Challenging Times Ahead: A Historical Look at the Future of Food and Agriculture

Peter A. Coclanis

(*Albert R. Newsome Distinguished Professor of History, and Director, Global Research Institute UNC-Chapel Hill, Chapel Hill, NC, USA*)

挑战的时代:对食物和农业未来的历史展望

文章从农业和农业历史的角度出发,特别强调在当前和未来的农业语境下,历史经验的重要作用,然后提出和讨论一些重要的关于食物/农业的趋势性问题。最近几十年来关于食物和农业讨论日渐稀少。但是世界上约有三分之一的男性劳动力受雇于农业,有将近40%的女性是劳动力,农业对城市工业/后工业社会仍然是不可或缺的。虽然今天恩格尔系数越来越低、农业生产效率越高,但是关于环境退化和食物供应安全的问题经常被提上日程。

经济全球化包括农业全球化是曲折反复的,最近甚至发生了"逆全球化",然而到21世纪中叶,我们将不得不养活比现在多出大约25%的人口,同时资源条件更加恶劣。人口红利消减的时代,饥饿问题是我们最优先考虑的问题,饥饿问题日渐复杂化和复合化,除了吃不饱之外,营养不良、营养过剩、食品安全都应纳入考量,这些都危及人类健康。影响农业的各种各样的环境问题也是如此,气候变化,特别是全球变暖也许是这些问题中最重要的一个,此外还有环境污染、供水不足、土地退化、人口/生产力不对称等,都非常急迫。

幸好,世界各国政府都注意到了,以多种方式作出反应,今后几年似乎可能继续,甚至加大力度,确保基本食品的国家安全。"转基因"食品虽然目前备受争议,事实上,转基因生物可以减少对人类健康的危害,因为它们减少了杀虫剂的使用,减少了传统农业造成的环境问题,因为转基因生物通常需要更少的肥料、杀虫剂和水。从某种意义上说,转基因生物可以让我们"购买时间",因为它可以解决人口压力的压力,至少在2050年左右之前,这种压力预计会很强烈——就像20世纪60至80年代的人口激增期间的绿色革命一揽子技术一样。

农产品国际贸易的保护主义甚嚣尘上,显然,各方都有许多姿态和虚伪,如果我们要为农产品创造一个更自由、更公平和更公正的贸易制度,各方将需要更多的善意、现实主义和妥协。

最后,从根本上改变人们饮食的可能性。文化认同是个人问题,区域、国家,甚至是文明的往往有着固定的饮食文化,但是饮食偏好会需要大量的资源/生物能源生产,导致地球承载力愈发严重,但是如果通过营养的精密配置,会极大地改变食物/资源的状况。此外,我们还需通过更有效的加工方法、更好的储存设施、加强物流以及减少或消除食品浪费的更大努力,以减少作物总产量与净产量的差额。

Although many present-minded commentators fail to acknowledge the fact, history is not merely useful, but often indispensable for analyzing and interpreting the food and agricultural challenges ahead. Whether we are speaking of possible adaptive responses to climate change or of questions regarding the governance of trans-boundary waterways--both of which concerns are obviously central to agriculture--it behooves us, before moving ahead, to spend a bit of time looking backward to see how our predecessors have dealt with analo-

gous issues. In so doing, we can, if we are lucky, learn some lessons, avoid certain pitfalls, and, at least in some cases, gain confidence that we have encountered and generally overcome or at least survived similarly difficult problems in the past.

With these points in mind, this essay will begin with a few general points about agriculture and agricultural history, particularly about history's usefulness for contextualizing the present and future of agriculture, then lay out and discuss some of the biggest food/agricultural issues——megatrends, if you will——that humankind will face over the next half century or so.

Being an American, I feel it necessary to point out that until relatively recently food and agriculture had been out of favor for decades with both scholars and possessors/dispensers of cultural authority in the U.S. As a result, these two topics came to occupy an increasingly marginal place in the American psyche and imagination, which is unfortunate for many reasons, ranging from moral and ethical to physiological. Regarding the last, let us turn briefly to a passage from George Orwell, seldom a bad strategy. This one is from his classic 1937 book The Road to Wigan Pier, a sociological/ethnographic look at the pinched and impoverished lives of industrial workers in Wigan, in northern England during the Great Depression.

*"A human being is primarily a bag for putting food into; the other functions and faculties may be more god-like, but in point of time they come afterwards. A man dies and is buried, and all his words and actions are forgotten, but the food he has eaten lives after him in the sound or rotten bones of his children. I think it plausibly can be argued that changes of diet are more important than changes of political systems or even of religion."*①

One need not accept Orwell's rather sociobiological perspective completely to concede that he is on to something here. To be sure, human beings are more than platforms for the transmission of genetic material, but Orwell's key point is well taken nonetheless: Food and food history have traditionally been neglected by scholars with full stomachs, which allow them to focus on more lofty concerns. Both the producers of food and the process of food production have often been neglected as well, relegated to the dustbin——or, more appropriately in this case——to the scrap heap or compost pile of history.

To be sure, things have gradually been changing in recent years. Authors such as Eric Schlosser, Michael Po llan, and Michael Moss have written best sellers on food and eating; the genre of so-called commodity studies——viewing the past through the history of one or another commodity (sugar, cotton, coffee, tobacco, chocolate, rice, etc.)——has gained traction; glitzy magazines such as *Gastronomical* are selling well; and in the U.S. the Food Channel has hit shows. Still, in this day and age——when about 1% of the labor force in my country, the U.S., is directly involved in agriculture and when a little over 1% of US GDP comes from agriculture——it is unlikely that food will become one of the hot-button issues in one of our upcoming political campaigns.② After all, how can arugula or mace, China's growing demand for meat (including its strategic pork reserve), or even McDonald's decision to serve breakfast all day compete for attention with Russia's purported

① George Orwell, *The Road to Wigan Pier* (New York:Berkley Publishing Company, 1961; originally published 1937), p. 85.

② The percentage figures in the text are from: U.S. Department of Labor, Bureau of Labor Statistics, *Labor Force Statistics from the Current Population Survey, Household Data, Annual Averages, 18b, Employed Persons by Industry and Age*, last modified February 8, 2017, [https://www.bls.gov/cps/cpsaat18b.htm], Accessed December 13, 2017; U.S. Department of Agriculture, Economic Research Service, Ag and Food Sectors and the Economy 015], last updated October 18, 2015, [https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/ag-and-food-sectors-and-the-economy/], Accessed December 13, 2017. Note that the labor force percentage refers to workers involved in crop production, animal production, and aquaculture in 2016. The percentage figure for agricultural share of GDP is for 2015.

election meddling, Hillary Clinton's emails, or Donald Trump's tweets?

This sad truth is unfortunate for many reasons, not least of which relates to the fact that even in recent times about one third of the world's male labor force is employed in agriculture, as is almost 40 percent of the female labor force. ① Moreover, it is important to remember that even in Developed Countries, as people therein move further and further from immediate experience with agriculture, agriculture remains indispensable to urban industrial/post-industrial society. In this regard, we can readily point to some very important links between agriculture and urban/industrial/postindustrial society. In the US case, for example, we see four such links:

(1)Because of the historical efficiency of American agriculture, over time food has constituted an increasingly small proportion of national and personal income (today less than 13%-8% on food at home, and 5% at restaurants/take out). This has "freed" a considerable proportion of income for other uses--other forms of consumption and/or savings/investment of various kinds.

(2)Many of the efficiency gains in agriculture historically have come from labor-saving mechanical and chemical/biological inputs in agriculture that drastically cut agriculture's relative labor requirements (per acre or per hectare). This had the effect of freeing or releasing labor for other uses--manufacturing, services, etc.

(3)Agriculture's need for mechanical and chemical/biological inputs has served as an important source of demand for American industry--whether we mean John Deere, Case, IH, and Caterpillar, or Monsanto, DuPont, and Syngenta.

(4)Many other urban manufacturing concerns are involved in processing food and fiber produced in America's farm sector (food processing, meatpacking, cotton, textiles & apparel, boots, shoes, leather, ethanol, etc. By some reckonings, the food industry, broadly conceived, is still the largest industry in the country.②

Indeed, in light of the experience of OECD Countries like the US, many development economists today working in LDCs push strategies referred to as ADLI (Agricultural Development-Led Industrialization), focusing on the importance of first building a healthy and efficient agricultural sector, and underscoring the close historical links between farm and city, between factory and field.③

Let us now return to the question of the relevance of history. We started with a quote from Orwell. Since I teach in the U.S. South, let me also invoke in this regard my region's most famous novelist, 1949 Nobel Prize winner William Faulkner, who in his 1951 novel *Requiem for a Nun*, wrote what are arguably his two most famous lines: "The past is never dead. It's not even past."④

A brief historical exercise on the matter of globalization will illustrate parts of the larger point Faulkner

① FAO, *FAO Statistical Yearbook 2012: World Food and Agriculture*(Rome: 2012), p. 18, [http://www.fao.org/docrep/015/i2490e/i2490e01b.pdf], Accessed December 13, 2017.

② This four-part analytical breakdown draws from the work of William N. Parker, the great economic historian of agriculture. See Parker,"Agriculture," in Lance E. Davis,et al., *American Economic Growth: An Economist's History of the United States* (New York: Harper & Row, 1972), pp. 369-417, esp. pp. 372-375.

③ For an introduction to ADLI, see Irma Adelman, Jean-Marc Bourniaux, and Jean Waelbroeck, "Agriculture Development-led Industrialisation in a Global Perspective," in *The Balance between Industry and Agriculture in Economic Development*, ed. J.G. Williamson and V.R. Panchamukhi, International Economic Association Series (London: Palgrave Macmillan, 1989), pp. 320-339. On agriculture's role in the development of the U.S. manufacturing belt, see Brian Page and Richard Walker, "From Settlement to Fordism: The Agro-Industrial Revolution in the American Midwest," Economic Geography 67 (October 1991): 281-315.

④ William Faulkner, *Requiem for a Nun* (New York: Vintage Books, 1975; originally published 1951), p. 80.

was trying to make. Picture this scene: Increasingly integrated world markets for agricultural products and farm labor, the result in large part of dramatic improvements in transportation and communications. Unstable commodity prices and ruthless competition. Breakthroughs in biology, genetics, and biotechnology, giving rise to fierce opposition. Questions about environmental degradation and the safety of the food supply. Concerns that laborers in both agriculture and food processing were being exploited, leading to movements calling for governments to act against large-scale farming operations, big processors, and "Big Business" more generally. Sound familiar? It should, but we are talking about the state of the world in the early 1900s, not the world of today!

Generally speaking, present-day news accounts don't give us a good sense of the historical analogues between the agricultural world of the past and that of today. But they are there in spades. For every Eric Schlosser campaigning against the creation in America of a "fast-food nation", there was an Upton Sinclair exposing the corruption, inequities, and health-related problems associated with what he called "The Jungle," the early meatpacking industry in Chicago. Fears about problems such as Salmonella or about tainted (melamine-laced) food from China? Well, remember that it was Daniel E. Salmon of the USDA who in the late nineteenth century first identified the bacillus that now bears his name, and diseases like bovine tuberculosis were responsible for thousands of human deaths annually in the early twentieth century. Concerns over Biotech and GMOs? The Mendelian Revolution scared the bejesus out of many and the so-called Haber-Bosch process for synthetic nitrogen fixation (via ammonia)--which was 100 years old in 2013--had its critics too. Rugged battles over agricultural tariffs, subsidies, and NTBs (non-tariff barriers)? The same was the case one hundred-odd years ago, especially in Europe, concerned as it was with the "American grain invasion," which disrupted traditional suppliers. Concerns over the power of Big Ag? Think about the so-called Bonanza farms in the Dakotas in the 1880s, many of which were over 10,000 acres in size, with some over 50,000 acres. Migrant farm workers causing stresses and strains? A global market for farm labor existed in the late nineteenth- and early twentieth centuries too, engendering considerable political controversy in both Asia and the West. Who knew?

Economic globalization, the case of food and agriculture demonstrates, is not new. In fact, to scholars it is hardly even news, with some tracing its genealogy as far back as five thousand years. ① Moreover, by taking a ong-term historical approach to economic globalization--defined here as a process occurring when transnational economic flows of one kind or another (products, capital, or people, for example) outpace the overall growth of total world production, the capital stock, or the labor force, etc., over a sustained period of time--we find that the process is not only not new, but also not linear, not inevitable, and not irreversible. Globalization--including agricultural globalization--has ebbed and flowed repeatedly over time, with the most recent period of deglobalization occurring in the period between 1914 and 1945, which period is sometimes referred to as the second "Thirty Years War."

The wave of globalization we are currently living through--a wave that began after World War II and accelerated in the late twentieth century--may be reversed, too. Time will tell.② Until it does, however let me let out some of the key issues relating to agriculture and food that I think that we will be facing in the years

① See, for example, *The World System: Five Hundred Years or Five Thousand?*, ed. Barry K. Gills and Andre Gunder Frank (London and New York: Routledge, 1993). Also see Peter A. Coclanis, *Time's Arrow, Time's Cycle:Globalization in Southeast Asia over la LongueDur é e* (Singapore: Institute of Southeast Asian Studies, 2006).

② See Peter A. Coclanis, "Back to the Future: The Globalization of Agriculture in Historical Context," *SAIS Review* 23 (Winter-Spring 2003): 71-84.

ahead. Remember, though, it is always tough to make predictions——especially about the future——an observation some attribute to Niels Bohr, the Danish physicist who won the Nobel Prize in 1922. Remember, too, that I'm a historian, not a futurist. As an economic forecaster once told me, he who lives by the crystal ball must learn to enjoy the taste of broken glass. With these provisos in place, let us proceed.

Many of the key issues can be captured and conveyed in a kind of short-hand form by pointing out that world population in December 2017——about 7.6 billion——is currently projected to reach between 9.7 and 10 billion by 2050 and 11.2 billion by 2100. How on Earth will we find ways to provide these growing numbers with a sufficient quantity of nutritious food, particularly since we will almost assuredly be employing an increasingly debased "operating platform" to do so? That is to say, by the middle of the twenty-first century, we shall have to feed roughly 25 percent more people than we currently do, and do so using less agricultural water (much of it of lower quality), on increasingly degraded land and much diminished natural fisheries, while employing less fertilizer and fewer pesticides. All of this in a time of climate change, and during a period in which much of the world's population, having achieved higher incomes and living standards, will likely demand more resource——intensive protein——and dairy-rich diets. We have our work cut out for us, in other words.

Although many of these issues obviously are inter-related, let us break them down for analytical purposes into five categories——concerns relating to food production and distribution, health-related issues, environmental matters, scientific/technological options-along with a fifth, residual category that we can label either new frontiers or emerging possibilities.①

Let us turn first to matters relating to food production and distribution, in which matters hunger claims our highest priority. Over the past twenty-five years we have clearly made great progress in reducing the proportion of people in the world who are living in extreme poverty (currently defined as subsisting on less than US$1.90 per day). Such efforts are at once highlighted and reflected by assessing our progress in meeting the UN's celebrated Millennium Development Goals (MDGs), adopted following the UN's Millennium Summit (2000). Many of the MDGs goals were in fact met in the fifteen years between 2001-2015——including one to cut in half the proportion of the world's population living in extreme poverty in 1990 (35 percent). Indeed, by 2010 the proportion had fallen to 14 percent and by 2013 to under 11 percent, which progress was largely due to Asia,

① My "predictions" about the most important issues relating to food and agriculture going forward are based on a lifetime working in the field. Such predictions grow out of some of my own work and my reinterpretation of some of the best recent work on agriculture. In organizing the discussion in the text I found useful many reports and data compilations done under the auspices of the FAO, IFAD, the World Bank, U.S. Department of Agriculture, IFPRI, CGIAR, and the Bill and Melinda Gates Foundation among other bodies and institutions. Among the many recent works on agriculture that I found helpful in putting together my "predictions" were: World Bank, *World Bank Development Report, 2008: Agriculture for Development* (Washington, D.C.: The World Bank, 2007); Lester R. Brown, *Full Planet, Empty Plates: The New Geopolitics of Food Scarcity* (New York: W.W. Norton & Company, 2012); Robert Paarlberg, Food Politics: *What Everyone Needs to Know*, 2d ed. (New York: Oxford University Press, 2013); Erik Millstone and Tim Lang, *The Atlas of Food: Who Eats What,Where, and Why, Revised*, Updated, with a New Introduction (Berkeley: University of California Press, 2013); Jayson Lusk, *The Food Police: A Well-Fed ManifestoAbout the Politics of Your Plate* (New York: Crown Forum, 2013); Howard D. Leathers, with Phillips Foster, *The World Food Problem: Toward Understanding and Ending Undernutrition in the Developing World*, 5th ed. (Boulder, Colorado: Lynne Rienner Publishers, 2017). For an introduction to the Bill and Melinda Gates Foundation's agricultural development programs, see: [https://www.gatesfoundation.org/What-We-Do/Global-Development/Agricultural-Development], Accessed December 14, 2017.

particularly to China.①

Such progress notwithstanding the FAO estimates that over 800 million people in the world are still living in extreme poverty and are suffering from hunger ("the want or scarcity of food"), especially from what is known as protein-energy malnutrition (PEM), an absolute lack of calories and protein. Today, this situation exists in a food-surplus world, wherein roughly 40 percent of the world's food crops are used to feed livestock or to produce ethanol. ② Indeed, in 2011 the U.S. sent fully one-third of its total grain production to ethanol distilleries alone.③ The problem right now is thus as much one of priorities and food allocation/distribution as one of production *per se*, although most experts caution that production itself will become a more pressing issue in the decades because of population growth, changing food consumption patterns, and the environmental problems touched on earlier.

Complicating and compounding the question of "hunger" is the fact that food inadequacies do not begin and end with calories and protein alone. Nutrition scientists, public health experts, endocrinologists, and auxologists are increasingly viewing "malnutrition" problems as comprising both *undernutrition* (whether in the form of marasmus or edema) and *overnutrition* (overweight or obesity) as well as one or another vitamin-deficiency syndrome. When viewed in such broad terms, "malnutrition" becomes a huge and ever-growing problem among all kinds of populations in both LDCs (less developed countries) and the most developed countries in the world. Problems such as wasting and kwashiorkor co-exist, then, with iron-deficiency anemia, pellagra, rickets, etc., as well as with problems related to obesity such as diabetes, gout, hypertension, and certain cancers. Although promising approaches to all of these problems are emerging--none more so than personalized food regimens growing out of developments in metabolomics--"hunger" in varying forms, will be with us for generations to come.

Moreover, problems relating to food and health transcend undernutrition, overnutrition, and concomitant disease syndromes. Many such problems are inter--related with food--safety issues. Here, I am not referring to possible or imagined problems associated with Genetically Modified Organisms (GMOs)--"Frankenstein Foods," as their critics sometimes call them--but to a wide variety of bacterial, viral, and parasitic diseases associated with tainted, spoilt, or improperly prepared foods, and with impure water. Such diseases affect tens of millions of people annually around the world, debilitating sizable numbers, and killing many. What types of diseases are we speaking of? For starters, diseases such as diarrhea and allied diarrheal diseases, cholera, ty-phus, dysentery, Salmonella, Norovirus, Listeria, and Campylobacter. And lesser known diseases such as liver fluke, a big problem in parts of Asia, caused by worms entering the body from insufficiently cooked fish. Speaking of diarrheal diseases alone: Although the number of deaths from such diseases fell by almost half between 2000 and 2015, such diseases still killed 1.4 million people worldwide in the latter year.④

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① For these figures, see World Bank, *Understanding Poverty* (2015), "Overview" section, [http://www.worldbank.org/en/understanding-poverty], Accessed December 14, 2017. For a thoughtful exploration of extreme poverty, its correlates and causes, see Paul Collier, The Bottom Billion: *Why the PoorestCountries are Failing and What Can Be Done About It* (Oxford: Oxford University Press, 2007).

② See Emily S. Cassidy,et al., "Redefining Agricultural Yields: From Tonnes to People Nourished per Hectare," *Environmental Research Letters* 8, No. 3 (2013)[http://iopscience.iop.org/article/10.1088/1748-9326/8/3/034015/meta], Accessed December 14, 2017.

③ Brown, *Full Planet, Empty Plates*, p. 9.

④ World Health Organization (WHO), Media Centre, "The Top 10 Causes of Death," Fact Sheet, Updated January 2017 [http://www.who.int/mediacentre/factsheets/fs310/en/], Accessed December 19, 2017.

Diseases associated with food and water occur everywhere, but, not surprisingly, their incidence and impact are greatest in less developed countries. In such countries, in fact, diarrheal diseases rank as the second greatest cause of deaths, behind only lower respiratory tract infections (pneumonia, bronchitis, and the like).① So common and widespread are such diseases——and other great killers such as malaria——in LDCs that their incidence has in recent decades led health economists and development experts to rethink the relationship between disease and extreme poverty. Whereas it was generally the case in the past that scholars and practitioners in these fields believed that people were sick because they were poor, the new thinking is that causal links are more complicated, and often reversed. That is to say, more and more people are arguing that in many cases people are extremely poor largely because they themselves are sick or sickly, or because one or both of their parents are sick, chronically debilitated, or died prematurely because of illness. Think about it: A sick child might not be able to perform well in school or even attend. A sick parent might not be able to get a job, much less retain one. If a sick person does work, chances are his or her performance will be adversely affected. These things add up and compound over time, often making impoverishment plausible, understandable, and, in extreme cases, almost inevitable.②

So much for food and human health, which are obviously going to remain hot-button issues going forward. So, too, will various and sundry environmental issues affecting agriculture. We alluded briefly to some of these issues earlier in this essay, but let us look at a few of the most important of them again, this time with a bit more context. From an agricultural standpoint, adjusting to climate change, particularly global warming is perhaps the single most important of these issues. It is certainly the most highly publicized. Already warming is causing problems for farmers: Increased night temperatures are causing greater plant stress and affecting yields in various crops, including rice. ③ Rising sea levels induced by melting polar ice caps have led to salt-water intrusion in many low-lying agricultural areas, adversely affecting coastal Bangladesh and the lower Mekong delta among other places.④

Climate change will likely occasion even bigger effects on agriculture in the future, changing cropping patterns and agricultural geography across large stretches of the world. The net effect of such changes is still unclear, as some areas lose, others will gain. And we know from recent scholarship——the rich work of agricultural economists Alan Olmstead and Paul Rhode comes immediately to mind——that farmers in the past have adapted relatively well and relatively quickly to changing climatic possibilities. In the case of wheat, for example, they found that farmers in North America have pushed the wheat belt much further over time by developing

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① *Ibid.* See Table: "The Top 10 Causes of Death in Low-Income Economies, 2015."

② See, for example, James P. Smith, "Healthy Bodies and Thick Wallets: The Dual Relationship between Health and Economic Status," *Journal of Economic Perspectives* 13 (Spring 1999): 145-166; Pierre Gourou, *The Tropical World: Its Social and Economic Conditions and Its Future Status*, 2d ed., trans. E.D. Laborde (London: Longmans, Green,1958), pp. 6-12; Jeffrey D. Sachs, *The End of Poverty: Economic Possibilities for Our Time* (New York: Penguin Press, 2005), pp. 188-209 and passim.

③ Shaobing Peng, et al. "Rice Yields Decline with Higher Night Temperature from Global Warming," *Proceedings of the National Academy of Sciences of the United States*101, no. 27 (July 6, 2004): 9971-9975 [http://www.pnas.org/content/101/27/9971.full.pdf], Accessed December 19, 2017; P. Krishnan, et al., "High-Temperature Effects on Rice Growth, Yield, and Grain Quality," in *Advances in Agronomy*, vol. 111, ed.Donald L. Sparks (Burlington: Academic Press,2011), pp. 87-206.

④ On the problems caused by salt-water intrusion in the lower Mekong Delta, see the essays included in *Environmental Change and Agricultural Sustainability in the Mekong Delta*, ed. Mart A. Stewart and Peter A. Coclanis (Heidelberg and New York: Springer, 2011).

new varieties better to withstand cold temperatures or to mature more quickly. ① Thinking historically, then, gives us at least a margin of hope about the future.

Pressing issues relating to soil and water--still agriculture's *sine qua nons*--abound. The amount of good soil available for agriculture is shrinking for a variety of reasons: Leaching, erosion, water logging, compaction, organic carbon loss, acidification, contamination, urban sprawl/peri-urban growth, etc. Such problems are particularly severe in LDCs. According to a massive 2015 report by the FAO, *Status of the World's Soils*, one-third of the world's soils are now moderately to highly degraded. Here, too, though, there is some cause for optimism, as the FAO points out in the report that the current situation can be reversed with concerted effort and commitment given expression in better cultivation practices via precision farming, no-till cultivation, greater use of nitrogen-fixing cover crops, more sustainable rotation schemes, reduced employment of fertilizers, etc.②

Water problems, ranging from supply insufficiencies to increased pollution, may be more severe. Various factors are involved: Salt-water intrusion and increased salinity of traditional water sources, aquifer depletion, algae blooms, the drying up of bore wells and tube wells, increased pollution of freshwater sources, etc. Problems relating to freshwater are obviously extremely serious, given the fact that only 3 percent of the world's water is freshwater, with two thirds of that existing(as of yet) in frozen form in ice caps. Roughly 70 percent of the freshwater available worldwide is used in agriculture, and irrigated farmland is roughly twice as productive as non-irrigated land.③ So, anything that adversely affects freshwater will almost certainly have a profound "ripple" effect on agriculture.

As was the case with land degradation, there are some reasons for hope going forward regarding the world's freshwater. There is now widespread recognition of the seriousness of the situation, which has already had positive effects, to wit: Greater efforts at conservation, technological innovations (drip irrigation, more efficient desalinization processes, etc.), and the development of new plant varieties (whether through conventional breeding or GMOs) that use less water. Perhaps most important of all have been innovations in the ways weapproach water in conceptual terms, particularly the development of the concept of "embedded" or "virtual water" by Tony Allan among others, which calculates the amount of water used to produce a unit of agricultural production (whether a crop or animal). ④ This concept has gotten more and more people thinking about establishing more rational agricultural systems--about not growing "thirsty" crops such as almonds and alfalfa in semi-arid parts of California, for example-and has gotten governmental and private-water authorities to start pricing water more rationally. In many parts of the world, agricultural water has traditionally been "dirt cheap, if not free, and, as a result, has often been used with great profligacy.

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① Alan L. Olmstead and Paul W. Rhode, "Adapting North American Wheat Production to Climatic Challenges, 1839-2009," *Proceedings of the National Academy of Sciences of the United States* 108, no. 2 (January 11, 2011): 480-485 [http://www.pnas.org/content/108/2/480.full.pdf], Accessed December 19, 2017.

② FAO, "Soils are Endangered, but the Degradation can be Rolled Back," *FAO News Story*, December 4, 2015 [http://www.fao.org/news/story/en/item/357059/icode /], Accessed December 19, 2017. This FAO story summarizes the principal findings in its massive 2015 report: FAO, *Status of the World's Soil Reserves, Main Report* (Rome: FAO, 2015) [file:///C:/Users/coclanis/Documents/FAO%20report,%20World's%20Soil%20Resources,%202015.pdf], Accessed December 19, 2017.

③ FAO, *World Agriculture: Towards 2015/2030, Summary Report*(Rome: FAO, 2002), p. 4 [http://www.fao.org/tempref/docrep/fao/004/y3557e/y3557e.pdf]. Accessed December 19, 2017. Note that in the case of cereals the difference in yields on irrigated and non-irrigated land is even greater.

④ See Tony Allan, *Virtual Water: Tackling the Threat to our Planet's Most Precious Resource* (London: I.B. Tauris, 2011).

But change at long last is now afoot, which is none too soon, particularly for highly populated LDCs in sub-Saharan Africa and South Asia, where all of the above problems bear more urgency. Many such areas suffer from what might be called population/productivity asymmetries, that is to say, very high population densities and low agricultural productivity. This situation is generally reversed in developed countries, where population densities are typically lower, and agricultural productivity much higher. While the environmental problems outlined above affect farmers worldwide, their combined and concatenating impact is greatest in these poor, densely populated, low--productivity agricultural zones. ① Unless strong steps are taken to reduce such asymmetries in the future, whatever progress we make elsewhere will from a global perspective unfortunately seem limited and incomplete.

In light of the difficult issues discussed above, it is not surprising that questions relating to "food security" have become increasingly prominent in recent years, and show no sign of ebbing any time soon. More and more governments around the world have broadened the way they define national security so as to incorporate considerations relating to climate change, and the so-called *nexus* connecting energy, water, and food. ② Regarding food and water *per se*, both academic specialists and governmental policymakers have taken note of real-world connections between food shortages and political instability, pointing, for example, to the uprisings in North Africa and the Middle East between December 2010 and the middle of 2012 known collectively as the "Arab spring." They have, in addition, also drawn connections between decade-long water shortages in Iraq and Syria, and the protracted period of instability in these areas.③

Such concerns have recently led numerous academics to reassess their interpretations of historical phenomena as well, whether we are speaking of Jared Diamond in his 2005 bestseller *Collapse*, wherein he links the decline of entire civilizations to environmental stress or Timothy Snyder in his much talked-about 2015 book *Black Earth*, wherein he makes the case that Hitler and the Nazis were motivated in large part by a concern for securing lands in the east for purposes of food security.④

Clearly, other factors as well played roles in raising the profile of food as a security concern in recent years. The price volatility of food and other commodities (including oil) between 2008 and 2010--just before the "Arab Spring" uprisings--also heightened anxiety in other parts of the world, as did the news in 2009 that

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① On this problem, see, for example, Millstone and Lang, *The Atlas of Food*, pp. 20-21.

② On the "nexus" concept, see *The Water, Food, Energy and Climate Nexus: Challenges and an Agenda for Action*, ed. Felix Dodds and Jamie Bartram (London and New York: Routledge/Earthscan, 2016).

③ See, for example, Marco Lagi, Karla Z. Bertrand, and Yaneer Bar-Yam, "The Food Crises and Political Instability in North Africa and the Middle East," Report, New England Complex Systems Institute, Cambridge, Massachusetts, September 28, 2011, [http://necsi.edu/research/social/food_crises.pdf], Accessed December 19, 2017; "Ines Perez, "Climate Change and Rising Food Prices Heightened Arab Spring," *Scientific American*, March 4, 2013 [https://www.scientificamerican.com/article/climate- change-and- rising-food-prices-heightened-arab-spring/], Accessed December 19, 2017; Joshua Bailey, "Water and U.S. National Security," Council on Foreign Relations, Discussion Paper, January 2017, [https://www.cfr.org/sites/default/files/pdf/2017/01/Discussion_Paper_Busby_Water_and_US_Security_OR.pdf], Accessed December 19, 2017; Kris Hartley, Cecilia Tortajada, and Asit K. Biswas, "Confronting Global Security in an Era of Water Instabilities," *Foreign Policy Journal*, February 3, 2017 [https://www.foreignpolicyjournal.com/2017/02/03/confronting-global-security-in-an-era-of-water-instabilities/], Accessed December 19, 2017.

④ Jared Diamond, Collapse: *How Societies Choose to Fail or Succeed* (New York: Viking Press, 2005); Timothy Snyder, Black Earth: *The Holocaust as History and Warning* (New York: Crown, 2015).

the urban proportion of the world's population had passed the 50 percent mark for the first time. Although the fact that the world was tipping "urban" meant nothing in and of itself, it did get more people talking about food security as the urbanization process continued and accelerated. At the same time, globalization and the increased importance of long-distance food supply chains seemed overly risky, if not foolhardy to many, as did the diversion of food grains(maize and sugar in particular) to ethanol. All of these factors--in a time of climate change, water scarcities, population pressure, growing concerns about the "carrying capacity" of the Earth as population grew and people everywhere became wealthier, increasing demand for foods with higher income elasticities (meat and dairy products), often with larger environmental "footprints"--focused people's attention around food and risk.

Governments all over the world took notice, responded in numerous ways, and in the years ahead seem likely to continue and even step up efforts to ensure national security in basic foodstuffs. Not for nothing does China maintain its famous strategic pork reserve, for example, and Chinese efforts to set up long-term contracts with suppliers of key commodities(soybeans in Brazils, dairy products in Australia, etc.) and Chinese firms' acquisitions of major international food processors--the Shuanghui Group's purchase of the giant U.S.-based meat processor Smithfield Foods in 2013 comes immediately to mind--should be viewed in the same light. Public and private interests in other countries have followed suit, sometimes in controversial ways such as buying up lands or signing long-term leases on agricultural lands in land-abundant LDCs (and sometimes in land-abundant developed countries) and setting up farm facilities in the same places in order better to reduce food risk and better guarantee food access going forward.①

Less controversial steps have also been taken to improve food security. Investment in all phases of agriculture has increased significantly in real terms in recent years and likely will continue to do so in the future. In addition, the diffusion of more sophisticated tools for farm-market intermediation--even tools as basic as cell phones in LDCs--have enhanced food security in many areas, as have developments such as increasing access to crop insurance, and the introduction and diffusion of various income-smoothing schemes among farmers around the world.

All of the above steps should be seen in the context of the broadening of the concept of national security so as to include food security. Such steps are understandable, and most, on balance, will likely prove helpful. At the end of the day, though, the best guarantor of food security--in my view at least--is a nation's economic power, however achieved. A nation with a well-functioning economy, which generally means an economy pursuing its comparative advantages, will generate sufficient income and wealth to acquire sufficient stocks of nutritious food if and when it needs it. The wealthy city-state of Singapore, with a tiny agricultural sector of the boutique variety, is a case in point.

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① See, for example, "Outsourcing's Third Wave: Buying Farmland Abroad," *The Economist*, May 21, 2009, [http://www.economist.com/node/13692889], Accessed December 19, 2017; Lorenzo Cotula, et al., *Land Grab or Development Opportunity: Agricultural Investment and International Land Deals in Africa* (Rome and London: FAO, IIED, and IFAD, 2009);Shepard Daniel, "Land Grabbing and Potential Implications for World Food Security," in *Sustainable Agricultural Development: Recent Approaches in Resources Management and Environmentally-Balanced Production Enhancement*, ed. M. Behnassi, S. A. Shahid, and J. D'Silva (Heidelberg and New York: Springer, 2011), pp. 25-42; Amadou Sy, "What Do We Know about the Chinese Land Grab in Africa?" Brookings, *Africa in Focus*, Blog, November 5, 2015 [https://www.brookings.edu/blog/africa-in-focus/2015/11/05/what- do-we-know-about-the-chinese-land -grab-in-africa/], Accessed December 19, 2017.

Invoking Singapore and boutique agriculture leads us to yet another issue that will likely become bigger and bigger in the future, particularly in rich and middle-income countries: The often tense relationship between "Big Agra"--large, efficient, "factory" farms--on the one hand, and small, local-oriented (boutique) units, on the other. Sometimes the two "sides" are framed as conventional agriculture, striving to produce large quantities of agricultural outputs at the lowest cost possible, and L-O-S (local, organic, slow) agriculture, which is concerned more with producing small "batches" of high-quality (and generally high-price) agricultural outputs as sustainably as possible.

Those involved in these competing farming regimes and those that prefer consuming the products they produce are often adamant about the regime they prefer, and, in so doing, sometimes frame their analysis of the issue in reductionistic, overly simplistic binary fashion. Both "sides" are often highly suspicious and distrustful of one another. Against "Big Agra" you will see charges hurled about its supposedly unethical, unsustainable practices, its cruelty to farm animals, its gross commercialization, and about the negative externalities it is said to create. Against "boutique" farming, one hears charges of price gouging, self-righteousness, elitism, anti-scientism, inefficiency, and market irrelevance. Although there is some truth to all such charges, they are all overstated, and in reality the two regimes are not as distinct and demarcated as this binary framing suggests.①

In my view, both regimes will likely have a place in meeting the world's ever more complicated food needs going forward. Perhaps a degree of reconciliation will come about and with it a "middle way" production strategy will emerge, with "Big Agra," much more efficient, producing the vast majority of the inexpensive and decent-quality food needed to feed the mass of the world's growing population, and the "boutique" sector filling small niches for people willing and able to pay high prices for food thought (by some) to be of higher quality and providing more status and cultural capital. Indeed, as part of this "middle way", we may even see the coming together in some regions of scaled-up boutique farms producing via organic GMOs, as researchers Pamela C. Ronald and Raoul W.Adamchak wrote about a few years ago in their provocative book *Tomorrow's Table: Organic Farming, Genetics, and the Future of Food.*② Stay tuned!

The mere mention of GMOs makes ears perk up, exciting large numbers of people, who laud them as the next stage of scientific breeding, but raising the hackles of just as many, who believe that they are both unsafe and unneeded. It is impossible in a short discussion to treat GMOs and the controversy surrounding them with the thoroughness these subjects deserve, but neither GMOs nor the controversy surrounding them is going away as an issue, so a few words are in order, given the purpose of this essay.

Let me start by acknowledging that few issues in contemporary agriculture are as hotly contested, and this has pretty much been the case since the first GMO crop was put on the market in 1996 (twelve years after the first GMO plant was produced in 1984). Since 1996 myriad studies have been published on GMOs, the results of which, though generally positive regarding GMO, have not succeeded in bringing about any consensus on their usage. Ironically, many of the same people who urge everyone to accept the findings of the vast majority of

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① On these matters see, Peter A. Coclanis, "Is Industrial Agriculture a Success or Failure?" in *Food Fights: How the Past Matters to Contemporary Food Debates*, ed. Chad Ludington and Matthew Booker (Chapel Hill: University of North Carolina Press, forthcoming). For a brief version of the argument in the reference above, see Coclanis, "Trying to Teach Big Agra in a Hotbed of Locavores," *Wall Street Journal*, August 29-30, 2015, A9.

② Pamela C. Ronald and Raoul W. Adamchak, *Tomorrow's Table: Organic Farming, Genetics, and the Future of Food* (New York: Oxford University Press, 2008)

climate scientists regarding global warming reject the findings of the vast majority of plant scientists when it comes to GMOs!

More to the point, the most comprehensive and authoritative systematic reviews of GMOs that have appeared over the years have overwhelmingly concluded that the GMOs that have been developed and commercialized thus far pose no harm to human health, pose no significant risks to the environment, and bring benefits to farmers and consumers (although up until now most of the benefits have gone to the former rather than to the latter). GMOs, in fact, can sometimes reduce harm to human health because they reduce pesticide use, and reduce environmental problems posed by conventional agriculture because GMOs often need less fertilizer, pesticides, and water.①

To be sure, although I support GMOs, I wish that control over them was not so heavily concentrated in the corporate sector, unlike the case with the seeds associated with the green Revolution (especially HYVs or high-yielding seed varieties), which were largely in the hands of international organizations and NGOs. That said, so-called Golden Rice--developed in large part by researchers at the International Rice Research Institute in Los Banos, Philippines, who have waived their patent rights--have yet to find a market. ② Fears die hard, it seems.

Despite considerable opposition, particularly in Europe, GMOs dominate the international markets for a variety of crops, particularly soybeans, maize, canola, and cotton. GMOs will likely play bigger roles in markets for other crops in the future, though their progress will likely remain uneven. Without claiming too much for them--as some ardent admittedly proponents do--I see GMOs as part of our arsenal for helping to produce sufficient quantities of food to meet the needs of the world's growing and increasingly affluent population. In a sense, GMOs can allow us to "buy time," as it were, to deal with population pressure--pressure which is projected to be intense at least until 2050 or so--much like the Green Revolution package of technologies did during the population explosion of the 1960s, 1970s, and 1980s.

Almost as controversial, albeit for different reasons, are the seemingly endless battles over international trade in agricultural products. In this regard, one concern holds an especially prominent place: Protectionism. Battles over protectionist policies in agriculture are linked to issues relating to food security, of course, but powerful farmers' organizations and lobbying groups have played key roles as well, particularly in Europe, the U.S., and Japan. LDCs and middle-income countries--most notably, the so-called Group of 21 developing nations that helped derail the protracted Doha Round of trade negotiations--have not always played constructive roles either. Clearly, there has been a lot of posturing and hypocrisy on all sides, and if we are to create a freer, more fair and equitable trade regime for agricultural goods more good will, realism, and compromises will be necessary by all parties involved.

Before concluding, let me touch briefly on three sets of issues that are at once interesting and likely to

① See, for example, Wilhelm Kl?mper and Matin Qaim, "A Meta-Analysis of the Impacts of Genetically Modified Crops," *PLoS ONE* 9 (11): [http://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0111629&type=printable], Accessed December 20, 2017; National Academies of Sciences, Engineering, and Medicine, *Genetically Engineered Crops: Experiences and Prospects, Consensus Study Report* (Washington, D.C.: National Academies Press, May 2016), [https://doi.org/10.17226/23395], Accessed December 20, 2017. See esp. "Report in Brief," pp. 1-4.

② On the history of Golden Rice and its development at IRRI, see: http://www.goldenrice.org/index.php, Accessed December 20, 2017.

grow in importance in the years ahead. The first pertains to diet, or, more precisely, the possibility of changing people's diets in fundamental ways. First, it must be conceded that it is extremely difficult to change diets and food ways more generally. Questions of cultural identity——whether personal, regional, national, or even civilizational——are often linked closely to food and eating, and historians, anthropologist, and social psychologists who have studied food and foodways generally agree that they are often among the most important factors in creating and maintaining bonds of social affinity.

The problem is that going forward something may have to give. That is to say, growing population and increasing affluence may tax the Earth's carrying capacity so severely and lead to so much overconsumption of biomass as to compel people to eat differently, cultural predilections and preferences notwithstanding. Whether this means limiting intake of meat and dairy products, which require large amounts of resources/bioenergy to produce, or adopting vegetarian or vegan diets, or moving more toward insects as protein sources, time will tell.

But other possibilities are also rapidly opening up, such as reconstituting food out of different substances and growing it in ways and places that reduce resource usage. Already, scientists in Silicon Valley and high-tech hotspots such as the University of Maastricht in the Netherlands are working assiduously (and increasingly successfully on) producing lab-grown milk and cultured meat in research facilities, urban factories, and in high-rise "vertical farm" settings. In this regard, companies such as Muufri and Beyond Meat among others are closing in on producing artificial milk and meat at price points (and at what one might call "taste points") that render such products viable in the marketplace. In so doing, they are attracting investment from large agribusiness concerns such as Tyson Foods, which recently bought a 5 percent stake in Beyond Meat. Again, time will tell, but this could be a potential game changer.①

So, too, could precision nutrition via metabolonomics. Advances in this arena could conceivably produce much the same results regarding resource savings as changes in diet or in the composition and constitution of food, while at the same time improving human health. ② Let me explain. Many scientific studies on rats and other animals suggest that longevity can be extended via diets with radically lower daily caloric intake. Can we extrapolate such results to humans too? ③ We may soon see. Scientists working in the field of precision nutri tion are now hard at work on designing healthy, complete, and satisfying diets targeted for individuals based on

① See, for example, Ronald Bailey, "The End of Farming," *Reason*47 (June 2015): 22-23 [http://reason.com/archives/ 2015/ 03/20/the-end-of-farming], Accessed December 20, 2017; Nicholas Kristof, "The (Fake) Meat Revolution," *New York Times*, September 19, 2015, [https://www.nytimes.com/2015/09/20/opinion/sunday/nicholas-kristof-the-fake-meat-revolution.html?_r=0], Accessed December 20, 2017; Stephanie Strom, "Tyson Foods, a Meat Leader, Invests in Protein Alternatives," *New York Times*, October 10, 2016, [https://www.nytimes.com/2016/10/11/business/tyson-foods-a-meat-leader-invests-in-protein- alternatives.html], Accessed December 20, 2017; Selina Wang, "The Future of Farming is Looking Up," *Bloomberg Business week*, September 11, 2017, pp. 62-67.

② For a review of some recent developments in metabolomics and precision nutrition, see, for example, Juan de Toto-Martín, et al.,"Precision Nutrition: A review of Personalized Approaches for the Prevention and Management of Metabolic Syndrome," *Nutrients*, 9 (8) August 22, 2017, [https://www.ncbi.nlm.nih.gov/pubmed/288 29397], Accessed December 20, 2017.

③ See, for example, Leonie K. Heilbronn and Eric Ravussin, "Calorie Restriction and Aging: Review of the Literature and Implications for Studies in Humans," *American Journal of Clinical Nutrition* 78 (September 2003): 361-369 [http://ajcn.nutrition.org/content/78/3/361.full], Accessed December 20, 2017; Changhan Lee and Valter Longo, "Dietary Restriction with and without Caloric Restriction for Healthy Aging," *F1000 Research, 2016*, 5(F1000 Faculty Rev), [https://f1000research.com/articles/5- 117/v1], Accessed December 20, 2017.

a person's personal metabolic characteristics. ② By eliminating unneeded calories from one's diet, significant cuts can be made in daily food consumption. Currently, the average person in the world consumes 2870 kilocalories per day (which figure is much higher in most developed countries). Employing the world average, slightly less than 6000 calories of food feeds two people daily. With precision nutrition, the same 6000 calories could feed three or four people, and do so in a healthier way. Even assuming no radical changes in the foods we consume or in food-production technologies, precision nutrition could change the food/resource picture dramatically.

The possibilities discussed in the paragraphs above still need a bit of time before they can be scaled up. Another important way to render more efficient both our food supply and resource usage is already readily attainable: Reducing the difference between gross and net crop yields. As agronomists and soil scientists have pointed out repeatedly in recent years, it is getting harder and harder to achieve continued gains in gross crop yields. Given this fact, greater attention is long overdue to shrinking the difference between gross and net yields through more efficient milling practices, better storage facilities, enhanced logistics, and greater consumer efforts to reduce or eliminate food waste. In less developed countries half of the crop is often lost after the harvest, for example, but lots of "appropriate" technologies are already available to store, transport, vend, preserve, and redistribute/repurpose higher proportions of foods harvested (particularly cereals, fruits, and vegetables) thereby in effect increasing yields by shrinking the distance between gross and net output. Although potential gains are greatest in less developed countries, significant gains are also possible in developed countries, particularly by eliminating consumer waste.③

How, then, shall we conclude this historically-grounded gaze into the future? For one thing, by pointing out that we have hardly exhausted the list of important issues relating to food and agriculture. For another, by reiterating yet again that food and agriculture are still with us, regardless of how few of us are directly involved in agriculture and regardless of how many levels of intermediation exist between our meals and farmers' fields. We may be more than "bags for putting food into"--to quote Orwell once again--but nonetheless at the end of the day food is the first thing, as Berthold Brecht put it in *The Three penny Opera*, and "human rights and dignity begin with breakfast," as an African adage goes. Whatever other lofty pretensions humans might have.

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① To learn more about recent developments in precision nutrition, see, for example, the website of the North Carolina Research Campus in Kannapolis, North Carolina: https://transforming-science.com/

② See Peter A. Coclanis, "Low-Hanging Fruit: The Fight for Food Security," *Le Monde diplomatique* [English edition], December 29, 2015 [http://mondediplo.com/blogs/low-hanging-fruit-the-fight-for-food-security], Accessed December 20, 2017; Coclanis, "There is a Simple Way to Improve the World's Food Systems," *Aeon*, February 27, 2017, [https://aeon.co/ideas/there-is-a- simple-way-to-improve-the-worlds-food-systems], Accessed December 20, 2017.