Climate-Friendly Land Use

Paths and policies toward a less wasteful planet

Union of Concerned Scientists

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We have but one Earth, so in using it to satisfy human needs we must not squander the planet's land and other resources. Yet our current global land use system, dominated by agriculture and forestry, has inefficiencies that cause enormous waste and pose threats to our health and the global climate.

Thus it is essential that we find better paths. We must create effective policies for moving the system toward the more efficient use of land in producing the biomass, food, and feed we require.

Patterns of demand are critical; they are largely responsible for the waste that exists today, and they also represent the changes that would reduce it. In particular, changes in diets and other consumption patterns could make an enormous difference. Moreover, the global interconnected nature of the land use system makes it important to look at the world economy as a whole when seeking feasible solutions.

Beef is a key area of inefficiency. Compared with its alternatives, beef uses larger amounts of land, generates much higher quantities of global warming emissions (even without taking into account the deforestation that beef causes), consumes greater quantities of biomass and net primary production, and requires higher levels of feed and fodder. Yet the beef production enterprise produces relatively little food. This is the case not only in comparison with plant-based foods but also with other animal-based sources such as chicken, pork, eggs, and milk. Similar inefficiencies occur in the use of land to make wood products, generate bioenergy, and produce palm oil (a major industrial and food commodity).

Population growth is no longer the major driver of increasing global food demand. Rather, diet change, which is occurring rapidly throughout the world, is the most important factor in the twenty-first century. Trends on the demand side, such as rising bioenergy use and the "nutrition transition" toward more animal products, vegetable oils, and sugars—along with decreased consumption of grains and root crops—are changing land use patterns rapidly, often in directions that are negative for public health and the climate.

But we could encourage other, more positive, transitions. Simply shifting some of the meat demand from beef to chicken, for example, would have multiple benefits. It would lessen competition for land (thereby reducing prices and allowing for the manufacture of wood products without disturbing natural forest), enable more sustainable production of biofuels, and help the palm oil industry be a plus for the climate rather than a serious minus.

Policies that could shift trends in positive directions include carbon prices on food and wood products, land use planning and zoning, loosening mandates that lead to the overproduction of bioenergy, and the promotion of innovative research on the causes of diet change, on the value of multispecies plantations, and on the effect of bioenergy on competition for land. A global holistic approach is needed to reduce inefficiency in the food and land systems, thereby creating a less wasteful society.

[CHAPTER 1]

Introduction

Only One Planet

Humanity is recognizing more and more that because we have only one planet to sustain us, we need to take good care of it. As the signs of demonstrators at international climate negotiations have attested, "There is no Planet B." We will have to satisfy human needs for food, shelter, energy, biodiversity, and a livable climate by using our one Earth wisely. It's the only way to survive in the long run.

Precisely because there is no Planet B, we need a Plan B for global land use, as the way we use Earth now is wasteful and damaging. Further, this inefficiency means that our planet produces much less food, and other things that humans need, than it could. Moreover, our misuse of land creates serious, sometimes fatal, problems for the rest of the world's creatures.

This report looks at some Plans B, C, D, and E. It considers more efficient ways for human society to live on Earth and shows their potential to reduce the waste of land. It uses the most recent science to explore new paths we might take and policies that could help keep us on track.

Paths and Policies

The *paths* we survey are possible future trends in land use, with initial conditions based on the outcomes of recent decades. Often these paths can be expressed as curves, extending from past into future, that show potential outcomes such as increasing emissions, more forests cleared for pasture, or the growing consumption of beef. The *policies* we explore are social and political actions to bend those curves, moving them in more sustainable directions. But both pathways and policies are constrained by current reality.

Therefore we don't try to describe the best path imaginable, assuming that policies would somehow be able to make it happen no matter how much it differed from today's trends. Rather, our analysis is constrained both by need and feasibility. We don't ask what we would do "if we ruled the world." We do look for paths that can be found and policies that can be implemented, starting from where we are now. There is a place for utopian visions, but that is not what this report is about.

Waste in the System

In recent years, there has been increasing recognition of how much waste is associated with the production and consumption of food (Garnett 2013; Foley et al. 2011). Grain is eaten by rats in the granary and is never turned into bread. Milk spoils for lack of refrigeration. Most of the steak is left on the plate in the restaurant and gets thrown out with the trash.

Such losses are serious and substantial, but there is another kind of waste that is seldom discussed and yet may be even larger. This is the waste built into the world food system, occurring because of the ways in which land is used, crops and livestock are produced, and food is consumed. This is due to the inefficiency of the system not when it malfunctions but when it behaves in its perfectly normal way. And not only does the food system have this kind of waste built into it; so does human land use as a whole.

For example, some (but not all) kinds of livestock production use enormous amounts of land, consume large

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Cows graze on land that has been converted from forest to pasture.

quantities of grain and legumes, and emit millions of tons of heat-trapping emissions, yet account for only a minuscule fraction of humanity's food. Some (but not all) kinds of forest management produce very little wood, despite causing forest degradation and increasing the chances of total deforestation over large areas. Whether we look at protein, calories, economic value, or the flows of biomass and net primary production as measures (Krausmann et al. 2008), there simply are some parts of the global land use system that give us very little in return for the amount of resources they consume and the damage they inflict. This is what we mean by the inefficiency of the system itself.

There simply are some parts of the global land use system that give us very little in return for the amount of resources they consume and the damage they inflict.

Although deforestation is one of the clearest examples of inefficiency, our analyses of beef production emphasize the land needs and emissions from normal production on already cleared land and natural pasture. Our arguments do not depend, for example, on the egregious case of deforestation in the Amazon to clear new pasture, which is extremely wasteful both from an economic and environmental viewpoint (Bowman et al. 2012; Boucher et al. 2011).

If these parts of the system yielded products that we just couldn't live without, or that we valued very highly, perhaps their inefficiency in producing food for people could be justified. But such what-ifs are not at all the case. On the contrary, there are desirable substitutes and alternatives for all of them, as shown by demand in the global market. Meanwhile, the inefficient parts of the system that take away resources—e.g., land, feed, water, fertilizer, capital, human effort—from these much less wasteful alternatives are degrading the productivity of the system as a whole.

> ***Consumption patterns worldwide have been changing rapidly—probably more quickly than at any previous time in human history.***

Consumption Patterns Are Key to Inefficiency

Consumption and the demand it generates are key to these inefficiencies because supply, and ultimately land use, respond to them. Often, current consumption patterns are taken for granted: they are assumed to represent innate human desires that cannot be changed. If this were the case, the demands on the land would simply reflect the number of people on Earth. Increasing production would be the only way to feed our growing population.

This too is not at all the case. In fact, consumption patterns worldwide have been changing rapidly—probably more quickly than at any previous time in human history (Foley et al. 2011; Popkin 2011; Popp, Lotze-Campen, and Bodirsky 2010). The current patterns result from recent changes in the food system, not from innate human needs. These ongoing changes are expected to continue for decades to come, and although some changes are quite positive nutritionally, other impacts—on global warming, food security, and public health—could potentially be disastrous (Cassidy 2013; Pan et al. 2013; Pan et al. 2012; Popkin, Adair, and Ng 2012; Foley et al. 2011; McAlpine et al. 2009; McMichael et al. 2007). Seeing how we could alter them, therefore, is vital to our future.

Land Is Globally Connected

The global land use system is a network of many links. Some derive from the simple need to choose, given that a piece of land cannot simultaneously produce a crop of wheat, provide pasture for cattle, and grow a forest. Other links are a matter of basic biology: grazers such as cows can convert grass into meat, but at the cost of methane being emitted by microbes in their ruminant stomachs. And others are due to the economics of a globalized world, in which soy produced in Brazil and sent to feed pigs in China affects biodiesel prices in Germany.

These properties not only make the system complicated but also can cause unexpected and even counterintuitive results (Avetisyan et al. 2011). To try to deal with this complexity, we use global econometric models such as that of the Global Trade Analysis Project (GTAP) to predict how the system would respond to changes in policies and to other "shocks." The results of our GTAP modeling of the substitution of chicken for beef in global diets are described in Chapter 4 and presented in greater detail in an online Appendix 1 (*www.ucsusa.org/lesswastefulplanetappendix*), and we also draw on the work of others using GTAP and other models of varying size and sophistication (Bryngelsson and Lindgren 2013; Golub et al. 2012).

Given these systemic connections, the effects of policy alternatives can be synergistic—in combination they may provide even greater total benefits than the sum of each of them alone. For example, we find that shifting meat consumption from beef to chicken not only reduces grain needs and global warming emissions but also makes land available for reforestation, which takes carbon dioxide out of the atmosphere and reduces global warming even further. Some of the former pastureland could also be converted to crops, either for food, feed, or to produce biofuels, without creating upward pressure on agricultural prices. These are the kinds of combined pathways we need to seek if we want to create a more prolific and less wasteful planet.

[CHAPTER 2]

A Wasteful World

This chapter examines several sectors of the global land use system—beef and, to a lesser extent, vegetable oils, wood products, and biofuels—and the waste they cause. All contain major inefficiencies compared with feasible alternatives that are just as desirable. These alternatives, if favored by policies, could make a big difference in the shape of the world to come.

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Milk production requires far less land than beef and is just as good a source of protein.

Beef versus Alternative Meats

Beef represents only a small part of humanity's food—less than 5 percent of the protein and under 2 percent of the calories (Boucher et al. 2012). Its total consumption is small not only compared with plant sources of protein but also relative to other animal sources—e.g., about 6 percent of our protein is from pork, 6 percent is from seafood, 9 percent is from poultry and eggs, and 10 percent is from milk. Yet the cost of producing beef, whether in terms of land, crops for food and feed, global warming, biomass, or primary productivity, is very high.

The recent analysis of Smith et al. (2013) traced the global flows of feed and biomass (for energy and materials) from the land used to grow the food that ends up on people's tables. Ruminants—overwhelmingly, cattle—yield about 0.14 billion tons of food annually (measured as dry biomass), which is about the same as the total of 0.12 billion tons from the "monogastric" animals (mostly chickens and pigs). Yet the ruminants need much more land to produce a ton of food: 28 hectares, versus just 1.4 hectares for the chickens and pigs. Even if one totally ignores the grazing land used by ruminants and just counts the amount of *cropland*, the ruminants are considerably less efficient as a way to produce a ton of food: they need 2.8 hectares of cropland, versus just half that area for chickens and pigs (Smith et al. 2013).

The above figures don't even show the full inefficiency of beef production because, as noted earlier, a bit more than twice as much protein comes from milk as from beef (the comparison of 10 percent with less than 5 percent). Separating out the land needs of milk versus beef cattle becomes complicated, given that old milk cows and their male calves generally go to produce beef, but life cycle analyses have found that milk production requires between 2.6 and 5.4 hectares per ton of protein while beef production requires from 7.5 to as much as 210 hectares (Nijdam, Rood, and Westhoek 2012). Thus milk is comparable in its land needs with pork, eggs, and poultry meat (4.0 to 7.5, 2.9 to 5.2, and 2.3 to 4.0 hectares per ton of protein, respectively), while beef is many times higher.

> ***Animals are less efficient than plants as sources of food, but beef is the least efficient by far.***

Global warming emissions of beef compared with other meats are even more disproportionate—45 to 643 kilograms of carbon dioxide equivalent (kg CO_2eq) per kg of protein for beef, versus 28 to 43 for milk, 20 to 55 for pork, 15 to 42 for eggs, and 10 to 30 for poultry meat (Nijdam, Rood, and Westhoek 2012). A substantial part of the difference is due to the methane emitted by cows, which is a strong heat-trapping gas—25 times as potent per molecule as CO_2 in causing global warming. However, this isn't the whole story, as shown by the much smaller emissions of dairy cattle. Milk is simply a far more productive way to produce protein than is beef.

Comparing cattle with other animals in terms of the needed biomass or the net primary production (the plant matter produced by photosynthesis) gives a similar story. Ruminants consume 6.22 billion tons of biomass annually, versus just 0.79 billion tons for the monogastric animals, yet the amount of food they produce is practically the same.

Current production of animal protein consumes 36 percent of calories produced on croplands (Cassidy et al. 2013) and only a small fraction of those calories end up contributing to human diets. Cassidy et al. (2013) find redirecting feed calories away from beef and more toward pork and poultry could increase efficiency: "Shifting grain-fed beef production equally to pork and chicken production could increase feed-conversion efficiencies from 12 percent to 23 percent[,] . . . representing 357 million additional people fed on a 2,700 calorie per day diet."

Other studies, and reviews of multiple studies (e.g., Cederberg et al. 2013; Krausmann et al. 2013; de Vries and de Boer 2010; Wirsenius 2003), have come to the same conclusion: animals are less efficient than plants as sources of food, but beef is the least efficient by far.

Better Uses for Forests

Using natural forests to produce wood products such as timber, particularly in the tropics, represents a different kind of inefficiency. Here the comparison is with fast-growing young forests, whether plantations or secondary forests (those that were established naturally after land was abandoned by agriculture). There is good evidence that, with careful management and using techniques such as reduced-impact logging (Putz et al. 2008), environmental damage to mature natural forests from logging can be minimized and these forests can maintain their productivity and much of their biodiversity over long periods of time (Putz et al. 2012). But their output of wood will be much less than that of young forests, whether natural or artificial. Thus mature natural forests may well be unable to compete as a way to produce timber, paper, or other wood products (Shearman, Bryan, and Laurance 2012).

For example, Onyekwelu, Stimm, and Evans (2010) estimate that tropical plantations produce from 3 to 10 times as much commercially valuable wood as mature natural forests. Thus while plantations represent less than 5 percent of tropical forest area, they produce much larger proportions of the tropical output of different kinds of wood products: about 25 percent for sawn wood and plywood, 85 percent for paneling, and more than 90 percent for pulpwood (Elias et al. 2012).

The growth of biomass can be quite high too in young secondary forests that were established naturally after land abandonment rather than from being planted (Bonner, Schmidt, and Shoo 2013). This growth is generally less than in plantations, but is compensated by the fact that these forests store considerably more of their carbon underground, where it will stay out of the atmosphere when the trees are cut. Thus if both wood product production and carbon sequestration are valued, young secondary forests may actually be preferable—even without considering that they are cheaper to establish, and maintain higher biodiversity than monoculture plantations (Chazdon et al. 2009; Nichols, Bristow, and Vanclay 2006; Lamb, Erskine, and Parrotta 2005).

What then should be the role of mature natural forests? If managed for timber, they are likely to lose about 25 percent of their carbon and some fraction (perhaps small) of their biodiversity (Putz et al. 2012)—assuming that subsequent deforestation, which logging roads often stimulate, can be prevented.

Often it is argued that this is a reasonable tradeoff, as they are at least producing some economic return and thus will not be cleared for agriculture. However, in some regions (e.g., Southeast Asia) the value of crops such as oil palm will be higher under current economic conditions than the value of sustainably managed timber; in other areas (e.g., Amazonia) forest clearing for pasture is often an indirect way to speculate on increases in land values (Bowman et al. 2012). In either of these cases, the economic pressure to deforest is likely to overcome the relatively small returns that come from sustainable forest management for timber. This holds even more strongly for fuel wood production, given that sustainable approaches (e.g., firewood collection in the understory, mostly of already dead trees and branches) will have produced much less market value than unsustainable approaches (e.g., charcoal production for urban markets) (Boucher et al. 2011).

Producing wood products, however, is not the only value of tropical forests, and in a warming world perhaps not even the most important value. An alternative purpose for young forests, whether planted or naturally established, can be to restore already cleared land, which will sequester carbon and increase in biodiversity as the forest grows (Brockerhoff et al. 2013; Chazdon et al. 2009). In this case the growing forest is not harvested, or only a small percentage of its most valuable species are harvested, and it eventually will become similar to mature forests in many important respects (Elias and Lininger 2010).

Energy from Land

Bioenergy production, whether for electric power or motor fuel, has become a controversial land use in recent years. It now seems clear that bioenergy does compete to some extent with cropland, thereby increasing food prices, and that it has indirect land use effects that lead to global warming emissions in other regions and countries (e.g., corn ethanol causing Amazon deforestation). The question now is: how strong are these impacts and what can be done to minimize them?

This will depend, logically, on how much bioenergy is demanded. Consider ambitious increases such as the five-fold

BOX 1.

The Oil Palm: Wasted Potential

Because the oil palm is a highly productive tree crop that grows well on abandoned land—and can sequester substantial amounts of carbon if grown in these areas—it is particularly ironic that oil palm is currently one of the main drivers of tropical deforestation (May-Tobin et al. 2012). Oil palm is especially harmful if it is planted on peat soils, which contain very large amounts of carbon that is emitted to the air as CO_2 when the peat decomposes (Carlson et al. 2012).

Between 1975 and 2007 palm oil output increased rapidly, by an average of 8 percent per year. Unfortunately, unlike the situation with other crops, most of that growth came from expansion of the area planted, not from increases in yield (Villoria et al. 2013). Current estimates project that palm oil cultivation in Indonesia alone will grow from 6.5 million hectares in 2010 to between 16.5 milion and 26 million hectares in 2020 (Gibbs et al. 2010).

It may be possible, however, to continue to produce palm oil without expanding into high-carbon forests and causing increased global warming emissions (Wicke et al. 2011). Candidate strategies for doing this include: planting on low-carbon degraded land, replacing the crops in older plantations with higher-yielding varieties, efficient and precise application of fertilizer and other chemical inputs, improved harvesting standards, and reduction of waste by quickly transporting fruit to the mill (Wicke et al. 2011).

All in all, palm oil is a leading example of what could be a productive and low-emissions crop but that at present is expanding in an inefficient way—one that wastes its potential and makes it highly damaging to the climate rather than beneficial (Figure 1, p. 8).

Palm oil is used in everything from food to personal care products to biofuels, but has a significant impact on the ecosystem in which it is grown.

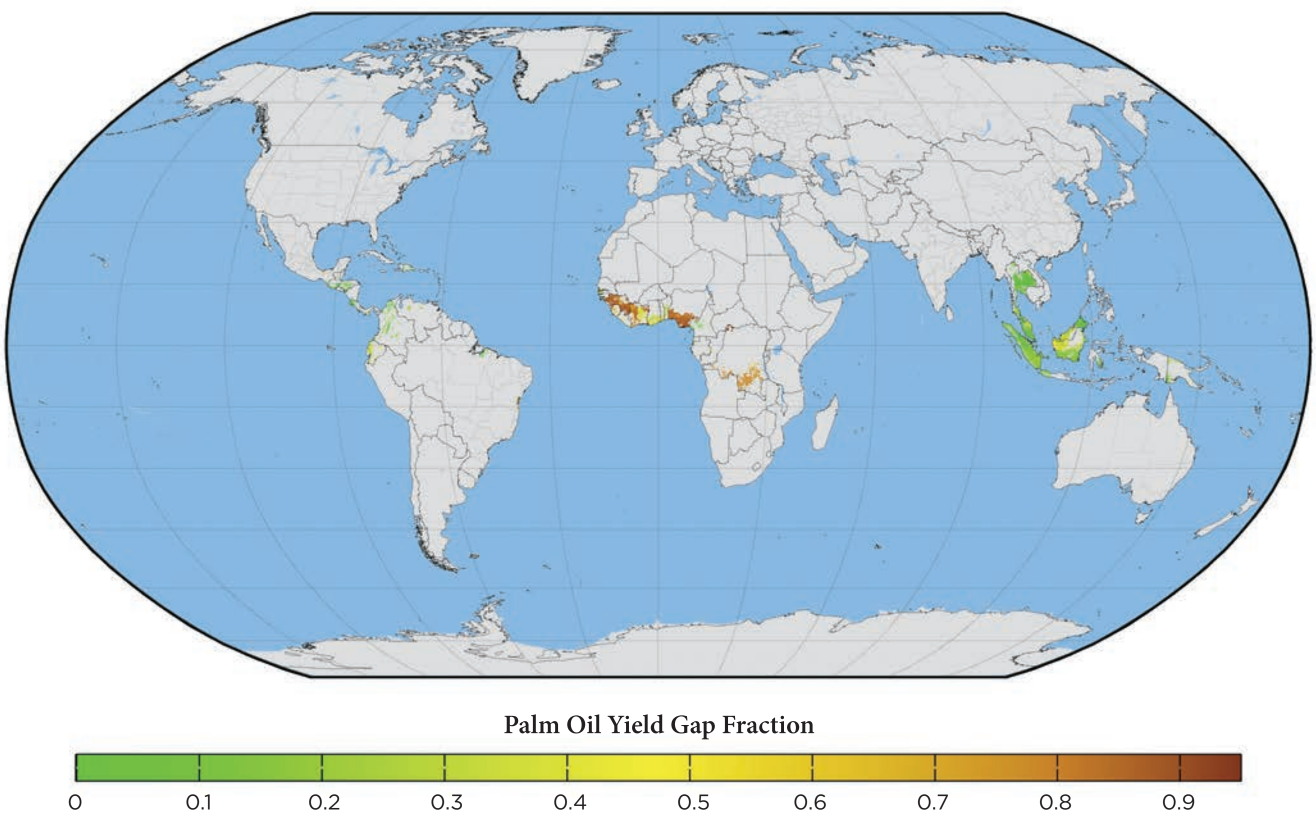
growth by 2050 that Krausmann et al. (2013) model in their Scenario E. This growth would increase the proportion of the biosphere's productivity appropriated by humans to 44 percent, compared with 25 percent currently and 27 to 28 percent in various non- or low-biofuels scenarios. Such a large increase in the demand for biomass—and for land—would substantially increase the competition between food and energy.

Two commonly suggested distinctions ("solutions") with respect to bioenergy might not help as much as is usually thought. The first solution is to avoid using food crops as feedstocks. But all the major bioenergy crops are also used for food (e.g., maize, rapeseed, oil palm, sugar cane) and they have been bred for high levels of productivity. Thus confining bioenergy production to nonfood crops such as jatropha would require more land to produce an equivalent amount of bioenergy. The second solution would make a distinction between marginal land and fertile land, with bioenergy only being encouraged on the former. This too would result in lower productivity unless input levels were increased so as to raise the marginal land's fertility.

Whether one confines bioenergy to marginal crops or to marginal land, the lower productivity would have a

Most U.S. corn ethanol production is currently occurring in the upper Midwest, on some of the most fertile and productive soils in the world.

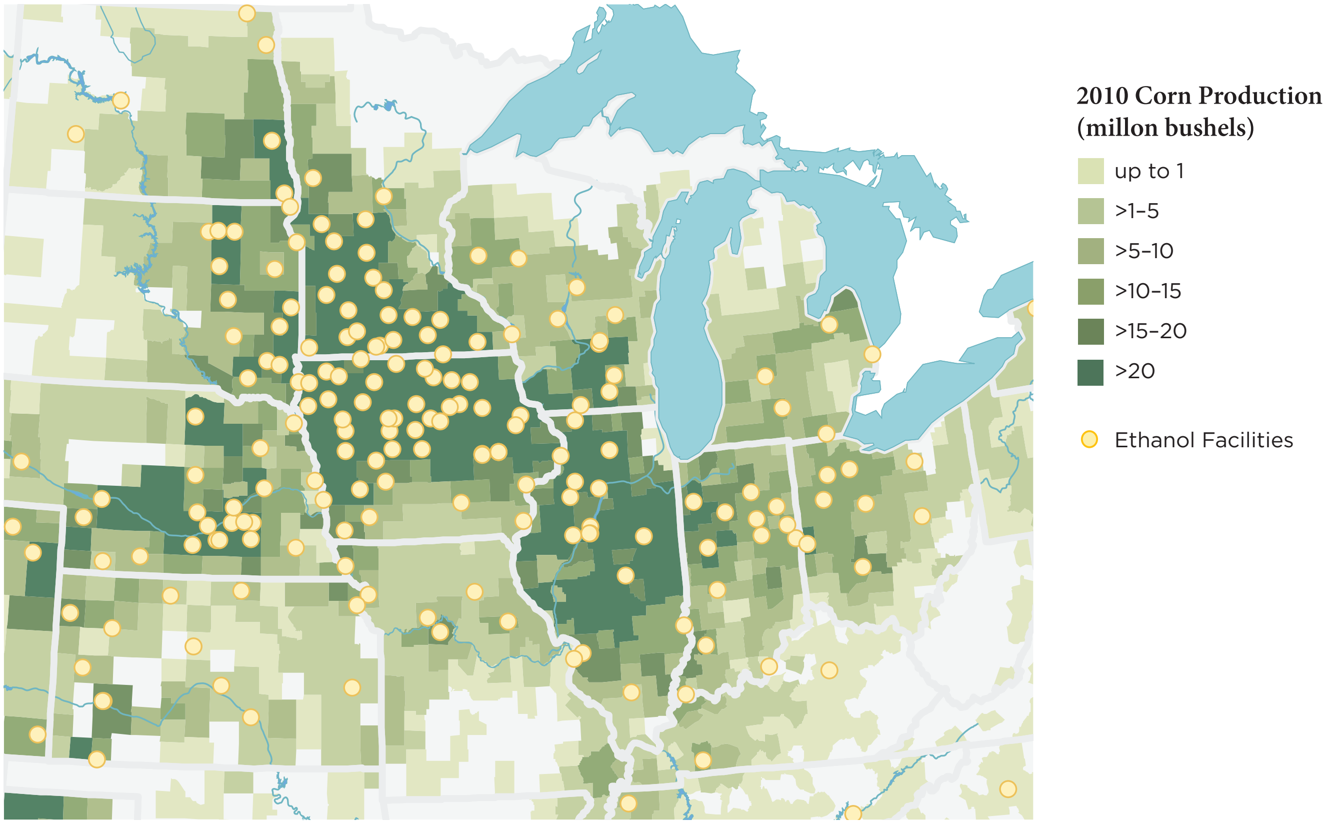
FIGURE 1. The Palm Oil Yield Gap



Palm oil production can be increased substantially, without using more land, by closing its "yield gap," which measures the difference between potential and current oil palm productivity. This gap is currently 50 percent or more over substantial parts of the crop's range. Higher yield gaps (more red) indicate a larger opportunity for improvement.

SOURCE: FOLEY ET AL. 2011

FIGURE 2. Ethanol Plants and Maize Production in the Upper Midwest of the United States



U.S. corn ethanol production is concentrated in some of the most fertile farmland in the world, with record high yields of corn (maize).

perverse effect if a certain quantity of biofuel were mandated (as is currently the policy both in the United States and the European Union). More land would actually be required. The inefficiency of this kind of land use—and this kind of mandate—is clear.

Bryngellson and Lindgren (2013) have shown that the economics of biofuels drives them to be produced on fertile land, if they are produced at all. If produced they will compete with food crops and raise their prices, regardless of whether the fuels are derived from food crops or not. It is the competition for land that matters, not the crop species.

Indeed, most U.S. corn ethanol production is currently occurring in the upper Midwest, on some of the most fertile and productive soils in the world (Figure 2). If the same region were being planted with switchgrass instead, the economic effects would nonetheless be the same: less corn available on the market, higher prices for it, food insecurity, and indirect land use change.

The situation with oil palm (Box 1) is somewhat different, as it can actually sequester substantial carbon if planted on already cleared land. Thus while oil palm does compete with forest and peatland, it could potentially be beneficial to the climate if expansion onto high-carbon lands were prevented.

Whatever the bioenergy case being examined, the fundamental questions remain the same: What is the effect on total global demand? How much new demand for land is created? How much already-cleared land is available to satisfy it? Reducing the land needed for pasture and feed production could help avoid the negative consequences of bioenergy, but only if the demand for it were kept within bounds (Powell and Lenton 2012).

Rising Demand, Changes in the Land

Demand Is Growing—but Why?

If the demands for food, biomass, and land are what matter, what are the factors that make them grow? A simple approach is to split demand into two factors that can be multiplied together: the number of people, and their average per capita consumption. Although this approach has its problems—e.g., the average conceals differences between countries, classes, and genders, making inequality invisible—it still can have value in testing the conventional wisdom that production must grow simply to supply the needs of a growing population.

POPULATION GROWTH IS SLOWING DOWN

Although the estimates differ, it is frequently predicted that the demand for food will increase by about 60 percent (or even 70 or 100 percent) by 2050 (Alexandratos and Bruinsma 2012). But a little bit of arithmetic shows that if this range of numbers were correct, global population growth would not be the reason. The current global population is slightly more than 7 billion, and it is predicted to be just over 9 billion in 2050. Simple division shows that this is less than a 30 percent increase, not 60 percent or more.

Actually, global population growth has been slowing down everywhere, and in some regions quite dramatically, over the past few decades (Bongaarts 2009). The best way to express long-term population growth is in terms of what demographers call the total fertility rate (TFR)—the average number of children who will be born to a woman over her lifetime. In the simplest of cases, then, populations with TFR > 2 will grow, those with TFR < 2 will shrink, and those with TFR = 2 will be stable. In reality, given instances of mortality before the end of the reproductive period, the cutoff point is closer to 2.1 than 2.0 in most modern populations.

*[**Global population growth has been slowing down everywhere, and in some regions quite dramatically, over the past few decades.***

Southgate (2012) shows how in developed countries the TFR has already fallen to 2.1 or well below. It reached that level in the United States in 2007 and is much less than 2.1 in Europe and Japan. In Germany and Russia, for example, the TFR is about 1.4.

This trend is evident in developing countries as well as developed ones. China's TFR is 1.7, Brazil's is 1.9, Iran's is 2.0, and Mexico's is 2.1. India's TFR is 2.7, which will result in continued growth there, but this measure in India is barely half of what it was 30 years ago. Overall, the global TFR is expected to reach the stable level in the next decade. The world population will continue growing for several more decades because of the large number of young people entering their childbearing years, but it is likely to stabilize in the mid- to late twenty-first century (Bongaarts 2009).

This will represent a dramatic change from the situation in the twentieth century. While global population grew by about 2.5 percent annually over the last four decades, in the four decades between now and mid-century it will only be increasing at about 0.8 percent per year.

DIETS ARE CHANGING

If population growth does *not* represent most of the predicted 60 percent increase in food demand by 2050, then changing consumption patterns—changes in diet—must be the answer. The 60 percent estimate is based on the relationship between food demand and expected growth in average income, but a trend that is manifesting itself most strongly is what is called the "nutrition transition" in the developing world. This transition is the increase in demand for meat, other animal products, vegetable oils, and sugars, with a concomitant decrease in per capita consumption of grains and root crops (Popkin, Adair, and Ng 2012).

It is in middle-income developing countries such as China, Brazil, and Mexico, and among those individuals entering the middle class, that the nutrition transition is mainly evident. Thus it does not alter nutrition greatly among the poor, and in fact some aspects of the nutrition transition are not improvements for the middle class either. It is leading to increased obesity and higher rates of heart disease, cancer, and diabetes, among other problems (Pan et al. 2013; Pan et al. 2012; Popkin, Adair, and Ng 2012; Lock et al. 2010; McMichael et al. 2007)

The reason why the nutrition transition is increasing the demand for crops and land, then, is not principally because people are eating more food in general or more healthy food in particular. Rather, the transition represents a shift to animal products such as beef, which require more feed grains, more grazing land, and in general more production of biomass per unit of human-consumed food. Given that the creation of 0.26 gigatonne (Gt) of animal-product food requires growing 7.0 Gt of plant biomass in the twenty-first-century agricultural system (Smith et al. 2013), even a small shift to more animal-based foods can require a large increase in agricultural production.

Thriving local-food systems are increasingly important as we witness both land use and population change around the world.

Land Use Trends

Responding to these changes in demand, land use is changing too. Cropland area has increased somewhat and, at least in the 1980s and '90s, most of the increase came at the expense of tropical forests (Gibbs et al. 2010). But this change conceals an important difference between the tropics, where cropland has been expanding (e.g., soy in Amazonia, oil palm in Southeast Asia), and the temperate zone, in which cropland has actually decreased.

Pasture has also expanded, and with the same difference in temperate-tropical (or developed-developing) patterns. In the Amazon of Brazil, for example, the large majority of the land deforested in recent years has gone into pasture, either directly or after a few years in crop production. As mentioned earlier, a considerable amount of this forest clearing has been speculative, done not to produce meat but rather to establish a claim on land in the expectation that its value will increase (Bowman et al. 2012).

Rates of deforestation, almost all of which is happening in the tropics, have dropped in the last decade but are still high (FAO 2010). Brazil has seen the most dramatic reduction, by more than two-thirds in just six years, and similar trends are apparent in Mexico, Peru, and other countries.

Palm oil is the most rapidly growing driver of deforestation, largely in Southeast Asia. Because of the time lag between the clearing of forest and peat and the establishment of plantations, the crop area is likely to continue expanding for at least several years more, although probably not by the double-digit percentages of the early 2000s.

In terms of agricultural production, for the majority of crops recent growth has mostly come from higher yields, not from expanding area. However, palm oil and pasture are exceptions to this generalization, with relatively little increase in productivity in recent years (Krausmann et al. 2013; May-Tobin et al. 2012). This means that as their output grows, so does their demand for land.

Different Directions

As previous chapters have shown, current global land use is wasteful and inefficient in many ways. What could be done—in the real world, not a utopian one—to improve it? What kinds of changes in current trends would be both feasible and beneficial?

Different Kinds of Meat

Animal products require much biomass and large tracts of land, they emit significant quantities of global warming gases, and they create public health problems (Pan et al. 2013; Pan et al. 2012). Yet they produce quite limited amounts of food. This is true of all kinds of meat products but most especially beef, which is about 20 times as land-hungry as chicken or milk (Chapter 2). Therefore just reducing beef consumption and increasing that of chicken or other protein sources would have quite a positive effect. Both cropland and grazing land areas would drop, as would global warming emissions, and biomass available for other uses could be increased substantially.

GTAP MODELING

This argument is based, however, on simple calculations using land ratios; it doesn't take into account the economics of the system, the spatial distribution of the likely changes in land use, or the impact on trade. To explore these aspects more fully, we modeled two kinds of diet-change "shock"[1]—one that simply reduced beef consumption and the other that reduced beef while increasing chicken—using the econometric computable general equilibrium (CGE) modeling system called GTAP (see Appendix 1 online at *www.ucsusa.org/lesswastefulplanetappendix*).[2] We did not examine a totally meat-free diet in this study, given our emphasis on current trends and the near-term feasibility of alternatives, but see the work of Stehfest et al. (2009) for the modeling of one such option.

Just reducing beef consumption and increasing that of chicken or other protein sources would have quite a positive effect.

The objective of these scenarios was to look at land use in a world in which meat is consumed but is not an excessive part of people's diets. The first consideration, therefore, was to ensure that everyone gets enough protein. Almost all individuals who consume enough energy (calories) consume enough protein, as it is found in many common grains (FAO 1992); however, as countries become richer there will likely be shifts to consuming more meat. Therefore we modeled a scenario in which 16 percent of an individual's protein

1 *Shock is a technical term in econometric modeling, simply indicating a change in parameters.*
2 *Note that GTAP calculates areas in acres rather than hectares (1 hectare = 2.47 acres).*

requirement is met with meat, which is the global average, but any increases from current consumption (for those currently below 16 percent) are met with poultry/pork. The results reflected only current production practices, and did not assume any changes in how crops and livestock are produced.

Another health consideration was a world in which no one eats more beef than is medically recommended, which leads to increased consumption of lower-emissions meat sources.

We calculated the total amount of beef, poultry, and pork consumed based on the following parameter changes:

- In countries that underconsume protein from meat, the level was brought up to the amount that would provide the country's inhabitants with an average of 42 grams/day, based on the health results of Pan et al. (2012). We used only poultry/pork to fill the gap between the current and required consumption.
- In countries consuming more than 42 grams/day of beef, consumption was reduced to this level.

We focused on the results of the less-beef/more-chicken scenario but also compared it both with the current situation and the less-beef-only scenario.

With the combined shocks of reduced beef and increased chicken consumption, U.S. domestic beef production declines by 36 percent and chicken production increases by 36 percent. This corresponds to a decline of 31 percent in domestic cattle herds and a 19 percent increase in the poultry population, which are the intermediate inputs used for beef and chicken production.

In response to the lower demand for beef, cereal grain acreage in the United States declines by a little more than 5 percent, or about 4.5 million acres. In Australia, beef production falls by 22 percent while chicken production increases by 37 percent. In Latin America, beef production falls by 24 percent while chicken production increases by 7 percent. As in the beef scenario, there is only a slight decline (less than 1 percent) in domestic cereal grain production both in Australia and Latin America. In India, chicken production increases by the largest percentage: 166 percent. In Africa, chicken production increases by 22 percent while beef production falls by 1 percent.

With the decline in beef production, pastureland acreage declines in most regions. The largest percentage declines are in India (22 percent), the United States (16 percent), Latin America (8 percent), and Australia (3 percent). Most of the

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As non-ruminants, chickens provide a great source of protein and have a far smaller environmental footprint than cattle.

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Promoting reforestation helps encourage and support healthier ecosystems and economies on a local level.

Young secondary forests can substitute for plantations effectively, particularly when the primary goal is restoration of diverse native forests rather than producing wood products.

decline in Indian pastureland results from a decrease in milk production, as consumers' demand for milk drops with the increase in protein consumption from chicken.

In absolute terms, however, the order of the pastureland reductions is different. The largest reductions are 98 million acres in Latin America and 95 million acres in the United States. Elsewhere the changes are considerably less: 20 million acres in Australia, 25 million acres in Africa, 11 million acres in the European Union, and 6 million acres in India. Overall, the changes are by and large in the expected directions and of the expected order of magnitude.

Not only less pastureland but also less cropland is needed because of the dietary shift from beef to chicken. This is consistent with the higher efficiency with which chickens convert feed into meat.

Creating New Forests

Evidence indicates that multispecies plantations of native trees could supply a major share of the world's wood needs.

In 2005, 109 million hectares globally were productive forest plantations, representing 2.8 percent of global forests (FAO 2005). Of that area, about 67 million hectares were for sawlogs, 27 million for pulpwood and fiber, and the rest split among bioenergy; nonwood forest products such as cooking oil, coffee, fruit, and rubber; or other products (Kanninen 2010).

The use of plantations for producing raw logs has increased dramatically over the past several decades—from 5 percent in 1960 to 30 percent in 2005 (Kanninen 2010), and by mid-century plantations are expected to produce 46 percent to 75 percent of the world's raw logs (Kanninen 2010; Seppala 2007). It may even be possible to move this percentage up to 100 and not use natural forests for wood production at all.

Where could this expansion come from?

Estimates predict that only 73 million hectares of well-managed plantations would be needed to meet today's entire global demand for raw logs. This would likely grow to around 83 million hectares by 2020 (Seppala 2007). Plantations could be established on degraded land and abandoned pasture. The previous section of this report has shown that considerable areas of pasture could be freed up (about 100 million hectares in all) simply by adjusting beef and chicken consumption to levels recommended for health reasons.

Although currently about 30 to 50 percent of wood for paper comes from plantations (Brown 2000), pulp production from recently planted forests is expected to increase in Latin America so as to meet the demand. Therefore no forests should need to be cleared for further pulp and paper production.

Tropical secondary forests' carbon sequestration rates depend on the type of forest and previous land use, but on average they can store about 6.2 tonnes/hectare/year during the first 20 years of regrowth (2.9 tonnes/hectare/year over 80 years) (Silva, Ostertag, and Lugo 2000). This means that young secondary forests can substitute for plantations effectively, particularly when the primary goal is restoration of diverse native forests rather than producing wood products.

Houghton (2012) has calculated that a few hundred million hectares of reforestation in the tropics would sequester enough carbon to cause a significant and salutary effect on global temperatures in the second half of the 21st century. The land for this sequestration—comprised of plantations, newly established secondary forests, or a combination of the two—could be made available by a relatively limited shift in the type of meat consumed, which would also be beneficial for public health.

Limits on Bioenergy

An important constraint on bioenergy development and regulation should be to limit competition for land between crops raised for bioenergy and those raised for food and feed. The reduction in the need for feed grains would come from a shift in human diets away from beef and toward more chicken, which would help provide some of the land for bioenergy.

This would not be sufficient, however, if there were incentives to produce too much bioenergy. Under these circumstances, limiting bioenergy to nonfood crops or to marginal lands would still increase the amount of land needed. The land that is used, rather than the characteristics of the feedstock, determines whether there will be competition—which has negative consequences for food prices and causes indirect land use effects that produce emissions in other regions or countries.

By contrast, the analyses of the effects of changing diets in a positive direction (analyses based on calculations of land ratios, as well as those based on GTAP modeling) suggest that more chicken and less beef consumption would reduce demand both for pastureland and cropland.

The Palm Oil Pathway

Because the oil palm is a tree that can sequester appreciable quantities of carbon over its growth cycle, it is different from other crops. Whether the resulting palm oil is used for food or as a feedstock for biodiesel is not as important as the amount produced relative to the demand or as the kind of land taken up. As with other bioenergy crops, there is an incentive to expand onto fertile soils, which needs to be countered with effective land use planning. Peat lands should be protected from oil palm expansion especially strongly, given that they can produce very substantial global warming emissions over many years if cleared, drained, and put into production.

Because the high yields of oil palm relative to other oil crops (three to four tonnes per hectare, versus less than one tonne per hectare for alternatives such as soy or rapeseed) give it a cost advantage, increased global demand for any kind of vegetable oil is likely to be met mostly by palm oil (Schmidt and Weidema 2008). Because palm oil is less expensive than the alternatives, more of it tends to be produced whenever global vegetable oil demand increases. Thus it is the total global demand for vegetable oil, rather than for palm oil specifically, that makes the most difference. Simply shifting the feedstock to another oilseed species (e.g., rapeseed) just creates a shortfall in the food market that will be made up by increased palm oil production, defeating the purpose of reducing global warming emissions. Both aspects—the land used for the biofuel feedstock, and the overall demand for vegetable oil—need to be controlled if oil palm is to contribute to reducing global warming rather than increasing it.

[CHAPTER 5]

Policies for New Paths

How do we move in these new directions? What kinds of policies would change the wasteful paths we are on now and move us onto better (i.e., more efficient) ones? This chapter considers how to reorient land use, both in developed and developing countries, and recommends steps that governments and support providers could take.

Economics Matters

Overall, the new land use policies should encourage low production of global warming emissions, restoration practices on lands that have low carbon stocks, or both.

Where are these lands? To some extent, carbon stocks reflect broad climate and soil differences, based largely on geography (Figure 3). These differences can now be estimated fairly well from maps based on remote sensing data, including new techniques such as LIDAR. However, at a finer scale, past land use is a key factor, and this is often much harder to map remotely. Thus detailed fine-scale planning based on on-the-ground data will be necessary to guide development in climate-friendly directions.

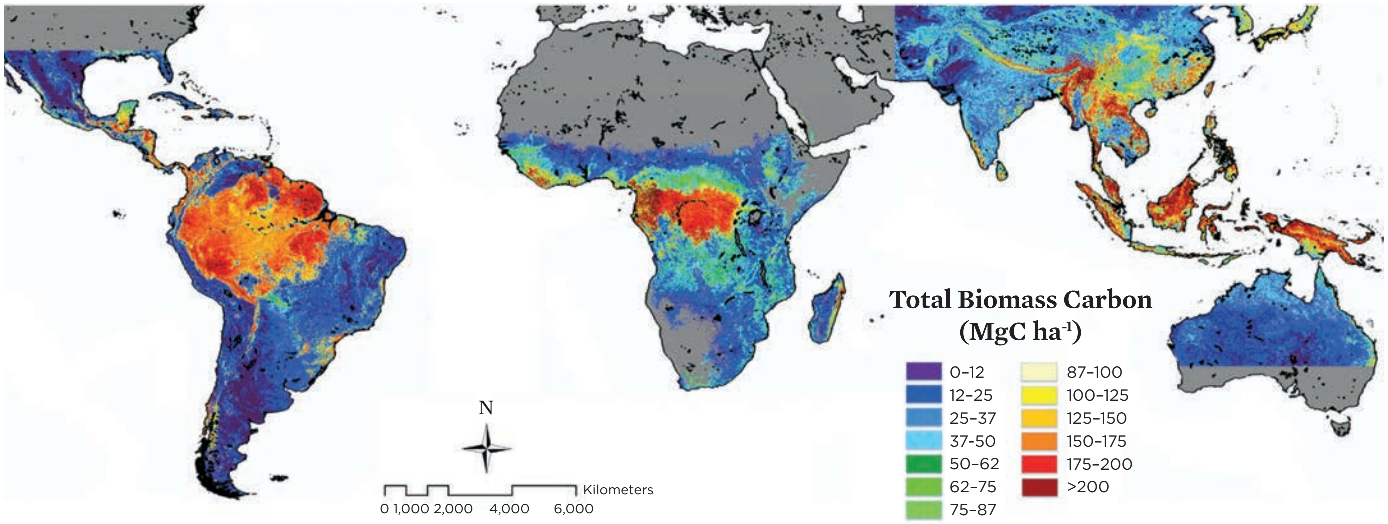
But planning by itself is not enough. Land use, being fundamentally an economic process, critically depends on economic variables, some of which act directly: the price of land, patterns of land ownership and tenure, and the availability and cost of credit. Other variables, just as important, have indirect effects. Infrastructural elements—e.g., roads and ports—make it possible to transport meat and livestock to domestic and export markets; storage facilities stockpile grain and other feedstuffs; electricity powers refrigeration; markets and other collection and transformation points all tend to lower the overall cost of production. In general, the more extensive kinds of production, such as beef or timber, tend to benefit especially from these kinds of investments, which reduce the costs of using large areas of land.

Taxes and subsidies—including the exemption of products from taxes applied to other sectors—similarly change the prices of food products, but to different degrees. Thus taxes and subsidies shift the competitive balance among these products. Import and export policies also have major impacts, as do the exchange rates of a country's currency.

Finally, economic policies can be an important factor in creating demand where it doesn't otherwise exist. Biofuels mandates, requiring the blending of specified amounts of ethanol or biodiesel, are an obvious example of such demand creation. Other kinds of programs, such as REDD+,[3] essentially create a demand for reduced emissions and thus give a market value to forests that are still standing. Similarly, they can support reforestation and restoration by giving future carbon sequestration a value (Elias et al. 2012; Elias and Lininger 2010).

3 *REDD refers to programs for "reducing emissions from deforestation and forest degradation." REDD+ goes further by also including conservation, sustainable management of forests, and enhancement of forest carbon stocks.*

FIGURE 3. Carbon Density Varies Substantially across the Tropics



The amounts of carbon in biomass differ greatly between regions and are influenced strongly by climate and soils. However, there is also some important variation due to previous land use, at a scale much finer than most current mapping methods show.

SOURCE: SAATCHI ET AL. 2011

Recommendations

While the new policies should vary by country and sector and reflect comprehensive consideration of current policies and their (sometimes unintended) outcomes, certain principles should apply widely. Based on our results, here are the major kinds of policies we recommend to make global land use less wasteful.

CARBON PRICES ON PRODUCTS OF THE LAND

Extend "carbon pricing" (e.g., cap-and-trade systems, taxes, or other financial mechanisms) to food and other land-based products—that is, not limit such pricing to fossil fuels—based on these products' emissions footprints.[4] Use the raised funds to incentivize sustainable intensification, help beef producers shift to other kinds of production (e.g., dairy), and support reforestation and the restoration of other kinds of natural vegetation.

New agricultural subsidies, whether direct or indirect, should not be established for carbon-intensive practices or products (e.g., beef), and where such older subsidies do exist they should be phased out.

Carbon prices on land-based products would tend to increase the relative price of products that are associated with high emissions—e.g., of beef in comparison with chicken, pork, milk, and eggs—and thus shift consumption patterns. These prices would also incentivize more climate-efficient production practices, such as using already cleared lands rather than forests and peatland for the expansion of palm oil. Finally, the prices would encourage higher yields of crops, livestock, and wood products (without increasing the use of inputs such as nitrogen fertilizer) instead of resorting to more land area.

LAND USE PLANNING AND GOVERNANCE

Develop holistic land use planning and zoning policies that integrate the full land use system, including production, processing, packaging, distribution, and utilization. These policies should aim to identify synergies and avoid unintentional "downstream" consequences (Hammond and Dubé 2012).

The World Bank could help implement this recommendation. In the next 18 months the bank should develop a procedure to create systematic development packages—across sectors such as forestry, agriculture, and energy—at the biome

4 *Pricing should be applied not just to CO_2 but also to methane and other global warming gases.*

level. This process should involve the bank's identification of key feedbacks and links between key components, which could then be modeled to determine how land use decisions affect each other across sectors, scales, time, and jurisdiction. Using this computational approach would address some of the time delays traditionally incurred in creating system-wide policies.

The new policies should address the current lack of equity among smaller and poorer farmers and be flexible enough to work within various social, cultural, and economic contexts (Garnett 2012). Such a holistic approach could move policy approaches away from those that focus only on production (Garnett 2013) and instead identify the strongest and most appropriate approaches and tools.

LIMITS ON BIOENERGY

Government policies on biofuels should address their production and use but should also take food needs into consideration. Food and nutrition requirements, especially with respect to undernourished populations, should be prioritized, and this will likely require flexible, rather than mandated, biofuels policies. Thus these policies should include mechanisms that allow them to adapt to changes in supply and demand for food over time. Aside from allowing for unknowns about whether productivity gains will keep pace with world consumption patterns, the new biofuels policies could also address unknowns involving agricultural productivity alterations in a changing climate.

One step toward such policies could be demand-side measures such as certification, carried out under global and transparent multi-stakeholder standards systems such as the Roundtable on Sustainable Biomaterials (formerly Biofuels). (See *www.rsb.org*.)

Emerging economies could implement these recommendations by deviating from the inflexible biofuels policies now in place in the United States and Europe. Taking into account the demand for biofuels elsewhere and other domestic demands for land, the new policies could include biofuels in their energy portfolios in ways that do not threaten food security.

NEW KINDS OF RESEARCH

Food, agriculture, and forestry research has fallen well short of needs in recent decades, but aside from restoring adequate levels of funding to lapsed critical projects, governments and international agencies should support additional and innovative kinds of research as well. Such research could address:

DIET CHANGE

Diets are changing rapidly in many countries, with important implications both for land use and health (McDiarmid 2013; Popkin, Adair, and Ng 2012). But our knowledge is still limited concerning the factors that influence adoption of different kinds of diets—particularly in developing countries, where they are changing most rapidly (Kearney 2010). Many economic models simply project future meat consumption, for

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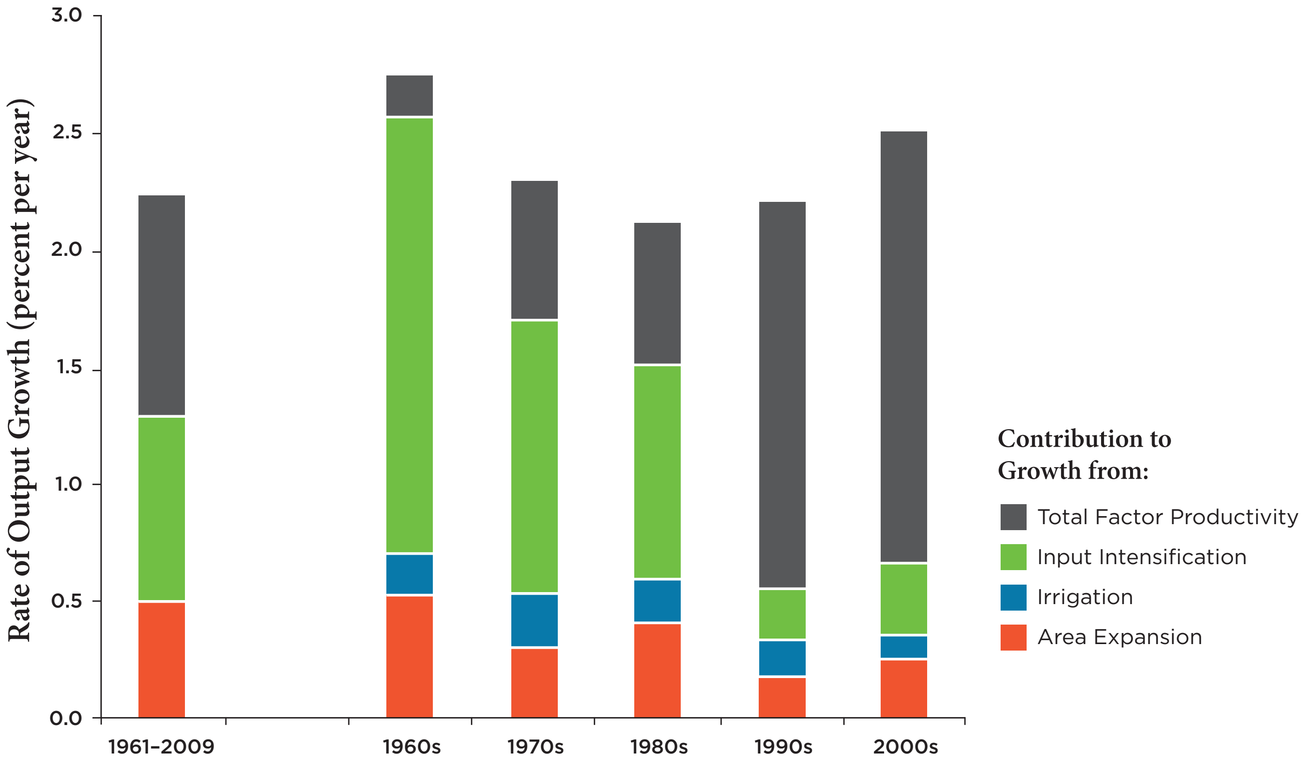
Forests are cut down to make way for palm oil across parts of Africa and Southeast Asia, but sustainable solutions are possible.

FIGURE 4. Most Recent Growth in Agricultural Productivity Has Come from Better Use of Inputs Rather Than from More of Them



Total factor productivity (TFP) indicates how efficiently inputs are transformed into yield. While most of the increase in global agriculture from the 1960s through the '80s came from increased inputs and expanded area, in the succeeding two decades the situation changed. Now the majority of the growth is coming from higher TFP.

SOURCE: FUGLIE AND NIN-PRATT 2013

example, based on expected trends in income, without differentiating between the various kinds of meat. Moreover, such models are unable to explain why some dramatic changes have already occurred in developed countries—e.g., the decrease of U.S. per capita beef consumption by a third since 1975, during which time per capita chicken consumption doubled (Boucher et al. 2012).

More research on how and why diets are changing, and how they are affected both by relative prices and cultural factors, could be quite beneficial in designing effective policies to reduce the climate impact of food while ensuring food security.

MULTISPECIES NATIVE REFORESTATION

There is a great need to support research and development on multispecies native plantations—especially in the tropics, where a lack of technical and physical resources has limited forest species use (Onyekwelu, Stimm, and Evans 2010). Also, researchers should explore ways to create financial incentives for growing larger and more diverse stocks of native species. Recent studies show that multispecies plantings can not only be comparable with monocultures in their productivity but also be considerably better at providing ecosystem services (Bonner, Schmidt, and Shoo 2013; Brockerhoff et al. 2013; Elias and Lininger 2010). However, the details of how to encourage, establish, and manage multispecies plantings need much more investigation.

NEW WAYS TO INCREASE PRODUCTIVITY SUSTAINABLY

There are a number of ways in which agricultural output can increase (Figure 4). Greater yield can come from planting or grazing more area or from using more inputs (such as irrigation water, fertilizer, and pesticides), but there are alternatives.

Total factor productivity (TFP) measures increases in output for given amounts of land, labor, capital, and material inputs (Fuglie and Nin-Pratt 2013). It indicates gains due to more efficiently using inputs rather than from increasing their amounts. When, for example, higher levels of organic matter lower the loss of nutrients from the soil and thus lead to better crop growth, this will lead to a higher TFP.

Opportunities to maintain the trend of increasing productivity while using less land and fewer inputs include: closing yield gaps, which can result in 28 to 56 percent gains in production without new land (Mueller et al. 2012; Foley et al. 2011; Licker et al. 2010); raising the number of crops harvested on a piece of land in a year (Cassman 1999); improving soil fertility (Cassman 1999); using perennial crops (Gomiero, Pimentel, and Paoletti 2011); and reducing losses, such as those due to excessive irrigation and fertilizer use and to postharvest spoilage (Foley et al. 2011).

These are the kinds of productivity enhancers that will be more and more important as we see diminishing returns and greater environmental damage from inputs such as nitrogen fertilizer. But they will need to be sustained by innovative approaches to agricultural research.

A Global Vision

Land use patterns are shifting rapidly, and their future character will have important impacts—for good or ill—on public health, global warming emissions, energy supply, and food security. Competition among potential land uses driven by high overall demand could undermine even the most effective policies at the local level. Conversely, greater efficiency and less waste in the system would reduce competition and make different land uses more compatible.

To be effective, therefore, policies to shift the trends in land use need to consider alternative paths from the point of view of the world as a whole. They need to combine considerations of food security and climate change mitigation. And they need to take into account all three of the factors posited by Garnett (2013)—production, consumption, and socio-economic/governance—to ensure benefits for all.

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Supporting research and development on multispecies native plantations has many positive impacts on forest species and ecosystem services.

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Climate-Friendly Land Use

Paths and policies toward a less wasteful planet

Our current global land use system, dominated by agriculture and forestry, wastes resources and threatens both our health and the global climate.

Global land use at present is extremely wasteful, concludes this new report, which reveals the modest yields of food, wood, and other products in several sectors despite the use of enormous amounts of land and biomass. The authors show how these inefficiencies create large quantities of heat-trapping pollution and cause unnecessary competition between important goals such as food security, human health, carbon sequestration, and bioenergy generation.

The greatest inefficiency is in beef production, which is wasteful compared not only with plant-based foods but also with milk, eggs, pork, and chicken. Using econometric modeling and other analytic techniques, the authors demonstrate how shifting our diets toward less beef and more chicken would have benefits for land, climate, public health, and biodiversity while helping to create a more harmonious, efficient, and sustainable planet.

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