smart policy choices. We need to channel our policy investments so that return will be greatest in terms of increasing food production to meet growing demand, limiting greenhouse gas emissions, and minimizing other environmental impacts such as biodiversity loss, natural resource depletion, and degradation (especially water). As we better understand the overall climate impacts of food production, it is becoming clear that "food miles" is too simplistic a label to encapsulate how to make our food systems more climate friendly. Instead, based on the increasingly sophisticated analyses of complex data being done by researchers such as David Tilman, we should pursue "moneyball" policies that will maximize the chance for meeting both imperatives.

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77. *See, e.g.*, DANA GUNDERS, NATURAL RES. DEF. COUNCIL, WASTED: HOW AMERICA IS LOSING UP TO 40 PERCENT OF ITS FOOD FROM FARM TO FORK TO LANDFILL (2012).

78. *See id*. at 16 (noting that the European Parliament adopted a resolution to reduce waste by 50% by 2020).

79. *Id*.

80. *See id*. at 17 (citing research that such reform can reduce household food losses by as much as 20%).