KEYNOTE ADDRESS
Can we feed a growing world and sustain the planet?

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Can we feed a growing world and sustain the planet?

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Abstract

Increasing population and consumption are placing unprecedented demands on agriculture and natural resources across the planet. Today, approximately a billion people are chronically malnourished while our agricultural systems are concurrently degrading land, water, biodiversity and climate on a global scale. To meet the world’s future food security and sustainability needs, food production must grow substantially, while at the same time agriculture’s environmental footprint must shrink dramatically.

This paper outlines a framework for potential solutions to this dilemma, showing that tremendous progress could be made by halting agricultural expansion (especially into tropical forests), closing ‘yield gaps’ on underperforming lands, increasing cropping efficiency (especially in terms of water and nutrient use), shifting diets and reducing waste. Together, these strategies could help us double food production while greatly reducing the environmental impacts of agriculture.

The scramble for natural resources, the topic for this conference, reflects the fact that agriculture is going to be absolutely fundamental to the success of our civilisation moving forward. It has been so for ten thousand years and it needs to continue to be so for the next ten thousand years, because one of the big challenges for the world is food security.

There are roughly 7.2 billion people on the planet and, depending which estimate you look at, roughly a billion of them are food-insecure and malnourished. Feeding them adequately is already a huge challenge. On top of that, we have to meet the future food demands of the world which are partly driven by the size of the population. The world’s present population of 7.2 billion is heading to, at a median estimate, 9.5 billion sometime before 2050.

More important than population growth, though, is that diets are changing. Already here today on this planet, about 4 billion people are becoming richer and joining a global ‘middle class’. There has never been a global middle class before. There have been a few rich people and many very poor people, but that is changing. In that transition those 4 billion people are adopting a kind of western diet, with more calories, more meat, more oils and other rich components. It turns out that this change is a much bigger factor than population growth in the demand for food.
Our estimate, which differs from that of the FAO, is that the expected changes in diets and population double the projected global demand for calories by 2050. In other words, in the next 38 years demand will outpace the gains made by all previous agricultural innovations combined.

How do we feed everyone now and also meet the food needs of the future without further disrupting the planet? This is a really serious issue because agriculture in many ways is the biggest disruption this planet has ever experienced, at least during the time of *Homo sapiens*. One reason for that is the extensive area of land devoted to feeding the world.

About 16 million km², which is roughly the size of South America, is the total area of the world’s land devoted to growing crops. The world’s pastures occupy approximately 34 million km², which is about the size of Africa. These add up to 40% of the parts of Earth’s land mass not subject to ice. Most of the other land is in the Siberian tundra or the northern Canadian arctic, or the rainforest in the Amazon and the Congo and the Indonesian Archipelago — and use of rainforest or desert or arctic areas is not a good solution to the problem of feeding the world.

Agriculture is also by far the world’s largest user of water. Depending on how you do the bookkeeping, agricultural production takes up either 70% of water globally or 90% of the consumptive use of water (that is, taking water out of a catchment or ‘watershed’ and not returning it to the same catchment).

Agriculture is also the biggest source of water pollution globally, not because agriculture is especially dirty but because it is so widespread. Naturally, the activities that occupy 40% of the world’s land make very large contributions, in aggregate, to water pollution in lakes, rivers and even coastal waters, mainly in the form of nitrogen and phosphate. That is also of concern.

A further concern is climate change: both how climate change will impact on agriculture, and also the impacts of agriculture on climate change itself. When most people think about climate change they think of fossil carbon, coal, oil and gas being burned and contributing greenhouse gases. Yet it turns out that, of all the economic sectors in the world, agriculture is the largest contributor of greenhouse gas emissions: roughly 35%. Most of that contribution comes from tropical deforestation — in Amazonia, the Indonesian Archipelago and parts of Africa. The second largest contribution is nitrous oxide emissions and methane emissions from livestock, paddy rice and excessive use of fertilisers. The sum of those emissions is very large, and a huge contributor to climate change. To put that into perspective, the emissions from all the worlds’ transportation contribute only 15%. Therefore, if you want to stabilise climate change, you first must consider agriculture, before anything else.

That makes three challenges: feed the world, feed the future, address sustainability. Each one of those challenges is daunting, and we must solve all three, and at exactly the same time, over the next 30–40 years. This new combined challenge is unprecedented in human history, and it brings in multiple disciplines and multiple outcomes.
How are we doing so far? In a word, badly.

First, most of the gains in global production in agriculture have not come from land expansion. In the last 20 years there has been just a small increase in the total amount of land put in production. Some of that has occurred in the tropical parts of the world, through deforestation, but agricultural land has also been lost in the mid-latitudes, especially in China, India, Europe and the United States, where farmland has been taken up for suburbs and urban expansion. As a net result there is really not much more land in production.

Gains in production have, instead, been the fruit of the Green Revolution which has increased yields per hectare. Those yields per hectare are not really being sustained, as Ken Cassman¹ and others have been pointing out. In the last decade especially, yield improvements have flattened off in many parts of the world.

Looking at global rice production, in a number of regions during the last decade 2002–12 there has been no statistically significant improvement in yield. The graph of yield versus time has been, essentially, flat in 35% of all the rice-growing regions on the planet. For wheat globally, 40% of productive areas have not increased yield, and that includes Australia. The very severe droughts during that period of time are partly responsible, but the picture is widespread. It is the same in China, India, Europe and even the great plains of North America. These two grains feed more people than all the others in the world combined. Wheat and rice provide over half the world’s calories, but in 30–40% of the wheat- and rice-producing areas there has been no progress in yield improvement. This is extremely alarming and very important. The point is that yield improvements cannot be taken for granted; they will need significant investment.

In the United States and much of the rest of the world there is an idea that it is possible to achieve food security and double the production of calories by 2050, just by growing more food. Yet, the current systems are neither improving food security nor keeping up with demand, and, as I have pointed out, they are completely non-sustainable in relation to land, water and climatic resources.

Strategies for security of food supply and environment

I posit that we have to develop entirely new kinds of strategies that think about food security and environmental security together as an interwoven problem. It is a problem that has to be solved not just by growing solutions but by managing the entire system differently. Food security and environmental security are both parts of the same problem — a problem with multiple dimensions.

The world needs to produce approximately double the current total amount of food, and there are also challenges in the distribution, access and resilience of that food production system. The environment is subject to damage that may be several orders of magnitude larger than the sustainable limit. This is the picture today: not enough food security for the future, and excessive harm, even beyond 2050, in loss of biodiversity, deforestation, climate change and other ways.

¹ University of Nebraska–Lincoln; Chair, CGIAR Independent Science & Partnership Council
Can we deliver more food security? Can we perhaps double food access and resilience and availability by mid-century, and dramatically cut the environmental costs of agriculture, so that we achieve truly a world with food security and environmental security together for the first time?

It is, in fact, possible to do that. The strategies outlined briefly here, when put together, might just let us attain a food-secure and environmentally-secure world by the middle of the century. These are abstract ideas at the moment, and it is the job of all of us in this room, and others, to make them practical.

(i) Stop deforestation

First, consider deforestation. The area, the footprint, of agriculture in the world is expanding only through deforestation. There are parts of the Amazon or Kalimantan or West Africa that could be further deforested; yet that process is causing severe environmental disruption. In Rondonia in Brazil, virgin forest is being cleared, mainly to grow soybeans for export, mostly to Europe and China.

Is this a good trade-off, for clearing the last remaining virgin forest of the tropics? There are huge amounts of carbon and unique biodiversity in these landscapes. They are being exchanged for animal feed such as soybeans, or for palm oil, or maybe for timber or beef production. The bottom billion people who are food insecure today never benefit from this large-scale deforestation. The products are not intended for them but for the global middle class, whether in North America or Europe or, increasingly, Asia.

Deforestation now is not benefiting the people who need food. It is badly damaging the environment and while it is increasing wealth it is gaining no real improvement in global food security.

I argue that deforestation is very bad for the planet and it should not happen.

(ii) Intensify production

If the footprint of agriculture cannot be extended, there must be intensification of production on land already cleared, to boost yields per hectare on existing farmland.

There are many many opportunities for this around the world. In the grain belts in North America, western Europe, China, Brazil and Argentina, all good growing regions, yields are already at maybe 80–90% of the current ceiling of yield. There are also regions all over the world which produce a fraction of their yield ceilings, especially in Africa but also in Latin America and even in Europe, especially eastern Europe. Eastern Europe currently produces only 25% of the yield they should be getting. This area was one of the world’s greatest ‘breadbaskets’, but it has been damaged by years of neglect and institutional problems relating to land tenure and ownership, investment, distribution, governance, and other issues. In other places, yield improvements have not begun yet: for example in parts of Africa and other places all over the world. There there are huge opportunities to intensify production.

It is not necessarily genetic factors that limit productivity in most of these places in the world. Instead, the limiting factors may be disease and pests and
also nutrients. Places where yield improvements are genetically limited are mainly the United States, western Europe and possibly parts of Brazil and Argentina. Elsewhere, again and again it turns out that nutrients and water are the keys to improving productivity at the base of the production pyramid: in Malawi for example, and other places. Therefore there is enormous potential for sustainable intensification at the base of the pyramid — but what will that sustainable mode of intensification really be?

(iii) Same water, fewer chemicals

How can food production and nutrition be dramatically improved using no more water and fewer chemical additives?

In much of the world, growers are applying far more nitrogen fertiliser, whether in chemical form or in manure, than plants could ever use. The excess runs away as nitrate, in groundwater or river water. For example, nitrate entering the Mississippi River in the United States flows into the Gulf of Mexico and destroys the fisheries there by making the waters anoxic, devoid of oxygen. There is a similar situation in China and India, the most highly polluting agricultural landscapes in the world per hectare in terms of nitrogen. In all three countries, excess nitrogen also escapes as nitrous oxide (N₂O) into the atmosphere where it is a powerful greenhouse gas. Those losses of excess nitrogen could be cut with no losses to food security, as discussed below. Yet other parts of the world — such as in Africa — need to increase their use of nitrogen, potash and phosphate. This is the ultimate Goldilocks problem: half the world applies too much fertiliser, the other half applies too little, and almost nobody is just right except for maybe some of the Europeans and the Australians.

The same observation can be made for water. The amount of water it takes to grow one calorie of food through irrigation, on average, globally, is 1 L. That means we all, if we are vegetarians, carry around 3000 L of water daily from our irrigation-grown food. However, there are large variations in water-use efficiency. For example, Israel may be two to three times more efficient than that because they use drip irrigation for reasons of water security and national security. Other parts of the world, especially Pakistan, Rajasthan and parts of India, may use three to four or five times more water than the global average. The amounts of water it takes to grow the same amount of the same kinds of crops in similar climates can differ by a factor of 10 or 20 between the best and worst producers. There could be as much as a hundred-fold difference in the water productivity of food systems around the world. Therefore, we see huge opportunities to improve the productivity of water, of nutrients, of energy and other inputs, because there is so much waste in agricultural systems.

There is potential for ten-fold and hundred-fold improvements in the efficiency of agriculture using very simple technologies already in use. This is not inventing anything but instead deploying existing techniques.

(iv) Consider diet, biofuels and food-waste

In the United States there is currently disagreement about whether crops should be used for food production or biofuels — especially ethanol — and also about
food-waste. To balance our existing opportunities to improve food production and supply, it is also vital to improve the demand side of the equation: how foodstocks are used.

In India, China, most of Africa, a lot of Australia, crops are grown to feed people: rice, wheat, cassava, fruits and vegetables and nuts and so on. By contrast, in northern China, most of western Europe and in the United States breadbasket, crops are grown to fuel cars and feed cows. It is true that the cows in turn feed people eventually, with large losses of energy and calories along the way. In an ideal world, human uses would be the top and first priority, and there could also be some crop production for energy and livestock.

There is a real debate about this situation in places like the United States. Only 14% of crops grown in the US breadbasket end up as human calories, mostly in dairy. In the US only 60% of crop production is for food, while 35% is for livestock and 5% for biofuels. On top of that, about 30–40% of food is wasted all around the world. In North America the grain-growing areas grow mostly corn and soybeans; about 40% of that corn is turned into ethanol; about 36% is turned into animal products, mainly.

Some animal production can be quite efficient: dairy for instance. Converting corn and soybeans into milk is about 40% efficient; into eggs, maybe 20%. Producing chicken is quite an efficient process in relation to protein, but less so in relation to calories. So, as the saying goes, the real ‘elephant in the room’ in this case is a cow! Converting grain calories to meat calories has 3% efficiency, which means 33 kg of corn is used to produce 1 kg of steak — an unsettling situation to consider at table. This system is well established in the US and is spreading to other parts of the world as well.

If a food chain system wastes 97% of the original calories, doubling yield is not likely to make it more efficient. Food-waste undermines the idea of growing more food to feed the world and the future. The supply side of the food chain may be manageable, but it is important to also manage the demand side better.

We can do this!

Overall, applying these multiple strategies — not just improving yield but also taking care with deforestation, taking care with the remarkable material efficiency gains we can see in agriculture, and thinking about diet, biofuels and food-waste around the world — there is more than enough capacity to double the world’s calories by 2050 and simultaneously cut greenhouse gas emissions, perhaps by as much as 80%. We could eliminate losses to biodiversity from agriculture, and virtually eliminate unsustainable water withdrawals and water pollution.

I stress again that these goals cannot be achieved with ‘business as usual’. We must not think only about improving the yields of crops, nor only of some crops, such as corn, which do not actually feed people in most of the world. We have to think much more broadly than that. New approaches are needed.
Can we feed a growing world and sustain the planet? — Foley

New solutions need new mental frameworks as well. It is easy to spend time in ideological mind traps, whether about genetically modified organisms (GMO) or about local and ‘organic’ food systems. An interesting fact is that most of the food in the world is neither GMO nor ‘organic’. Only about 1% of the calories grown in the world are ‘organic’. Certified ‘organic’ crops and genetically modified crops occupy about 10% of the acres of the world in production. That means that 90% of the food in the world is in neither of those categories. They are like a sideshow compared to present-day global food production systems.

While avoiding ideological mind traps and learning how to collaborate, it is also important to identify factors and systems that can assure food and environmental security in the future.

Consider climate change. Two countries — Brazil and Indonesia — and only five commodities produce 15% of the world’s CO₂ emissions. Those five crops in two countries are equal to every car, truck, airplane and lorry on the planet added together. Why then is there such a focus on transport? For other greenhouse gases, say nitrous oxide, four countries and three crops produce more than two-thirds of global emissions.

Considering water pollution, those same four countries and only three crops are responsible for two-thirds of the nitrogen pollution to the world’s oceans and 75% of the leakage of phosphorus into rivers and lakes. Suitable policies suitably targeted potentially could make a dramatic global difference.

In conclusion, we all know agriculture is central to the success of civilisation. I urge us all to take a broader view and recognise the environment as another central pillar for the future of civilisation. I am convinced that we can solve the problems of food security and environmental security simultaneously and in complementary ways, and in fact I think we have no other choice.

We have to get this right for our civilisation to endure beyond this century.

Professor Jonathan Foley is the director of the Institute on the Environment (IonE) at the University of Minnesota, where he is a professor and McKnight Presidential Chair in the Department of Ecology, Evolution and Behavior. He also leads the Global Landscapes Initiative of the IonE. Foley’s work focuses on the sustainability of our civilisation and the global environment. He and his students have contributed to understanding of global food security, global patterns of land use, the behaviour of the planet’s climate, ecosystems and water cycle, and the sustainability of the biosphere, and that has led him to be a regular adviser to large corporations, non-government organisations and governments around the world.