16 December 2012

<u>Peak Farmland</u> (Title Slide)

Lecture for the 18 December 2012 Symposium in Honor of the 80th Birthday of Paul Demeny and his retirement as editor of *Population and Development Review*

Jesse H. Ausubel[1]

"Peak oil" has become a familiar phrase referring to the possibility that humanity's use of petroleum is at its maximum, whether because of exhaustion of oil in the ground or success of oil's competitors. About 20 years ago Paul Waggoner and I observed the pervasiveness of projections of unremitting deforestation, owing largely to extension of agriculture, and we asked the question, "How much land can 10 billion people spare for Nature?" To our surprise, we calculated that large expanses of land could be spared if population growth slowed, tastes changed, and yields continued rising. In the new supplement of *Population and Development Review* (*PDR*) honoring editor Paul Demeny, we are excited to report together with Iddo Wernick that we believe that humanity has reached Peak Farmland, and that a large net global restoration of land to Nature is ready to begin. Happily, the cause is not exhaustion of arable land, as many have feared, but rather moderation of population and tastes and ingenuity of farmers.

Editor Demeny's exhibition of courage more than a decade ago gives us special reason to praise him. Bad news is far more popular in environmental studies than good, and papers raising alarms often receive uncritical review while those outlining a favorable turn or solution have a hard time. Bias arises from the reasonable fear that good news may relieve pressure on society to green itself while bad news is good for funding both research and advocacy. In the mid-1990s, Paul, Iddo, and I did a case study on land use in the United States and submitted it to *PDR*. The paper received angry, negative reviews but editor Demeny gave us the chance to reply and revise, and in 1996 the paper was published as "Lightening the Tread of Population on the

[1] Jesse Ausubel is Director of the Program for the Environment, The Rockefeller University, http://phe.rockefeller.edu Ausubel@rockefeller.edu. This lecture draws heavily on Jesse H. Ausubel, Iddo K. Wernick and Paul E. Waggoner, "Peak Farmland and the Prospects for Sparing Nature," Population and Public Policy: Essays in Honor of Paul Demeny, eds. Geoffrey McNicoll, John Bongaarts, and Ethel P. Churchill, supplement to *Population and Development Review*, vol. 38. New York: Population Council, 2013. Thanks to co-authors Iddo and Paul.

Land: American Examples." We found that both farmers and foresters could spare enough land, even as cities expand, to allow a substantial restoration of American Nature. In 2001, again after a tough passage, *PDR* published our paper "How much will feeding more and wealthier people encroach on forests?' The paper, which looked at 75 nations including China, Brazil, and Indonesia again reported evidence of humanity sparing cropland. Today we go so far as anticipating that cropland's expanse may have peaked.

When *PDR* began in 1975, the nexus of the issues and the fears of exhaustion of arable land and famine was India. Now India offers a signal example for the reality of sparing by improved wheat growing alone. As SLIDE 2 shows, to achieve the yield of 2010, if Indian farmers still farmed as they did in 1961, they would have needed an additional 65 million hectares. Indian wheat farmers have spared an area the size of France relative to what might have been.

Mao Zedong passed away in 1976, PDR's second year, three years before the application of China's one-child policy, and China may have rivaled India for worries about population and development in the journal's early years. But China's farmers also decoupled the quantity of food they produced from the area of land they tilled. In 2010 China's maize farmers spared 120 million hectares from the land that would have been required with the yields of 1961, twice the area of France.

Indian wheat and Chinese maize production are striking examples. However, affecting the *global* sum of cropland requires changing far more nations and more crops. National cropland hectares can be summed, of course. But to be sure that sparing cropland is not accomplishing an environmental goal by growing less food and leaving more people hungry also requires adding the mixture of crops, the apples and oranges produced. The Production Index (PIN) of the UN's Food and Agriculture Organization (FAO) of all crops weighted by the value or price that people put on them permits the required addition (SLIDE 3).

The PIN from 1961 to 2009 shows that land farmed grew by only 12% while PIN rose about 300%. The rising production allowed global daily food supply to rise by more than a quarter from 2200 to 2800 kilocalories per capita. Without lifting crop production per hectare, farmers would have needed about 3 billion more hectares, about the sum of the USA, Canada, and China or almost twice South America. The expanded cropland would have come at the expense of other covers, especially forest and grassland. In fact, we would already live on what David Victor and I have called Skinhead Earth.

I have celebrated farmers, but more actors of course impact land cropped. In our view the main actors (SLIDE4) are parents changing population, workers changing affluence, consumers changing the diet (more or less calories, more or less meat) and also the portion of crops entering the food supply (corn can fuel people or cars), and farmers changing the crop production per hectare of cropland (yield).

More formally, we offer an identity (SLIDE 5) with arable land on the left side of the equation equaling the number of people times the GDP/person times the consumption of food per GDP times the crop PIN per kilocalories of food times the arable land per crop PIN. Checking the dimensions of the variables representing the actors proves that multiplied together they are identical to the impact of hectares of cropland. Being an identity, the chain is iron. A change of one of the links immutably changes hectares. Or specifying hectares requires links to support it.

But to compare, say, the leverages on cropland area of population with the leverage of affluence or crop yield, their leverage must be in commensurable units. Fortunately the changes in *percent per year* of the links have the same dimensions, are commensurable and can be added, subtracted, and compared. The relatively few variables of ImPACT, its commensurable leverages or %/year changes, and its nature as an identity render it a transparent and hence dependable model.

A single table (SLIDE 6) of three rows and their sums highlighted in yellow organize our retrospect and prospect. The top row of the table tells what changed cropland area during the half century 1961-2010, the middle row what changed it during the most recent 15 years, and the bottom row our projection for the half century beginning about now. The labels at the heads of the table set out the commensurable percent changes and the final column shows their sum and the identical change in cropland.

With regard to population, note the slowing from 1.68 in the first row to 1.24 during the last 15 of the 50 years and the 0.9 UN projection in the third row. This slowing by parents subtracts from the anticipated spread of cropland. Although we know that some African populations still grow and do not share this alleviation of pressure on cropland expansion, their plight focuses concern but dims rather than extinguishes the global relief.

With regard to changes in affluence in column 2, workers might wish for more and politicians certainly promise more. Globally per capita GDP the past half century has grown yearly only about 1.67% and 1.53% in the more recent interval. Affluence has and is expected to grow at variable rates from year to year but over the long span the rates range only a little. We give workers the benefit of the doubt and propose 1.8% growth, causing affluence to add to expansion of cropland.

Let's now turn to diet or food supply per GDP, column 3. A familiar rule wisely states that per capita consumption of staples does not rise in step with affluence and tempers the rise of food consumption. Far the most land of course is used for staples, especially wheat, maize, rice, and soy. The response to wealth is caught between the limits of starvation below about 2,000 kcal/ca/day and obesity near 4,000. Meat more than caloric consumption rises with affluence, but even in rapidly enriching China, after a burst, meat consumption is rising only moderately. In India meat consumption per capita has changed little with rising affluence. Globally we think consumers will devote fewer and fewer marginal dollars to calories and thus project a dematerialization of calories at a rate of -1.6% year. Consumers may spend more in restaurants but they will not eat more potatoes even as they spend more per potato. Satiety will relieve a considerable portion of upward pressure of population and affluence on cropland expansion.

The second choice for consumers is whether to demand non-food products from land. Historically, these included cotton and flax for clothing, hemp for rope, tobacco for smoking, and hay to fuel horses and other farm animals. Farmers are always searching for profitable crops. Over the span of the past half century crop production rose faster than food supply, but only 0.24%/yr faster. During the most recent 15 years, however, the rise of crop production surprised us by outdistancing the improvement of food supply by fully 1.04%/yr. Reading the clamor against burning corn and expanding palm oil plantations and the expense and water consumption of alcohol distillation, we foresee a leveling of crop PIN per food and project a return to a mild rate of increase. That does allow a considerable but steady production of biofuel. Or rum, bourbon, or vodka.

Finally, we come to arable land per crop PIN, the inverse of yield. Decades after the Green Revolution, can the remarkable rise of yields and fall of land per crop production continue? A comparison of row 1 for years 1961-2010 that span the Green Revolution and recent 1995 – 2010 displays a reassuring continuation of the rising yields and sparing of cropland.

Looking ahead, one must ask if a biological limit on photosynthesis will soon constrain the rise in yields and accordingly slow farmers sparing land. While yields of corn and other crops may eventually form S-curves that hit a ceiling, the evidence is that farmers are still far from the ceilings (SLIDE 7). In recent decades, when many pessimists said yield gains would be exhausted, average corn yields kept rising, fastest for the world as a whole, and almost as fast for the USA, and even for top USA growers. A clue about biological limits lies in the rise of the winning Iowa yields in the National Corn Growers Association contest, which continue to maintain their margin far above both the US and world average yields. Much headroom remains for farmers to lift yields.

We conservatively project a slowing of the reduction of cropland per production of -1.7 % per year globally, slower by far than the -2.4 of the past 15 years, and a little slower than global corn growers the past 30 years. Annual improvement of 1.7 percent sustained to 2060 would multiply world production per area by 2.3 times. For corn, the average global yield in 2060 would resemble the average US yield in 2010. Thus, we think each of our projections for 2060 is reasonable (SLIDE 8 – repeat of slide 6).

Before summing, qualifications need stating, for example:

-The levers may interact as, for example, rising affluence may speed innovation and the decline of land per crop.

-Nations may stubbornly depart from the global pattern as, for example, some African populations continue to grow fast.

-If people fall below about 2,000 kilocalories per day or rise above 4,000 and grow fat, income will affect little.

-For single nations, exports eliminate a response of food supply to national food production.

Despite all these cautions, a clear hopeful view of sparing land for Nature remains. (SLIDE 9) With conservative assumptions about each of the five ImPACT factors, the outlook is a net reduction in use of arable land, totaling 2.5 times the area of France and returning global cropland to the level of 1960.

Every person in this room could raise or lower each of the five factors, transparently, and calculate a different net result. My own view is that the factor most likely to differ substantially from our projection is demand for non-food crops, in particular, a loss of favor of biofuels. Such a change could owe to environmental concerns, taxpayer disillusionment with subsidies, or success of cars operating on batteries or fuel cells. A plausible drop in the non-food factor and/or slower population or GDP growth or faster rise in yields could spare a couple of hundred million hectares more.

Importantly, sparing land usually means sparing water. And substituting bits or information in Precision Agriculture can also spare inputs of energy and nitrogen and other materials. Precision agriculture includes better weather forecasts, better seeds, closer spacing of plants, better and more judiciously applied fertilizers, smart farmers, and other factors. Basically the strategy for high yields is more bits going into agriculture, not more kilowatts. Land spared can become habitat for wildlife or carbon orchards.

To summarize, our analyses over the past twenty years witness food decoupling from land. For millennia food production tended to grow in tandem with land used for crops, a fundamental relationship in population and development. Now land for food is flat. If yields had remained at prior levels, immense, continental areas of forest and range and desert would have been shaved or ploughed for human food during the past 50 years. Surprisingly, instead, we find humanity gradually moving toward what we call, with deliberate hyperbole, landless agriculture. Paul, Iddo, and I believe humanity now stands at Peak Farmland, and the 21st century will see release of vast areas of land, hundreds of millions of hectares, more than twice the area of France for nature.

Thanks for your attention and to editor Paul Demeny for elevating Land Sparing and now Peak Farmland in *Population and Development Review*. (SLIDE 10)



Peak Farmland

Jesse Ausubel, Iddo Wernick, Paul Waggoner

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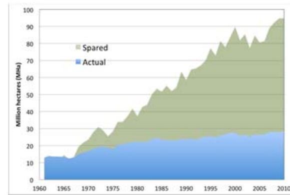
Lecture based on "Peak Farmland and the Prospect for Sparing Nature" *Population and Development Review*, Vol. 38, 2013.

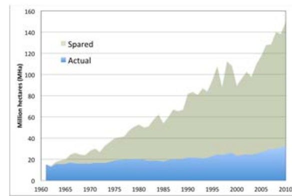
Decoupling of quantity of food from land

Actual (blue) & potential land (green) used for selected crops 1961-2009 to produce actual crop with 1961 yield



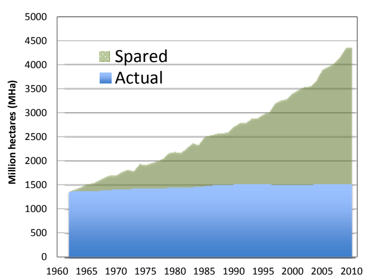
Indian Wheat

Chinese Maize



Source: Ausubel, Wernick, and Waggoner, 2012

Global Decoupling



Actual & potential land used for Global Production (PIN) 1961 – 2009

Source: Ausubel, Wernick, and Waggoner, 2012

Im — Cropland

P — Population
Parents

A — Affluence
Workers

C — Consumption
Consumers

T — Technology
Farmers

Arable Land

≡

Population X Affluence X Consumption X Technology

P | GDP / P | Food Supply / GDP X Crop Production / Food Supply | Arable Land / Crop Production

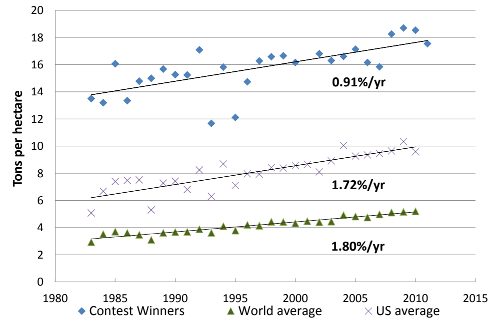
Parents | Workers | Consumers | Farmers

Annual Changes in ImPACT factors

	Population	GDP per capita	Food supply/ GDP	Crop PIN/ Food supply	Arable land/ Crop PIN	Arable land
Data for 1961-2010 (%/yr)	+1.68	+1.67	-1.2	+0.24	-2.15	+0.24
Data for 1995-2010 (%/yr)	+1.24	+1.53	-1.35	+1.04	-2.42	+0.04
Projections for 2010-2060 (%/yr)	+0.9	+1.8	-1.6	+0.4	-1.7	-0.2

Source: Ausubel, Wernick, and Waggoner, 2012

Corn yields for Iowa contest winners, US farmers and World



Source: Ausubel, Wernick, and Waggoner, 2012

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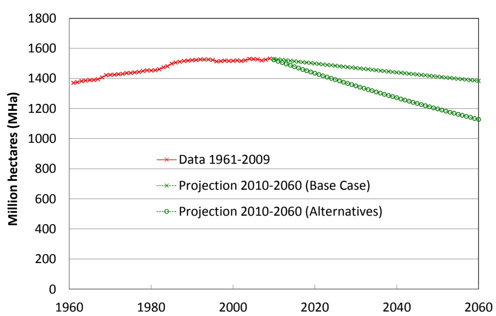
Source: Ausubel, Wernick, and Waggoner, 2012

Peaking farmland

Global arable land 1961-2009 & projections to 2060



Source: Ausubel, Wernick, and Waggoner, 2012

Thanks Editor Demeny!
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