Simultaneously Addressing Food Security and Global Sustainability Challenges: A Summary[1] *of Jonathan Foley's Verbal Presentation*

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Feeding the World

- The question of how we will feed 9 billion people by 2050 is daunting. In 2011 the global population increased to over 7 billion. Two billion additional people will constitute a 28% increase. More people will be economically prosperous and will want to eat meat and other nutritious foods, and there will be increasing demands for biofuels; these factors, with population increase, will require a doubling of global agricultural output.
- While meeting the challenges of doubling output, agriculture will have to be reinvented so that it doesn't contribute to environmental damage in the long term. Doubling output while reinventing agriculture will make what is already a huge problem instantly larger, because we need to think in terms of agriculture's already vast environmental footprint.
- The acreage that is used to grow food is by far the largest use of land in the world. Arable farming occupies about sixty times more land than all of the cities and suburbs in the world combined—about 18 million square kilometers, equivalent to the size of South America. Pastures constitute the largest ecosystem, larger than any biome by far at about 34 million square kilometers, equivalent to the size of Africa. Together, agriculture already uses about 40% of the earth's land surface to grow food, leaving rainforest, Siberia, Antarctic and the Sahara and other deserts.

[1]From a transcript of *Solutions for a Cultivated Planet: Simultaneously Addressing Food Security and Global Sustainability Challenges*, a verbal presentation made at NABC 23 by Jonathan Foley, University of Minnesota, St. Paul, Minnesota, jfoley@umn.edu.

Water

- Withdrawals from the Colorado River—primarily for irrigation—are such that it no longer flows into the ocean from Mexico. The Aral Sea, between Kazakhstan and Uzbekistan, provides another example. One of the four largest lakes in the world with an area of 68,000 square kilometers, in the 1960s its tributaries were diverted by the Soviet Union for irrigation, mainly of cotton. By 2007 it had declined to 10% of its original area.
- Agriculture is the biggest user of water globally. About 70% of water withdrawals are for agriculture. It is 80% to 90% in terms of consumptive use, *i.e.* taken out of a watershed, used in some process, and then not returned to the water shed. Industry uses water, as do we in our homes, but most of that returns to the water shed in one form or another. Water that is transpired to the atmosphere is consumed by plants rather than used and returned to the water shed.
- Agricultural practices, because they are so vast, are the single largest cause of pollution of water.
- Through agricultural applications, the amount of available nitrogen in the environment—especially in water—has quintupled in the past 60 years, and phosphorus has doubled.

Crop Productivity

- Crop productivity is plateauing and even declining in many places; rice, over the past 20 years, provides a good example. On the other hand, maize has shown significant gains in productivity in the richest areas of the world, where incomes and infrastructure foster it—Iowa, Minnesota, Europe, parts of South America—but with declines in most of Africa except South Africa.
- On the other hand, total crop production has increased because the area of land that is harvested has increased. Fewer crop failures occur and more of the world is becoming double and triple cropped; land is being used more efficiently.
- Two strategies are available for the production of more food: expanding agriculture into new areas, and intensification of agriculture. The former has far-reaching implications for carbon emissions/climate change and biodiversity decline. Intensification usually requires increased inputs of water, fertilizers and energy, with increased environmental pollution.
- The total amount of farmland in the world has increased by only 2.5% over the last 20 years. However, this statistic conceals a more subtle picture. Agriculture has expanded considerably in the tropics whereas agricultural lands have been lost in the mid-latitudes due to urban expansion and agricultural abandonment—mostly in China, some in Europe and less in the United States.
- An international team just finished a 2-year study, evaluating core strategies to double food production with acceptable trade-offs in environmental impacts.

- It was strongly recommended that agricultural expansion be slowed. Theoretically agriculture could be expanded in Africa, Latin America and Indonesia, but only at the expense of biodiversity and reserves of carbon in savannahs and rain forests. The damage to the environment would not justify relatively minor increases in food production; the ratio of carbon loss to food gained would be unfavorable.
- Also recommended was closure of yield gaps. Huge variations in crop yields exist around the world, by a factor of about 100 between the least productive and most productive corn farmers, for example. This variation is partly due to climate, soils and crop genetics, but it is mostly due to management, including providing enough water and fertilizers for the genotype in question. Yield attainment—how well a farmer is doing compared with other farmers with the same soil and climate—was found to vary from 0% to 100%. Farmers in the United States and Western Europe, as well as parts of China and Brazil are doing well, achieving 90% to 100% of current maximum yields. In some places, farmers are doing poorly: parts of sub-Saharan Africa and even Mexico. In the latter, some farmers, using modern hybrids and farming practices, are achieving 100% of their yield potential, whereas farmers close by, using open-pollinated varieties with no fertilizers or irrigation, on collectively owned land, are getting 10% of their maximum yields. Probably the best place in which to add more calories to the world is Eastern Europe. Although, at one time that region was the breadbasket of Eurasia, farming under the Soviet regime was inefficient, and deteriorated further after the collapse of the USSR. Yield attainments stand at about 20%, and much farmland is underutilized and even abandoned. Huge opportunities for increased crop production exist in parts of Africa, Latin America and Eastern Europe.
- For a modest boost in yield of 20%, most of the world doesn't need more genetics; genetic engineering won't help. Areas of the world that are limited by genetic potential are the Midwest and parts of Europe and China. Yields in the rest of the world are limited by resources—fertilizers and/or water—not genotype improvement. On the other hand, for 50% yield improvements, genetics become more important, and to double yields genetic improvements are essential. A phased-in approach is needed in some of the poorly performing regions, with nutrients and water limitations addressed first and genetic improvements made later.
- If the productivity of the worst-performing farmers is improved to that of the best-performers for all of the major crops, 50% to 60% more food could be added to the world. Improvements via molecular genetics and traditional breeding would significantly increase food production further. Clearly, opportunities exist, but it is vitally important that this intensification of agriculture is achieved sustainably.

Efficient Use of Resources

- We need to increase crop productivity with less nitrogen, less phosphorus and less irrigation water. On average it takes about 1 liter of water to make 1 calorie; however, the worst farmers and the best farmers are 100-fold different from each other in this regard. In parts of northwestern India, for example, 30 liters of water are used per calorie, whereas in Israel and in places in the United States farmers use 0.1 liters per calorie of extra yield. So, the marginal benefits from irrigation vary hugely around the world, suggesting that adoption of improved practices may be broadened. Also, irrigation may be curtailed, especially where it is most damaging and/or least sustainable.
- The same thing pertains with nutrients. The amount of fertilizer applied per unit of extra yield gained is relatively low for the United States, and much higher for India and China where perverse policies encourage much more fertilizer use than is recommended or even logical, causing tremendous environmental damage. These problems present significant opportunities for improvement.

Diet and Bioenergy

- Overall, some 60% of global crop production is used directly as human food, 35% as animal feed, and roughly 5% is converted to biofuels. In India, Africa and China, 90% to 100% of crop production—grains, cereals, pulses, fruits, vegetables, *etc*.—is directly consumed by humans. In the United States only 10% to 15% of crop production is eaten directly by humans; the rest is mainly animal feed, which eventually becomes human food after loss of about 95% of its energy, or it goes into biofuels. We need to think hard about how we use the crops we grow, both in terms of diet and bioenergy.
- As a thought experiment, if everyone were vegetarian, how many calories would be delivered to the world? We could have grazing animals, but delete grain-fed animals and grain- and sugar-cane-derived ethanol from consideration. What if our crops constituted 100% of food instead of 60% of food? In fact, we could add 50% more calories to the world.
- Certainly, something we can all agree upon, regardless of what one thinks of diet and bioenergy manipulation—is the need to save the roughly a third of the food in the world that is wasted one way or the other. In rich countries, wastage occurs often at the consumer end, in refrigerators, restaurants and cafeterias, whereas in poor countries wastage occurs more often at the production end, from crop failure, poor distribution and post-harvest losses to pests. However, losses occur all along the supply chain—different in different regions—presenting many possibilities of increasing calories available for human consumption.
- By adding up these solutions, global food availability could be doubled while simultaneously cutting in half greenhouse-gas emissions from agriculture, water

losses, water-quality problems, *etc.* No one solution is good enough, but altogether we could get where we need to go, albeit with very little margin for error.

Greenhouse Gasses

- When we discuss climate change, it is often in terms of greenhouse gasses from power production and transportation, and it is true that fossil-fuel combustion is the single largest contributor to atmospheric CO_2. However, if considered in terms of economic sectors, agriculture, including land use, is responsible for 30% to 35% of greenhouse-gas emissions, more than all of the world's transportation. Transportation is responsible for about 18% of global emissions, and industry about 15%. Electricity production is responsible for about 19%.
- Contrary to popular belief, food transportation uses only about 1% of global petroleum. Similarly, production of fertilizers and pesticides uses relatively little energy.
- Most of the greenhouse-gas emissions from agriculture come from deforestation by burning and conversion of the land for agricultural use, mainly in Brazil, Indonesia and parts of Africa. Then comes methane production from paddy rice and cattle, and nitrous oxide from overuse of N-fertilizers with flooding.

Climate Change

- Food productivity will be affected by climate change. For some crops in some locations, yield losses of 20% to 40% are predicted. On the other hand, for some crops in some locations yield gains of up to 200% are predicted. Furthermore, the overall picture may be even more positive if we simultaneously boost yields while climate change is occurring.
- If we allow adaptive capacity to work, *i.e.* let farmers be flexible and smart, develop new crops, and use appropriate technologies, we may be able to adapt to the issues concomitant with climate change, but it will be hard work.
- We need to get to work on adaptation to climate change as well as mitigation. There are ways to adapt—especially regarding water use—but they will not be easy.

In Conclusion

- The "Michael Pollen vs. Monsanto" debates are not helpful. Let's bring all stakeholders to the table for fact-based conversations.
- Agricultural production has doubled six times in history. Doubling it again is equal to all the previous effort combined, and it must be achieved in only 40 years. It's a huge challenge. Fortunately there are levers in the system: slowing the rate of expansion into sensitive ecosystems; closing yield gaps; raising crop-yield ceilings; improving the efficiency of environmental resource use; diet modification, at least a little; bioenergy strategy modification; and waste reduction.

- Foley is working with Google to put relevant global environment and agriculture data online free to everyone around the world to foster fact-based conversations about how we will meet the simultaneous food security/environmental sustainability challenge. Whether located in North America, South America, Europe, Africa or Australasia, everyone will have access to the same information and the level playing field will foster fact-based honest-brokered conversations.
- The task is to feed the world while sustaining the planet. Failure is not an option. Civilization depends on solving this problem literally. We have to get it right and we get only one try at it. We'd better get to work.